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Pest and Pesticide Management in the Caribbean

Consortium for International Crop Protection

Proceedings of Seminar and Workshop

CICP/USAID 3–7 November 1980

VOLUME I SUMMARY PAPERS

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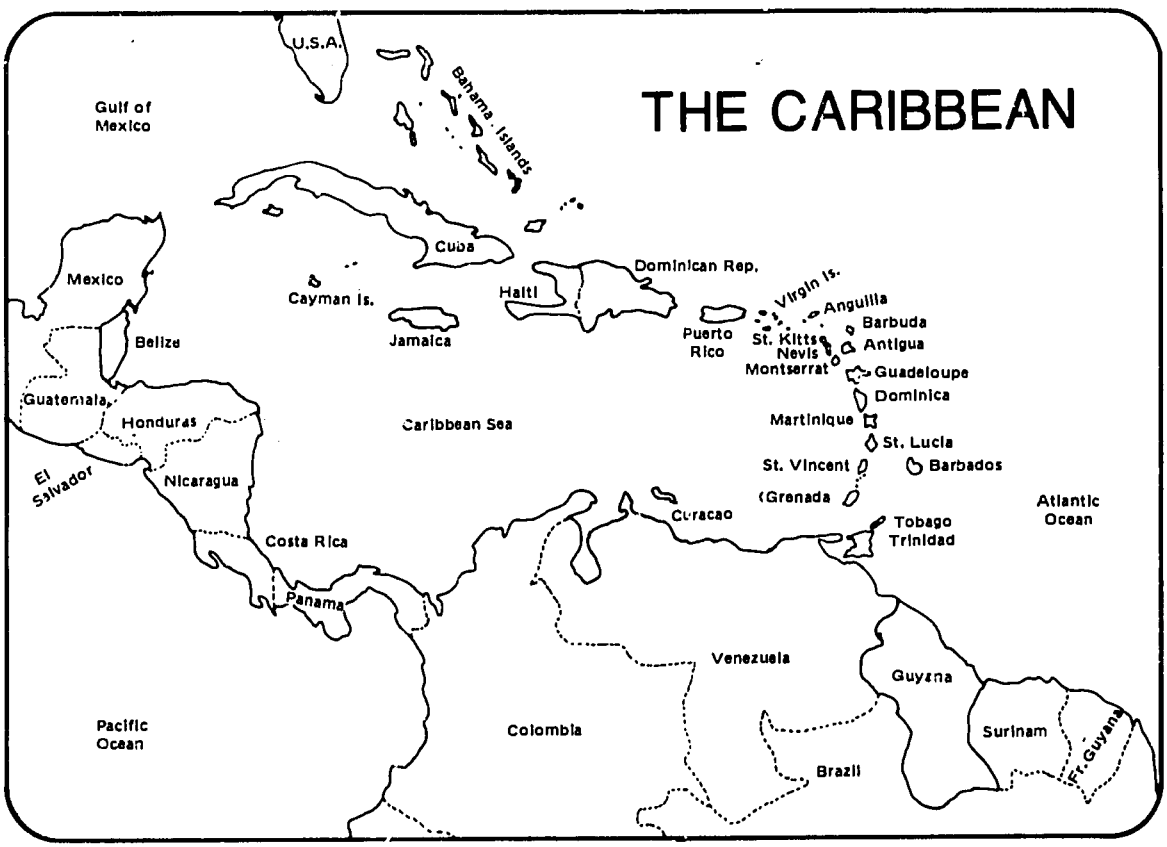

BRIDGETOWN, BARBADOS, W.I.

Report of Seminar/Workshop held at the Dover Convention Centre, Barbados, November 3-7 1980, sponsored by the Consortium for International Crop Protection (CICP) and the United States Agency for International Development (USAID) through Contract DSAN-C-0252 to CICP, and co-sponsored and organised by the Ministries of Agriculture, Food and Consumer Affairs and of Health and National Insurance of the Government of Barbados, the Caribbean Agricultural Research and Development Institute (CARDI), the Caribbean Community Secretariat (CARICOM), the Pan-American Health Organisation (PAHO) and the University of the West Indies (UWI).

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PEST AND PESTICIDE MANAGEMENT IN THE CARIBBEAN

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Volume I

SUMMARY

OF THE

"SEMINAR AND WORKSHOP

ON

PEST AND PESTICIDE MANAGEMENT

IN THE CARIBBEAN"

November 3-7, 1980

CHRIST CHURCH, BARBADOS

VOLUME I

CONTENTS

		Page
PREFACE		5
ACRONYMS USED IN VOLUME I		6
SUMMARY		7
I	OBJECTIVES OF THE SEMINAR/WORKSHOP	7
II	BACKGROUND TO THE SEMINAR/WORKSHOP AND ORGANISATION	7
	1. The role of CICP	7
	2. Sponsors and Organisers of the Seminar/Workshop	7
III	THE PARTICIPANTS	7
IV	THE SETTING OF THE SEMINAR/WORKSHOP	8
	1. Promise and Problem	8
	2. Special Problems in the LDC's	9
	3. Improved Systems of Pest Management and Pesticide Management – The Seminar/Workshop Goal.	9
V	SIGNIFICANT DEVELOPMENT OF THE SEMINAR/WORKSHOP	9
	1. Need for IPM Emphasized	9
	2. The Agromedical Team Approach – An Important Part of Pest and Pesticide Management.	9
	3. The Workshop Reports and Recommendations	10
VI	FOLLOW-UP ACTIONS	10
	Annexes	12
	1. Programme of Seminar/Workshop	12
	2. Participants at the Pest and Pesticide Management Seminar/Workshop	16
	3. Keynote Address "Essential Role of Pest Control in Human Health and Food Production" – Perry L. Adkisson	21
	4. Report of Workshop Groups.	26
	A. Regulatory Aspect	26
	B. Extension and Education	27
	C. The Agromedical Team Approach	30
	D. Research Needs	33
	5. Opening Address by the Hon. Billie A. Miller	36
	6. Closing Address by Mr. LeRoy Sisnett.	38

PREFACE

Three publications will ensue from the **Seminar and Workshop on Pest and Pesticide Management in the Caribbean**, held at the Dover Convention Centre, Christ Church, Barbados, November 3-7, 1980:

Volume I.	Summary (This volume)
Volume II.	Proceedings (Compilation of the invited papers presented at the Seminar and Workshop).
Volume III.	Status of pest and pesticide management in the Caribbean (Compilation of position papers prepared by participants representing Caribbean countries at the Seminar and Workshop).

The objectives of the volumes are to: (1) set forth the principles and techniques of pest and pesticide management, (2) review the pest and pesticide problems affecting the Caribbean, (3) identify obstacles hindering the development of economically and environmentally sound pest and pesticide management programmes in this region, and (4) identify needs and steps that various national and international institutions can take to remove these obstacles.

We hope that technical specialists in agriculture and health, administrators and government officials in those fields, and members of the chemical industry find the volumes useful. Additional copies may be obtained by writing one of us:

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ABBREVIATIONS USED IN VOLUME I

CARDI	Caribbean Agricultural Research and Development Institute
CARICOM	Caribbean Community Secretariat
CICP	Consortium for International Crop Protection
IPM	Integrated Pest Management
LDCs	Less Developed Countries
PAHO	Pan-American Health Organisation
UC/AID	University of California/U.S. Agency for International Development
USA (U.S.)	United States of America
USAID	U.S. Agency for International Development
UWI	The University of the West Indies

SUMMARY

I. OBJECTIVES OF THE SEMINAR/WORKSHOP

The Seminar and Workshop on Pest and Pesticide Management in the Caribbean was held at the Dover Convention Centre, Christ Church, Barbados, November 3-7, 1980. Its objectives were:

(1) To review the principles and techniques of pest and pesticide management;

(2) To examine the status of pesticide use and other pest management activities in the Caribbean;

(3) To stimulate better dialogue and exchange of information among agricultural and health specialists working on pest and pesticide management programmes in the Caribbean; and

(4) To develop recommendations for needs in pesticide regulation, extension and teaching, the agromedical team approach, and research which will lead to improved pest and pesticide management programmes in the Caribbean.

The Seminar and Workshop spanned a full five days. Four days were consumed by presentations by individual lecturers and panel members on a range of topics on pesticides and pest management. The other day was devoted to workshops covering the following topics: pesticide regulations, extension and education, the agromedical team approach, and research on pest and pesticide management. The full Seminar and Workshop Programme appears as Annex 1.

II. BACKGROUND TO THE SEMINAR/WORKSHOP AND ORGANIZATION

1. The Role of CICP

The purpose of the Consortium for International Crop Protection — an outgrowth of the UC/AID Pest Management and Related Environmental Protection Project, initiated in 1972 — is to aid countries requesting assistance to improve their capability for developing economically efficient and environmentally sound pest control systems. Nine U.S. Universities — University of California, Cornell University, University of Florida, University of Hawaii at Manoa, University of Miami School of Medicine in Florida, University of Minnesota, North Carolina State University, Oregon State University, and Texas A&M University — and the U.S. Department of Agriculture, form the CICP membership. The Consortium's administrative staff is headquartered at the University of California, Berkeley. CICP is financed in part by the U.S. Agency for International Development, and it works with this agency in carrying out pest and pesticide management programmes in the less developed countries. One of CICP's missions is to develop seminars and workshops that focus on pest and pesticide management problems in given regions.

2. Sponsors and Organizers of the Seminar/Workshop

The Seminar and Workshop was sponsored by CICP and USAID. Co-sponsors and organizers were the Ministries of Agriculture, Food, and Consumer Affairs and of Health and National Insurance of the Government of Barbados, Caribbean Agricultural Research and Development Institute, Caribbean Community Secretariat, Pan-American Health Organization, and The University of the West Indies. The Planning Committee, composed of representatives of the above organizations and chaired by CARDI's Chief of Programmes, Dr. John L. Hammerton, organized the Seminar and Workshop.

III. THE PARTICIPANTS

The Seminar and Workshop was organized primarily for Caribbean specialists working on pest and pesticide management problems affecting agriculture and public health. More than 100 participants, representing 18 countries, attended the Seminar and Workshop. The Caribbean countries represented were: Antigua, Bahamas, Barbados, Belize, Curacao, Dominica, Dominican Republic, Grenada, Guyana, Haiti, Jamaica, Montserrat, St. Kitts-Nevis, St. Lucia, St. Vincent, and Trinidad. The neighboring country of Mexico was represented, as was the United States of America.

Participants from the Caribbean countries prepared and brought with them to the Seminar and Workshop position papers which described the status of pesticide use and pest and pesticide management programmes in their countries. These papers will be published separately, as Volume III.

The names and addresses of the participants appear in Annex 2.

IV. THE SETTING OF THE SEMINAR/WORKSHOP

1. Promise and Problem

For many centuries human settlements, both agricultural and urban, have had to contend with a variety of unwanted and sometimes harmful insects, weeds, microorganisms, rodents, and other organisms — collectively, "pests". Many biological, physical, cultural and chemical methods have been developed to combat these organisms.

During the last four decades hundreds of synthetic organic pesticides — carbon-based compounds synthesized from petroleum derivatives — have been introduced to control pests, and a major chemical industry has emerged to develop and market the materials. Although agriculture has been the primary market for the pesticide industry, pesticide products also have been developed for pests affecting forests, livestock, public health, and urban areas.

The synthetic organic pesticides have had a major impact upon control of agricultural pests, particularly insects and weeds. They have become a primary means of pest control in many agricultural regions of the developed world.

The synthetic organic pesticides also have had a major impact upon the concept and implementation of the "Green Revolution" by providing a major mode of pest control for the new high yielding varieties of wheat, rice, maize, and other food crops introduced into the developing countries. They have produced equally spectacular results against pests that directly affect human health and comfort. Widescale employment of DDT, for example, has resulted in the temporary riddance from entire countries of serious public pests, such as malaria mosquitoes.

As the various reports of this volume and the other volumes of the series indicate, chemical pesticides are — and will continue to be — of considerable importance in food and fiber production, forest management, public health, and urban pest control programmes. Despite the gains realized from using the materials, however, technological and biological limitations are becoming increasingly apparent.

By virtue of the nature of their use and the fact that they are designed to be biologically active, pesticides often present many potential hazards to human health. Also, some of the materials may seriously harm important beneficial nontarget organisms — fishes, birds, and other wildlife, honey bees and other important pollinators, natural enemies such as insect predators and parasites, economic and non-economic plant species, and livestock — resulting in ecological disruptions, deterioration of environmental quality, and economic losses.

In addition to concern about their environmental and human health effects, other limitations to chemical pesticides are apparent. First, the price of synthetic organic pesticides and the cost of their applications have risen significantly in recent years, placing an increasing burden on those farmers and others who use large quantities of the materials. Second, tremendous losses to pests are occurring despite the advances in modern chemical control. The loss of crops to pests is enormous. It has been estimated that the amount of land currently being cultivated, worldwide, is 50 percent greater than would be required if there were no pest losses to crops. Third, and potentially of even more concern, significant groups of pests have developed strains that are genetically resistant to chemical pesticides. Worldwide, in 1980, 432 species of insects, mites, and ticks, about 50 species of plant pathogens, five species of weeds, and two species of nematodes were known to possess strains resistant to one or more chemical pesticides. The resistant groups include some of the world's most serious insect pests affecting agriculture and public health.

The keynote address of the Seminar and Workshop, "Essential Role of Pest Control in Human Health and Food Production", presented by Dr. Perry L. Adkisson, provided an overview of the global pest situation and appears as Annex 3.

2. Special Problems in the LDCs

In the USA and many other developed countries, public concern about impacts of pesticides on health and the environment has led to more stringent regulation of their use and to complete prohibition of specific compounds. In addition, the public institutions have invested large sums of money and personnel resources in the development of pesticide safety and pesticide public awareness programmes, and research on ecologically based systems of pest control.

In the less developed countries the problem is much more perplexing. These countries often lack the resources and the personnel for developing effective regulatory, educational, and research programmes. Yet the incentives for using pesticides in the LDCs may be quite high, especially where large estate crops such as cotton, sugarcane, and rubber or new high yielding varieties of rice, maize, or other cereals are involved.

3. Improved Systems of Pest Management and Pesticide Management – The Seminar/Workshop Goal

If the world's food production system is to meet the pace of human population growth and a good quality of life is achieved and maintained, pests must be managed. Pesticides also must be managed so as to protect human health and the environment and to achieve optimal benefits from their use. Hence, the goal of the Seminar and Workshop – improved systems of PEST MANAGEMENT and PESTICIDE MANAGEMENT for the Caribbean.

V. SIGNIFICANT DEVELOPMENTS OF THE SEMINAR/WORKSHOP

1. Need for IPM Emphasized

Various speakers discussed the concepts, components, and control techniques of integrated pest management – IPM – also known as integrated pest control. Integrated pest management is the reduction of a pest species or group of such species to a level at which they constitute no significant restraint to a crop or other resource, through an understanding of their ecology and the use of a variety of methods and techniques. Speakers noted that IPM seeks maximum use of naturally occurring pest controls, including weather, disease agents, predators, and parasites. Use of crop varieties possessing pest resistant characteristics and cultural or environmental management techniques (such farming practices as crop rotation, planting and harvesting schedules, and destruction of postharvest crop residues) are emphasized as primary management components. Artificial control measures, notably chemical pesticides, are employed only as required to reduce and maintain pests at tolerable levels based on criteria developed to identify when and where control is truly justified. The ultimate objective of IPM is to control pests in an economically efficient and environmentally sound manner. By using pesticides selectively and judiciously, IPM promises to prevent needless insult to the environmen and human health at minimal costs.

An important premise when developing an IPM programme is that any control procedure may produce unexpected and undesirable effects. Use of chemical pesticides has dramatized the point that any single control procedure can have unexpected and undesirable consequences. But the unilateral use of any of the alternative techniques – even biological control and pest resistant crop varieties, for example – can have similar consequences and must be carefully considered in an ecological context before and after adoption.

Though the term integrated pest management was first articulated by insect control specialists, the IPM concept is applicable to all classes of pests and all the pest control disciplines have shared in its development and implementation. Numerous examples were given during the Seminar and Workshop to show that IPM promises cost-effective solutions for a wide variety of pests. Although IPM has not developed significantly in any crop or other resource in the Caribbean, participants from the region showed much interest in the approach and identified several areas where it has promise.

2. The Agromedical Team Approach – an Important Part of Pest and Pesticide Management

The Seminar and Workshop was the first organized effort to bring Caribbean agricultural and health specialists together to address pest and pesticide problems mutually affecting their discip-

lines. The discussions at this gathering clearly illustrated the advantages of integrating the disciplines of agriculture and health when developing policies and programmes in pest control. The agricultural and health disciplines share many similar concerns — improved nutrition, worker safety, and environmental protection, for example. Yet the efforts of one discipline may conflict with the other, if efforts of the two are not coordinated. For example, heavy use of DDT to control cotton insect pests in Central America has so modified the mosquito habitat as to result in the evolution of insecticide-resistant malaria mosquitoes, thus adding to the human health problem.

The so-called "agromedical" team approach strives to coordinate the activities of agricultural and health disciplines in the development of pest control policies and programmes and, in doing so, to prevent such conflicts of interest. The approach involves the interdisciplinary application of agriculture, applied chemistry, and medicine in producing and supplying wholesome food to the population.

The Seminar and Workshop hopefully stimulated keener awareness and appreciation of the advantages when policies and programmes of agriculture and public health are synchronized and when they evolve together under a set of common goals.

3. The Workshop Reports and Recommendations

Participants of the workshops, noted above, developed reports in four areas: pesticide regulations, extension and teaching, the agromedical team approach, and research, and these appear in Annex 4. For each area, the state-of-the-art is reviewed, the obstacles and needs are identified, and recommendations are proposed.

In the opening address, the Honorable Billie Miller, Minister of Health and National Insurance of Barbados, challenged the Seminar and Workshop participants to develop recommendations concerning steps that the ministries of agriculture and health and various other institutions in the Caribbean can take to foster more environmentally sound and safer pest control (refer to Annex 5). As evident from the recommendations in the workshop reports, the participants responded admirably to the Honorable Minister's challenge. If implemented, the recommended steps undoubtedly would lead toward environmentally sound, safe, and effective pest control policies and programmes.

In the closing address, Mr. LeRoy Sisnett, Parliamentary Secretary in the Ministry of Agriculture, Food, and Consumer Affairs of Barbados and Acting Minister, assured Seminar and Workshop participants that the Barbados Government would do its utmost to follow-up and to implement the recommendations, as appropriate (refer to Annex 6).

VI. FOLLOW-UP ACTIONS

A number of important actions will be required before the Seminar and Workshop recommendations are implemented. The Planning Committee will communicate the recommendations to various national and international institutions responsible for pest and pesticide management policies and programmes in the Caribbean. However, no one of these institutions can implement the recommendations by itself. All must contribute and cooperate fully in fostering cohesive policies and programmes best suited for the region.

Increased emphasis on training in pest and pesticide management — at all levels: farmers, extension officers, researchers, and government officials — was one of the priority needs identified in the workshop recommendations. Many of the participants expressed interest in a follow-up Seminar and Workshop in 1-3 years.

CICP may assist in various aspects of training, if institutions in the Caribbean request this assistance. The University of the West Indies at Trinidad has approached the Consortium about sponsoring a three-week course on the principles and application of integrated pest management. The course is planned tentatively for August or September 1981 in St. Augustine, Trinidad. It will be developed collaboratively by UWI, CARDI, CICP, and perhaps other institutions (e.g., Commonwealth Institute of Biological Control) and structured for plant protection officers in the region.

The Seminar and Workshop Proceedings (Volume II in this publication series) and the position papers that describe the status of pesticide use and pest and pesticide management in those Caribbean countries represented at the Seminar and Workshop (Volume III) will be published concurrently with this volume.

ANNEX I

Programme of Seminar and Workshop on Pest and Pesticide Management, held at Dover Convention Centre, Christ Church, Barbados, November 3-7, 1980.

MONDAY, NOVEMBER 3

09.00	**Session 1**	**Opening Ceremony and Keynote Address**
	Chairman:	Mr. J.A. Bergasse
	Opening Address:	Hon. Billie Miller – Minister of Health and National Insurance – Barbados
09.30	Keynote Address:	"Essential Role of Pest Control in Human Health and Food Production" – Dr. Perry L. Adkisson
10.00		REFRESHMENT BREAK
10.30	**Session 2**	**The Pesticide Situation in the Caribbean**
	Chairman:	Dr. Lionel Smith

"The Pesticide Situation in the Caribbean: The Public Health Perspective" – Dr. E. Tikasingh

"The Role of Pesticides in Food Production in the Commonwealth Caribbean" – Dr. C.W.D. Brathwaite

"The Chemical Pesticide Industry Perspective – Future Trends of the Pesticide Industry and its Relevance to the Caribbean" – Dr. Richard A. Herrett

"The Pesticide Situation in the Caribbean with Special Reference to Trinidad and Tobago" – Dr. Gene Pollard

12.30		LUNCH BREAK
14.00	**Session 3**	**Current Perspectives in Pest Control**
	Chairman:	Dr. C.W.D. Brathwaite

"Methods and Approach to Rodent Control in Tropical Agriculture" – Dr. Walter E. Howard

"Current Perspectives in Insect Control in the Commonwealth Caribbean – Dr. S. Parasram and Dr. B.K. Rai.

"Current Perspectives in Disease Control in the Caribbean" – Dr. R.H. Phelps, Dr. S.Q. Haque and Dr. N.D. Singh

15.30 REFRESHMENT BREAK

16.00 "Weed Problems and Weed Control in the Commonwealth Caribbean" – Dr. John L. Hammerton

"Problems with External Parasites of Livestock in the Caribbean" – Dr. Roger O. Drummond

"The Integrated Pest Management Approach" – Dr. Ray R. Smith

"The Current Situation of some recently Introduced Pests" – Dr. A.L. Brown

18.00 RECESS FOR DAY

TUESDAY, NOVEMBER 4

09.00 **Session 4** **Background on Pesticides**

Chairman: Mr. Arnold Cruickshank

"Classification and Toxicology of Pesticides" – Dr. Virgil H. Freed and Dr. John E. Davies

"Part I: Classification, Chemistry and Toxicology of Pesticides".

"Part II: Toxicologic and Human Health Considerations of Pesticides and their Limitations to use".

"Movement of Pesticides and their Breakdown in the Environment" – Dr. Virgil H. Freed

"The Importance of a Proper Monitoring Programme" – Mr. Aziz Ali

12.00 LUNCH BREAK

14.00 **Session 5** **Background on Pesticides (Con't)**

Chairman: Mr. E.G.B. Gooding

"Guidelines for the Proper Storage, Handling and Disposal of Pesticides" – Dr. S. Parasram, Dr. B.K. Rai and Mr. J.R. Suah

"Implications of the Development of Resistance to Pesticides" – Dr. George P. Georghiou

15.00 REFRESHNENT BREAK

16.00 "The Role of Education and Communication in Pest and Pesticide Control – Dr. L. Marshall McGlamery

16.45 Plenary Session on Organization of Workshops and Preliminary Meeting of Workshop Groups

17.00 RECESS

19.00 A.Public Showing of the Film – "INSECT ALTERNATIVES"

This film has been highly acclaimed in the U.S.A. for its critical but fair-minded and realistic presentation of alternatives to pesticides, and the concept of integrated pest control, in scientifically accurate but straight-forward language. It runs for an hour.

WEDNESDAY, NOVEMBER 5

09.00 **Session 6** **The Agromedical Approach and Legislation in Pesticide Management**

Chairman: Dr. L. Harney

"The Concept of the Agromedical Approach to Pesticide Management – Dr. John Davies

"Caribbean Perspectives and Concerns in Pesticide Usage" – Dr. Phillip Boyd

11.00		REFRESHMENT BREAK
11.30	"Goals and the Purpose of Pesticide Legislation and Regulations" — Dr. Carroll Collier	
12.30		LUNCH BREAK
13.30	**Session 7**	**Panel Discussion — "Problems in the Implementation of Pesticide Regulation"**
	Chairman:	Mr. Percy Jeffers
	Panel	Dr. J.I. Tudor
		Mr. F. MacDonald
		Mr. Errol Whyte
		Dr. Richard A. Herrett
		Dr. Marshall McGlamery
		Dr. Phillip Boyd

Topics will include: Registration of Uses; Quality Control; Labelling; Transport, Storage and Disposal; Performance and Efficiency; Application; Recommendations for Use; Residues etc.

15.30	Field Trip (Organised by Dr. Eslie Alleyne)
18.00	Return to Hotels and Recess for the Day

THURSDAY, NOVEMBER 6

09.00 to 12.30 & 14.00 to 17.30	**Workshop Sessions** (Concurrent)	
	A.	"Regulatory Aspects" Leader — Mr. Percy Jeffers
	B.	"External and Education" Leader — Dr. Tom H. Henderson
	C.	"The Agromedical Team Approach" Leader — Dr. E. London
	D.	"Research Needs" Leader — Dr. E. Alleyne

FRIDAY, NOVEMBER 7

09.00	**Session 8**	**Human Intoxication and Pest Management**
	Chairman:	Dr. A.V. Wells

"Interactions of Human Nutrition and Pesticide Intoxication" — Dr. Miguel Gueri

"Benefit/Cost Analysis of Integrated Pest Management — Dr. Ronald D. Lacewell

11.00	REFRESHMENT BREAK
11.30	"Alternatives to Chemical Pesticides in Pest Management — Dr. Dale G. Bottrell
12.30	LUNCH BREAK

14.00	**Session 9**	**Reports of Workshop Groups**
	Chairman:	Dr. Mervyn U. Henry
	A.	"Regulatory Aspects"
	B.	"Extension and Education"
	C.	"The Agromedical Team Approach"
	D.	"Research Needs"
15.30		REFRESHMENT BREAK
16.00	Final Workshop Recommendations and Future Action	
17.00	Closing Address:	Mr. LeRoy Sisnett -- Acting Minister of Agriculture, Food and Consumer Affairs – Barbados.
17.30	Adjournment	

PLANNING COMMITTEE

*Dr. Eslie Alleyne	Ministry of Agriculture – Barbados
*Ms Jo-Ann Bergasse	CARDI – Public Relations
Dr. C.W.D. Brathwaite	University of West Indies
Dr. Dale Bottrell	CICP
Dr. Carroll Collier	USAID – Washington
*Mr. Peter Foye	Ministry of Health & National Insurance – Barbados
*Mr. Flynn Fuller	USAID
*Dr. John L. Hammerton	CARDI – Chairman
*Mr. Thomas King	USAID
Mr. Frank MacDonald	Ministry of Agriculture – Guyana
Dr. Ray Smith	CICP
*Dr. Augusto Villenas	Pan American Health Organization
Mrs. Isla Gilkes	CARDI – Secretary

*Local Committee

ANNEX 2

PARTICIPANTS AT THE PEST AND PESTICIDE MANAGEMENT SEMINAR/WORKSHOP

NOVEMBER 3-7, 1980

ADKISSON, Dr. Perry L. Deputy Chancellor for Agriculture, Texas A&M University System, College Station, Texas, 77843, U.S.A.

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BROWNE, Mr. Glenroy. Agronomist, CARDI, Kingstown, St. Vincent.

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CHINNERY, Dr. Louis. Lecturer in Biology, University of the West Indies, P.O. Box 64, Bridgetown, St. Michael, Barbados.

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ANNEX 3

KEYNOTE ADDRESS

ESSENTIAL ROLE OF PEST CONTROL IN HUMAN HEALTH AND FOOD PRODUCTION

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ABSTRACT

Agricultural technology has greatly increased the yields of many of the world's major food crops. However pests still inflict average annual losses of as much as 30% or more on many crops in spite of treatment with pesticides. These losses must be reduced if the world's food production system is to keep pace with the growth of the human population. Over the long term, integrative ecological approaches to crop protection must be developed that will greatly reduce pest losses while providing less danger to human health and the environment.

1. Introduction

Agricultural technology during this century has greatly increased the yields of many of the world's major food crops, most notably rice, wheat and corn. The Green Revolution has promised to feed the exploding world population. However, one only has to review statistics on population and nutrition to realize that the world food system is not working adequately for either the rich or the poor countries of the world. Possibly as many as 450 million to a billion people are hungry and malnourished, most of whom live in the developing countries where populations are destined to grow to well into the future (NAS, 1977). The United Nations Food and Agriculture Organization estimates that food production must be nearly doubled by the year 2000 if a world population that will have increased to 6 billion from a present 4.3 billion people is to be fed. In addition, this huge amount of food will have to be grown on less land as more and more of the world's best farmland is being consumed by urbanization, industrialization, recreation and other enterprises.

The National Research Council of the United States in 1977 issued a comprehensive report on world food and nutrition problems which I will briefly summarize. Associated with hunger are other matters of increasing importance, namely the rising costs of food production, unstable market conditions and increasing evidence that the quality of diet is a major contributor to health problems in all countries (NAS, 1977). All these factors affect the supply, distribution and cost of food and influence the problems of hunger and malnutrition.

The increasing costs of petroleum is compounding the problem because the productivity of the high-yielding varieties has been based on large doses of petro-derived nitrogen fertilizer and pesticides. Soaring energy prices now hinder further increases in the productivity of the world's most important food crops. Riding in close tandem with the energy crisis is a food crisis. With present agricultural technology, the two cannot be separated.

Over the long term, new gains in the productivity of food crops must be accomplished through a technology that is not so dependent on petro-energy. We must develop better methods for reducing pest losses (30% or more to many crops) by non-chemical methods. We must use new bio-engineering techniques to develop higher yielding varieties of food crops that are more nutritious, that resist the multiple adversities of pests, drouth, and soil factors that reduce yield, and that manufacture their own nitrogen.

2. The Problem of Alleviating Hunger

A. Increasing the Food Supply

If the developing countries are to increase the amount of food available to each person by at least 1 percent per year, they must increase the production of food over the next 25 years by an average rate of 3 to 4 percent per year. The amount of increase per capita will depend on how much the rate of population growth declines (NAS, 1977).

Expanding the amount of land planted to crops and increasing yield per acre are the two ways for increasing food production. Increases in land planted to crops probably will not exceed an average of 1 percent per year over the next 25 years and could be much less. Thus, increases in yield need to average 2.5 percent per year. This will not be easy to achieve or sustain, but it is encouraging that food production in the developing countries was increased on the average by almost 40 percent during the period 1965 to 1975. Major efforts, organized around improved technology, will be needed to achieve the necessary rates of increase (NAS, 1977). It is obvious that one way to achieve these goals is to reduce pest losses to crops in the field and in storage.

B. Reducing Poverty

The rapid expansion of employment and an increased supply of food are requisite to the reduction of poverty. Maximum employment of the work force simultaneously expands output and personal income, particularly for those in the lower end of the income scale. Expanding the food supply can meet the needs of the poor at lower cost and at the same time increases the national income. Simultaneously, the expansion of employment, food supply and the well being of the work force depends greatly on the introduction of more productive technologies throughout the food system that makes better use of available resources (NAS, 1977).

In many developing countries it may be more practical and profitable to expand food production by labor intensive methods rather than by adopting the agricultural technology of countries such as the United States where production is based on petroleum energy intensive methods. The question is: How do you keep the labor on the farm? This is an increasingly important problem in many countries and one that requires more attention by social researchers and government policy makers.

C. Stabilization of Food Supplies

Local, national and international measures are needed to prevent sudden shortages in food supplies and market gluts that discourage production and cause sharply fluctuating food prices. Improved technology can reduce food losses caused by weather and pests. However, appropriate national and international policies are needed to reduce instability in food supplies and prices (NAS, 1977).

D. Population Growth

Over the long term, there does not appear to be any way that technology can expand production at a rate faster than the present growth of the world's human population. There must be a reduction in the human birth rate if there is to be an ample food supply for future generations. At national and international levels, policy makers in agriculture and human health must work more closely together to appraise needs and establish goals for matching the population with the production and availability of food.

E. Role of Research and Development

A strong research base is essential if the world food supply is to be increased, if poverty is to be reduced and the instability of supply is to be moderated. There must be better adaptation of existing technology by farmers, and new technology, technology that is not so dependent on fossil fuels, must be developed if the food demands of the future are to be met (NAS, 1977).

My discussion to now has been devoted to a broad overview of the world food problem. Now I wish to discuss more specifically the problem of how crop yields may be increased by the use of integrated pest control technologies.

3. Relation of Pest Control to Food Production and Human Health

A. General Concerns

Two of the major means used to increase crop production have been largely pursued in an isolated, unilateral fashion, indifferent to potential counterproductive ecological consequences which are now evident. Firstly, vulnerability to pests has been increased in certain crops (corn to blight and cotton to certain insects) by narrowing the genetic base of varieties designed only to produce the highest yields without concurrent inclusion of genetic factors which provide resistance to pests. Secondly, the advent of new synthetic organic pesticides, such as DDT and 2,4-D, following World War II produced such spectacular control of crop pests that chemistry and merchandising of toxic chemicals has replaced the biological foundations on which control should be based.

The steady improvement in worldwide agricultural yields is directly attributable to the use of chemical pesticides and fertilizers in combination with improved varieties, irrigation, mechanization and production practices. We presently are dependent on pesticide chemicals to maintain current levels of production. The removal from use of these pesticides would lead to an immediate drop in supply and increase in price of food supplies (NAS, 1975); but, because of the problems that have been encountered in the use of pesticides, their high price and the threat of shortages in the future, new pest management systems must be developed which are less dependent on chemicals.

B. Crop Losses to Pests

Crop pests clearly cause large annual decreases in yield, and the levels of loss that would occur without the use of pesticides are difficult to estimate. In the United States, even with the use of pesticides, the annual loss to pests is estimated to be about 30 percent for cotton and soybean and 10 to 20 percent for fruit. The economic impact of the increased pest losses that would occur if no pesticides were used on grains and soybeans would increase the prices of food grain, feed grain and oilmeal by 60, 200 and 71 percent, respectively (OTA, 1979).

Even greater losses are being sustained in many developing countries where technologies are not equal to those in the U.S. Tremendous losses to pests are occurring even though vast amounts of pesticides are being applied for their control. In fact, the amount of land currently cultivated is 50 percent greater than would be required if there were no pest losses to crops. The amounts of fertilizer, energy, labor, capital and other inputs to crop production are also correspondingly greater (OTA, 1979). The total direct loss of food to pests is enormous. The world cannot continue indefinitely to sustain this amount of pest-inflicted crop loss without serious consequences to our ability to produce needed quantities of food. In fact, improved pest control technology offers one of the best and quickest ways for increasing food production on a global scale. What is needed is ample funds for research and development and for training and employing the people needed to implement the technology.

C. Vulnerability of Contemporary Crop Production Methods

The very success of pesticidal chemicals has led to the great reliance on their use and much of the world's agriculture is dependent on a chemical technology. Yet there are signs of vulnerability in this system of pest control that distress those concerned with the future of crop protection.

The continued development of genetic resistance to pesticides in major pest species constitutes one of the most important problems facing agriculture and the pesticide chemical industry today. Efficacy of many existing chemicals is decaying and for insects the rate of discovery of new classes of effective chemicals is not keeping pace with the advent of new resistant strains. There now are well over 200 species of insects and mites which are resistant to one or more chemicals. More recently, pesticide-resistant strains of plant pathogens and weeds have been discovered (NAS, 1975).

D. Disruption of Natural Control

Chemicals applied for crop protection frequently have an adverse affect on non-target species, and particularly on the natural enemies of pest insects and mites. Thus, when cotton farmers spray for the boll weevil or lygus bug they may unleash severe outbreaks of bollworms (Bottrell and Adkisson, 1977); when fungicides are applied to apples they may induce problems with

spider mites; use of herbicides to control weed and ground cover vegetation in orchards may cause a reduction in predators of certain spider mites of apples (Croft and McGroarty, 1973); fungicides applied to soybeans for plant disease control may unleash equally damaging outbreaks of foliage-feeding caterpillars; and insecticides applied to alfalfa for aphids may drift into adjoining soybean or cotton fields unleashing attacks by *Heliothis* sp. and other lepidopteran pests.

The numerous pesticide-induced outbreaks of secondary (or occasional) pests that have been observed in U.S. crops and orchards prove that many, if not most, insects and mites in a given agroecosystem have inherently effective natural enemies present. The enemies generally keep the pest populations below economically damaging levels, if not disturbed by external factors. The totality of actual and potential pests in a crop can be thought of as a pyramidal iceburg. The **actual** (or key) pests (those which lack effective natural enemies) show above the surface and are readily recognized, the potential pests (which represent 80 to 90% of the pest species) are hidden and will remain innocuous if their natural enemies are not decimated. The principal problem is how to control the 5, 10, or 15 percent of the main pests (the key pests) without upsetting the balance of the vast majority that are under natural control (DeBach, 1964).

E. Environmental Problems

The treatment of crops with pesticides has produced many unintended side-effects which have adversely affected farmers, i.e. killing of bees and other pollinators, contamination of milk with chemical residues, destruction of cotton by drifting phenoxy herbicides applied to corn, sorghum or pasture, etc. In addition, pesticides have affected all levels of ecological organization including: the killing of birds and insect and fish predators of mosquitoes; detrimental effects on the reproduction of raptorial birds; accumulation of pesticides in the high food chains; alteration of species composition; and development of insecticide-resistance in non-target pest species, namely several species of disease-vectoring mosquitoes that inhabit the cotton ecosystem.

There also is the direct problem of acute poisoning of farm workers, pesticide applicators and others who come into direct contact with these toxic chemicals. Perhaps, of even more concern, are the yet ill-defined long-term problems of cancer, birth-defects and nerve disorders that may have their origin in exposure to certain pesticides.

If world food production is to be expanded, it is essential that harmful crop pests be controlled. Chemicals presently provide the most reliable immediate solution for suppressing outbreaks of insects and mites and herbicides are being increasingly used to replace hand labour for controlling weeds. Chemicals will continue to be necessary for the control of certain pests. However, we must learn to use them strategically, in minimum quantities and with minimal hazard to people, other non-target organisms and the overall environment. We also must be sure that a chemical applied for one problem does not induce a second problem that requires the use of more, and perhaps, different chemicals. Over the long term, we must develop and implement an integrative ecological approach to pest control that will provide better protection to crops and less danger to human health and the environment than current methods which depend on the intensive use of chemicals.

4. Conslusions

A broad spectrum of research and development activities, ranging from the implementation of existing technology to the search for new scientific frontiers, is required if we are to meet the demands that will be placed on food production systems by the end of this century. There is a particular need for biological innovations which will lead to greater crop yields and for research on farming systems that will put all the pieces together. But science and technology alone cannot solve the world's food problem. The various governments are going to have to establish better policies and organizations for administering science and technology and for extending new knowledge to producers, processors and distributors of food. There must be better incentives and opportunities for the involved scientists and extension specialists.

Over the short-term, there is reason to be optimistic that we can produce all the food we need. But the resources of this earth are limited and in the long run nothing is more important for improving the world food problem than the reduction in the human birth rate. Here again, is a place where agricultural and medical policy makers should get together to determine optimum population sizes in relation to the capacity of the food production system.

This conference offers a small start in this direction by bringing agricultural and medical experts together to discuss an agro-medical appraoch to certain specific problems inherent in present methods of protecting crops from pests. I trust that our efforts will be successful and will lead to the expansion of an agro-medical approach to the future problems of food production and human nutrition.

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ANNEX 4

REPORTS OF WORKSHOP GROUPS

A. REGULATORY ASPECTS

Leader – Mr. Percy Jeffers
Rapporteur – Mr. Frank MacDonald

The Group firstly discussed existing Pesticide Legislation in the countries of the Caribbean, with a view to making recommendations for improving it and for ensuring that it was effectively enforced. Secondly, the Group studied the regulatory aspects of Pest Management and Plant Quarantine legislation, and made recommendations for improvements specifically in terms of a unified regional quarantine law.

1. PESTICIDE LEGISLATION

Some countries of the Region do have Pesticide Control Acts while other do not. In some countries where legislation has been enacted, it has not yet been proclaimed, or else has not yet been effectively enforced. In five countries the Regulatory Board has neither been appointed nor has it met.

The national Acts vary considerably in their scope but mostly are concerned with the importation, registration, sales, storage and use of pesticides. In one country the Act made provision for the licensing of pest control operators. Little attention has been given to impact montoring, including pesticide residue levels and general surveillance of the fate of pesticides in the environment.

Recommendations

- where there is currently no Pesticide Legislation, it is strongly recommended that appropriate legislation be enacted as expeditiously as possible. The model proposed by Dr. G. Gibbs of the former Commonwealth Caribbean Pesticide Unit is recommended.

- where Pesticide Legislation has been enacted but not proclaimed, it is recommended that this be done without delay.

- all Regulations under each act should be enforced, and should cover manufacture, formulation, registration, labelling, sales, use, protective clothing, application equipment, storage, transportation etc. Inspectors should be appointed and full and proper records kept of all matters pertaining to pesticides.

- facilities for pesticide and pesticide residue analysis should be expanded or increased, so as to be able to monitor pesticide quality, and residue levels in the environment. If national laboratories cannot be up-graded to carry out such analysis, the capacity to make extractions of materials to be sent to a reference laboratory should be developed. CARDI plans to expand its Pesticide Analysis Laboratory in Trinidad and two other less elaborate laboratories are planned for the Caribbean. CARDI and CICP should be asked to develop guidelines for the design and equipping of small laboratories to prepare material for the reference laboratory. Training of technicians will also be necessary.

The Group strongly endorses the Agromedical approach to Pesticide Managements, and recommends that Governments seriously consider adoption of such an approach. In addition the Group endorses the need for education and extension by all appropriate methods to make the entire community aware of the importance of proper pesticide management.

2. REGULATORY ASPECTS OF PEST MANAGEMENT

The FAO/Caribbean Plant Protection Commission has drafted a model Act for Plant Quarantine, which was approved and recommended for adoption in 1972. It has a series of regulations and schedules.

It is recommended that all Countries of the Caribbean adopt this model for Plant Quarantine Legislation as soon as possible.

It is also recommended that Countries up-grade their staff and facilities for an effective Plant Quarantine Service.

B. EXTENSION AND EDUCATION

Leader – Dr. T.H. Henderson
Rapporteur – Mrs. Janice Reid

The Group emphasised the unsatisfactory present level of pest and pesticide management in the Caribbean Region, and expressed concern at the lack of awareness of the subject in the Region. It was therefore strongly recommended that education and extension work in pest and pesticide management be improved and maintained at a high level.

The Group identified problem areas and the target groups where appropriate, and made specific recommendations as to the means whereby the awareness and the knowledge of these target groups could be increased.

"Extension" has been used to refer to all informal advisory work in Agriculture, Health, Community Development, Education, Home Economics and related fields.

The problem areas, target groups, objectives and means are outlined below.

1. LEGISLATION AND PESTICIDE CONTROL BOARDS

1.1 Enactment of Legislation regulating Pest and Pesticide Management and Enforcement of such Legislation.

Target Group: Policy Makers
Objectives: To generate awareness among Government Ministers and Officials in the Agricultural, Health and Finance Ministries of the need for legislation and for functional Pesticide Control Boards, and on the need for adequate resources to enforce the legislation.
Means: (i) These recommendations should be presented to the CARICOM Food and Nutrition Strategy Meeting, scheduled for November 24th, 1980, et seq. in Jamaica, and Dr. Philip Boyd of the CARICOM Secretariat should be asked to press for action on these recommendations*.

(ii) Government Officials attending that Meeting should be asked to make formal proposals to their Ministers for approval and implementation of these recommendations.

(iii) As a matter of urgency, effective Pesticide Control Boards should be established in those countries of the Region where they do not already exist.

1.2 Pesticide Control Boards

Objectives: To advise Governments on the pesticide legislation needed, and on any charges required, and to enforce such legislation.
Means: (i) The collection of relevant existing legislation on pesticides.

(ii) The maintenance of up-to-date information on legislation and regulations controlling pesticides.

(iii) The distribution of information on legislation and regulations to all importers, manufacturers and distributors of pesticides and to all persons concerned in the sale and use of pesticides.

* *Editor's Note: This was done by Dr. Boyd.*

1.3 Access to International Information by Pesticide Control Boards

Objectives: To establish channels for the flow of up-to-date information to Pesticide Control Boards on the international status of individual pesticides, including uses, restrictions, safety aspects, tolerances, etc.

Means: The Pesticide Unit of CARDI should be made responsible for the collection, collation and dissemination of information on pesticides. The Unit will need an increased budget and additional staff. To achieve this the Unit should establish contacts with the Environmental Protection Agency (of the U.S.A.), the Pan-American and World Health Organisations and other relevant national and international agencies.

2. INCREASE IN THE NUMBER OF PERSONS TRAINED IN PEST AND PESTICIDE MANAGEMENT IN THE REGION

2.1 Training of Professional and Para-Professionals

Objectives: To increase the number of persons with specific and locally relevant training in pest and pesticide management.

Means: (i) The establishment at the University of the West Indies of specific courses in pest and pesticide management at both the certificate and post-graduate diploma levels. The course content should be sufficiently comprehensive to service the following areas:

crop protection
animal health
public health
plant and animal quarantine
commercial pest control
agricultural extension
medicine
nursing

(ii) The urgent need for such training requires that funds be sought, or made available, as soon as possible for the establishment and operation of such courses.

(iii) The training of medical personnel (doctors, nurses and paramedics) should include adequate instruction in the identification and treatment of pesticide poisoning.

(iv) Refresher courses in both pest and pesticide management for agricultural extension officers and for medical personnel are needed as a matter of urgency.

3. SUPPORT FACILITIES

3.1 Laboratory facilities and other Resources for Pest and Pesticide Management Personnel

Objective: To provide or up-grade the laboratory and other facilities necessary for the correct identification of pests and diseases.

Means: (i) The provision in all countries of national or local laboratories with basic equipment (e.g. microscopes, hand lens, reference collections, manuals etc) for the proper recognition and identification of pests and diseases.

(ii) The preparation of simple illustrated guides or manuals for rapid in-field identification of pest and disease problems.

4. IMPROVEMENT IN COMMUNICATION

4.1 Improvement in Communication among Governmental Organisations

Objective: To develop better communications among Governmental Organisations concerned with pest and pesticides management so as to avoid wastage of resources and encourage more coherent inter-departmental and inter-organisational programmes.

Means: No specific means were agreed. The methodology must take cognizance of the organisational structure of the country. Pesticide Control Boards may possibly be the unifying agency and the main forum for the exchange of information.

4.2 Improvement in Communication between Governmental, Commercial, and Private Organisations

Objective: To develop better communications between Governmental Organisation (inlcuding Pesticide Control Boards), Commercial and Private Organisations concerned with pest and pesticide management, to ensure prompt exchange of technical and regulatory information.
Means: See 4.1 above.

4.3 Improvement in Communication between Regional Organisations

Objective: To ensure effective communication so as to avoid duplicaton of effort and inter-agency co-ordination in policy, planning and programmes.
Means: (i) The CARDI Pesticide Laboratory and Information Section should act as the primary repository for information on pest and pesticide management and serve as the main distribution centre. Funding will be required for this.

(ii) Other information agencies (e.g. the Information Section of the Technology and Energy Unit of the Caribbean Development Bank) could collaborate in this area.

5. GENERAL EDUCATION ON PESTICIDES

5.1 Users

Target Group: The public at large.
Objective: To increase public awareness concerning the hazards associated with improper and indiscriminate use of pesticides.
Means: (i) Under the aegis of the Ministries of Agriculture, Health, Education and Community Development, utilize all available communications media viz.

agricultural radio programmes
educational broadcasts
agricultural extension newsletters
newspapers and magazines
extension and information bulletins (including those published by UWI and CARDI)
television programmes

(ii) The holding, in each country of a "Pesticide Awareness Month',' as frequently as appropriate, and beginning as soon as possible.

5.2 Trainers

Target Group: All those concerned with training users and applicators of pesticides.
Means: (i) The provision of intensive short courses for pest and pesticide management personnel in relevant Ministries and regional organisations who are involved in training.

(ii) The provision of regular annual in-service refresher courses for such trainers.

5.3 Applicators

Target Group: All those handling and applying pesticides during the course of their work.
Means: (i) Train, through short courses and demonstrations, farmers and other applicators of pesticides in the proper handling and application of pesticides. Such courses should be organised as soon as possible.*

**Editor's note: A "train the trainer" programme for Jamaica is being organised in mid 1981. Funding has been obtained from CICP and USAID.*

(ii) Through the relevant Trade Unions and Ministries of Labour, emphasise and stress the need for correct handling of pesticides.

(iii) Make applicators aware of alternatives to pesticides, how these may be used and utilised in integrated pest management programmes.

6. COMMUNICATION BETWEEN RESEARCHERS, EXTENSION OFFICERS, AND USERS OF PESTICIDES

Target Groups: Researchers in National and Regional Organisations, Extension Officers in Pest and Pesticide Management, Crop Protection etc., and Applicators and Users.

Means: (i) Formalise regular meetings of all the target groups, as forums for the exchange of information on research problems and needs, and on research findings.

(ii) From these meetings determine what information is already available to provide solutions to problems, and what research is necessary.

(iii) Establish priorities for research and determine what agencies undertake this research.

(iv) Ensure that research results are widely disseminated among all target groups.

C. THE AGROMEDICAL TEAM APPROACH

Leader – Dr. E. Edgar London
Rapporteur – Dr. R. Doon

1. AGROMEDICINE – ITS NATURE AND SCOPE

The people of the Caribbean community have a vital stake both in increased food production and in the protection of human health from vector-borne diseases. Pesticides are essential if these goals are to be met, but must be used so as to avoid harmful effects. Clearly, both agriculture and medicine are inseparable partners in meeting these needs.

Out of this mutual concern between medicine and agriculture has developed an interdisciplinary subject – agromedicine. It is the mission of agromedicine to improve health, nutrition and economic welfare by promoting increased productivity and by preserving the integrity of the environment. The interdisciplinary practice of agromedicine involves an approach to community health of both man and his environment. This concept of raising food production is preventive, thereby avoiding the necessity of detailed recommendations that may constrain food production.

The use, or perhaps more properly the misuse, of pesticides entails three sources of risk to man, other organisms, and the environment:

- The risk of direct poisoning (of man) from over-exposure. This may occur during manufacture, formulation, transport or application of pesticides. Over-exposure may also occur from spray-drift or contamination of food and water supplies. Exposure may be by direct ingestion, respiration or by dermal contact.

- Accumulation in the environment of persistent residues of pesticides. This is a more subtle and long term source of risk.

- The development of resistance to pesticides on the part of pests. This is a major problem both in agriculture and in public health.

2. OBJECTIVES OF AGROMEDICINE

These are as follows:

To achieve an integrated programme of education and regulation to encourage safe pesticide management. Activities to be covered must include

Importation
Storage
Transportation
Use
Residues
Pollution Control (i.e. Environmental Protection)
Disposal
Worker Protection
Nutrition in relation to health, productivity and response to exposure to pesticides.

- To develop the capabilities for training at all levels, so as to produce the scientists and technicians necessary for agromedical programmes.
- To develop appropriate laboratory facilities for monitoring humans, food and the environment.
- To establish agromedical teams with sufficient support to conduct effective programmes.
- To prepare an inventory of the relevant manpower and material resources in the Region.

3. PROCEDURES

It is recommended that Agromedical Teams be formed at the national, district and village levels. The suggested composition of such teams is as follows:

(a) At the National Level, it is recommended that the Team be made up of representatives of the following

Ministry of Agriculture
Ministry of Health
Ministry of Labour
Ministry of Education and Culture
National Food and Nutrition Council
Scientific advisors representing the following disciplines: public health, entomology, toxicology, environmental science, chemistry (analytical and environmental), pharmacology, agricultural economics, and other as need indicates.

The responsibility of the National Teams should be as follows:

- The planning, direction, and administration of the agromedical programmes and co-ordination of the efforts of the district and village committees.
- The direction and support of technical activities and research.
- The collection and evaluation of statistics on agromedical data.
- The development of laboratories and laboratory services for monitoring food, feeds, humans and the environment, and to maintain a national quality assurance programme for other laboratories.
- The support of research on agromedical problems. Direction and co-ordination of the implementation of the agromedical program.

- A programme of public information to acquaint agriculture, industry, pesticide and agricultural workers and the general public with agromedical practices and problems.

- The development and implementation of training programmes for individuals responsible for the agromedical programmes covering such topics as integrated pest management, nutrition, hygiene, and disposal of chemicals.

- The provision of recommendations and appropriate regulations for pesticide applicators.

(b) At the district level, the agromedical team or committee should be comprised of experienced staff from the Ministry of Agriculture and such scientific advisors as may be necessary. In addition the assistance of the Ministry of Health and the Ministry of Labour would be sought as required.

The responsibilities of the district agromedical teams would be as follows:

- The supervision of the implementation of the agromedical program in the villages giving attention to nutrition, hygience, and pesticide management.

- The training of applicators in the proper use of pesticides for protection of themselves, the public and the environment.

- The provision of training for other concerned personnel.

- The compilation of information and statistics and appropriate reports.

- The conduct of investigations of problems that may arise from poisoning or other causes, and the assessment of any environmental impact.

- The medical surveillance of applicators and other exposed workers.

- The maintenance of a system of monitoring of pest populations to observe any changes that may occur.

- The conduct of a vigorous health education programme on agromedicine and all aspects of pesticide management.

(c) At the local or village level an agricultural extension officer with training in agricultural hygiene, preferably at university level, should work with volunteers of the village and appropriate health personnel.

The responsibilities of the agromedical personnel at the village level would be:

- The instruction and advising of farmers concerning appropriate agromedical practices in agriculture and health with special reference to pesticide management, nutrition, control measures, selection of proper chemicals, use of chemicals, and avoidance of poisoning.

- The delivery of first heath care (first aid) to poisoned individuals including the use of antidotes. Such individuals should be sent on to appropriate centres for more advanced treatment.

- The investigation of incidents of poisoning. The provision of reports and compilation of statistics. The training and retraining of applicators in the proper application of pesticides.

- The education of field workers, the general public, and employers as needed.

- The collection of samples for analyses including food, water, soil, and other environmental samples.

4. SUMMARY OF RECOMMENDATIONS

The establishment of agromedical programmes at the regional, national, local and district levels, integrating the existing skills and resources of the Ministries of Agriculture and Health.

The promotion of closer co-ordination and co-operation between member countries of the Caribbean region.

The early establishment of the proposed Caribbean Environmental Health Institute.

The strengthening and developing of lines of communication and co-operation betwen the Ministries of Agriculture and Health.

The implementation of a programme of Urban Pest Management with special reference to the operations of private pest controllers in the domestic environment.

The establishment of appropriate training courses for agromedical workers.

The establishment of laws or regulations on the safe use of Pesticides, where none exist, and the strengthening of the facilities for enforcement.

The establishment of a network for the diagnosis, confirmation and monitoring of human exposure to pesticides.

The establishment of a programme for the education of the general public in the safe use of pesticides.

D. RESEARCH NEEDS

Leader – Dr. Eslie Alleyne
Rapporteur – Mr. Tim Miklasiewicz

The Group recognised that the countries of the Caribbean are heavily dependent on agriculture, that pest problems of crops and livestock can result in unacceptable losses, and that such losses can be reduced by the use of chemical pesticides.

The Group was also concerned that pesticides have brought with them many problems, including those of pest resistance and environmental pollution, which have so far received little attention. They therefore concluded that there was a pressing need to reduce pesticide usage, and that relevant research was urgently needed.

The following specific research areas were identified:-

1. ADAPTIVE RESEARCH

Major emphasis should be placed on field-oriented research focusing on projects that will lead to increased productivity by reducing pest damage while at the same time protecting man's health and that of his environment. Careful selection of projects and programmes will be necessary, and priorities must be established.

Adaptive research should receive priority attention. The group recognised the need for background (or basic) research, but suggested that this be the responsibility of the University of the West Indies (UWI).

The Group cited, as examples, the following pest problems – both general and specific – that merit prompt attention.

Weeds are estimated to causes about 20% loss in yield of vegetable crops in the Region.

"Moko" disease destroyed over 12,000 acres of bananas in Trinidad a few years ago and is

now causing much damage in Grenada. It poses a serious threat in Dominica, Jamaica, St. Lucia and St. Vincent and elsewhere. Work has begun to remedy this problem in Grenada.

Froghopper control in sugar-cane in Trinidad presently costs about TT$600,000 (US$ 250,000). This insect has shown resistance to DDT, cyclodiene and malathion, resulting in increased difficulty and costs of control.

Virus infestation of yams in Barbados has been estimated to give 30 - 40% loss of yield. A new propagation technique has been developed to produce virus-tested planting material.

Insect pests of livestock reduce meat and milk production.

Insect pests of man continue to be vectors of malaria, dengue fever etc and are deterrents to tourism.

2. INTEGRATED PEST MANAGEMENT

An effective way of reducing dependence on pesticides and expenditure on pesticide imports is to maximise the use of other (non-pesticide) measures. The principles of this strategy of Integrated Pest Management (IPM) is already familiar to many scientists in the Caribbean. This does not, however, obviate the need for research, and certain components of IPM need to be researched, in order to better develop a "systems approach".

Population monitoring, to estimate population levels, has been attempted for some pests of crop and livestock, but probably not for public health or urban pests. **The development of sound sampling techniques is essential for effective pest monitoring.**

Economic threshold levels, at which economic losses in yield and/or quality occur are largely unknown for most pests of crops and livestock in the Caribbean. At present pesticide application is often routine, regardless of whether pest numbers or incidence, and the related damage, are likely to cause economic loss. **Research on Economic Threshold Levels is therefore urgently needed.**

Cultural Practices include the use of resistant varieties, crop rotation, mulching, cultivations etc. which can reduce the need for routine pesticide applications. **More research on such practices and their incorporation into IPM programmes is needed.**

Biological Control of pests should be encouraged by conserving indigenous natural enemies, by augumenting their number by releases and by the importation of exotic parasites, predators and pathogens. Barbados has a long history of biological control in sugar-cane, and the moth borer *(Diatraea saccharalis)* has been controlled primarily by this means, with an estimated saving of Bds$3M (US$1.5M) per year. **It is recommended that increased research on biological control be given priority, particularly in view of pesticide resistance in certain pests.**

Resistance to pesticides necessitates more frequent application, increased dosages or change of pesticide. All these can increase the cost of control, aggravate environmental contamination and destroy beneficial natural enemies. Resistance has been found in some of the major vectors of human disease in the Caribbean, especially in the mosquitoes *Culex quinquefasciatus*, *Aedes aegyptii* and *Anopheles albimanus*. Resistance to DDT and dieldrin in *A. aegyptii* has enabled the species to re-establish in the Region, despite its earlier eradication.

This species is presently resistant to some organophosphates and this may have been partially responsible for the recent epidemic of dengue fever. FAO has resistance test kits for some human health pests, but comparable kits are not yet available for agricultural pests. Reports suggest that resistance to certain pesticides is now present in several important pests of Caribbean agriculture, including sugar-cane froghopper (Trinidad), sweet potato weevil (Barbados), and diamond-back moth (Antigua). **It is recommended that techniques for the detection of resistance should be developed, so that the incidence of resistance can be rapidly detected and appropriate counter measures taken.** Procedures for detecting and monitoring resistance in several pests of agriculture have been published in FAO Plant Protection Bulletins.

Pesticide screening techniques should be developed and agreed among the Countries of the Region, and exchange of research results facilitated. This recommendation recognizes, notwithstanding earlier recommendations, that pesticides will continue to be important.

3. RESIDUES

Despite the widespread and continued use, over many years of pesticides in the Region, little is known about their fate in the various ecosystems. Such information is important, especially where contamination of drinking water may occur.

The CARDI Pesticide Laboratory in Trinidad should be expanded both in personnel and facilities. Consideration should also be given to the establishment of a second laboratory, in view of the distances between Countries.

4. PRIORITY PEST PROBLEMS

The Group drew up a list of major pest problems, which merit priority attention.

Smut and rust of sugar cane
Lethal yellowing, wilt and red ring of coconut
Nematode damage to vegetables
Rodent control
Bird damage to crops
Tick-borne diseases of livestock
"Moko" disease of bananas and plantains
Seed-borne pathogens of vegetables

ANNEX 5

Opening Address by the Hon Billie A. Miller, Minister of Health and National Insurance — Barbados.

Mr. Chairman, ladies and gentlemen, I am very pleased to be here with you today at the beginning of this Seminar. Any work aimed at preserving and improving the environment is of obvious importance. In Hanlon's book on Public Health Administration, there is a quotation ascribed to Hollis which says: "The need for a healthful environment is important to all peoples; it cuts across boundaries of occupation, race, class and politics. If it differs from neighbourhood to neighbourhood and from region to region, it differs not in fundamentals but only in complexity." This quotation came to mind when I saw from your programme the very impressive list of sponsors of this Seminar; when I noted its multi-disciplinary nature, and that persons were coming not only from the region but from further afield.

Pests and pesticides are, of course, very much a part of the environment. Diseases spread by mosquitoes, rats and other pests have scarred humanity through the course of history. Damage to the agricultural sector has been equally devastating in the light of the world's growing number of undernourished people. Although disease vectors and agricultural pests can be destroyed by genetic and other means, the use of pesticides is necessary at present.

There has been a tremendous increase in the use of these products in recent years and these chemicals, despite their usefulness, may be extremely hazardous. If such pesticides are to be utilized, proper precautions must be taken in their manufacture, their storage, their handling, their use and their disposal. In developing countries laws may be lacking and even where they do exist the governments may not have the means of implementing them. Communication between Ministries is often poor. Those in the field who actually use pesticides are often unaware of the dangers of the chemicals, so that if some threat to health or life inadvertently occurs, they may not recognize it or may not know how to deal with it. We are all aware of how difficult it is at times to get workers to wear protective clothing and this means that they really do not appreciate the risks they take.

Areas of environmental contamination are becoming for too common. The "Love Canal" catastrophe in the U.S. has drawn world-wide attention to the problems of chemical waste. Pesticide poisoning has resulted in tragic deaths in recent years:

In Mexico 16 people died from eating flour and sugar stored in paratnion drums.

In Columbia 63 people died and 165 became seriously ill from eating flour contaminated by parathion during transport by truck.

In Jamaica, flour contaminated by parathion caused the deaths of 17 people despite the fact that the chemical had been banned in that country for over 10 years. It was determined that the fateful flour was shipped by a West European Country.

These examples illustrate the need for proper inspection procedures, regulations and education.

Developing countries must be especially conscious of the need for scrutiny in matters concerning pesticides. Such countries must not become the dumping ground for unwanted chemicals. It is noted that an estimated 40 million kilograms of pesticides under United States Environmental Protection Agency (E.P.A.) jurisdiction, that were exported in 1975, were not approved for use in the U.S.A. Controllers and regulators of pesticides in various countries must carefully examine the scientific evidence that is now becoming more available, so as to protect the workers, the public and the overall environment.

Information on the hazardous properties of pesticides are supplied by various organizations and services including the World Health Organization and the International Register of Potentially Toxic Chemicals (IRPTC), established by UNDP. Such information and scientific data must be utilized by planners, scientists and other managers of our ecosystems.

Special care must be taken in the use of pesticides to ensure that the water resources of our countries are protected. We know that certain pesticides are very resistant to biological degradation and therefore persist in soils and leached water for many years.

Here in the Caribbean the problem of pests and pesticides has not gone unnoticed. The Caribbean Health Ministers Conference in 1977 requested the CARICOM Secretariat to prepare an Environmental Health Strategy for the Caribbean Community. This significant document was prepared in 1978 with the collaboration of numerous organizations, governments and agencies. I cannot mention them all but hope you will forgive me if I pay public tribute to one individual, Mr. Arthur Archer of Barbados, at present Manager of the Bridgetown Sewerage Project, who through the years has given unstintingly of his time and expertise for environmental matters in Barbados and the whole Caribbean.

The Environmental Health Strategy deals with the total environment, but I know that this Seminar will be discussing the section on pesticides and the follow-up which has been done since the preparation of the Strategy. You will be pleased to learn that at the last Caribbean Health Ministers Conference in Grenada in July of this year there were seven different resolutions on the environment; of these one was on the Environmental Health Strategy, one on the Regional Environmental Health Institute - which is to be located in St. Lucia - and one on Control of toxic pesticides.

In Barbados there is a Pesticides Control Act as well as Regulations made under the Act. I expect that at this Seminar this legislation will be carefully examined and improvements suggested. The Government of Barbados has just appointed a Sub-Committee of Cabinet to plan and implement a programme for continual clean-up of the environment. I do not think there is any doubt that this Government is committed to the improvement of the environment.

I am expecting participants of this Seminar to formulate sound recommendations on the management of pesticides and lay the frame-work for projects and action-plans which will realistically fulfil these recommenations. I would therefore like to suggest that these recommendations go into some detail. For example, if there is a recommendation on training, it should mention who should be trained, and where, and for how long; if there is a recommendation for closer collaboration of the private sector and government it should include suggestions as to how this should be achieved. And so on for recommendations on community education, research, and whatever you suggest. This will be the beginning and it is then for the governments to follow through. It is my sincere hope that in a year's time or so, if the question is asked of each government, "Do you have a National Plan for control of pesticides?" the answer will be a resounding "Yes".

It is only left for me to wish you all a successful week. This is an important meeting and I hope that your discussions will ensure that a safe and healthy environment exists and is preserved for future generations.

I have great pleasure in declaring the Seminar and Workshop open.

ANNEX 6

Closing address by Mr. LeRoy Sisnett, Parliamentary Secretary in the Ministry of Agriculture, Food and Consumer Affairs and Acting Minister.

Mr. Chairman, Ladies and Gentlemen: It is my pleasant duty to address you at the end of what I hope has been a very successful Seminar and Workshop. I am particularly pleased to see representatives from so many countries participating. Much concern has been expressed over the indiscriminate use of pesticides and I am sure that in your deliberations you would have examined such areas as the amount of pesticides left in food after harvesting, the residues of pesticides that may penetrate the water table, and the approach which should be made to pest management, research and dissemination of information.

I know that the Government of Barbados has been particularly concerned about the indiscriminate use – especially on edible crops – of pesticides, and Government is considering tighter control of the importation of pesticide and disposal of containers of potentially dangerous substances. The Pesticides Control Act came into operation in 1974 and a Pesticide Control Board established under this Act advises the Minister on matters relevant to the control and use of pesticides. Action has also been taken for the appointment of two Inspectors to monitor adherence to regulations and to check the use of pesticides after they have been sold.

I look forward to your conclusions and recommendations and assure you that the Government will do its utmost to follow up and to implement them as appropriate.

I have no doubt that the recently formed Caribbean Plant Protection Society, comprising plant protection specialists in the region, will play an important role in having such decisions and recommendations pursued as well as serving as a forum for the dissemination of plant protection information throughout the region. I wish them every success and hope that the Organisation will be very active and will become an integral part of the machinery for facilitating plans for agricultural development in our respective territories.

My Ministry has been examining the Plant Quarantine legislation and I hope to have the law enacted shortly.

I must thank the Consortium for International Crop Protection (CICP) and the United States Agency for International Development (USAID) for sponsoring this Seminar and bringing together so many of the Plant Protection Officers and Health Officers of the Region.

In thanking all those who have assisted in organising the workshop – organisers and participants alike – I should like to say a special word of thanks to Dr. Ray Smith of CICP and Dr. John Hammerton of CARDI who have been able to assemble so diverse and impressive an array of resource personnel including some who are internally recognised authorities in their fields.

I sincerely hope that all the participants have enjoyed their stay in Barbados and I wish you all a safe journey back to your respective countries.

I now formally declare the Seminar and Workshop on Pest and Pesticide Management closed.

A8

Pest and Pesticide Management in the Caribbean

Consortium for International Crop Protection

Proceedings of Seminar and Workshop

CICP/USAID

3–7 November 1980

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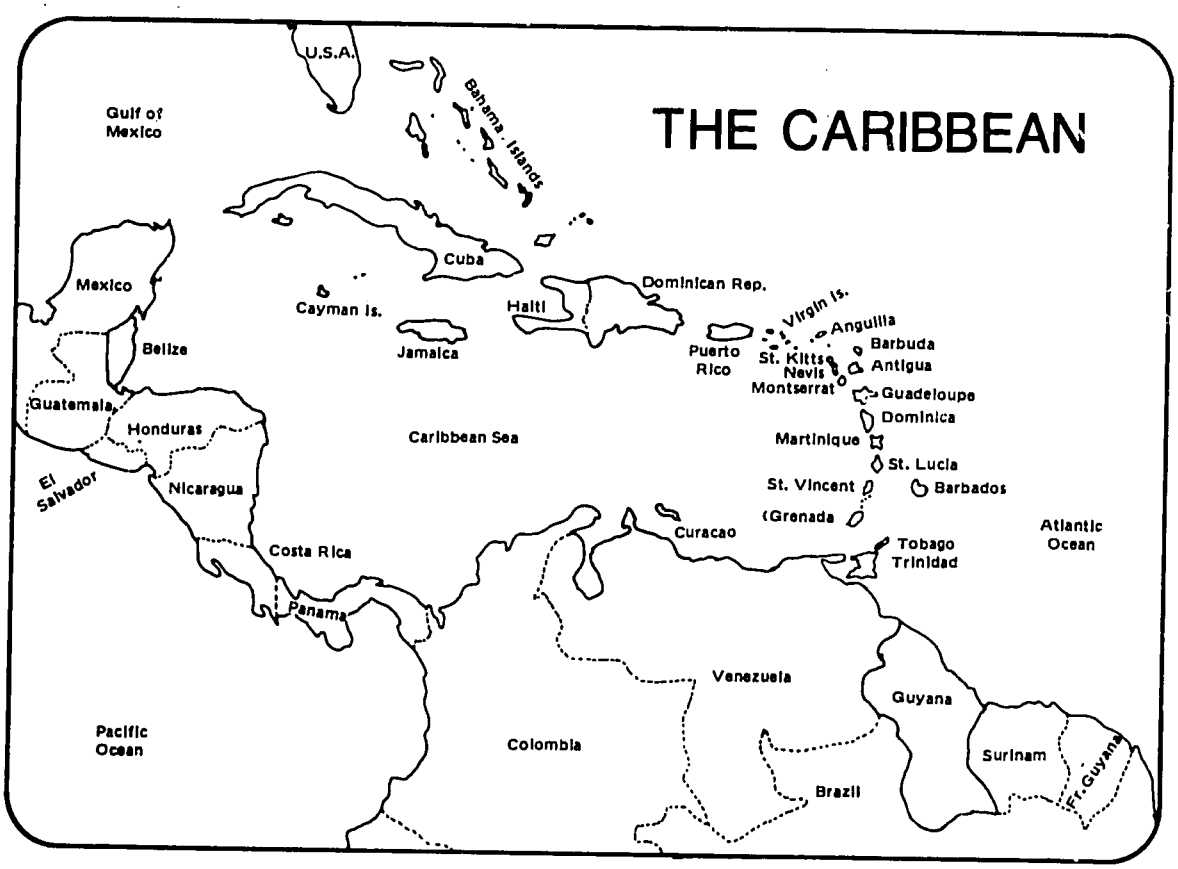

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PEST AND PESTICIDE MANAGEMENT

IN THE CARIBBEAN

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Volume II

INVITED PAPERS

OF THE

"SEMINAR AND WORKSHOP

ON

PEST AND PESTICIDE MANAGEMENT

IN THE CARIBBEAN"

November 3-7, 1980

CHRIST CHURCH, BARBADOS

VOLUME II

CONTENTS

		Page
CONTRIBUTORS		9
ABBREVIATIONS		10
EDITOR'S INTRODUCTION	E.G.B. Gooding	11
I. THE PESTICIDE SITUATION IN THE CARIBBEAN		
1. THE PESTICIDE SITUATION IN THE CARIBBEAN THE PUBLIC HEALTH PERSPECTIVE	E.S. Tikasingh	16
1. Introduction :Historical Background		16
2. Vectors of disease and/or nuisance value in the Caribbean		17
3. Pesticides in current use in the Caribbean		19
4. Resistance		21
5. Toxicological hazards		22
6. Future of chemical control of vectors		23
7. Training and monitoring		24
8. Conclusion		25
2. THE ROLE OF PESTICIDES IN FOOD PRODUCTION IN THE COMMONWEALTH CARIBBEAN	C.W.D. Brathwaite	30
1. Introduction		30
2. Factors limiting food production		31
3. Importance of pests		32
4. Importance and future of pesticides		35
5. Conclusions :Recommendations		37
3. THE CHEMICAL PESTICIDE INDUSTRY IN PERSPECTIVE – FUTURE TRENDS OF THE PESTICIDE INDUSTRY AND ITS RELEVANCE TO THE CARIBBEAN	Richard A. Herrett	39
1. Introduction		39
2. The future: Global 2000		39
3. Agricultural Productivity		40
4. Benefits of Increased Productivity		42
5. The pesticide business and its role in achieving increased productivity		43
6. Conclusions		50
4. THE PESTICIDE SITUATION IN THE CARIBBEAN WITH SPECIAL REFERENCE TO TRINIDAD AND TOBAGO	Gene V. Pollard	51
1. Introduction		51
2. Chemicals in use in the region		52
3. A case history – the control of froghopper in sugar cane		55
4. Discussion		57
5. Conclusion		58
II. CURRENT PERSPECTIVES IN PEST CONTROL, WITH PARTICULAR REFERENCE TO THE CARIBBEAN		
5. METHODS AND APPROACH TO RODENT CONTROL IN TROPICAL AGRICULTURE	Walter E. Howard	62
1. Introduction		63
2. Typical rodent problems		64
3. Requirements for successful rodent control		65
4. Principles of rodent control		68
5. Biological and general control methods		70
6. Research needs		74
7. Conclusion and Recommendations		74

			Page
6.	CURRENT PERSPECTIVES IN INSECT CONTROL IN THE COMMONWEALTH CARIBBEAN	S. Parasram and B.K. Rai	76
	1. Introduction		76
	2. Losses caused by insects		76
	3. Chemical control of insects		77
	4. Biological control of insects		78
	5. Other methods of insect control		79
	6. Organisation of Pest Control		79
	7. Training		80
	8. Conclusion		80
7.	CURRENT PERSPECTIVES IN PLANT DISEASE CONTROL IN THE CARIBBEAN	R.H. Phelps, S.Q. Haque and N.D. Singh	82
	1. Introduction, Background		82
	2. Plant Quarantine		83
	3. Eradication		83
	4. Protection		83
	5. Disease resistance		85
	6. Nematological perspectives		85
	7. Perspectives in virology		85
	8. Conclusion		86
8.	WEED PROBLEMS AND WEED CONTROL IN THE COMMONWEALTH CARIBBEAN	John L. Hammerton	87
	1. Introduction		87
	2. Effects of weeds		87
	3. Losses due to weeds		88
	4. The weeds		88
	5. Control methods		92
	6. Weed control research		95
	7. Conclusion		96
9.	PROBLEMS WITH EXTERNAL PARASITES OF LIVESTOCK IN THE CARIBBEAN	R.O. Drummond	98
	1. Introduction		98
	2. Livestock		98
	3. External pests		99
	4. Pesticide use		100
	5. Conclusion		102
10.	THE INTEGRATED PEST MANAGEMENT APPROACH	Ray F. Smith	105
	1. Introduction		105
	2. Principles for Application of Integrated Pest Management		106
	3. Conclusion		109
11.	THE CURRENT SITUATION OF SOME RECENTLY INTRODUCED PESTS	A.L. Brown	110
	1. Introduction		110
	2. Sugar Cane		110
	3. Avocado		111
	4. Coffee		111
	5. Mango		111
	6. Banana and Plantain		111
	7. Coconut		111
	8. Cassava		112
	9. Legumes		112
	10. Plant Quarantine		112
	11. Conclusion		113

Page

III. BACKGROUND ON PESTICIDES

12. IMPLICATIONS OF THE DEVELOPMENT OF RESISTANCE TO PESTICIDES — George P. Georghiou — 116
1. Introduction — 116
2. Status of research — 116
3. Resistance management — 122
4. Conclusion — 128

13. CLASSIFICATION AND TOXICOLOGY OF PESTICIDES — Virgil H. Freed and John E. Davies — 130

PART I Classification, Chemistry and Toxicology of Pesticides — 131
1. Introduction — 131
2. Classification of pesticides — 132
3. Specific chemical groups — 132
4. Organophosphates — 133
5. Carbamates — 133
6. Heterocyclic compounds — 134
7. Aromatic acids — 134
8. Ureas — 134
9. Structure of pesticides — 134
10. Properties of compounds in relation to toxicology — 142

PART II Toxicologic and Human Health Considerations of Posticides and their Limitations to use — 147
1. Introduction — 147
2. Categories of human pesticide exposure — 147
3. Toxicity of Insecticides — 148
4. Toxicity vs. hazard — 148
5. How exposure occurs — 148
6. Applicator poisoning — 149
7. Picker poisoning — 149
8. Child Poisonings — 150
9. First-Aid measures — 150
10. Management and treatment of acute organophosphate poisoning — 150
11. Chronic exposure — 151
12. Incidental exposure — 151
13. Toxicological concerns for quantitative estimates of exposure — 151
14. Toxicological concerns for exposure assessment — 151
15. Limitations as to use — 153
Appendix: Pesticide Protection – A Training manual for health personnel: U.S. Environmental Protection Agency — 156

14. MOVEMENT OF PESTICIDES AND THEIR BREAK-DOWN IN THE ENVIRONMENT — Virgil H. Freed — 210
1. Introduction — 210
2. The ecosystem and chemical movement — 210
3. Environmental processes in transport — 213
4. Transport and distribution — 222
5. Summary and Conclusion — 225
Appendix: Some metabolic reactions common to pesticides — 226

Page

15. THE IMPORTANCE OF A PROPER MONITORING PROGRAMME — Aziz Ali — 228
1. Introduction — 228
2. Dangers of pesticides — 228
3. Increasing use of pesticides — 229
4. Necessity for assessment and control — 229
5. Conclusion — 230

16. GUIDELINES FOR THE PROPER STORAGE, HANDLING AND DISPOSAL OF PESTICIDES — S. Parasram, B.K. Rai and J.R. Suah — 231
1. Introduction — 231
2. Environmental impact potential of pesticides — 231
3. Considerations in storage of chemicals — 232
4. Considerations in handling of pesticides — 233
5. Disposal of chemical pesticides — 234
6. Disposal of containers — 235
7. Extension work on pesticides — 235
8. Conclusion — 235

17. THE ROLE OF EDUCATION AND COMMUNICATION IN PEST AND PESTICIDE CONTROL — Marshall McGlamery — 237
1. Introduction – Education and Communication — 237
2. Pest and pesticide management — 237
3. The role of education — 238
4. The role of communication — 238
5. Conclusion — 239

IV. MANAGEMENT, HEALTH AND LEGISLATION

18. THE CONCEPT OF THE AGROMEDICAL APPROACH TO PESTICIDE MANAGEMENT — John E. Davies
1. Introduction — 242
2. Reasons for the agromedical approach to pesticide management — 242
3. Current agromedical pesticide management problems — 243
4. Potential for integrated pest control agromedicine — 246
5. Suggested ingredients for an agromedical program — 247
6. Conclusion — 254
Appendix: Reports from University of California/USAID Workshop, University of Alexandria, A.R. Egypt — 256

19. INTERACTIONS OF HUMAN NUTRITION AND PESTICIDE INTOXICATION — Miguel Gueri — 257
1. Introduction — 257
2. Factors affecting pesticide levels — 257
3. Distribution of pesticides in the body — 259
4. Effects of nutritional status — 260
5. Conclusion — 261

20. CARIBBEAN PERSPECTIVES AND CONCERNS IN PESTICIDES — Philip Boyd — 263
1. Introduction — 263
2. Health Policy in the Caribbean — 263
3. Environmental Health strategy — 264
4. Risks from pesticides — 265
5. Legislation and monitoring — 266
6. Conclusion — 267

			Page
21.	GOALS AND THE PURPOSE OF PESTICIDE LEGISLATION AND REGULATION	Caroll Collier	268
	1. Introduction		268
	2. Current role of EPA		274
	3. Pesticides and USAID programs		280
	4. Conclusion		282
22.	BENEFIT – COST ANALYSIS OF INTEGRATED PEST MANAGEMENT PROGHAMS	Ronald D. Lacewell and C. Robert Taylor	283
	1. Introduction		284
	2. Dynamics of production		285
	3. Micro-economic analysis		287
	4. Macro-enonomic analysis		294
	5. Conclusion		300
23.	ALTERNATIVES TO CHEMICAL PESTICIDES IN PEST MANAGEMENT	Dale Bottrell	303
	1. Introduction		303
	2. An Historical perspective		304
	3. The shift towards chemical control		305
	4. Alternatives for IPM programs		305
	5. Economic considerations		313
	6. Promises and Limitations		313

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ABBREVIATIONS

The following abbreviations have been used, sometimes without any easily found explanation, in various parts of the text, and are listed here in alphabetical order for the convenience of readers.

APHIS	Animal and Plant Health Inspection Service (of the USDA)
CARDI	Caribean Agricultural Research and Development Institute
CAREC	Caribbean Regional Epidemiological Centre
CDB	Caribbean Development Bank
CICP	Consortium for International Crop Protection
EPA	Environmental Protection Agency (of the United States)
FAO	Food and Agriculture Organisation (of the United Nations)
FEPCA	Federal Environmental Pesticide Control Act
FIFRA	Federal Insecticide Fungicide and Rodenticide Act (USA)
HRU	Herbicide Research Unit (Trinidad)
IRLG	International Regulatory Liaison Group
NAS	National Academy of Sciences (USA)
OECD	Organisation of European Community Development
OTA	Office of Technology Assessment (USAID)
PAHO	Pan American Health Organisation
PANS	Pest Articles and News Summaries
RPAR	Rebuttable Presumption against Registration
RRC	Regional Research Centre (U.W.I. Trinidad)
TSCA	Toxic Substances Control Act (USA)
ULV	Ultra Low Volume
USAID	United States Agency for International Development
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
USDHEW	United States Department of Health, Education and Welfare
UWI	University of the West Indies
WHO	World Health Organisation (of the United Nations)
WINBAN	Windward Islands Banana Association

EDITOR'S INTRODUCTION

The workshop and seminar on Pest and Pesticide management, held in Barbados from November 3rd to 7th, 1980, was directed primarily towards problems in the Caribbean area, but it was by no means parochial in approach. The sessions of the seminar took the logical pattern of examining first the current pesticide situation in the Caribbean, in particular problems of plant and animal pests and weeds, and techniques of control. This was followed by "Background" sessions, which discussed the toxicology of pesticides both towards pests and humans, factors affecting toxicity, and the importance of proper communication, education, and monitoring programmes. Further sessions dealt with the Agromedical approach and Legislation, both on a global and on a Caribbean scale, and with other aspects of pesticide management.

The invited papers were presented by experts from the Caribbean and from the USA, many being accepted world authorities.

To most agriculturists today it is perhaps not easy to realise for how short a time sophisticated chemical pesticides have been available. While a few chemicals were in use before World War II (e.g. Paris green (copper acetoarsenite) as an insecticide, and oxides of copper as fungicides), it was only in 1939 that the insecticidal value of DDT (discovered in 1874) was appreciated, and it was then used exclusively for military purposes (e.g. de-lousing and mosquito control) during the period of hostilities. However, wartime work on nerve gases, based on organophosphorous compounds, led to the development of the organophosphate insecticides, which are in many cases quite as effective as, and in general far less persistent than, the organohalogens, (as shown by Freed in Paper No. 14 in this volume), and are therefore less dangerous to the environment. Wartime pressures also stimulated research on herbicides, so that farm workers could be released for other types of war service. A notable example was the work carried out by Imperial Chemical Industries in the UK, where Templeman had been developing ICI "alpha' and "omega" (chlorophenoxyacetic acids) and Dr. G.E. Blackman of the Imperial College of Science and Technology, London, led a team testing these products in the field. (The writer had the valuable experience of serving both on a Cambridge research team synthesising organophosphates and on Dr. Blackman's team).

Since that time the growth in chemical pesticides has been phenomenal. Freed (op.cit) states that there are now about 900 to 1,000 chemical compounds in 35,000 to 40,000 different formulations, though "only about 150 of those chemicals are very widely used". No wonder the feeling that chemicals have all the solutions to our pest problems is common among farmers (and, too often, their advisers). Nevertheless, there is abundant evidence as to the magnitude of crop losses avoided, and the consequent increase in productivity per unit of land, achieved as a direct result of the use of chemical insecticides and herbicides, and of the vital importance that the reduction of such losses has for the future of mankind (see Adkisson, Keynote address in Volume 1 of these Proceedings, for an overall perspective, and Tikasingh Paper No. 1 in this volume, Brathwaite, Paper No. 2, and Alleyne, Paper No. 3 in Volume 111 for Caribbean data). As Mellanby (1977) says "Man must learn to live with pesticides," "and this sentiment is stressed in and underlines many of the present papers.

The fact that they are now an essential part of man's economic development does not mean that pesticides do not pose dangers. They are definition toxic substances, thus there is a real possibility of environmental contamination. The persistence and spread of DDT and other organochlorines are, of course, the classic examples, and their adverse environmental effects upon bird life, fish and some mammals are well documented (e.g. Mellanby 1967, 1976). Such occurrences, coupled with the extent to which bioaccumulation of DDT has taken place throughout the human population, have been seen as a cause for alarm, (Gueri, Paper No. 19 in this Volume examines some of the factors affecting accumulation in man), but there is no clinical evidence to show that harm to human beings is actually caused at "normal" levels of accummulation. However, the presence of a foreign substance in the body, with possible unknown long term properties, is obviously undesirable. It is clearly preferable then to use short-lived pesticides, wherever possible, thus minimising potential pollution of the environment. It would seem that actual serious damage to the environment, other than by chlorinated hydrocarbons, has been relatively slight (Mellanby 1976). Balanced perspectives are required. As Mellanby says "it is clear that pesticides can be pollutants, that they may cause environmental damage, and that they do cause widespread but apparently harmless contamination. It is impossible to prove a negative and to be certain that this does not add up to more damage that would, at first, appear. For that reason many people think it is wise to control the use of such substances. If millions of citizens in a developing country would die from malaria unless there was a fairly generous use of DDT,

it would probably be right to risk some temporary effects on wild life. In a wealthy Western country it may be sensible to use a more expensive and less efficient pesticide which is less likely to have side effects. The danger is that if the Western world bans persistent insecticides before adequate substitutes are available, less developed countries may follow their example with disastrous results". This places a heavy burden on the administrators of developing countries, and their advisers: a judgement has to be made on the basis of the best knowledge available. The papers in this book are a valuable source of up to date information of the kind essential for the making of such judgements. Similar judgements have to be made on the use and management of pesticides for agricultural use; only by the so-called agromedical approach can a balance between agricultural needs and public health requirements be met. Management practices in the agricultural operations are extremely important; interest in Integrated Pest Management is rapidly developing and is discussed in greater or lesser degree in many papers; the principles are outlined by Smith in Paper No. 10. The minimising of both pollution and direct costs resulting from reduced pesticide use (coupled with other agronomic techniques to minimise pest hazards), are both benefits worth pursuing, though Lacewell and Taylor have shown that careful economic planning is necessary if the expected financial benefits are to be realised. (Paper No. 22). Alternatives to pesticides are examined by Bottrell, in particular biological control by predators. (Paper No. 23).

In summary, it is clear that sophisticated methods of pest control are essential for the Caribbean if its agriculture is to survive. Insecticides and herbicides are in general use in the Caribbean among large scale enterprises and are rapidly being adopted, on the advice of Ministries of Agriculture, by small farmers. Indeed, the usage in some countries is high by any standards (as shown by the Table in the Introduction to Volume III); the necessity for such measures is due in part to the fact, sometimes forgotten, that in the tropics there is no winter during which insect control is virtually unnecessary and during which weed growth is minimal; pest control is an all the year round operation under Caribbean conditions. Moreover, rather on the basis of "if a little of what you fancy does you good, more must be better", there is a tendency to use more pesticide than necessary, and not only are unnecessarily costly practices common, but there are potential and possibly actual dangers to the environment and to man himself. Serious study of these problems is essential, aimed at developing systems of pest control in which insecticides will in most instances play a part, but be only part of a package of practices which will provide acceptable levels of control. It is to be hoped that a considerable region-wide research effort on these lines can be mounted, with adequate funding. There is, of course, no end to research of this type — by the time a system has been developed for one crop in a particular set of circumstances, new crops or new circumstances appear; resistance to pesticides develops and special techniques to handle this problem must be devised (e.g. Georghiou, Paper No. 12). Indeed we "have to run fast to stay where we are"

On the public health side it appears that a reasonable level of control of vector borne diseases (and quality of water) has been achieved in most countries. However, the hazards of (mainly) agricultural use, handling, storage and environmental effects, are not always fully recognised, nor is there always the institutional organisation (legal and educational) for handling these problems: the papers by Tikasingh (No. 1), Pollard (No. 4), Ali (No. 15), Parasram et al (No. 16) and McGlamery (17) highlight some of these problems.

The Country Papers (Volume III) show that although most Caribbean countries have passed some type of legislation aimed at regulating the use and handling of pesticides, implementation has often been neglected or half-hearted. The paper by Collier (No. 21) provides a valuable background to pesticide legislation in the U.S.A., and although newly independent countries such as most of those in the Caribbean tend to dislike following "foreign" patterns, the thoroughness with which the U.S.A. examines all aspects of the use and effects of pesticides must provide a very sound basis for pesticide legislation in small countries in which it would be absurd to attempt to reproduce the North American work.

The sections into which the seminar was divided were noted at the beginning of this introduction. The headings of the sessions have been maintained, and only a small re-arrangement of papers has been made in the compilation of this volume. An editor is always faced with the problem of exactly where a paper should be placed; many papers examine several facets of the subject. It is hoped that the arrangement set out in the Table of Contents (which differs only slightly from that adopted by the organisers of the Seminar) will enable readers to identify easily the papers dealing with those aspects of particular interest to them. Even the papers in Sections I and II have more than a solely Caribbean interest, and certainly most of the papers in Sections III and IV should be of interest to all those whose work impinges in any way on the use of

pesticides, whether agricultural, medical or legal, and this volume should be valuable far beyond the Caribbean region, for its wealth of source material.

E.G.B. Gooding

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I
THE PESTICIDE SITUATION IN THE CARIBBEAN

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1. THE PESTICIDE SITUATION IN THE CARIBBEAN THE PUBLIC HEALTH PERSPECTIVE

E. S. TIKASINGH

CONTENTS

		Page
1.	INTRODUCTION: HISTORICAL BACKGROUND	16
2.	VECTORS OF DISEASE AND/OR OF NUISANCE VALUE IN THE CARIBBEAN	17
3.	PESTICIDES IN CURRENT USE IN THE CARIBBEAN	19
4.	RESISTANCE	21
5.	TOXICOLOGICAL HAZARDS	22
6.	FUTURE OF CHEMICAL CONTROL OF VECTORS	23
7.	TRAINING AND MONITORING	24
8.	CONCLUSION	25

1. INTRODUCTION: HISTORICAL BACKGROUND

In 1877 Ross working in China announced the discovery that a mosquito was the vector of Bancroftian filariasis. Four years later, Carlos Finlay working in Cuba, postulated that a particular mosquito which today we call *Aedes aegypti* was the vector of yellow fever. His experiments with this mosquito were inconclusive and it was left for the Walter Reed U.S. Yellow Fever Commission in 1900 to prove conclusively that *Aedes aegypti* was indeed the vector of yellow fever. Between these two major discoveries, Grassi with Bastianelli and Bignami finally in 1898 proved that the *Anopheles* mosquito was the vector of human malaria. Thus in the short space of 23 years three mosquito genera were shown to transmit three major diseases of man, with three distinct pathogenic agents: a virus (yellow fever), a protozoan parasite (malaria) and a nematode (filariasis).

The discoveries that mosquitoes were vectors of human diseases led to a new approach in the control of these diseases i.e. if you control the vector, you can control the disease. This idea was put into good practice in Havana at the turn of the Century. Control of yellow fever became the control of *Aedes aegypti* and the attack measures commonly referred to as source reduction were directed at the larval stages of the mosquito. There was a massive clean-up of the environment; larvicidal oils were used in drains and ditches; containers with drinking water were covered; and occasional fumigation of houses with pyrethrums was introduced. The results were dramatic. From an average of 500 deaths per year for the preceeding 10 years, there were only 17 deaths in 1901 and none for the next three years. There was an outbreak in 1905, but this was quickly brought under control by reapplication of the anti-mosquito measures.

The Panama Canal provides us with another success story. Building of the Canal was achieved principally through the control of the malaria vector *Anopheles albimanus*. This species breeds at the edges of swamps and streams where vegetation provides a suitable cover. Clearing of vegetation and draining of swamps controlled this species (Gorgas 1915).

The 1940's saw the emergence of the use of DDT. Results of operational research conducted by the Rockefeller Foundation in Sardinia using DDT (Logan et al 1953) formed the basis of much of *Anopheles* control as we know it today. When DDT was applied as emulsions to walls of houses at the rate of 2 g/m^2, a long lasting effect was achieved. Malaria was controlled in Sardinia and this success story was repeated in many parts of the world (see review article by Brown et al., 1976). Thus, by the 1960's all West Indian territories excepting Hispaniola were certified free of malaria by World Health Organization (Garcia-Martin 1972).

2. VECTORS OF DISEASE AND/OR OF NUISANCE VALUE IN THE CARIBBEAN

Anopheles mosquitoes — With the exception of Barbados, *Anopheles* mosquitoes are present in all countries of the Caribbean. Malaria, however is present only on Hispaniola and the mainland countries bordering the Caribbean. The number of cases for 1977 to 1979 is given in Table 1. DDT is still the insecticide of choice.

Aedes aegypti — vector of yellow fever and dengue is present in all countries in the Caribbean except the Cayman Islands, Aruba and Tobago. While there has been no recent urban transmission of yellow fever by this mosquito, it vectored a Caribbean-wide epidemic of dengue in 1977-78 (PAHO, 1979). The number of cases reported for 1977-1979 is given in Table 2.

Aedes taeniorhynchus — is suspected of having transmitted eastern equine encephalitis (EEE) in Guyana in 1962 (Tikasingh et al, 1965). This mosquito is present wherever salt-marsh is encountered in the Caribbean and is a serious pest in the Cayman Islands.

Culex fatigans — a domestic species of considerable nuisance importance is present throughout the Caribbean. It is the vector of Bancroftian filariasis in Suriname, Guyana, Haiti, Dominican Republic and in a limited focus in Trinidad (Hawking, 1979). No direct effort is being expended to control the vector of this disease in any of the above-mentioned countries.

Lutzomyia — is a vector of leishmaniasis in Belize, Trinidad, Guyana and Suriname, but the disease is not a significant public health problem.

Simulium black flies, fleas and lice are involved in the biological transmission of diseases elserwhere, but not in the Caribbean.

Flies and cockroaches are mechanical transmitters of diseases and are household pests. Most attempts at controlling these pests are by householders themselves or through private pest control operators.

Culicoides sand fly is a serious pest in many parts of the Caribbean. Three species *(C. furens, C. barbosai* and *Leptoconops becquaerti)* are serious enough to affect tourism (Linley and Davies, 1971) and many hoteliers have sought assistance and advice from our staff in controlling them.

Ticks are vectors of diseases elsewhere, but there are no known recorded outbreaks of human diseases caused by these arthropods in the Caribbean. However, when present in large densities in areas where farmers must work they can become a serious nuisance. Aitken et al (1958) recorded an outbreak of the Cayenne tick *(Amblyomma cajennense)* in southeastern Trinidad. Labourers in a coconut plantation refused to work because of severe infestations. DDT (50%) w.p., gamma BHC, chlordane and dieldrin were all used in various places in the plantation and in all cases reduction of densities of ticks were satisfactory.

Of the mites only *Sarcoptes scabei* is of public health importance in the Caribbean.

The snail *Biomphalaria glabrata* is the vector of schistosomiasis in Suriname, Martinique, Saint Lucia, Montserrat and Puerto Rico.

Rabies is transmitted by vampire bats *(Desmodus rotundus)* in Trinidad, but in Grenada and Puerto Rico the disease in man and animals is transmitted by a species of mongoose *(Herpestes).*

Rats and mice are reservoirs of leptospires, but the true incidence of this disease in the Caribbean is not known.

Table 1 Malaria Cases Reported 1977-1979

COUNTRIES WITH INDIGENOUS MALARIA	CASES REPORTED		
	1977	1978	1979 (a)
Grenada		58	1(b)
Belize	880	1,220	1,400
Suriname	990	910	790
Guyana	1,560	927	2,297
Haiti (SNEM)	27,700	62,000	31,000
Dominican Republic	740	1,530	1,550
Venezuela	5,300	5,100	4,800

a. Provisional (Jan. 1980)
b. Imported

Source: CAREC Statistical Unit

Table 2 Dengue Cases reported 1977-1979

COUNTRIES WITH EPIDEMICS	CASES REPORTED		
	1977	1978	1979(a)
Turks & Caicos Islands	51	2	-
Virgin Islands (U.K.)		12	-
St. Kitts/Nevis	151	390	1
Dominica	400	6	-
Grenada	15	25	4
St. Vincent	1	7	-
Saint Lucia		117	26
Bahamas	930	10	-
Barbados	1	115	43
Suriname	1	35	-
Guyana	23	41	1
Trinidad & Tobago	6	330	38
Jamaica	11,900	4	25
Puerto Rico	10,800	12,600	920
Haiti	270	86	110
Cuba	447,000	na	na

a. Provisional (Jan. 1980)
Source: CAREC Statistical Unit

3. PESTICIDES IN CURRENT USE IN THE CARIBBEAN

Perhaps I should start this section of the discussion by stating that the only up to date data available on the use of pesticides in the Caribbean come from those countries which have active programmes in mosquito control. Trinidad and Tobago only recently passed laws and there are also regulations in Barbados and Jamaica (Poison and Drugs Board) and some of the other Caribbean countries governing the use and importation of pesticides into their respective countries. The Trinidad and Tobago laws include the licensing of pest control operators, but some of the other countries do not have laws which would regulate the use of pesticides and license private pest control operators. In those countries without Pesticide Laws anyone can start a Pest Control Company and start disseminating pesticides in the environment. As a consequence there are no accurate records in any of these countries which could give some indication of the quantities of pesticides used. Rai (1979) gives approximate figures of the quantities used in Guyana over a 4-year period, but these are imported by Governmental agencies. Table 6 (at end of paper; pp 25 to 28) lists all insecticide formulations which were available at sometime over the last five years in five countries. The list is long, but quantities are not available.

1. Mosquito Control

Two species of *Anopheles* are being controlled in this area; *A. darlingi* in Guyana and Suriname, and *A. albimanus* in Haiti and Belize. In the interior of Guyana intra-domiciliary spraying with DDT which leaves a residue of 2 g/m^2 has been in progress since 1966 and in Suriname for at least a decade in the attack areas. Normally two cycles of spraying are completed in one year. There is resurgence of malaria in Belize and a programme for *Anopheles* control using DDT has just been started.

The majority of the countries of the Caribbean have had some programme either in the past or currently for *Aedes aegypti* control. These programmes are generally coordinated by PAHO/WHO. In larvicidal programmes, the standard procedure is to treat potable water, bird baths and animal drinking containers with one percent abate sand granules. It is a highly toxic larvicide for the target species, but it has a very low mammalian toxicity. Tests performed by Laws et al, (1967) have shown that human volunteers tolerated 64 mg/day for four weeks without clinical symptoms as side effects.

Perifocal spraying for adults is carried out with malathion. Malathion is perhaps one of the safest insecticides currently used. Apart from the fact that it is a versatile insecticide in terms of application it is a low hazard to man, domestic animals and wildlife. Permanent effects on the environment are low because it does not persist in soil or water. It is generally replacing DDT for killing adult mosquitoes. Both abate sand granules and malathion are recommended by WHO for use in mosquito control programmes.

In the Cayman Islands Dibrom is used routinely as aerial applications at the rate of 30 gm/ha to control the pest mosquito *Aedes taeniorhynchus* (Giglioli, pers. comm.) mainly around mangrove swamps. The sprays can be irritating to people and may cause sneezing and coughing. It is moderately toxic to humans.

A list of insecticides available for *Aedes aegypti* control in the Caribbean is given in Table 3.

Table 3 Insecticides available for use in Aedes Aegypti Eradication Programmes — Caribbean Area

Countries	Fenthion 40% Wettable Powder (kg)	Abate 1% Sand Granules (kg)	Malathion in (gals) 91 - 96%	Other Insecticides
Anguilla	272	1,000	-	Methopreme (Altosid) Brisquet 56,00 kg
Antigua	-	5,094	150 kg	-
Barbados	750	1,000	55	-
Cayman Is.	-	181	442	Dibrom 85% - 700 g. Bioresmethrin - 93% - 125 kg. Permethrin - 97% - 100 kg. Kothrine - 100% - 100 kg Methopreme (Altosid) - 105 lb
Dominica	-	-	-	-
French Guiana	40% - 900	6,520	4,800 w.p.d. - 50% 215	Dibrom 14 - 960 ℓ
Grenada	31.75	972	110	-
Guadeloupe	2,000	11,650	3,729.47 w.p.d. 50%	Naled (Dibrom 14) - 1% - 1,200 ℓ
Jamaica	12,364	11,925	-	-
Montserrat	175	675	28	-
St. Kitts/Nevis	-	12	57% - 5	Diazinon 45% - 3.5 ℓ
Saint Lucia	-	-	110	-
St. Vincent	-	1,650	130	-
Suriname	-	-	-	Foxitrothin - 95% - 275 ℓ
Trinidad & Tobago	6,500	15,774	775	Technical Grade DDT - 181 kegs Dieldrin Conc. - 165 gal Baytex Granules - 140 lb Malathion Conc. - 50% - 48 gal Abate Powder - 800 lb

Source: (Mr. R. Aarons, PAHO/WHO, Trinidad)

2. Other Arthropods

Attempts at controlling cockroaches and flies are made through householders themselves and/or private pest control operators.

3. Molluscs

There have been experimental control studies for the snail vector *(Biomphalaria glabrata)* of schistosomiasis in the Caribbean, but no long-term programmes. For example, in Saint Lucia niclosamide (25% a.i.) was used for a period of 4 years (1970 to 1974) in one small valley (Jordan, 1977) and in Suriname (Heinemann, 1971).

4. Vertebrates

About 15 to 20 years ago, attempts were made to control mongooses which transmitted rabies in Grenada. Zinc phosphide and arsenic sulphate were used in these programmes. However, these pesticides were replaced about 10 years ago with sodium fluoracetate. The usual method of poisoning was to mix the pesticide with boiled cowhide with the bait being placed at strategic points. The entire eastern half of the island was covered in 1974 (Everard, pers. comm). The baits were not placed near human habitations and no untoward effects were reported in humans or domestic animals.

One method of vampire bat control in Trinidad was the utilization of strychnine poison. Where reports of serious bat bites to animals occur, the poison was issued to the farmer who applied a drop of strychnine on the wound. The intention was that when the bat returns the following night for a blood meal (they normally feed at the original site of the wound) they will be poisoned. There have been no reported human accidents when this programme was active. The anticoagulant diphacinone is currently being used in Trinidad to reduce populations of vampire bats, but effects on non-target species are not known.

Rat and mice control are usually effected through householders themselves using coumarin compounds.

4. RESISTANCE

Table 4 lists the mosquitoes in the Caribbean area that are resistant to DDT, Dieldrin/HCH and some of the organophosphorus (OP) compounds. In some areas in Haiti *A. albimanus* is still susceptible to DDT. Tests conducted in Guyana recently have indicated that *A. darlingi* is also susceptible to DDT (Tikasingh and Rai, unpublished data). *Aedes aegypti* is not yet resistant to malathion and abate; however these insecticides should be monitored regularly to determine if and when resistance appears.

Table 4 Insecticide resistance in Mosquitoes in the Caribbean*

Species	DDT	Dieldrin/HCH	Organo-Phosphorus
Anopheles albimanus	Haiti	Haiti Belize Jamaica Cuba Dominican Republic	
A. aquasalis		Trinidad	
A. neomaculipalpis		Trinidad	
Culex fatigans	General	General	
Aedes aegypti	General	General	Virgin Islands Barbados St. Lucia Guadeloupe Dominica St. Vincent Grenada Curacao Jamaica
A. taeniorhynchus	Cayman	Gr. Cayman	

* From WHO Tech. Rept. Series No. 585, 1976.

5. TOXICOLOGICAL HAZARDS

We have been fortunate in the Caribbean in that there has been no serious poisoning of pesticide operators due to improper handling of pesticides, but accidents such as the 1976 episode in Pakistan could occur if careful handling of pesticides is not observed. In the Pakistani episode, 2500 cases and five deaths were recorded from a group of 7500 field workers who handled a water dispersable powder of malathion. Investigations by the Center for Disease Control and the World Health Organization showed that there were impurities of other OP compounds in the malathion powder, which enhanced the toxicity of the compound. They also noted that there was a failure to observe elementary precautions in the handling and spraying of the compounds (WHO Chronicle, 1978).

Accidental deaths and suicides due to poisoning with pesticides appear to be a common occurence in some countries. Mootoo and Singh (1966) reported on an episode of poisoning due to the ingestion of flour contaminated with parathion which occurred in Guyana in 1962. Epidemiological investigations were not undertaken so it was not known how the flour became contaminated. There were 88 cases in this episode of whom 10 died. Diggory et al., (1977) investigated an outbreak of accidental parathion poisoning in Jamaica where 79 persons were acutely poisoned of whom 17 died. The investigation showed that all cases had consumed flour which was contaminated by parathion. The authors suggested that the flour was contaminated at a European port where parathion and flour were handled in the same area.

Other accidental and suicidal poisonings have also been recorded from Jamaica. Burke and Wynter (1963), for example reported on OP poisons in children under 9 years, but the number of cases were not given. Later Miller (1973) recorded five cases (ages were not given) of OP poisoning. In both reports the types of OP compounds were not specified. Another 10 cases were mentioned by Lawrence (1977) at the Cornwall Regional Hospital in a two-year period (1974-1976), and the author mentions the "toddler aged 1 to 4 years was the most frequent victim of poisoning". The pesticide poisons were identified simply as "spray inhalations", "rat poisons", along with a category of "unknown pesticides".

Mootoo and Singh (1966) also reviewed cases of poisoning in Guyana during the period 1959 - 1964. They noted that there were 46 deaths due to malathion. At the time in Guyana, the 57% solution of malathion was sold in beer bottles. Three of the 46 cases who were under the influence of alcohol had ingested the malathion from beer bottles; the other 43 deaths were suicides. In addition, there were 14 other suicidal deaths due to the ingestion of poisons labelled simply as "pesticides and insecticides", but the types were not specified.

Ratan (1978) reviewed retrospectively 224 cases of poisoning seen at the General Hospital, Port of Spain, Trinidad, 1962. Eight per cent of the children ingested "insecticides and pesticides". At the San Fernando General Hospital 43 cases of poisoning due to insecticides occured during the period 1964 - 1973. Twenty-five of the cases were due to chlorinated hydrocarbons and 18 to OP compounds (Mohammed, 1978).

In another series of studies from 1974 to 1976 at the Port of Spain General Hospital Ramchander, et al., (1978) reviewed 1,394 cases of poisoning. Rat poisons and insecticides were mentioned as substances ingested by children under 10 years, but the actual types of pesticides were not mentioned nor the number of cases given.

Parathion (Fosferno) is most commonly used for suicidal poisoning in Trinidad. Edwards et al., (1975) reviewed 97 cases during the period 1972-1974. Ninety-four of these were due to insecticides. Some of these suicides might have been gestures following family disputes resulting in unforseen consequences. Fosferno is readily available in Trinidad. It has a high mammalian toxicity and it is estimated that "a pinch" to one teaspoonful of the technical insecticide is sufficient to cause death in a 150 lb man (Hayes, 1963). Many people do not know how little is needed to kill an adult.

While the cases I have just been discussing were acute cases of poisoning, we have little information about subtle effects that may be caused by the continual ingesting of low doses of pesticides which are sprayed on vegetables and fruits by inexperienced farmers. Pesticide residues in humans in Trinidad were reported by Edwards et al. (1975). They found DDT and Dieldrin in samples taken from 15 post-mortems. Levels of the pesticide residues however, were much lower than the toxic levels.

Table 5 summaries reported cases of pesticide fatalities in the Caribbean between 1959 and 1974, though for some countries the figures are clearly not fully up to date.

Table 5 Reported cases of Pesticide (accidental and suicidal) Poisoning in the Caribbean

COUNTRY	PERIOD	NO OF CASES	NO OF DEATHS	PESTICIDE	REFERENCE
GUYANA	1959 - 1964	88	10 46 14	Parathion Malathion "Pesticides & Insecticides"	Mootoo and Singh (1966) "
JAMAICA	1961 - 1973	5		Organophosphates	Miller (1973)
JAMAICA	1959 - 1962	?		Organophosphates	Burke & Wynter (9163)
JAMAICA	1974 - 1976	10		"Spray Inhalation" Rat Poison Unknown	Lawrence (1977)
JAMAICA	1976	79	17	Parathion	Diggory et al (1977)
TRINIDAD (North)	1962	18		"Insecticide & Pesticide"	Ratan (1978)
TRINIDAD (South)	1964 - 1973	25 18		Chlorinated Hydrocarbons Organophosphates	Mohammed (1978)
TRINIDAD (North)	1974 0 1976	?		Insecticides & Rat Poisons	Ramchandar et al (1978)
TRINIDAD	1972 - 1974		94	Insecticides	Edwards et al (1975)

6. FUTURE OF CHEMICAL CONTROL OF VECTORS

The continued use of chemical pesticides has generated much controversy over the last two decades resulting in restrictions being placed on certain compounds. In addition to high costs and environmental pollution with pesticides, attention is being directed to biological control and the use of insect growth regulators as alternatives. Nevertheless, these are still in the experimental and operational research stages. DDT is still the cheapest insecticide and is considered to be only moderately toxic to man. A WHO expert committee (1975 Tech. Rept. No. 560) stated that when "considering the risks associated with the use of pesticides in vector control programmes, it is essential to bear in mind the benefits to health that may result from effective vector control". With the use of pesticides in agriculture and public health enough experience has been gained to make a realistic assessment of the toxic hazards of pesticides. The Group further stated that acceptable insecticides which include "the pyrethrins, DDT, and compounds with anticholinesterase activity, all exert their effects by an essentially reversible action on the nervous system. These compounds with the exception of a few organophosphorous compounds not used in vector control, do not produce structural damage to the nervous system in mammals, so there is no basis for undue concern about the effects of exposure to low doses." (WHO, 1975, Tech. Rept, No. 560). It would seem therefore, vector control programmes will continue to use chemicals until cheaper, non-pollutant and non-toxic (except for target species) methods are

available. However, with an integrated approach to control it is possible to reduce the reliance on chemical control only.

Another WHO Expert Committee (1975, Tech. Rept. No. 561) found that there were considerable losses during application of insecticides and these losses based on the amount reaching the target sites vary between 40 to 80 percent. Operational research at the local level to determine the most effective control methods could go a long way in reducing the amount of insecticide used and in the final analysis the cost of application.

7. TRAINING AND MONITORING

Operator Safety

While we have not had a reported case of pesticide poisoning in pesticide operators, we must not be complacent; staff must be adequately trained in terms of safety. Governmental agencies which operate control programmes do have training programmes for their personnel. Once trained, staff are allowed to operate without regular checks with a consequence sloppy habits become the norm. Even when Governments contract short term consultants (STC) to examine their vector control programmes these STCs look mainly into the reduction of vector densities and their respective diseases; very little attention is devoted to the safety of operators and of the broadcasting of pesticides in the environment. As far as I am aware, cholinesterase levels are monitored only in Haiti and Trinidad and Tobago.

In countries which license pest control operators, it is in fact the supervisor who is licensed and not the operator who is actually handling the insecticides.

Application of Pesticides

Some countries with industrial health programmes monitor activities of pest control operators working in the Health Departments. However, in these countries agricultural workers who use most of the pesticides are not monitored through industrial health programmes. Poor application techniques by professional pest control companies have been observed in several Caribbean Countries (Diggory, Pers Comm).

Packaging

When a pesticide leaves its manufacturers' warehouses there are usually clear instructions governing its use together with safety precautions which should be taken. However, when these pesticides are consigned to local distributors for the retail market, instructions for their use are not normally included in the labels. Containers include paper bags for solids and soft drink and beer bottles for liquids. Further, it is not uncommon for pesticides to be placed (labelled or unlabelled) on the same shelf where foodstuffs are stored in supermarkets. Such shelf space is at a premium in shops in the rural areas where the pesticide may have its greatest market. It is important that these pesticides are clearly labelled with simple instructions and clear warning to keep them away from children.

Transport and Storage

Although large shipping lines maintain strict control of the shipment of pesticides (Inter-Governmental Maritime Consultative Organization) and because of the size of the ships can provide dangerous-cargo holds, the same control is not practiced by inter-island shippers using schooners. In addition, there have been problems with the shipment of pesticides in unsatisfactory containers. For example, Trithion was shipped to one country in 1965 in multiwall paper bags which were damged, spilling the powdered pesticide. As the ship arrived on a Sunday, the cargo was not stored in the dangerous cargo shed, but instead was stored in a shed with food destined for other Caribbean Countries. Some dock workers handling the pesticide developed dermatitis and the entire contents of the shed had to be inspected item by item with considerable condemnation of food. There was also a massive clean-up of pallets, fork-lifts and trucks. The Government of the country concerned immediately introduced legislation to control the packaging of pesticides being imported (Diggory, Pers. Comm.)

Some countries have dangerous-cargo sheds, but others, particularly the smaller ones, do not have this provision and rely on allocated space for chemical storage. Possibilities of cross contamination could occur with the common use of slings, pallets, fork lift trucks, cranes and, most of all, common transport vehicles. The risks continue in the warehouses and transport

vehicles of wholesalers and distributors, with increasing risk down the transport chain to common vehicle delivery to village shops and farmers.

Monitoring for Resistance to Insecticides

There is very little or no monitoring for the development of resistance to insecticides. This activity should be a built-in feature of any control programme. With the early detection of resistance of vectors to insecticides a timely change of the operational plan can result in a more efficient programme with lowered cost of operation. The Pan American Health Organization through its AMRO-0700 programme provides a service for the testing for insecticide resistance of *Aedes aegypti.*

Training

There should be regular refresher training of personnel on the safe use of pesticides. They should be constantly reminded of the potential danger to themselves and others if pesticides are carelessly handled, and this can come only from regular training and motivation. WHO has prepared three self instructional courses on toxicology (level of MD, supervisor and worker). These courses are available through its Washington and Geneva Offices.

There is a need for good epidemiological investigations following outbreaks of poisoning such as the parathion episode in Jamaica, (Diggory et al., 1977). It is only after correct information is available that the necessary corrective steps can be undertaken.

Legislation

As mentioned earlier Trinidad and Tobago enacted the Pesticide and Toxic Chemicals Act, in 1977 which regulates "the importation, storage, manufacture, sale, use and transportation of pesticides and toxic chemicals and to provide for the licensing of pest control operators and for matters incidental thereto." However, this Act has not yet been proclaimed. In Jamaica, control of peticides is governed by the Poison and Drugs Board. In many of the so-called Lesser Developed Countries, laws have been enacted over the last 10 years. However, in many the necessary mechanisms for carrying out the laws are not yet in force.

8. CONCLUSION

In my presentation, I have pointed out that there is no control on the type and quantities of pesticides that are being imported in most of these countries; that pesticide operators need proper training in the safe handling of the compounds; that there should be constant surveillance of the pesticide operators; that there should be adequate labelling and storage of the compounds; and that there is indiscriminate spraying of fruits and vegetables by farmers inexperienced in the use of pesticides.

We are therefore, likely to witness a rise in pesticide poisoning unless Governments enact and enforce the necessary laws for the control and use of pesticides.

Table 6 Insecticides available in five countries in the Caribbean +

Brand Name/Alternative Name	Antigua	Barbados	Grenada	Guyana	Trinidad
Actellic 50		*			
Agrocide					*
Albolineum					*
Aldrin			*	*	*
Aldrin 40		*			
Ambush 50	*	*			
Aprocarb					*
Azinphos-Ethyl					*
Azinphos-Methyl					*

Brand Name/Alternative Name	Antigua	Barbados	Grenada	Guyana	Trinidad
Baygon			*		*
Belmark 10		*			
Benzene Hexachloride				*	*
Blitzem		*			
Bromofos					*
Bromofos-Ethyl					*
Calcium Arsenate					*
Carbaryl				*	*
Carbophenothion					*
Carbophenothion-Methyl					*
Chlordane	*		*		
Chlordane Dust 5%		*			
Chlordane 8EC					*
Chlordecone					*
Chlorfenvinphos					*
Chlorphenamidine					*
DDT				*	*
Decis			*		
Decis (2.5 EC)		*	*		
Demeton					*
Memeton-Methyl					*
Diazinon		*	*		*
Diazinon 60E	*				
Dichlorvos					*
Dicofol					*
Dicrotophos					*
Dieldrin			*		*
Dimethoate			*	*	*
Dinocap					*
Dioxathion					*
Dipterex			*		*
Dipterex 95%	*				
Disulfoton (LSO)					*
Dursban			*		
Endosulfan					*
Endrin				*	*
EPN					*
Etrofolan					*
Fenchlorphos					*
Fenitrothion				*	*
Fensulfothion					*
Fenthion			*	*	*
Ficam 80		*			
Furadan	*	*			
Gammalin 20		*			
Gardona 25%	*				
Gold Crest C-10-20		*			
Gusathion L 20	*				
Heptachlor			*		*
Heptachlor 3EC		*			
Kelthane			*		
Kelthane 18.5%	*				
Kelthane (42 EC)		*	*		
Lannate					*
Lannate L	*	*			
Lindane (WP, EC)				*	

Brand Name/Alternative Name	Antigua	Barbados	Grenada	Guyana	Trinidad
Maladrex 50		*			*
Malathion (EC)			*	*	*
Malathion 5E		*			
Malathion 57%	*	*			
Malathion U.L.V.		*			
Mecarbam					*
Menazon					*
Mesurol					*
Metasystox (R)			*		*
Metasystox R 25%	*				
Metaldehyde 5%		*			
Methiocarb					*
Methomyl					*
Methoxychlor 25%		*			
Methoxychlor					*
Mevinphos					*
Mirex				*	*
Mocap					*
Monocrotophos				*	*
Naled					*
Nudrin 1.8		*			
Omethoate					*
Orthene 75 S		*			*
Oxamyl		*			
Oxy-Demeton-Methyl					*
Parathion					*
Parathion-Methyl		*			*
Perfekthion		*			
Perfekthion 20%	*				
Phosdrin 24%	*	*			
Phosmet					*
Phosphamidon					*
Phosphamidon EC				*	*
Phosvel		*			
Phosvel (3E)	*				
Phoxim				*	*
Pirimiphos Methyl (EC)				*	
Proxol 80SP		*			
Pyramin		*			
Ratak		*			
Rogor E	*				
Rogor 40		*			
Rotenone					*
Schradan					*
Sevin (5%)		*	*		
Sevin 85%	*	*			
Sevin 80 W.P.		*			
Sulfotep					*
Supona	*	*			*
Surecide 25 EC	*				
Systoate 40		*			
Tamaron					*
Temophos (Granules)				*	
TDE					*
Thimet					*
Thionex		*	*		
Thuricide		*			*

Brand Name/Alternative Name	Antigua	Barbados	Grenada	Guyana	Trinidad
Trichlorex 80 SP					* *
Trichlorphon SP					*
Toxaphene					*
Unden		*		*	*
Vapona 48		*			
Vydate L					*
Zectran					

EC Emulsifiable Concentrate

+ Source: Adapted from various authors and organisations as follows:
Clive Thomas (Chemistry Food and Drugs Division, Ministry of Health, Trinidad & Tobago).

Pesticide Unit, CARDI, Trinidad

B.K. Rai (1979)

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2. THE ROLE OF PESTICIDE IN FOOD PRODUCTION IN THE COMMONWEALTH CARIBBEAN

C.W.D. BRATHWAITE

CONTENTS Page

1. INTRODUCTION 30

2. FACTORS LIMITING FOOD PRODUCTION 31

3. IMPORTANCE OF PESTS 32

4. IMPORTANCE AND FUTURE OF PESTICIDES 35

(i) Are Pesticides really necessary? 35

(ii) The future role of pesticides in the region: Integrated Pest Management 36

5. CONCLUSIONS – RECOMMENDATIONS 37

1. INTRODUCTION

The Commonwealth Caribbean comprises the former colonies of the British Empire which are now joined in a socio-economic unit called the Caribbean Community or CARICOM. This unit includes Antigua, Barbados, Belize, Dominica, Grenada, Guyana, Jamaica, Montserrat, St. Lucia, St. Kitts, St. Vincent and Trinidad and Tobago. Except for Trinidad and Tobago where petroleum resources and petroleum exports contribute substantially to the economy, all other countries are dependent to a greater or lesser extent on agriculture as a source of food, employment and foreign exchange earnings. (Anon, 1975, Chernick, 1978). This region with a population of five million souls imports about US $1 billion annually in food. This bill is for a range of food items including cereals, dairy products, meat, legumes and vegetables. The man in the street in the developed world is likely to ask what is the nature of the agricultural system in the Caribbean. The only answer to this question is that we have an agricultural system oriented for the production of export corps and dominated by the production of sugar from sugar cane.

A classic example of the relationship between food production and consumption can be observed from data extrapolated from a paper by Buckmire (1976). In 1973, Trinidad and Tobago consumed about 3,887,186 lbs. of carrots of which 13% was produced locally, 8% was imported from CARICOM sources and 79% was obtained from extra regional sources.

In spite of a large number of policy statements and diversification programmes since the 1930's, only limited progress has been achieved in attempts to satisfy the food needs of the region by local production. This limited progress exists in times when there is considerable pessimism about the global food situation (Anon, 1980) and the challenges to increasing food production in the region are increasing (Brathwaite, 1980).

Food production in the region is still limited to a large number of small farms scattered either on the edges of or in between large farms producing export crops. The medium sized family farm as a viable agricultural entity in Caribbean agriculture is yet to emerge.

Table 1 Some statistical characteristics of the countries of the Commonwealth Caribbean

Country	Population 1000	Agriculture as % of GDP	Area sq. km
Antigua	69.8	6.9	441.6
Barbados	241.0	12.4	429.9
Belize	136.0	15.3	22966.0
Dominica	76.2	37.8	787.4
Grenada	107.6	24.9	344.5
Guyana	791.0	30.5	215000.0
Jamaica	2008.0	7.8	11424.0
Montserrat	11.6	16.0	102.3
St. Lucia	108.0	20.6	616.4
St. Kitts	46.8	30.4	352.2
St. Vincent	91.0	21.4	384.0
Trinidad and Tobago	1070.0	4.7	5128.0
	4757.0		257976.3

Extracted from Table 1 in 'the Commonwealth Caribbean' by S.E. Chernick, 1978.

2. FACTORS LIMITING FOOD PRODUCTION

The factors which limit food production for regional self-sufficiency in Caribbean agriculture are multifaceted and involve socio-economic, historical, structural, technological and biological components.

In 1974, the regional governments adopted a proposal by Dr. Eric Williams, Prime Minister of Trinidad and Tobago, for the implementation of a regional food plan. The plan envisages a regional effort in the production, processing, storage, distribution and marketing of food. The main priorities of the plan are:

1. Production of grains (corn, soyabean, peas and other beans) in Guyana and Belize for both human consumption and livestock feed.

2. Production and marketing of dairy products.

3. Production, processing and marketing of vegetables, fruits and peanuts.

4. Production of meat from poultry, pigs, sheep, goats and cattle.

5. Production of hatching eggs for the regional poultry industry.

6. Catching, processing and the distribution of fish.

7. Bulk purchasing and distribution of agricultural chemicals including fertilisers.

Although there has been considerable progress in the identification, formulation and appraisal of regional projects within the plan, actual production of some of the commodities identified has been slow. This is especially true for the crop production enterprises. This is partly so because the commodities which the plan proposes to produce have not been produced traditionally on a large scale and the technical and managerial know how for their successful large scale production is still being acquired.

The successful production of food crops on the scale envisaged by the plan will require among other things attention to the control of pests, diseases and weeds. There is abundant evidence to show that in traditional agriculture consisting of small farms and mixed cropping systems, plant pests, diseases and weeds, although important, are far less devasting than where large areas of land are planted with genetically similar germplasm.

3. IMPORTANCE OF PESTS

In order to evaluate the role of pesticides in food production in the Commonwealth Caribbean, I will first attempt to evaluate the significance of pests, diseases and weeds in crop production in the Caribbean, with special reference to three groups of food crops proposed in the Caribbean Food Plan viz. legumes, fruits and vegetables.

All food crops grown in the Caribbean region are subject to the ravages of pests. Damage varies from slight or negligible to complete loss. The work of Fennah (1954), Parasram (1973), Buckmire (1976), Sommeyer (1974) and other have all shown that there is a large number of insect pests of good crops in the region. These include a large number of pod borers of leguminous crops, fruit flies of fruits and leaf-eating insects of vegetables. In the legumes, *Heliothis virescens* (F), *Fundella pellucens* Zeller and *Ancylostomia stercorea* are recognised as major pests of pigeon pea which can result in as much as a 68% reduction in yield. These insects usually lay their eggs singly on the young leaves, buds and flowers. The newly hatched larvae feed initially on flowers and young leaves and later bore into the pods. Bruchids, *Callosobruchus* spp., attack the seeds of most legumes and are major storage pests. In soyabean productioon, the occurrence of species of *Anomis, Hydeleptera, Ceratoma* and *Anticarsia* can result in total loss of the crop and therefore successful production of this crop in the Caribbean will require effective control of these pests. Pest problems of *Vigna* spp. (including *V. unguiculata* which is widely grown) and of *Phaseolus vulgaris* have also been reported and will require effective control for the successful production of these crops.

Plant disease pose a serious threat to successful production of legumes on a large scale in the region. Brathwaite (1980), Pierre (1979), Phelps (1979), Haque and Phelps (1973), Haque (1979) have all documented the disease problems of leguminous crops in the Caribbean. The data presented indicate that plant diseases are one of the major limiting factors in the production of grain legumes regionally, especially in the case of the common bean, *Phaseolus vulgaris* L. The major disease problems of leguminous crops are anthracnose of bean *(Colletotrichum lindemuthianum)* Cercospora leaf spots of *Vigna (Cercospora canescens* and *C. cruenta)* and peanut *(C. arachidicola* and *C. personata),* rust on bean *(Uromyces phaseoli* var, *typica)* on peanut *(Puccinia arachidis)* and on pigeon pea *(Uredo cajani).* In addition to the above, there are a number of root diseases caused by species of *Macrophomina, Rhizoctonia* and *Sclerotium,* bacterial diseases caused by species of *Xanthomonas* and a number of virus disease problems e.g. cowpea mosaic virus. These diseases can severely reduce yield of crops. In studies in Jamaica, Pierre and Turner (1972) obtained substantial increases in yield of peanut by controlling leaf spot and rust. In their studies, while control plots yielded 1655 kg/acre, plots treated with Benlate, sulphur or Kocide gave yields of 2580, 2725 and 2347 kg/acre, respectively. While soyabean, because of its rather recent introduction to the region has relatively few disease problems, it is important to be aware that there are many severe diseases of soyabean which if introduced into the Caribbean could become of considerable economic significance in the production of this crop.

Vegetable production represents another area of priority in the Caribbean food plan. There is a large number of vegetables currently produced in the Caribbean, but pests, diseases and weeds can be limiting factors in their successful production in some areas. In cabbage production in Jamaica, Suah and Ellis (1974) have shown that cabbage pests, particularly cabbage diamond back moth, *Plutella xylostella,* can have a significant effect on yield of cabbage. They tested a range of insecticides for pest control and obtained the results in Table 2. They concluded that insect control with insecticides in cabbage production was economically justifiable.

Table 2 The effect of insecticides used for the control of cabbage pests on yield of cabbage in Jamaica

Treatment	Production (kg/ha)	% of control
Basudin	24,216	188.96
Dipterex	19,990	153.50
Thuricide	17,767	136.43
Malathion	17,692	135.86
Dipel	16,704	128.27
Control	13,022	100.0

Source: adopted from Suah and Ellis (1974).

Similar studies by Alleyne (1978) in Barbados have shown that increases in the weight of cabbage heads of as high as 300 per cent can be obtained by controlling *Plutella xylostella* and cabbage white butterfly *(Ascia monuste)* with insecticides. In this trial best yields were obtained with a low hazard pyrethroid compound. Other important insect pests of vegetable crops include pin worm *(Keiferia lycopersicella)* on solanaceous crops, a variety of mites, flea bettles, aphids and white flies.

Important diseases of vegetable crops include bacterial wilt of solanaceous crops caused by *Pseudomonas solanacearum*, black rot of cabbage caused by *Xanthomonas campestris*, southern blight caused by *Sclerotium rolfsii*, and a large number of other leaf spots, wilts and root disease problems.

One of the most devasting but not well recognised group of pests associated with vegetable production in the Caribbean is plant parasitic nematodes. Nematodes of the genus *Meloidgyne*, root knot nematodes, are widespread on crops in the region. In addition, reniform nematodes, *Rotylenchulus reniformis*, and lesion nematodes, *Pratylenchus* spp., are also common. Studies by Brathwaite (1974) and Singh (1974) have shown that nematode problems can be severe limiting factors in vegetable production in the region.

Nematode control has resulted in substantial increases in yield in tomato (Singh 1975), sweet pepper (Singh 1974) and other crops (Brathwaite, 1974). In carrots improvement in yield and quality has been obtained by controlling nematodes in St. Vincent (Singh, unpublished report).

Citrus and banana are the two most widely grown tropical fruits in Caribbean agriculture. There are several of important pests of these crops which must be controlled if commercially acceptable yields are to be obtained. These include for banana Sigatoka leaf spot caused by *Mycosphaerella musicola*, banana borer, *Cosmopolites sordidus*, and plant parasitic nematodes, *Radopholus similis*, root knot nematodes, *Meloidogyne* spp., reiniform nematodes, *Rotylenchulus reniformis*, and spiral nematodes, *Helicotylenchus multicinctus*. In citrus production, the control of virus diseases, foot rot caused by species of *Phytophthora* and plant parasitic nematodes, are important. The significance of pest and disease control in citrus production is evidenced in the citrus industry of Trinidad and Tobago.

Citrus production was once a thriving agricultural enterprise in Trinidad and Tobago. More recently, citrus has been and is being imported into Trinidad and Tobago as a result of a decline in the industry. Socio-economic factors are involved in the decline, but there is evidence to show that virus diseases, plant parasitic nematodes and soil management problems are also contributing factors.

There is a large number of other tropical fruits which have the potential to contribute to the food and nutritional demands of the Caribbean people. However, their production is limited to small areas and backyard fruit orchards, usually of one or two trees of any one species. While it is true that improved cultivars of these crops are required for commercial production, pest and disease problems have limited the expansion of these crops in some cases.

Mango *(Mangifera indica)*, guava *(Psidium guajava)* avocado *(Persea americana)*, pawpaw *(Carica papaya)*, and pineapple *(Ananas comosa)* are all fruits with considerable potential for production in the Caribbean. Mango is affected by the disease anthracnose caused by *Collectotrichum mangiferae*, guava is widely attacked by fruit flies, *Anastrepha* spp, avocado suffers from fruit rots caused by *Collectotrichum gloeosporioides* and from dieback associated with infection by *Phytophthora cinnamomi* and nematodes. Pawpaw is affected by bunchy top to the extent that in some areas it is very difficult to grow the crop successfully. Pineapples are subject to attack by plant parasitic nematodes.

Hutton (1978) has demonstrated the significance of the control of plant parasitic nematodes in the commercial production of pineapple in Jamaica. The data presented in Table 3 shows that in some cases the application of nematicides resulted in 200% increase in yields.

Table 3 Effects of nematicide treatments on yield, suckering, development of reddening and/or tip dieback symptoms of parent and first ratoon crop of Smooth Cayenne pineapple plants

	Parent Crop*			First Ratoon Crop*				
Nematicide Treatments	Av. fruit weight (kg)	Av. suckers per 3.0 x 7.5 m	% plants with reddening and/ or leaf dieback	% plants bearing fruit	Av. fruit weight (kg)	Av. suckers per 30 x 7.5 m	% plants with reddening and/ or leaf dieback	Yield (tons/ ha)
Untreated	1.05	2	80^{d}	32^{a}	0.73^{a}	5^{a}	100	8.1^{a}
DD (390 l/ha)	1.76	6	30^{c}	59^{cd}	1.68^{b}	21^{b}	63	34.6^{b}
DD – DBCP (11 l/ha)	2.30	6	15^{ab}	51^{bc}	1.74^{b}	22^{b}	58	30.7^{b}
DD – Nemaphos (11.2 kg a.i./ha)	1.47	4	18^{ab}	64^{d}	1.68^{b}	20^{b}	60	37.2^{b}
DD – Nemacur (11.2 kg a.i./ha)	2.61	4	10^{a}	56^{c}	1.64^{b}	21^{b}	60	31.8^{b}
DBCP (33.5 l/ha)	2.38	3	25^{bc}	61^{cd}	1.32^{b}	13^{ab}	78	28.0^{b}
DBCP – DBCP (11 l/ha)	2.00	6	18^{ab}	56^{c}	1.72^{b}	23^{b}	78	34.4^{b}
DBCP – Nemaphos (11.2 kg a.i./ha)	2.29	6	13^{a}	58^{cd}	1.39^{b}	19^{ab}	68	27.8^{b}
DBCP – Nemacur (11.2 kg a.i./ha)	2.69	6	13^{a}	46^{b}	1.72^{b}	27^{b}	48	27.3^{b}

Source: Hutton 1974.

*Means followed by the same letter not significantly different at the 5% level
** First nematicide applied preplant; second at 10-monthly intervals.

It is well documented that effective weed control is essential to the successful production of food crops (Hammerton, 1974). Studies carried out by Brathwaite (1974), Kasasain, and Seeyave (1969), Hammerton (1974) and Donelon (1974) have all confirmed the view that successful weed control is vital for the production of high crop yields. In general, weeds must be controlled for the first one-third of the crop's expected duration if maximum yields are to be obtained. Hammerton points out that weed control need not be total but that there is a threshold density below which weeds will not significantly reduce yields. Brathwaite and Ferguson (1974) have also obtained increased yields of bodie beans, *(Vigna unguiculata* (L.) Walp.*)* by successful weed control. Their studies showed that all herbicidal treatments yielded less than the clean-weeded control, but generally more than the unweeded controls. These and many other studies have shown that successful weed control is important but as Hammerton points out weed control is not synonymous with herbicide application. Non-herbicidal weed control has the following advantages:

(1) lack of residues

(2) good selectivity

There are advantages however to herbicide use which include:

(a) greater timeliness of control

(b) control of weeds during wet weather

(c) control of perennial weeds

(d) reduction of human energy required for weeding

(e) sometimes much cheaper than manual labour.

In addition to the above problems, the Heads of Plant Protection of the Caribbean at a recent meeting held in Mexico City recognised the following as the most urgent pest and disease problems in Caribbean agriculture.

(1) Red ring disease, wilt and lethal yellowing of coconuts

(2) Leaf cutting ants

(3) Smut and rust disease of sugarcane

(4) Moko disease of banana and plantain

(5) Coffee berry borer

(6) Pin worm on solanaceous crops

(7) Seed-borne pathogens

4. IMPORTANCE AND FUTURE OF PESTICIDES

The data presented above idicate that there is a large number of pest, disease and weed problems associated with food production in the Caribbean. The data also show that in some cases substantial increases in yield can be obtained by the use of pesticides. The major questions which I would like to consider in the final part of my paper are:

(1) are pesticides really necessary?

(2) what is their future role in crop production in the region?

Are Pesticides really necessary

The use of pesticides as a unilateral approach to the solution of plant protection problems is associated with considerable difficulties. This is one of the lessons which must be learned without modification or dilution from the experience of the developed countries of the world.

Prior to 1940, pesticides were rarely used in plant protection. After World War II, however, the use of the new organic pesticides were widely advocated for pest control and resulted in unprecedented increases in yield in a number of food and industrial crops. These achievements, however, did not last for very long and in less than two decades it became clear that pesticides alone were not the answer to plant pests and diseases. The difficulties included unwanted residues, deleterious effects on wild life and the environment, and the development of insect resistance to pesticides.

In the 1960's, it began to appear to both scientists and layment that control measures should not necessarily be designed to kill the pest but rather prevent the pests from reducing crop

yield. This realisation resulted in a shifting of the emphasis in control from an "eradicative" approach to a "protective" approach and from this latter approach the concept of integrated pest control or pest management was born.

2. The Future role of Pesticides in the Region: Integrated Pest Management

Integrated pest management implies utilisation of all the control methodology available in a harmonious manner to reduce the population of the pest to a level below that at which it causes economic losses".

The concept implies a knowledge of the total agro-ecosystem, information on pest levels which cause economic damage and the ability to integrate methods of control. The reduction in the number of required applications of an insecticide, based on monitoring and evaluation of insect population and activity, has been obtained in a number of cases in the developed and developing world (Brader, 1979).

But can the present or prospective farmer or farm manager of the Caribbean be expected to use pesticides in a manner that is compatible with bringing about minimum disturbance of the environment? Can we expect the present generation of Caribbean farmers to count insects, determine economic threshold levels, rotate the use of pesticides, utilise natural enemies, and adopt cultural methods when they know that a pesticide will kill the pest immediately. The answer to this question cannot be given as yes or no. What is required in the Caribbean are studies by researchers to determine the biology of common pests and their interaction with the crop plant and the physical environment. The integrated control approach can only succeed where there is an understanding of the entire ecology of the crop/pest situation. When this information has been obtained then the need for effective pesticide use will emerge. This information must be carefully transmitted to the extension officers who will then devise methods of transmitting it to the farmer in a language which is compatible with the farmer's social and cultural environment.

Such programmes have been successfully utilised in the integrated control of cotton pests in Peru, in the control of rice pests in India and in the control of pests of cotton, maize and rice in China (Brader, 1979).

The recent studies by the Caribbean Agricultural Research and Development Institute on the integrated control of pests of sugar cane and vegetables is a step in the right direction and the data obtained from their studies and similar studies will be vital if we are to use pesticides in food production in a responsible and rational manner.

In these studies, attempts are being made to combine biological and chemical control of insect pests of sugar cane and vegetables in a compatible system. For example, in cabbage production it has been found that there is a number of arthropods which attack diamond-back moth, *Plutella xylostella*. These include *Cycloneda sanguinea*, *Nephus* sp. and various species of *Chrysopa* which occur naturally, and *Apanteles plutellae* and *Terrastichus sokolowskii* which have been introduced. These enemies appear to be providing good control of *Plutella* in areas where chemical use is moderate. The suggestion is made that reduced chemical application will probably result in more economical control of *Plutella*.

All available data suggest that we will need pesticides and there may be instances where pesticide application may be the only answer to sustaining yields of food crops. However, in such circumstances we must take steps to ensure that we devise methods to cope with the consequences. A relevant case is that reported by Bennett (1976) in which he speculates that the widespread use of pesticides to control froghopper in sugar cane in Trinidad has resulted in destruction of the natural enemies of sugar cane borer, *Diatrea saccharalis*, and this insect which was of little or no significance in sugar cane production in Trinidad is now a serious pest.

Pesticides alone will not solve some of the vexing plant protection problems in Caribbean agriculture, e.g. the control of smut and rust disease of sugar cane, or lethal yellowing of coconuts. In these cases, studies on the development of resistant varieties are vital. This approach to control will be important in many other crops. The recent development of a variety of cowpea resistant to cowpea mosaic virus is a significant achievement.

The removal of crop residues can be most important in the control of some diseases, e.g.

blackpod of cocoa caused by *Phytophthora palmivora*. In some cases such actions may reduce the inoculum to levels where pesticide use is unwarranted.

A dangerous trend in the Caribbean at the moment is that local agents for pesticides go directly to farmers with prescriptions for immediate solutions to their problems. In the interest of public safety, it is necessary to control the sale, distribution and promotion of pesticides in developing countries. The recent passage of legislation controlling the sale, distribution, etc. of pesticides in Trinidad and Tobago and the appointment of pesticide inspectors in Barbados are actions that are commendable. This is necessary because pesticides which have been banned in the developed countries are being sold boldy in developing countries. Moreover, as a result of these approaches, some farmers have become "hooked" on chemicals as a drug addict could be hooked on cocaine, spraying religiously with a cocktail of dangerous chemicals every 7-10 days. This wanton dumping of chemicals into the Caribbean environment may have severe ecological consequences in the future.

5. CONCLUSIONS – RECOMMENDATIONS

(1) That pesticide control agencies be set up in each country of the Caribbean to ensure that our environment remains free of toxic chemicals.

(2) That International organizations and transnational chemical companies fund projects aimed at the integrated control of pests in the Caribbean.

In conclusion, devastation by pests and diseases poses one of the most imporant risk factors in increasing the production of foods from plants. Their control is vital to increasing yields and to the maintenance of these high yields. However, in controlling pests, let pesticides be only one in the package of practices which we apply in order to maintain a wholesome environment.

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3. THE CHEMICAL INDUSTRY PRESPECTIVE – FUTURE TRENDS OF THE PESTICIDE INDUSTRY AND ITS RELEVANCE TO THE CARIBBEAN

RICHARD A. HERRETT

CONTENTS Page

1. INTRODUCTION 39

2. THE FUTURE – GLOBAL 2000 39

3. AGRICULTURAL PRODUCTIVITY 40

4. BENEFITS OF INCREASED PRODUCTIVITY 42

5. THE PESTICIDE BUSINESS AND ITS ROLE IN ACHIEVING INCREASED PRODUCTIVITY 43

6. CONCLUSIONS 50

1. INTRODUCTION

I welcome this opportunity to discuss the perspective of the chemical pesticide industry, future trends and their relevance to the Caribbean. Although employed by one of the major pesticide producers in the world, ICI, I also have the honor of serving as Chairman of the NACA Research Directors Committee and it will be from this latter vantage point – as a representative of industry that I shall present my views. My views should not be considered a mandate from the Industry, indeed it is rare when the 24 major companies represented on my committee achieve unanimity on any point. Rather my views are personal, tested over the years by exposure to comments of friends and colleagues in the business both in the USA and around the world.

The definitions of perspective include – "the relationship of aspects of a subject to each other and to a whole", "a subjective evaluation of relative significance" and "a point of view". I shall consolidate each of these definitions into my discussion by examining the relationship of the pesticide chemical industry to some of the external and internal constraints facing it. This will include a subjective evaluation of the significance of pesticides and an examination of the challenges facing all of us from the point of view of the pesticide industry. The challenges of the Caribbean are in some instances unique but in a broader context, they are not dis-similar to the rest of the world especially when viewed in relationship to the dominance of the universal importance of the maintenance and improvement both quantitative and qualitative of human health and nutrition.

2. THE FUTURE – GLOBAL 2000

Before gazing into the crystal ball at possible future trends within the pesticide industry, it may be wise to examine some projections of what the world might look like as we enter the 21st Century – just 20 short years from now. My reference point is the recent report, Global 2000*, issued by the President's Council in Environmental Quality and co-sponsored by the State Department. The basic message of the report is that the capacity of the environment to provide goods and services can no longer be taken for granted. Not only is the population and per capita consumption outstripping the capacity of the environment, but the ecological systems that provide those goods and services are being undermined, extinguished and poisoned.

Certain conclusions of the report are important and germaine to our discussion of the pesticide industry.

* *Global 2000 (1980). The Council on Environmental Quality and Department of State, U.S. Government Printing Office, Washington D.C. (Three volumes).*

Included among the conclusions are the following:-

Highlights of Global 2000

World population will grow from the current 4 billion to 6.35.

Available land will increase only 4%.

World oil production will have peaked.

World food production is projected to increase 90%.

Regional water shortages will become more severe as population growth alone will cause requirements for water to double in nearly half the world.

Commercial timber supplies will have declined by 50%.

40% of the world's forest cover will have disappeared.

Firewood needs will exceed available supplies by 25%.

Atmospheric concentrations of CO_2 and ozone-depleting chemicals are expected to threaten the global climate.

These highlights are based on the following assumptions:

Assumptions of Global 2000

A general continuation around the world of present public policies relating to population stabilization, natural resource conservation and environmental protection.

Rapid rates of technological development and adoption will continue. Agricultural productivity will continue increasing as rapidly as it has over the past few decades including the Green Revolution.

No major disruptions of international trade, disturbances of international monetary system or political disruptions.

3. AGRICULTURAL PRODUCTIVITY

Agricultural productivity is key to the achievement of the goal of a 90% increase in supply over the next 20 years and therefore, it is important to examine historical perspectives of this productivity.

Man and agriculture have moved through some 12,000 years of history together. Today people in their new-found freedom from the soil in many parts of the world have forgotten the basic relationship which binds us – a relationship that allows freedom but not independence. Food is the only indispensable product that man produces and that makes us totally dependent on the farmer.

Man's success in his efforts to provide food and fiber of acceptable quality has been achieved through a complete system of interdependent parts including fertilizers, high yielding varieties, cropping systems, irrigation, mechanization and crop chemicals.

One measure of this success can be seen in the yield of corn (maize) in the USA. (Figure 1). The relatively constant yields per acre betwen 1880 and 1940 was followed by an almost explosive increase in productivity.

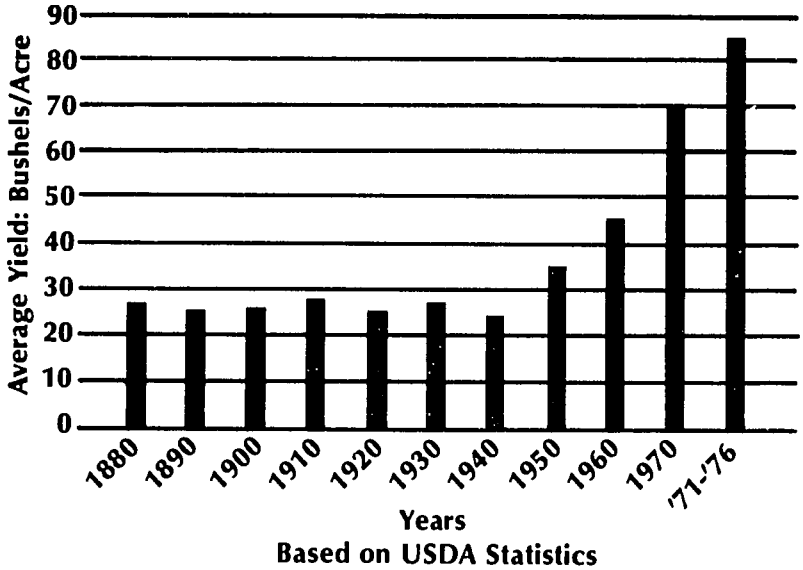

Figure 1. U.S. Corn (Maize) Production

One measure of this success may be seen in the number of persons supplied with farm products by one farmworker (Figure 2). There is relatively shallow growth between the early 1800's and 1940 followed by an explosive growth in productivity.

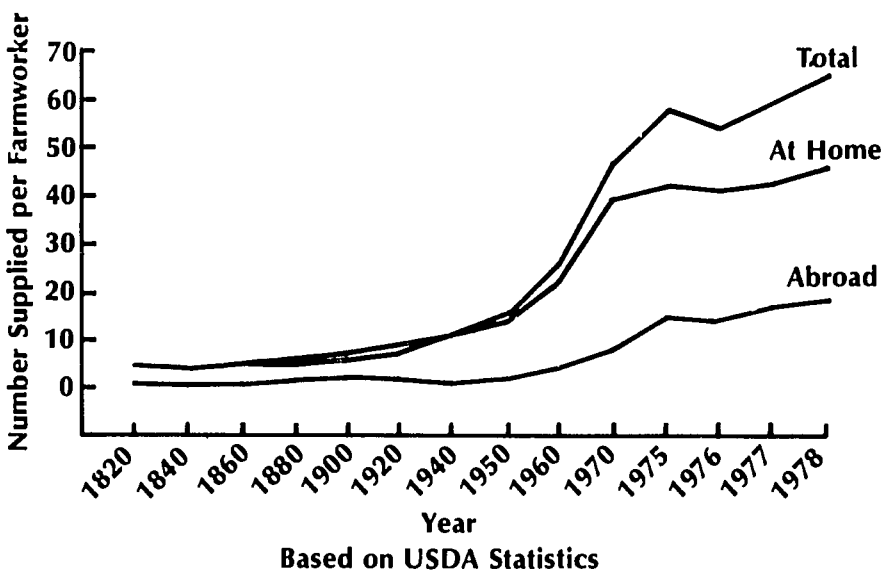

Figure 2. Number of Persons Supplied with Farm Products by One U.S. Farmworker

One of the problems associated with the massive population shifts from the farm is the lack of awareness and understanding of the problems associated with food production. The appearance of even one apple maggot in a polyethylene pack of apples will induce cries of anger at the local grocery store. In terms of productivity, we are dealing not only with quantity but also in quality. The demands placed on the quality of the finished product by the consumer today are

far greater than those of forty years ago. These demands undoubtedly have resulted in reduced hazards from naturally occurring contaminants such as aflatoxins and insect debris.

Thus, in considering the vast growth in productivity, we are really addressing the last 40 years of agriculture – an extremely short period of time within the span of man's agricultural endeavors. The significance of improved productivity is to allow man to meet the expanding food requirements of the world and at the same time allow him to engage in non-agricultural activities.

What has accounted for the dramatic changes in productivity? As a member of the agrochemical industry I could point to DDT and 2,4-D both discovered in the late 30's and available to commercial agriculture in the mid-40's and claim it was a consequence of pesticides. Pesticides are the only large scale practical way to protect crops against insects, fungi and weeds; however, they are only part of the story. Other major technological advances occurred during this period such as improved fertilizers, hybrids and resistant varieties, each of which had a major impact on productivity. It is unimportant which advance was most significant. Of far greater importance is the fact that the development and application of this new technology resulted from a three-member team approach. The members of the team consisted of the scientists and teachers from our land grant universities, the USDA and industry. Without anyone of the three, the others would collapse into obsolescence.

4. BENEFITS OF INCREASED PRODUCTIVITY

The two significant benefits of improved productivity have been mentioned:

The ability to provide quality food and fibre to meet the demands of an expanding population; and,

The ability to shift people resources from agriculture to non-agricultural pursuits and subsequently to provide goods and services.

There are other less obvious benefits:

The discretionary use of land. It has been estimated an additional 380 million acres of farm land would have been required to produce the yields in 1976/78 based on productivity of 1938/40;

The conservation of natural resources. Wood preservatives lengthen the life of timber used for poles, posts and structural lumber by approximately five times. Thus the annual consumption of approximately 1 billion cubic feet per year would have to be increased accordingly to make up the loss. This would require forests covering roughly twice the area of New England. This is a saving of 80 million acres and the energy associated with the management of the area.

The conservation of soil and energy. The concepts and practice of no-till cultivation are especially significant to the conservation of soil and energy. Pesticides represent 2% of the energy consumed by agriculture which itself is about 4% of the total energy consumed.

The impact on agrochemicals on production by overcoming extremes caused by infestations. This enables better planning, and reduces social upheaval.

There has been increasing concern however that the rapid increase in productivity may be declining. Two weeks ago the Wall Street Journal ran a front page story entitled:

"Crop Squeeze – As world needs food, US keeps losing soil to land Developers – Eased gains in productivity, temptations to sell out make for a bleak outlook."

Two major points were stressed. One was the decline in basic knowledge. As Dr. Anson Bertrand, Director of Science and Education Administration of USDA stated, "We have used up most of our storehouse of knowledge and applied it widely. But it simply isn't being replaced fast enough and our crop yields are topping out."

Secondly, the average gains in output per acre have drifted down from 3% a year in the 50's to barely over 1% in recent years. This has occurred during a period when foreign demands for food have been increasing rapidly going from 6 billion to more than 32 billion dollars in the last decade.

5. THE PESTICIDE BUSINESS AND ITS ROLE IN ACHIEVING INCREASED PRODUCTIVITY

Pesticides play a vital role in agriculture today.

In developed countries yield increases of 10 to 20 per cent are common. Studies in the UK have demonstrated yield losses of 24 to 67 per cent in various crops grown without pesticides. In Germany, apple production in the absence of pesticides was reduced 40 per cent and marketable produce dropped from 80 to 30 per cent.

But pesticides are not an end in themselves – with the exception of growth regulators they do not increase yields. They are unique because they permit other entities that enter the crop system to perform to their maximum potential. For example, benefits derived from a plant resistant to the first brood European corn borer would not be obtained if, because of the lack of a seed protectant, the seedlings were lost to soil insects or pathogens.

There is a variety of effective options when used either alone or in combination with agrochemicals (Table 1). These options take on even greater importance as Society demands that basic pest control decisions by individual farmers are based on economic and social considerations as well as technical possibilities. Growing awareness of the nontarget costs of chemicals have placed added emphasis on the efficient use of pesticides.

Table 1 Principal Control Tactics Used against Major Pests in Several Regional Cropping Systems

	Major Pests 1/			
Crop and Regions	Insects	Nematodes	Pathogens	Weeds
Wheat (Great Plains)	2,1,3	2	3,2	1,2
Corn (Corn Belt)	1,2,3	-	3,2,1	1,2
Soybeans (SE)	1	1,3,2	1,2	1,2
Apples (N)	1	1,2	1,3,2	1,2
Potatoes (NE)	1,2	2,1,3	2,1	1,2
Cotton (TX)	1,2,3,	3	3,2,1,4	1,2
Melons (CA)	1,4	1	2,3	1,2
Cole (CA)	1,4	1	2	1,2
Lettuce (CA)	1,2,4	1,3	2,1,3	1,2
Tomatoes (CA)	1,2	1,3	3,2	1,2
Strawberries (CA)	1	-	2	1

1/ Control tactics

1. Chemical (insecticides, nematicides, fungicides, herbicides);
2. Cultural (cultivation, crop rotation, planting dates, sanitation);
3. Plant resistance (growth varieties genetically resistant to pests);
4. Biological (predators, parasites, microbials).

Pesticides as part of the total production system account for 3% to 4% of the grower's expenditure. Compared to the rising costs over the last decade pesticides are the least inflationary component of production (Table 2).

Table 2 Trends in prices paid for Pesticides and other Farm Inputs and prices received for Farm Commodities 1970-79

	Price indices (1976=100) 1970 1/	1979 2/	Percentage change 1970-79
	Index		Percent
Prices paid:			
Pesticides	98	151	54
Fertilizer	88	211	140
Tractors and self-propelled machinery	116	302	160
Other machinery	116	305	163
Fuel and energy	104	318	206
Feed	101	208	106
Seed	112	295	113
All purchased inputs		255	128
Prices received:			
Crops	100	224	124
Livestock and livestock products	118	250	112
All commodities:	110	237	115

1/ Annual

2/ As of November 15

Critical to the pesticide industry and to agriculture is the continued appearance of significant new products. Four major forces act upon the industry. Although I have isolated these forces, they are interactive and not independent variables.

A. Commercial opportunities

These are based on the needs primarily perceived by the grower and are essentially external to the pesticide producer, although assessed and assimilated by the producer. These include the size of the market and opportunities for future growth.

The worldwide use of pesticide in 1978 was estimated at 8.67 billion dollars (Table 3). Rapid growth, 15% per annum occurred during the 1960's. This settled down to 6-7% in more recent times and is projected to grow at 4.7% through 1984. When compared to projected growth rates of 15 to 20% of other industries such as computers, this appears slow, but when one considers a 1% growth rate generates the same income today as 10% of the world sales did in the late 50's, it takes on a different dimension.

There will be considerable differences in growth around the world; Western Europe and North America are expected to lag while Central and South America are expected to exceed the average in some countries growing at greater than 10%.

Table 3 World Pesticide Use in 1978 and Projected Use for 1984

	Estimated Use in 1978 Million dollars	Projected Increase 1978-84 Percent	Projected Increase Annual Increase Percent
Herbicides	3,716	29	4.8
Insecticides	3,028	11	1.8
Fungicides	1,539	28	4.7
Other pesticides	387	38	6.3
Total	8,670	28	4.7

B. Business constraints — Financial, Social and Political Constraints

Of critical importance is the balance between size of investment, the risk involved and the potential reward. This may be illustrated in an examination of the economics of pesticide development.

The basic assumptions include the price ($3.33/lb) volume (10 million lbs/year), net profit after taxes (14% of sales), fixed capital (20 million dollars), working capital (50% of sales), sales and support expenses (3 million dollars), advertising (1.5 million dollars) and six years of cumulative R/D efforts (14 million dollars). These assumptions can be displayed in a typical cash flow curve (Figure 3). Profit to the company does not occur until after the costs have been covered — year 13 in this case. The shape of the curve after patent expiration will depend upon competition.

The impact of additional costs, in this case a million dollars, as a result of additional registration tests do not impact greatly on the overall cash flow (Figure 4). However, if delays occur because of changes in registration, there is a major impact in profitability. In this case, a two-year delay reduces the profit essentially by half (Figure 5).

The likelihood that the risk will pay off is significantly influenced by the size of the market. If we examine the US market for pesticides, we see the major markets exist for herbicides and insecticides, with smaller markets for fungicides, (Table 4). Based on crops, the major markets for pesticides are corn, soybeans and cotton. Clearly, these influence the direction for risk taking.

Many major companies have considered a minimum target market of 14 million dollars and for markets below that there is too great a risk for an investment of resources.

Most of the major agrichemical producers exist within much larger chemical organizations. The pesticide component usually represents some 3 to 5% of total sales. Clearly if the balance tips to the point where risks outweigh the likely rewards, these large organizations will look elsewhere for profitable investment. It is also important to recognize the sensitivity of top management if the reputation of a company is at potential risk. It will not readily jeopardize the 95% of its business for 5%.

The impact of future trends on perceived needs is another important factor. Integrated Pest Management is an example of this. This technique calls for minimizing pesticide use. At first glance, one might expect industry would be opposed to this, but this is not the case. Industry supports the basic principles of IPM. We believe the judicious use of pesticides is in the best

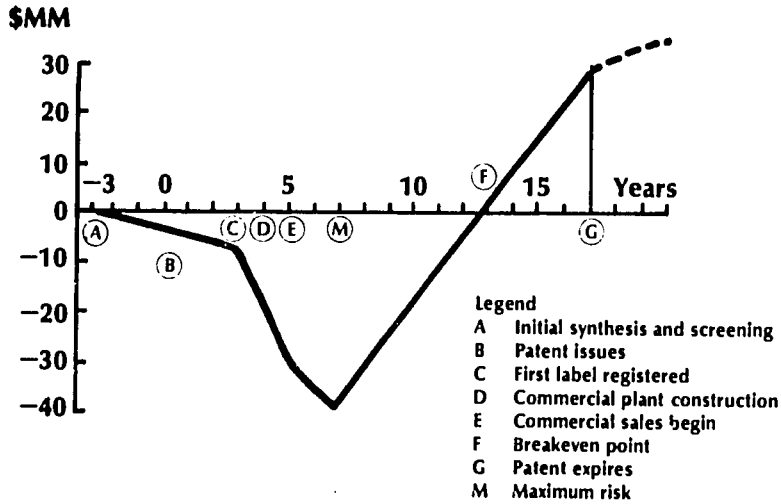

Figure 3. Cumulative Cash Flow — Hypothetical Pesticide

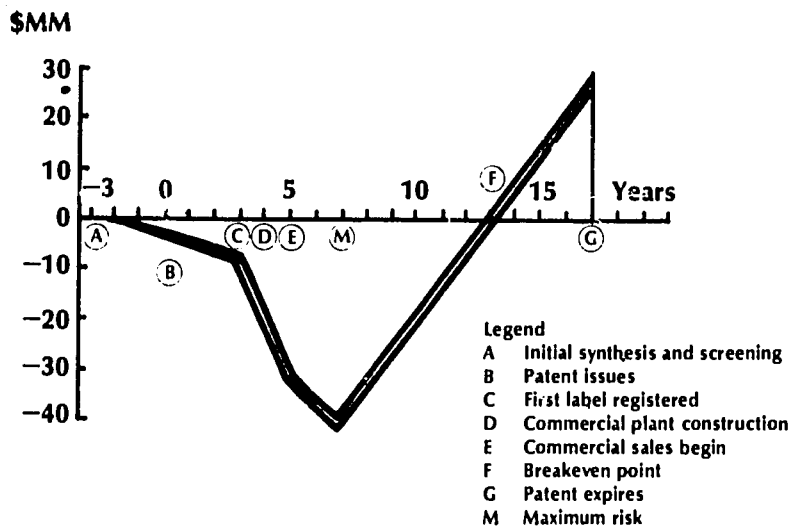

Figure 4. Cumulative Cash Flow — Additional Research/Development Costs

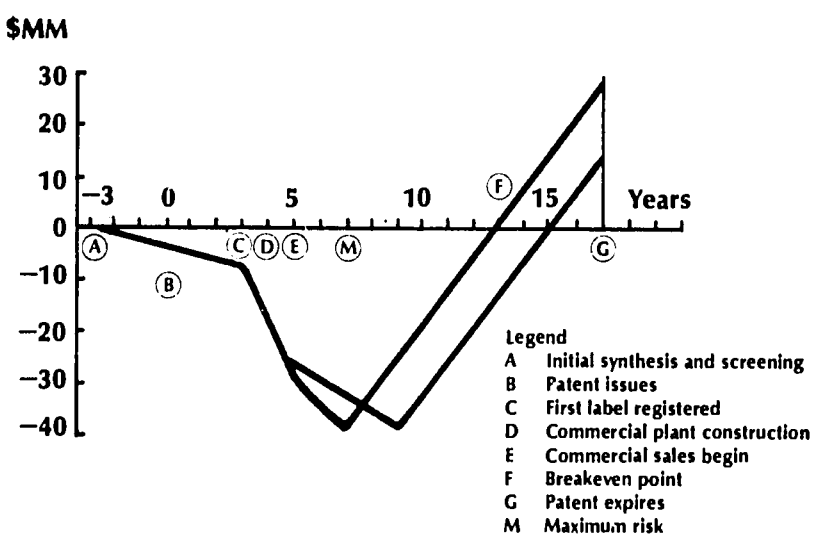

Figure 5. Cumulative Cash Flow — Two Year Delay

interests of all. Our immediate concern is the potential misuse of the techniques of IPM before the science of IPM is fully understood. Another pitfall of concern is the overstatement of potential offered by IPM.

Table 4 Leading U.S. Markets Estimated for Herbicides, Insecticides and Fungicides, 1978

Type of pesticide and crop	Millions of Dollars Purchased	Percentage of Market
Herbicides:		
Corn	658	38
Soybeans	550	32
Cotton	128	7
Wheat	69	4
Other crops	327	19
Total	1,732	100
Insecticides:		
Corn	208	26
Cotton	207	26
Fruits and nuts	125	16
Vegetables	88	11
Other crops	181	21
Total	809	100
Fungicides:		
Fruits and nuts	63	33
Vegetables	32	17
Peanuts	27	14
Soybeans	13	7
Cotton	13	7
Other crops	42	22
Total	190	100
All pesticides:		
Corn	871	30
Soybeans	593	21
Cotton	348	12
Other crops	1,048	37
Total	2,860	100

Technical Capability

This is the basic ability to discover new molecules which represent significant advancements and are useful in filling perceived needs. There are many high performance standards available today making significant discoveries less likely.

Discovery is still due in large measure to serendipity. It is the combination of the happy chance occurring and being observed by an individual with both the insight to recognize its significance and the opportunity to communicate it to the people who can decide what happens next.

The probabilities of discovery based on the number of compounds synthesized and screened have changed dramatically over the past few years, (Table 5), from one in 1800 in 1956 to 1 in

25,000 today. This factor plus the additional time required to achieve registration has driven the R/D cost per compound up nearly 20-fold in the last 24 year.

Table 5 Probabilities, Time and Costs associated with the Introduction of a new Pesticide

	1956	1969	1972	1980 (est)
Survival Rate a/	1800	5040	10,000	25,000
Time b/ (months)	58	60	110	95
Costs c/ (millions of dollars)	1.2	4.1	10.0	20.0

a/ Number of compounds screened to achieve one commercial product.

b/ Elapsed months from discovery to first commercial sale.

c/ Uninflated costs of research and development for each commercial success, exclusive of production capital costs which can exceed R/D costs 3 to 5 fold.

It is also worth reemphasizing the point mentioned earlier of Dr. Bertrand, that we are not replenishing our storehouse of basic scientific knowledge is fast as we are calling upon it. This will surely have a negative impact on the technical capability in the future.

Regulatory Influences

In the US, there is a clear trend toward increasing regulation and the testing required to obtain registrations. This was seen in the length of time between discovery and first registration. It is also reflected in the number of registration granted over the past 5 decades (Figure 6). There was an uptrend from 1930 to a high of 28 new registrations in 1965. Subsequently there was a decline to the lows of 3 in 1977 and 2 in 1978. It is too early to tell if the uptick in 1979 is real but there are indications the corner has been turned with the introduction of conditional registration. None of the 5 registrations in 77 and 78 were granted to companies with sales volumes in excess of 100 million dollars per year yet those same companies spent over 400 million dollars on R/D during that period.

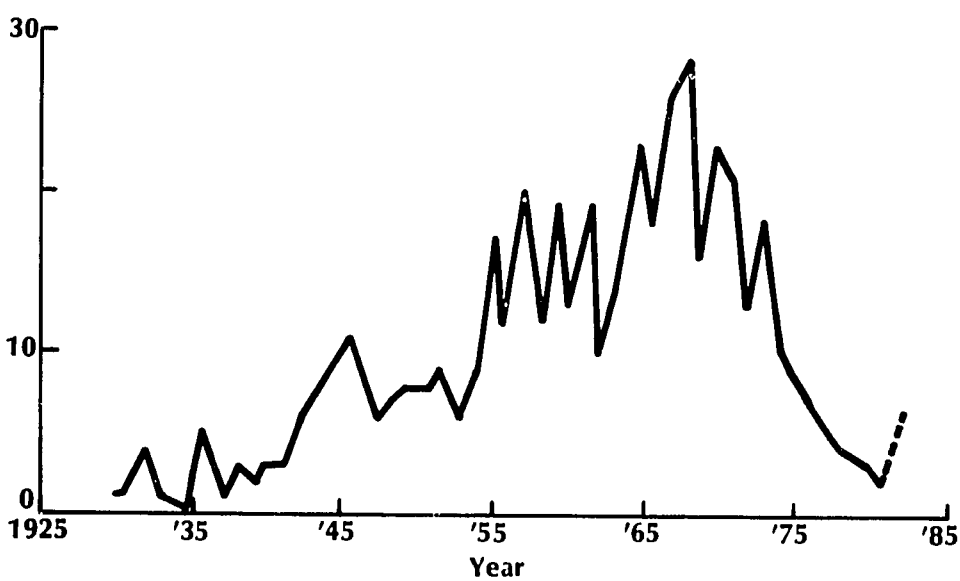

Figure 6. Number of Pesticides Introduced Each Year from 1930 to 1979

Although it is easy to blame EPA for this trend, I believe industry recognizes the Agency is mirroring and enforcing the public's demand for safety and precaution embodies in most environmental legislation. What does concern the industry is in the implementation of these demands, the impact of uncertainties and subsequent delays. I've already illustrated how this impacts on the industry. Also of concern is the potential impact of EPA action on the rest of the world.

One consequence of regulatory action has been on the shift of technical resources (Table 6). Resources required to defend RPAR positions has esculated dramatically while basic research efforts have remained essentially statis. This clearly impacts the basic science and does not help alleviate the problem mentioned under technological capability.

Table 6 Comparisons of Expenditures for Basic Research and RPAR

	1976	1977	1978	1979
Basic Research	6.4 (est.)	6.8	4.6	8.8
RPAR	1.1	6.8	6.3	9.4

Given the constraints mentioned, where do I see the trends in pesticides in the future. Some of them include the following:

Trends in Pesticides for the Future

More costly
Fewer available
Greater specificity against target pests
More compatible with the environment
Greater sophistication in formulations
Revolution in application techniques
Electrostatic spraying
Movement toward crop production systems:-
Integrated Pest Management systems
Bioengineering Techniques

There undoubtedly are vast differences in the social, economic and political forces impacting on the type and uses of pesticides throughout the world. These differences must be recognized. They become even more important as the level of sophistication increases. Of major importance is the basic need for education and technology transfer. This must be achieved recognizing the local constraints. Adoption of this technology in the Caribbean must take into account the:-

Diversity in land masses – from tiny islands to large countries
Diversity in culture, background and language
Diversity in endowments – from exportable oil to single crop agriculture
Diversity in per capita income from 170 to 13,000 dollars per year.

Also it must be recognized that there is severe competition for financial resources among crop protection chemicals, fertilizers and machinery to improve productivity, and that optimum production will occur from a reasonable balance of several inputs.

In the final analysis, there are specific needs which I believe must be fulfilled to achieve increased productivity. These include:

Public awareness of the problems associated with food production. Current crop loss assessment information will be important in developing this understanding.

Expanded research on a system approach to crop production utilizing both biological and chemical resources to maximize crop production potentials.

Sufficient economic incentive to discover and develop new molecules with appropriate biological activity.

Realistic assessment of the risk/benefit equations in relation to the project for the 21st Century.

Improved mechanisms in education and technology transfer to minimize risks to human health and the environment.

6. CONCLUSIONS

There is a clear need to increase the worldwide productivity of agriculture. This will require the application of new technology and must be done in consideration of the changing social pressures for an improved environment.

The pesticide industry in concert with government and academic resources can play a major role in meeting this objective. It is essential to recognize the business, technical and regulatory constraints and that these must be set against regional constraints in resources and technology.

There is increasing evidence that the world is rapidly approaching the upper limits of its capability to produce quality food and fiber, and the constraints in technology, land and water must be factored into the thinking about the 21st Century. It is a sobering situation requiring new solutions to difficult problems; however, if approached with a realistic perspective, it is not a desperate one. I might close with the wisdom of Francis Bacon:

"He that will not apply new remedies must expect new ills; for time is the greatest innovator."

Francis Bacon 1630

4. THE PESTICIDE SITUATION IN THE CARIBBEAN WITH PARTICULAR REFERENCE TO TRINIDAD AND TOBAGO AN ENVIRONMENTALIST'S VIEWPOINT

GENE V. POLLARD

CONTENTS

		Page
1.	INTRODUCTION	51
2.	CHEMICALS IN USE IN THE REGION	52
3.	A CASE HISTORY – THE CONTROL OF FROG-HOPPER IN SUGAR CANE IN TRINIDAD	55
4.	DISCUSSION	57
5.	CONCLUSION	58

1. INTRODUCTION

Developing countries today face a double dilemma in their attempts to solve their food production problems. In the first instance, low crop yields result from traditional cropping systems and agronomic practices being applied to new hybrid varieties which usually require advanced farming techniques; not the least of these techniques are sophisticated pest control systems. Such systems are usually expensive to implement particularly where chemical control is concerned; pesticides are extremely expensive in developing countries today.

Apart from this problem of the advanced technology and concomitant expense that are necessary for optimum food production the other dilemma lies in the increased use of pesticides. While this is perhaps still absolutely necessary in developing countries to ensure the maximum yields necessary for growing population levels, the real problem is not simply increased pesticide use but rather their overuse and misuse and the resulting environmental contamination. While money is available in developed countries for the research and development of novel approaches to pest control (e.g. use of pheromones, insect growth, regulators, genetic mechanisms etc.) such financing, as well as trained personnel, is unavailable or extremely hard to come by in third world countries.

Today there is a move towards the development and implementation of integrated control or insect pest management strategies. Such programmes are even more out of the reach of developing countries. Even as strong an advocate of integrated control as the late Professor van den Bosch of the University of California, one who was fiercely against the use of chemicals as a single component strategy of pest control (in fact he had described himself as an *"eco-radical"* and an *"entomo-radical"*) had to admit that:

> *'pest management is a complex technology; . . . a holistic strategy that utilises technical information, continuous pest population monitoring, resource (crop) assessment, control-action criteria, materials and methods, in concert with natural mortality factors, to manage pest populations in a safe, economical and effective way.*

(van den Bosh, 1978). Very few developing countries, if any, in fact, can successfully mount such a programme on their own resources.

In the Caribbean region we are somewhat lucky in having various academic and research institutions (*viz.* the University of the West Indies; the Caribbean Agricultural Research and Development Institute; The Commonwealth Institute of Biological Control, to name the most important perhaps) which can provide a cadre of scientific personnel to deal with the various constraining factors limiting food production in the region. Yet, even so, pest control in the region has developed, and has remained essentially so, as a single component system depending almost exclusively on the use of chemicals. However, there have been examples of other systems

of pest control achieving very good success. The control of the sugar cane small moth borer, *Diatraea saccharalis* in Barbados using its natural enemies, the Cuban fly, *Lixophaga diatraeae* and the Indian wasp, *Apanteles flavipes* is perhaps one of the most successful (Alam et al 1971).

This paper will attempt to give a picture of the pesticide situation in the region generally and in Trinidad particularly and the possible environmental effects resulting from the use of these chemicals.

2. CHEMICALS IN USE IN THE REGION

Figure 1 indicates the total amounts of pesticides (insecticides, fungicides and herbicides) imported into four major countries in the Caribbean for the period 1970-1978. (Data were not available every year for each country and were compiled from overseas trade reports of the various countries). Trinidad, and more so Barbados, have shown a more or less constant level of importation over the period. However there is a general downward trend between 1970-1973 in Trinidad with a gradual increase in importation levels after that period to the present. Guyana has shown a general decrease in pesticide imports for the period reviewed. A very erratic pattern has emerged in Jamaica. In fact the very high figure of 8.7 x 10^6 kg for 1973 resulted from what appeared to be abnormally high import of 8.1 x 10^6 kg insecticide for that year.

Table 1 shows a more detailed listing of the usage pattern of various pesticide groups for the same countries under review. Generally greater quantities of insecticides were imported than other pesticide groups – almost the combined amounts of fungicide and herbicide imports. Data for the usage pattern of particular insecticide groups were not readily available. However Parasram (1971) listed 57 pesticides in common use in the region at that time. Neither fungicides nor herbicides were included in this listing but only insecticides, acaricides and molluscicides. The former group consisted of 97 per cent of the pesticides identified while organophosphates were more than twice as commonly used as the organochlorines (Table 2).

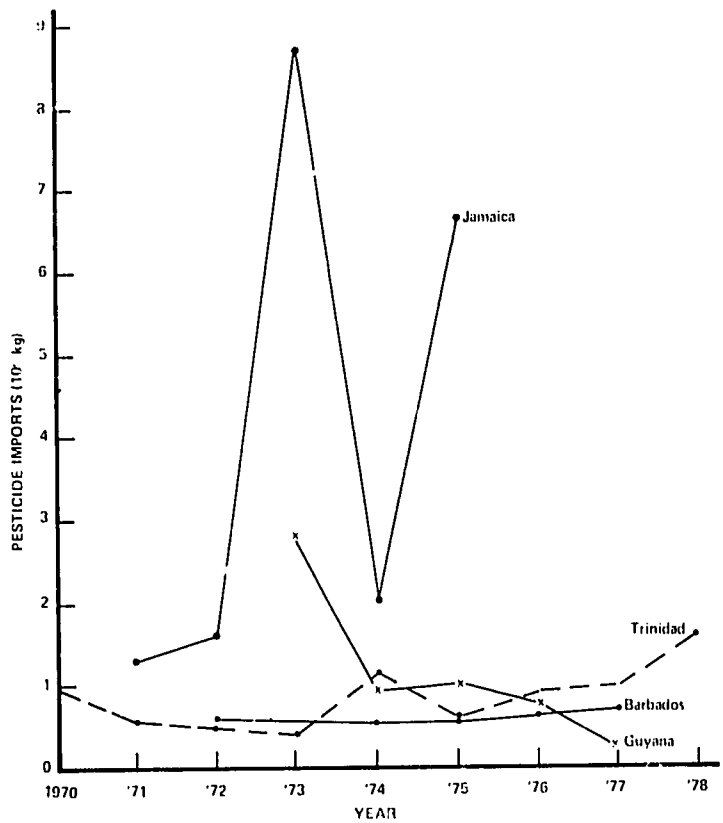

Figure 1 Total imports of pesticides into the four major countries in the Caribbean, 1970 - 1978

Table 1 Total imports of pesticides (Insecticides, Fungicides and Herbicides) into the major countries in the region for the period 1972-1977

		Amount (kg) Pesticide Imported				
		Barbados	Jamaica	Guyana	Trinidad & Tobago	Total[(ii)]
1972	Ins.	270,066	846,838		467,947	1,584,851
	Fung.	22,981	207,826	NA[(i)]	35,659	266,466
	Herb.	324,090	557,685		NA	881,175
1973	Ins.		8,133,550		314,763	
	Fung.	NA	329,344	NA	94,508	
	Herb.		288,407			
1974	Ins.	232,729	980,226	349,396	743,115	2,305,466
	Fung.	21,701	163,534	71,840	41,493	298,568
	Herb.	300,238	847,017	500,293	373,995	2,021,543
1975	Ins.	311,302	2,594,487	312,206	271,590	3,489,585
	Fung.	20,829	3,693,669	NA	30,201	3,744,699
	Herb.	245,852	435,263	733,524	207,579	1,622,218
1976	Ins.	347,241		287,544	476,406	1,111,191
	Fung.	42,454	NA	NA	56,354	98,808
	Herb.	254,867		488,417	371,750	1,115,034
1977	Ins.	387,241		189,308	540,388	1,116,937
	Fung.	9,252	NA	NA	84,407	93,659
	Herb.	286,815		31,929	359,006	667,750

(i) NA – Not available

(ii) Total imports are complete only for 1974; all other totals have missing data. The total figure for 1973 is not given since there is only one complete set (data for Jamaica.)

Table 2 Relative use of the main pesticide[1] classes commonly applied in the Caribbean (adapted from Parasram, 1971)

Pesticide Class	% Usage
Organochlorines	27.0
Organophosphates	56.0
Carbamates	9.0
Miscellaneous[2]	8.0

1 Exclusive of chemicals used for disease and weed control

2 Includes Arsenates, Metaldehyde, Molluscicides and *Bacillus thuringiensis*

Data from a preliminary survey of pesticides commonly used in Trinidad were available (Donawa, 1976). This survey was inclusive of insecticides, acaricides, molluscicides and herbicides. Of the twenty-three chemicals identified 87 per cent were insecticides of which organophosphates constituted 44 per cent, organochlorines 26 per cent and carbamates 17 per cent. These figures agree fairly closely with those of Parasram (1971) for the region except that there is a higher percentage carbamate use. This might be partly accounted for by the inclusion of Zectran, a chemical that Donawa (op. cit.) himself suggests is little used. These figures will certainly be currently shifted in favour of the organophosphates, given the increase in use of these chemicals generally and the consequent decrease in the use of the organochlorines over the past decade. This period too has seen the emergence of the synthetic pyrethroids, whereas at the time of Parasram's study pyrethrins and other naturally occurring compounds were only 'available to a very limited extent' in the region.

The total amount of pesticides imported for the period 1972-1977 was 4 468 261 kg with a yearly mean of 744,710 kg. This represents a pesticide load of 145.2 kg/km^2 of land surface in Trinidad and Tobago and 0.62 kg/capita of population/year. Similar data for Central America (Guatemala, El Salvador, Honduras and Nicaragua) show pesticide loads of 75 kg/km^2 of surface area and 2.0 kg/capita (ICAITTI, 1977).

Much of these pesticides imported into Trinidad, in fact 80 per cent, are used by a single estate, the Government owned Caroni (1975) Ltd. (G. Cumberbatch, pers. comm.). This estate comprises approximately 20,000 ha sugar cane in Central and South Trinidad. Much of the remaining 20 per cent would be accounted for by the much smaller Orange Grove Sugar Estate, the even smaller privately owned sugar estates scattered in central and South Trinidad and the numerous small-scale vegetable farmers mainly in the northeast region of the island. The use of these chemicals is spread over the island. This widespread use is of course of great potential significance for the general distribution of pesticide residues over the country. A large percentage of vegetables grown in Trinidad is located in the Aranguez region in the plains below the Northern Range – a mountain chain running in an east-west direction in the northern part of the island. Other farms are also located in the valleys of this mountain range. The run-off from these farms empties into the major river systems in this part of the island, some of these rivers still supplying water to some villages through which they pass. They are also used for recreational purposes. These rivers drain what is known as the Caroni River Basin. Apart from this farm run-off one study revealed that 264 factories of one kind or another produced waste into this basin. (Anon, 1976). These factories ranged from various processing industries to those producing paints, lead batteries, galvanized products, soaps, aerosol products (colognes, insecticides, etc.), rum and beer, cosmetics, inks, gravel, etc. One effect of all this has been changes in the faunal populations of the Caroni River and Swamp. The swamp, for example, has traditionally been a source of oysters, crabs, mussels, freshwater conch and other fish. However, over the past two or three years the traditionally farmed areas are now bereft of oysters while mussel populations are very low (P. Bacon, pers. comm). While other pollutants and as well as likely as not poor farming techniques are responsible, the effect of pesticide contamination of the swamp has probably played a contributing role in the demise of the shell fish populations. Shell fish are always very sensitive to toxicants in the environment. Unfortunately no quantitative data are available at present.

Donawa (1976) has also investigated pesticide residues in various plants and plant products as well as animal tissues in Trinidad between 1972 and 1975. Generally, the levels found were low for the commonly used pesticides with the organochlorines showing of course the highest levels. However, some levels did seem to be cause for concern. In one cauliflower sample there were residues of 8.0 ppm toxaphene and 34.0 ppm parathion. In one set of samples of animal tissue tested relatively high organochlorine levels were observed – 11.5 ppm DDE; 5.6 ppm DDT; 3.24 ppm Dieldrin. No reasons for these levels were suggested.

One interesting incident may perhaps be quoted at this point to indicate the difficulty in laying blame when environmental mishaps occur. In October 1976 in Trinidad at the western tip of the island in the Chaguaramas region, thousands of dead fish appeared on the beach. This continued for at least four weeks or so. There was much speculation at the time as to the cause. Local 'experts' in the newspaper and elsewhere suggested a 'red tide'; others 'acid rain'. A popular theory was that there was chemical leakage from a wrecked ship in the area. The cargo on this wreck was revealed to be one hundred drums of sulphuric acid and cyanide. The acid rain or 'killer rain' as it was called and the red-tide theories were easily dismissed while the suddeness of the kill tended to rule out the chemical leakage theory. Through private effort samples of the dead fish were sent for analysis to the Division of Biology and Living Resources at the University

of Miami's School of Marine and Atmospheric Science. Of the samples analysed (three different genera) they all contained heptachlor epoxide, DDE, Dieldrin and DDT; a number of heavy metals, including mercury, were also found to be present. To quote Professor Eugene T. Cocoran who performed the analyses:

> *"While these analyses certainly do not rule out other possible causes for the fish kill, they do indicate all of these fish had been in contact with water containing commercial DDT. The mercury content of Gerres cinerus was slightly higher than the edible limit for fish, but the other fish didn't indicate mercury poisoning". (Anon, 1978).*

While a finger could not be pointed at anyone directly responsible for this fish kill there are some pertinent facts to note:

Fact 1: there is present in the area a large agricultural concern — the Chaguaramas Agricultural Development Project of the Trinidad and Tobago Government. They are involved in both the development of new varieties of grain legumes including seed production and storage as well as in the commercial or semi-commercial production of various food crops.

Fact 2: mercurial dressings are widely used to treat seed while organochlorine insecticides are still widely used in Trinidad.

Fact 3: A river flows through the valley where these holdings are located and empties in the vicinity of Williams Bay where the fish kill appears to have started. However although no one was ever formally accused circumstantial evidence did seem to be sufficiently strong to indict the nearby agricultural project. Of course no one ever admitted responsibility. (The wrecked ship was quickly cleared of its sunken cargo after this incident).

One final point perhaps that emerges from the use pattern of insecticides in the region generally is the shift from organochlorines to organophosphates. One wonders if this is really the lesser of two eveils. On one hand the use of organophosphates is preferable since they are less stable and thus less persistent in the environment than organochlorines. On the other hand they are some of the most poisonous chemicals available and many farmers do not seem to appreciate this fact. The easy availability of these poisons perhaps is responsible for the increased rate of self-inflicted intoxication, particularly among young people in Trinidad. In fact this was one reason, according to the Attorney General, for the enactment of a pesticide regulation Act in 1979 in Trinidad.

It seems therefore that the 'pesticide treadmill' as it is described by van den Bosh (1978), once into gear, is difficult to stop.

3. A CASE HISTORY — THE CONTROL OF FROG-HOPPER IN SUGAR CANE IN TRINIDAD

Frog-hopper *(Aeneolamia varia saccharina,* Dist.*)* is a tiny plant-sucking insect — the nymphs feed on the roots of the sugar cane plant while the adults feed on the leaves. Adult feeding results in 'blight' of the leaves — a necrosis of the leaf which, in severe cases of attack, results in the complete leaf becoming necrotic. The cane field appears brown or 'scorched'.

Research into the froghopper and its control has been underway in Trinidad since 1910 (Fewkes, 1979). Insecticidal control first started in 1926 (T. Gopee, pers. comm.) and over the years a number of different toxicants have been applied in reaction to what has been described as 'frog-hopper phobia' by Gopee (1979). The introduction in 1966 of aerial spraying opened up a whole new world with insecticides literally being rained onto the crop. In one frog-hopper season (of six months duration coinciding with the rainy season) a few years ago over thirty aerial applications of insecticide were sprayed onto the crop — a rate of more than one per week (Gopee, pers. comm.). Currently insecticidal control is costing the company over $600,000 US per year (Mahadeo, 1979).

One result of this of course is that the pest now shows tolerance to all three of the major classes of insecticides. An entomologist at the Caroni Research Station is engaged almost full-time in the search for new chemicals to control this pest. Already some tolerance to the synthetic pyrethroids and to the new Nereis-toxin (Evisect) has been observed during evaluation studies

(Gopee, 1979). Table 3 gives some indication of the current status of insecticides used for froghopper control.

Table 3 The status of insecticides used in aerial spraying for froghopper in Trinidad since 1966 (Gopee, 1979)

Insecticide	Year first used	Year removed	Years of Use	Remarks
1. Sevin (Car)	1966*	1970	5	Resistance developed
2. Unden (Car)	1970	1975	6	Increased tolerance
3. Thiodan (OC)	1975	1978	4	Resistance developed; Originally used in 1965
4. Malathion (OP)	1969	1976	8	Increased tolerance
5. B.H.C. (OC)	1975	1977	3	Reintroduced after resistance developed in 1954
6. Kilval (OP)	1972	1980?		Variable results
7. Folimat (OP)	1972	1980?		Increased tolerance in one area (1978)
8. Supracide (OP)	1976	1984?		Increased tolerance in one area (1978)
9. Ekalux (OP)	1976	1984?		Increased tolerance in one area (1978)
10. Host (OP)	1978	1985?		Increased tolerance in one area (1978)

NB – Compounds 6 - 10 are currently in use
* – Aerial spraying first introduced
Car – Carbamate
OC – Organochlorine
OP – Organophosphate

It can be observed that insecticides used in the past had an effective life of five years on average. According to Gopee (1979):

> *'there is resistance, cross resistance, multiple resistance and just an overall increase in tolerance.'*

The situation therefore is one of classical insecticide addiction – higher does or new poisons required to achieve adequate kill. A similar tale has been described for cotton (ICAITTI, 1977; van den Bosch, 1978).

Another problem resulting from the widescale application of insecticides in sugar cane in Trinidad has been the increasing pest status of the small moth borer, *Diatraea* spp. which was

once considered to be a minor pest. This new pest status is thought to be a direct result of the increased chemical applications also reducing the natural enemy populations of the borer (Bennett, 1976).

The environmental effects of such massive programmes have not been determined or documented. However annual claims made to the company by inhabitatnts of villages bordering the sugar-cane fields to indicate that a problem does exist. Such claims include losses in a variety of food crops and lifestock; bee and fish kills have also been reported.

One claim for crop losses from nine farmers amounted to over $37,000 TT ($15,000 US) in 1979. Despite an agreement between Caroni Ltd. and surrounding bee-keepers whereby the company gives warning prior to and after spraying this doesn't always seem to work. For the period 1976-1978 over $18,000 TT ($7,000 US) was claimed for destruction of hives and decrease in honey production. One claim for fish losses in 1979 amounted to over $25,000 TT ($10,000 US). However, not all these claims are paid by Caroni Ltd. In many instances their investigations revealed little or no evidence that aerial spraying operations were in fact responsible; for example in the case above where $37,000 was claimed for crop loss pesticide residue analysis revealed that the pesticides identified *'were not chemicals or derivatives of the chemicals used in our Froghopper programme'* (Gopee, unpubl. report). For the current year so far the company has only accepted liability to the sum of $700 TT ($300 US) out of over $80,000 TT ($33,300 US) in claims made.

Apart from these alleged losses to crop and livestock there has also been an increase in reported incidences of people being srpayed. Although there have been no deaths reported so far these accidental sprayings have necessitated hospitalisation of some of the victims. In the current frog-hopper season there have been at least three reported instances of workers being accidentally sprayed. One such incident involved 30 field-workers being sprayed with the organophosphate, 'Ekalux'. This increase in reported incidents of accidental spraying does not necessarily indicate that the company is being any more lax in its operations. Rather it might be due to the greater public awareness of the hazards of pesticide abuse and misuse. This is quite a good development for it now forces the company, or any other involved in the handling and use of pesticides, to be much more cautious and careful in the manner in which such poisons are handled.

4. DISCUSSION

Environmental degradation resulting from abuse and misuse of pesticides has not been previously regarded as critical enough to warrant much concern in the region. The paucity of publisned literature bears testimony to this lack of concern. Such environmental concern as there is has come mainly from either conservationists regarding the safety of birds and mammals from the traps and guns of the hunter or from soil scientists and engineers concerned with soil and coastal erosion (Gelabert, 1979; Jackson, 1979). More recently there has been great concern over likely oil pollution in the region (Gajraj, 1978). In fact, this fear was what emerged out of a recent regional conference on environmental management in the smaller Caribbean Islands (Beller, 1979). One participant emphasised that *'the most critical pollution source is that derived from oil leaks, spills and oil-water discharges from tankers'* (Jackson, 1979). However this same author did recognise the danger of pesticide run-off contaminating rivers, particularly where inhabitants depend on river water for their needs. He in fact identified two such potentially dangerous situations in St. Vincent and in Dominica. Because of creeping cultivation in watershed areas with its accompanying pesticide usage the main supply of potable water for Kingstown, the capital of St. Vincent, is endangered while a similar situation in Dominica threatens a proposed reservoir supply in Roseau. The suspected pollution of the Caroni River and Swamp in Trinidad has already been mentioned above.

On a global scale van den Bosch (1978) has chronicled a number of instances of tragedies related to pesticide use, not only in the developing world but also in the more developed countries where regulations governing the use of pesticides are much more stringent and enforced. For example one such incident of which note should be very carefully taken in the region is alleged to have occurred in Pakistan in 1976 when twenty-nine hundred persons were poisoned with malathion while spraying for malaria control; five deaths resulted. Over the past few years in the Caribbean this same insecticide has been extensively used to combat outbreaks of Dengue

Fever in Jamaica and Trinidad and Yellow Fever in Trinidad. One would hope that such reports of malathion poisoning would have been carefully examined before implementing such wide-scale control programmes as was done.

A lesson should also be learnt too from the Central American experience with pest control in cotton. This has been well documented elsewhere (ICAITI, 1977). Perhaps though it is still worthwhile to repeat some of their warnings since we have an analogous situation, though on a somewhat smaller scale, with sugar cane in the region. The authors of the document referred to above (ICAITI op. cit.) make a very telling point where, because of a lack of legislation concerning the use of pesticides in Central America, the region was turned into a sort of experimental ground for pesticide manufacturing companies. Many pesticides used in cotton production in Central America were not approved for commercial sale in their country of origin (my emphasis). Cotton growers, it was reported *'could choose from more than fifty alternatives between products and mixes for the chemical control of one pest'* (my emphasis). Of course, there must have been a backlash for such abuse. Reported human poisonings between 1972 and 1975 were 14,138 with a high of 6,063 in 1972 and for the same period the report, in what appears to be a very cavalier fashion, notes that *'only a total of forty people'* (sic!) were reported dead from pesticide poisonings! A number of other human health, ecological and socio-economic effects are listed in the very comprehensive report. In fact the situation was such that it was blandly stated that *'organo-synthetic pesticides have become part of the natural and human environment'*. For example DDT levels in cow's milk were measured at 117.5 ppm in Nicaragua. In another study in Guatemala quoted by van den Bosch (1978), DDT residues in mother's milk were two hundred and twenty-four times higher than acceptable levels for commercial cow's milk in the U.S.A.

This is an extremely frightening picture and one wonders by what lucky draw have we in Trinidad, for example, been spared so far from more disastrous effects of the aerial application of pesticides for frog-hopper control. I say lucky for the pesticide load in Trinidad is nearly double per km^2 that reported for Central America.

There is also a similar problem of unsafe and hazardous chemicals in the region which have been banned or restricted in their countries of manufacture and are still being sold over the counters of farm and garden shops in the islands. Aldrin, Dieldrin and Heptachlor are all still readily available. Mirex is still being used and recommended for the control of various ant pests throughout Latin America and the region (Cherrett and Peregrine, 1976; Rai, 1977). And this despite the current view that the use of mirex is *'dangerous and unpredictable'* from an environmental point of view (National Academy of Sciences, 1978). Four years ago in Trinidad chlordane was attempted to be aerially applied for the control of cacao thrips. It was only a loud outcry from a few concerned individuals which prevented this. The use of chlordane was subsequently brought under restricted use. In fact it was only quite recently that the Trinidad and Tobago Government instituted a

> *'Pesticides and Toxic Chemicals Act (Act No. 42 of 1979) – to regulate the importation, storage, manufacture, sale, use and transportation of pesticides and toxic chemicals and to provide for the establishment of the Pesticides and Toxic Chemicals Control Board and for matters incidental thereto'.*

However as with all other bits of legislation the policing of the law is always the problem.

5. CONCLUSION

The point to be made of all this, therefore, is that today in the region we are at a stage, a crossroads, that many other countries have come to in the past. Many of these countries have taken the wrong path – some blindly and unknowingly; some have been wrongly led; while others, aware of the fate of previous travellers, have gone ahead anyway thinking that they were smart enough to find their way through. All these have paid the price for their ignorance or folly of pesticidal misuse and abuse in environmental backlashes. We in the region must choose our own path. We are in a position to choose the right path because of the mistakes of others in the past. However it is not an easy task. Increased pesticide usage dangles a big carrot of increased food production before our open mouths. This is the short term gain. Can we resist this lure? Reduced pesticide usage, in isolation, means a reduction in food production which also means a reduction in much needed foreign exchange for the region from the sale of

sugar, cacao, coffee, citrus, bananas. This again is the short term perspective. Can we do without this? Long term environmental gains are not easy to appreciate, particularly by the small-scale farmer in the Caribbean. Many times he starts off at a disadvantage — poor soils, lack of water, lack of farming equipment, etc. Pests and diseases he recognises as another constraint but one that can be overcome, he feels, given the right chemicals. Can or should his extension officer recommend a reduction in the use of chemicals? Any reduction in pesticide use must be as component of some larger pest management strategy.

It is now up to the plant protection specialists in the region to develop such strategies. It is not an easy task. As mentioned earlier pest management is a new technology. We have seen in other fields the slow pace of a local technological growth. More often than not we in the region have had to depend on a technology transfer from the developed countries. Unfortunately this is not possible in this situation. We cannot import a pest management technological package in a CKD form to be assembled and used locally. Each pest situation has to be taken on its own merit and a pest management strategy almost custom-designed to meet the needs of the particular situation. And this is the challenge of the decade upon us with which agricultural scientists in the region must come to grips.

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II

CURRENT PERSPECTIVES IN PEST CONTROL, WITH PARTICULAR REFERENCE TO THE CARIBBEAN

5. METHODS AND APPROACH TO RODENT CONTROL IN TROPICAL COUNTRIES*

WALTER E. HOWARD, Ph.D.

CONTENTS

		Page
1.	INTRODUCTION	63
2.	TYPICAL RODENT PROBLEMS	64
A.	Agriculture	64
B.	Miscellaneous Land Areas	64
C.	Villages and Cities	64
3.	REQUIREMENTS FOR SUCCESSFUL RODENT CONTROL	65
A.	Proper Political Structure and Adequate Support	65
B.	The Rodent Control Organization	65
C.	Vertebrate Pest Control Committee	66
D.	Adequate Funding	67
E.	Ample Equipment and Supplies	67
F.	Staff Training	67
G.	Publicity and Education	67
H.	Private Pest Control Operators	67
I.	Know the Laws and Regulations	68
J.	Keep Good Records	68
K.	Make it Safe, Simple, and Inexpensive	68
4.	PRINCIPLES OF RODENT CONTROL	68
A.	Prevent Damage Rather Than Try to Stop Crop Losses	68
B.	Rodents Require Both Food and Cover	69
C.	Make Proper Survey and Define Problem	69
D.	Identify Rodent Species Involved	69
E.	Know the Biology and Ecology of the Species	69
F.	Estimate Population Density	69
G.	Coordinate Adjacent Control Programs	70
H.	Keep Officials and Public Informed	70
I.	Prevent Accidents, Protect Nontarget Species	70
5.	BIOLOGICAL AND GENERAL CONTROL METHODS	70
A.	Predators and Bounties	70
B.	Habitat Modification	70
C.	Diseases	70
D.	Chemosterilants	70
E.	Exclusion	71
F.	Ultrasonic and Electromagnetic Devices	71
G.	Chemical Repellents	71
H.	Traps	71
I.	Fumigants	71
J.	Glue Boards	71
K.	Rodenticides	71
L.	Cereal Baits and Bait Stations	72
M.	Bait Acceptance Tests and Bait Shyness	72
N.	Water Baits	73
O.	Pelleted Bait and Paraffin Bait Blocks	73

P. Tracking Powder 73
Q. Ectoparasite Control 73
R. An Effective Control Program 74

6. RESEARCH NEEDS 74

7. CONCLUSION AND RECOMMENDATIONS 74

1. INTRODUCTION

It is indeed an honor for me to participate in this "Seminar and Workshop on Pest and Pesticide Management in the Caribbean." I am not a complete stranger to this beautiful part of the world, having been here during April and May 1979, on a UNDP/PAHO/WHO rodent control assignment, and my colleague, Mr. Rex E. Marsh, has been to Barbados on three such assignments.

I have prepared a detailed "extended outline" paper concerning rodent control in tropical countries based upon my numerous FAO and WHO assignments in many parts of the world. These points may serve as subject headings for workshop discussions. I will illustrate much of my talk today, however, with slides about rodent control activities in various parts of the world.

Please note that in the title of my presentation I have changed the word Agriculture to Countries. I have done this because most of the comments I am making apply equally well to both agricultural and urban situations. In fact, the word tropical is not very appropriate either because the main difference to controlling rodents in temperate climates is that in the tropics it is more difficult to control weeds and other vegetative cover used by rodents and agricultural crops provide food for rodents practically all year.

Rodent control, and other vertebrate pest-control operations, must be based on practical needs, an intelligent appraisal of the related biopolitical factors, the establishment of good lines of communication between all affected government and nongovernment parties, thorough planning, adequate inspection and enforcement of regulations, and sound ecology. To control rats and other rodent pests is not complicated biologically. Effective tools are available, and it is not difficult to determine which method is the least expensive, safest, simplest to apply, and most effective, if proper steps are followed. The difficulty lies in the political-economic problems which usually is the reason an effective rodent control program has not been developed. As with mosquitoes, it is not possible for individual farmers to independently control rats and other rodent pests, for these animals do not recognize property boundaries. Also, as with mosquitoes, rats cannot be controlled effectively if poisoned only once a year in an annual campaign; their reproductive potential is too great. In addition, it is important to recognize that rodent problems have much in common whether they are associated with agricultural crops, food storage, villages, cities, ports, or public health.

2. TYPICAL RODENT PROBLEMS

A. Agriculture

Before a rodent control program in agricultural crops can be considered effective, certain basic requirements must be met. The program must be simple to operate, inexpensive, safe to humans and nontarget species, effective under adverse weather conditions, adaptable to a variety of environmental situations, be designed so that inspectors can readily check to see that the recommendations are being followed, be politically enforceable should a farmer or some other person not wish to carry out their duties, and the methods employed must not require too frequent attention by either the farmers or inspectors.

Certain rodent species becomes serious agricultural pests because they happen to be so well adapted to the artificial environments man provides and have changed enough genetically to tolerate their own kind at population densities not naturally attained. Usually the presence of a new crop, for instance, sugar cane or rice, and the habitat conditions created in its production, make the environment so suitable seasonally that conventional biological control techniques are not adequate to control these rodent pests. Sanitation often provides considerable help in controlling field rats, but modifying the habitat enough so that rodents cannot be pests in many instances would also prevent production of the crop. Only when rodents are at low densities do natural predators provide effective biological control.

Since the methodology for controlling rats and other rodents is well known, one might logically wonder why so many rodent-control programs fail. The obstacles to effective rodent control in agricultural crops are rooted mainly in various human relationships; it is not because biological information is inadequate. The difficulty usually lies in not having the government structure organized properly for consideration of the economic, social, and political aspects of rodent control. Only with a proper government organization and interest can an effective program be implemented that will keep the country nearly rodent-free, yet in a manner that is inexpensive, safe, and simple to apply.

It is essential that good communications be established between all levels of government concerned with rodent control, so that the biopolitical climate toward control is favorable. The farmers who are directly concerned must be enthusiastic and have confidence in the program, and officials must have the necessary authority and staff to ensure that sustained year-round control is carried out. Unfortunately, farmers often lose interest in control programs once the rodents are reduced to a low level and crop damage is largely stopped, and, of course, this is the time when control is most effective.

The most difficult agricultural field rodent problems are with crops like sugar cane and rice. In these types of field crops, control should be preventive and done before the crop is planted. Also, it should include a very wide buffer zone surrounding the field to be planted. Once crops begin to mature, it is too late to control rodents with toxic bait. Since in poultry and pig farms, which are notorious for having difficult rodent problems, ample rodent food is always present, the solution is to seal all potential places rodents might burrow or hide.

B. Miscellaneous Land Areas

One of the major problems commonly confronted in controlling rodents in agriculture and cities is who is responsible for controlling these pests along rivers, railways, roads, low-value unused land, or other private or government-owned parcels where, if rodents didn't disperse to adjacent areas, they might not be of any economic or health concern.

C. Villages and Cities

It is very seldom that urban rodent problems can be independently resolved by the home-owners and other property owners. Government assistance and direction is usually essential to achieve any permanent reduction of rodent pests, and many of the more favorable habitats such as sewers, city drains, and refuse disposal sites are not privately owned, hence require government action. The potential health problems from rodents are usually greater in the urban environment than with the agricultural community because of the concentration of people. Rodent control is largely a people problem, and to be effective it first requires the resolution of many economic, political and social problems, which often are more complicated in cities than with agriculture.

Even though a national self-sustained rodent-control program with everyone responsible

for controlling his own rodents is feasible, it is still essential to have a highly trained well-paid rodent-control staff, with the necessary legal support, to insure that proper control procedures are carried out.

3. REQUIREMENTS FOR SUCCESSFUL RODENT CONTROL

A. Proper Political Structure and Adequate Support

No country can have a truly successful rodent-control program without first having an effective organizational structure that does not get sidetracked because of the complexity due to so many agencies being involved. The two principal ministries usually most concerned with rodent control are Agriculture and Health, and strong support for an effective control program in agriculture and cities must come from the top officials in these ministries. Each should have at least one officer well trained in rodent control. Research facilities do not have to be duplicated in both ministries. Rodent control has suffered badly in the United States because it is wrongly politically structured. At the federal level with U.S., animal damage control is administered by an assistant secretary in the Department of Interior, who is also in charge of National Parks, whereas all other forms of crop protection are in the Department of Agriculture. Also, too many city, county and state health departments are not very active concerning rodent control in their cities, as the responsibilities are not adequately spelled out.

B. The Rodent Control Organization

The unit of government responsible for rodent control, wherever it be housed and however it be administered, should become government's central research, training, and advisory group concerning rodent control. Their services and activities should primarily be limited to testing, trouble-shooting, perhaps doing the rodent control in government establishments, but with the day-to-day control being left to individual property owners and commercial pest-control operators.

The organization actually in charge of rodent control needs to coordinate its activities with many branches of government and other organizations. For examples, in Barbados, I have identified the following organizations that need to be contacted concerning rodent control:

Ministry of Health
- Health Education
- Public Health Inspectors
- Public Health Engineer
- Sanitary Service Authority
- Environmental Sanitation Unit
- Bridgetown Sewerage Project
- Superintendent of Works

Ministry of Agriculture
- Pest Control (Rodents) Officer (proposed)
- Extension Officers
- Pest Control Board
- Entomology Section

Ministry of Communications and Works
Grantley Adams International Airport
Hospitals
Schools
Public Markets
Parks and Beaches Commission
Port Management Division
Deep Water Harbour
Barbados Agricultural Society
Commercial Pest Control Operators
Sugar Producers Association

Some responsibilities of the organization in charge of rodent control are to:

1. Make sure (often through extension staff and public health inspectors) that all premises are properly baited at the right time.

2. Be the guardian to insure that no inferior rodent baits become available.

3. Promptly respond to analyse all reports of rodent-control problems received from agricultural and public health officers, commercial pest-control operators, and any other organization or person who thinks some phase of rodent control is not functioning properly.

4. Be generous in offering training services to other organizations, private pest-control operators, and anyone who may help control rodents.

5. Constantly advise people and organizations on how to destroy rodents' shelter by sanitation and sealing cracks and holes in and under buildings.

6. Advise sewage projects, waste disposal, airports, docks, engineers, and architects on how to obtain effective rodent-proofing.

7. Formulate the safest, most economical and most effective baits and conduct standard WHO tests for genetic resistance whenever anticoagulant baits seem to fail to kill.

8. Always be creative in trying to find even better ways of resolving the rodent problem through integrated pest management procedures.

C. Vertebrate Pest Control Committee

To provide the necessary support and guidance for an effective rodent-control unit, it may be highly advisable for government to appoint a Vertebrate Pest Committee. Such a committee should be composed of one representative from all government and private organizations having any vested interest in the development of an effective rodent-control program. The objectives of such a Vertebrate Pest Committee might be to:

1. Advise government on how to establish the most effective and desirable vertebrate pest-control organization.

2. Evaluate the control methods used, the staff training, publicity about rodent control, adequacy of education in schools about rodents, and any changes that crop protection services, extension, or public health inspectors may recommend for controlling vertebrate pest species.

3. Develop an integrated rodent-control program among all the agencies involved to reduce costs and increase effectiveness.

4. Suggest proper safety precautions to be observed to protect man and all nontarget species.

5. Develop lists of undersirable exotic species of vertebrates that are potential pests and therefore should not be allowed to enter the country.

6. Determine how much of the actual control work should be done by the government rodent-control unit and how much by farmers and landowners, and who should pay for it.

7. Suggest amendments to existing regulations, if needed, to insure that permanent rodent control can be carried out.

8. Advise government on how many officers will be needed in crop protection, extension, and as public health inspectors to implement an effective permanent rodent-free program.

9. Determine the economic benefits to farmers and the nation that result when vertebrate pest losses are kept to a minimum.

10. Insist that economic control be practised, where the benefits received from control are equal to or exceed the expenses of the program.

11. Establishment of bait-formulating (mixing) facilities to insure that only good baits and rodenticides are used. Where needed develop better government control over use of rodenticides.

12. Insure that adequate, applied, back-up research is being done to constantly improve on control methods and to evaluate new materials and approaches.

13. Develop an integrated pest management program that insures all rodent-control operations are adequately monitored and that the inspection system is able to detect any re-establishment of rodent populations.

D. Adequate Funding

Too often rodent-control personnel are undergraded (paid) for the degree of sophistication and public-health advisory functions they are trained to fulfill. Rodent control is usually not excessively expensive, but an effective program will be well worth its costs. However, there is little merit in attempting to develop an effective rodent-control program unless government is willing to provide the necessary financial support.

E. Ample Equipment and Supplies

Do not launch a permanent rodent-control program until a careful inventory shows that all the needed equipment and supplies are available in the country. For example, don't require the public to use bait stations unless there is an ample supply of bait and bait stations available for sale or distribution.

F. Staff Training

The success of a rodent-control program is completely dependent upon how well trained is the staff. Examples of subjects to cover in a training program, prepared by Rex E. Marsh in one of his Barbados reports, includes:

- Species identification and their biology
- Population dynamics
- Ecology of animal pest control
- Public health aspects and education
- Environmental sanitation
- Solid waste management
- Sewage mangement
- Government structure for effective control
- Practical application of control methods
- Ectoparasites
- Survey techniques
- Laboratory research methods
- Training trainers
- Elimination of habitat and rodent-proofing
- Safety and protection of non-target animals
- Predation and biological control
- Integrated control
- Rodenticides and other pertinent chemicals
- Bait and rodenticide shyness, aversive conditioning
- Frightening devices, chemical repellents and trapping
- Prebaiting
- Rodent bait stations vs. broadcast baiting
- Bait formulation, attractants, other additives
- Bait size, texture, durability, etc.

A well-trained rodent-control staff should never request or expect any method or program of rodent control to be carried out by others until they have first adequately demonstrated its feasibility.

G. Publicty and Education

It is paramount that wide publicity be given prior to any rodent-control program. Extension personnel and public health educators should strive to extend information about rodent control to the public and especially the schools. In agricultural areas where more hazardous rodenticides may be required, all members of the community including workers and children should know what the rodent bait looks like and its dangers.

As Mr. Marsh has stated, "An imaginative self-help program in rodent control relies on effective public education and public cooperation. The education of all age levels is important, but the education of the young, highly impressionable school-age children may, over the long run, be one of the most effective and rewarding methods of eliminating the all-too-frequent attitude of indifference towards rodents. As the children mature, their previous education on rodents, rodent-borne disease, sanitation, and rodent control will be reflected in their adult attitudes towards rodents and their strong desire to live in a rodent-free community."

H. Private Pest Control Operators

No rodent-control unit will or should be staffed to the extent that they can do all of the

rodent control. Rather, they should be mostly advisory. Therefore, it behooves such units to help make the private rodent-control industry as successful as possible, so they do an excellent job of helping solve the country's rodent problems. Private pest-control operators are often very knowledgeable about controlling rodents in hotels, food-processing plants, homes, and the like.

I. Know the Laws and Regulations

Quite often laws and regulations must be modified before an effective permanent rodent-control program can become truly effective. However, I urge caution here. Laws do not control rodents, and bad laws can destroy public support. Before suggesting a new regulation, make sure its need has first been demonstrated, not just theorized.

An example of a regulation that might be needed is: "The owner or occupier of every dwelling, house, business premise, institution, or other building shall maintain one rodent-bait station (box) or more if requested by a Public Health Inspector. The bait station must be properly located and maintained (i.e., it must contain either fresh rodent bait, or a spoonful of rice or other cereal to indicate that no rodents are present) within or adjacent to each building or other urban or rural sites identified by a medical or agricultural officer as being potential rodent harbourage."

J. Keep Good Records

Rodent-control organizations must keep good business records of all of their activities. Without good records of complaints about rodents, a log of materials distributed, detailed accounts of the activities of the entire staff, inventory of supplies on hand, etc., it is difficult for a control unit to show its accomplishments and to justify funds. Each assistant should carry a notebook to record his daily activities. Record-keeping could be a separate article to illustrate all the various potential types of certificates and methods of reporting available.

K. Make it Safe, Simple, and Inexpensive

With a well-trained staff and strong support clear to the top in government, a safe, simple and quite inexpensive rodent-control program can be developed.

4. PRINCIPLES OF RODENT CONTROL

A. Prevent Damage Rather Than Try to Stop Crop Losses

One of the most important rodent-control principles to recognize is that it is much more effective, safer and cheaper to prevent an agricultural rodent problem from ever occurring than trying to stop losses once rodents have started to do serious damage to a crop. The reason this is seldom done, however, is because if there is no current evidence of rodent damage, most farmers are not interested in controlling what seems to be an innocuous rodent population. Unfortunately, control methods do not recover the losses of damaged crops and also, once rodents have started feeding on a crop, bait acceptance is usually very poor. Rodent population densities fluctuate with the crops. When the ground is bare, at least in that site there will be few rodents, but as crops mature, the rodent population also generally multiples, peaking about harvest time in most situations. However, there is a minimum population density that is required before a rapid numerical increase can occur. This is one of the justifications for developing a control program that is effective enough to bring rodent populations to much lower densities than is usually done. It is also important to recognize that, once a rodent population is brought to a low level, it then becomes much less costly in bait materials and it is less hazardous to maintain the low population. When rate populations become quite low, natural predators, which usually are not of much help, then seem to assist in keeping them there and the survival rates of immigrants also seem to be less.

B. Rodents Require Both Food and Cover

Another significant rodent-control principle too often not adequately considered, is that no matter how much food is available, rodents cannot survive unless they also have adequate cover, and with most rats, also water. At garbage transfer sites and in feed mills, high rodent populations will be found only if there are numerous cracks in the floors or foundations, or other favorable shelter and breeding places close by. In agricultural situations, the time to locate where rodents are living is after harvest and before the new planting provides food for the rats and vegetative growth makes it difficult to detect the burrows.

When metal hooks are used to handle sacked grain, there will always be spillage, which for various reasons is never adequately cleaned up at the end of each working day. This surplus food can create serious rodent problems, but only if there are cracks and holes nearby providing shelter for the rats and mice. A little mortar and concrete can often be a very inexpensive way to effectively control rodents.

C. Make Proper Survey and Define Problem

The need to become fully familiar with all aspects of a rodent problem before initiating action is obvious, but too often it is not done. The problem cannot be considered properly defined until the information has been written.

D. Identify Rodent Species Involved

I am constantly amazed to find so many rodent-control campaigns that are started without really knowing what species are involved. One of the first things to do is to properly identify the rodent species involved, in fact, also know what other wildlife species are present.

E. Know the Biology and Ecology of the Species

No rodent-control program can be planned and effectively executed without a pretty good knowledge about the biology and ecology of the species. Many rodent pests have a high reproductive potential. They mature sexually quickly, have short gestation periods, may breed immediately following the birth of a litter, and produce large litters. If young rodents had the same chance of living long enough to reproduce as humans now have in the world, a single pair would have billions of living descendants in just a few years.

In addition, it is necessary with field-rodent control to have a good understanding of the farming practices in that locality. This information is needed so you can prevent rodent pests from moving back and forth between crops that are harvested at different times.

F. Estimate Population Density

It is not easy to even estimate the density of a rodent population, but it frequently is necessary to do the best you can. Usually all that can be done is to compare relative densities before and after control or between different areas. Sometimes this can be achieved by one or a combination of: the active burrows seen; presence of rodent trails, tracks, or droppings; amount of damage to crops; amount of ground meal, or other bait that can't be carried away, placed in bait stations that is eaten in one day. After the rodent food has been exposed for several days, divide the maiximum amount in grams that was eaten on any one day by 10. This will provide a minimum estimate of the number of rats that were feeding on the bait. To estimate a population by trapping is usually too difficult. Bait spots can be used to determine the percentage of the nontoxic baits, like a single sunflower seed, that is fed on.

It is much too difficult and impractical to try to determine how many rodents exist per hectare in a given locality. What is needed is a sensitive yet simple means of detecting whether any or more rodents have survived a control operation. In houses and other buildings this can be done by spreading small patches of flour or talc where rodents would be expected to travel and then examining them the first thing in the morning for tracks. Three to five patches per rural house is usually adequate. If a torch light is held at an angle it will produce shadows on the rodent footprints, making examination of tracking patches easier. In most instances a single night with tracking patches or tunnels is sufficient, unless a rodent-free certification is involved.

The same technique can be used to determine relative densities of rodents in crops by establishing tracking patches of flour or talc in small artificial tunnels, bait boxes, or bamboo tunnels. A satisfactory articificial tracking tunnel can be made from a board 3 1/2 x 8 inches with a curved roof made from aluminum or other material (9 1/2 x 12 inches) attached to the board with screws. The roof will extend 2 inches beyond the ends of the 8-inch board to keep rain off the boards. Treat the ends and the undersurface of the boards to repel ants if necessary. Do not use so much insecticide that the rodents are also repelled. Use about two tablespoons of flour or talc, smoothed over, as tracking dust.

The most important time to use these tracking tunnels is after each control operation with acute rodenticides and, with permanent anticoagulant bait stations, perhaps four times a year, to determine whether any rodents are present in each locality.

To obtain a relative estimate of the percentage a population has been reduced by a control

operation, use the following equation:

$$\frac{\text{No. of tunnels or patches with one or more tracks AFTER control}}{\text{Maximum no. of tunnels or patches that were positive for tracks on any one night PRIOR to the control.}} \times 100 = \%\ \text{reduction}$$

G. Coordinate All Adjacent Control Programs

When rodent control is needed in sugar cane, rice, or other crops, the control program should include all the surrounding area as well. These buffer strips should be about 1 km wide, or not less tham 1/2 km. This requires careful organization of the control program, because inevitably such a plan will involve many properties, houses, even villages, and numerous nonagricultural situations such as roads, rivers, rock outcrops, clumps of trees, etc. At the season when a field is inhospitable to rodents, due to soil cultivation, it is important to locate the adjacent sites where the rodents may still be able to survive. Such places serve as the reservoir where the new invaders will come from once the new crop matures enough to provide rodents with both food and cover. To carry out an effective area-wide control program, it is essential to develop close cooperation amongst all the landowners involved.

If socioeconomic-political factors make area-wide control impossible, it will be necessary to design a workable but more expensive program that may require a variety of control tools so that some form of control can be carried out continuously, to intercept invading rodents.

H. Keep Officials and Public Informed

Misinformed officials, or a misinformed public, can result in all sorts of obstacles evolving that will prevent the development of a successful rodent control program. People usually become misinformed only because they are uninformed. It is paramount that an extensive publicity campaign be launched prior to activating a program.

I. Prevent Accidents, Protect Nontarget Species

Consider all rodenticides dangerous enough to cause death. Use great care when rodent baits are put out to protect children, pets, domestic animals, and nontarget wild species. There are many publications listing precautions to take, and they should be studied and strictly adhered to.

5. BIOLOGICAL AND OTHER CONTROL METHODS

A. Predators and Bounties

If the environment (crop, building or other type of habitat) is favorable (provides food and cover) for rodents, cats and natural predators will not be able to prevent rodent damage. Predators are dependent on prey for food, but prey species are not controlled by predators except in very unusual situations. In South Korea I found that no matter how many cats were present, there would still be some rats, and it took more rice to feed one cat for a week than was needed in rodent bait to eliminate all rodents for a year.

B. Habitat Modification

Weed control is often very helpful in reducing rodent populations. Any habitat modification that reduces the amount of food and cover available is of great help.

C. Diseases

Conventional control methods with rodenticides are far more effective than food-poisoning bacteria *(Salmonella)*, the only disease used on rodents with any success at all. Myxomatosis, a virus, has been effective in controlling the European rabbit *(Oryctolagus)*.

D. Chemosterilants

Epibloc, a combination rodenticide and irreversible male sterilant, is the only antifertility agent registered that I know about. Since the major market for birth-control chemicals is with women, the chemical companies will no longer permit their sterilants to be used as rodent bait.

Genetic control, the introduction of lethal genes into a rat population, has not been successful.

E. Exclusion (Rodent-proofing)

When feasible, the most effective form of rodent control is, of course, to build them out.

F. Ultrasonic and Electromagnetic Devices

Ultrasonic sound devices are not effective in dispersing rodents in the field and most building situations. The electromagnetic rodent (and insect) control devices that have been tested were worthless. The average household has many types of motors that produce a stronger magnetic field than those being sold for rodent control. Our tests have all been negative with both ultrasonic and electromagnetic devices.

G. Chemical Repellents

It has been our experience that door repellents have little more than temporary benefits with rodents. Our research with rodent pheromones has shown that, unlike insects, when rodents detect an odor they do not respond reflexively but they have memory of many experiences which they consider along with the odor.

Repellents detected by taste can be more helpful if impregnated into packing material or other items to discourage gnawing. In general, however, taste and odor repellents are not very useful in solving today's rodent problems.

H. Traps

There is considerable literature on kill- and live-trapping of rodents, so I will not dwell on the subject. In general, trapping is just one more tool and it is especially helpful when very few rodents have to be removed, such as one rat or mouse in a house.

I. Fumigants

These are poisonous gases, so great care must be taken that they not be used where escaping gas might enter closed and occupied buildings. Fumigants work best when soil moisture is fairly high and for rodents which do not dig extensive burrow systems. Three fumigants commonly used to control rodents are calcium cyanide, which produces hyrocyanic acid (HCN), a very fast-acting lethal chemical; carbon bisulfide (CS_2), which is highly inflammable, explosive, and also damages plant roots; and methyl bromide (CH_3Br), which is not a fire hazard but can injure plants.

Fumigants should be used only by trained personnel.

J. Glue Boards

Many people find glue boards, though messy, very effective in trapping rodents, especially in buildings.

To prevent rodents from debarking roots and trunks of trees, W.R. Smythe and his colleagues in Pakistan developed a sticky compound from rosin and castor oil. By banding the trees with this sticky compound the trees were protected for two years. When voles damaged the roots of fruit trees underground, they excavated 12-15 inches (30-40 cm) around each tree and either coated the major roots with a stiffer version of the above sticky material or added rocks around the tree as a barrier to the small rodents.

K. Rodenticides

Much literature is available on this subject, so my comments will be brief. In general, anticoagulant (multiple-dose) toxicants are much safer to use than acute (single-dose, one-shot) rodenticides. Two of the newer anticoagulants (brodifacoum and bromadiolone) are often effective with only one feeding, but time to death is like other anticoagulants. They also help control animals that are resistant to other anticoagulants. Other anticoagulants include warfarin coumatetratlyl (Racumin), diphacinone, and chlorophacinone. Officials putting out anticoagulants, mainly to prevent problems. If people complain that a pet or domestic animal has eaten the bait, force-feed the subject a vitamin K pill. False accusations of many animals being poisoned fade away if vitamin K is available. Acute rodenticides like zinc phosphide, red squill (scilliroside glycoside), 1080, 1081, ANTU, and strychnine, should be used in cities only by trained personnel.

With anticoagulant baits, be sure to expose them for at least two weeks, use ample bait and bait stations, and cover a large area. If success is not the best, the bait may be poor choice, the

bait stations, and cover a large area. If success is not the best, the bait may be a poor choice, the rancid, insect-ridden, or contaminated with other material and should be replaced, or the quality of the anticoagulant is inadequate, e.g., we have seen warfarin that contained impurities which reduced its acceptance by rodents.

L. Cereal Baits and Bait Stations

It is usually best to use only commercial baits, or those formulated and mixed by someone trained in the subject; but sometimes farmers need to be trained on how to mix their own bait. In a forthcoming UN Food and Agriculture Organization Vertebrate Pest Control Manual for Pakistan, William R. Smythe et al. describe a very simple way of making a rat-cake bait. As they point out, a poisoning program is never any better than the baits used, and baits must be compatible with the poisons used and be easily procurable or formulated by the local farmers. Their zinc phosphide rat cake is made of 48% broken rice (or other local cereal that is known to be highly preferred by the species to be controlled), coarse local flour (48%), and a small amount of edible oil (2%), and 2% zinc phosphide. With the proper amount of the toxicant (2% if it is zinc phosphide) and enough water, the mixture is stirred to form a stiff batter, poured onto a flat surface and flattened, then scored into small pieces and dried. This amounts to 2.5 kg of cracked rice or maize), 2.5 kg of flour, 200 g of edible oil, 100 g of zinc phosphide, and enough water to make a stiff dough. The grain and flour are mixed first, then the poison is added. After the oil has been added and mixed, the water is applied. It may take 2 to 3 days to dry in the sun. Store in a cool dry place. With loose-grain baits, mix the grain and edible oil first, then add the anticoagulant or other toxicant.

Bait stations or bait boxes are desirable in buildings, cities, and field areas where permanent baiting is needed. They protect the baits from weather and act as a safeguard for people, pets and other animals. They may be of a variety of shapes and constructed of water-resistant cardboard, wood, plastic, metal, or concrete. The Rodent Control Unit in Barbados has developed a successful concrete bait station for use where disturbance by people needs to be minimized, where equipment cannot damage it, and to blend it in with the sidewalks and buildings.

M. Bait Acceptance Tests and Bait Shyness

To conduct bait-choice tests, with species that will enter bait boxes, requires at least 10 bait boxes (25-40 cm long and about 20 cm deep) with openings at opposite corners, for exposing 3 to 5 trays of potential baits. Floors of boxes are dusted with a thin layer of talc or ground clay or flour.

The top should fit securely, or be hinged. Where people are apt to disturb them, locks can be added. The two openings need to be designed so rain will not enter the box. Since ants may become a problem, it is probably desirable to add 1-inch high legs to the box and treat them with chlordane or another suitable anticide or ant repellent. Use sparingly, so that the rodents will not themselves be repelled. Once an untreated bait box is being visited by rodents, exchange it with one treated with ant poison to see whether rodents continue to use the box. Place boxes in good rodent habitat, and about 50 m apart to insure that different rodents are being sampled.

The same boxes can be used to determine acceptance of the proven preferred bait treated with different rodenticides at different concentrations, except that different toxicants cannot be compared in the same box unless only chronic (multiple feeding) anticoagulants are used. These boxes or stations can also be used to obtain a relative pre- and postcontrol census of rodent populations.

In general, rodents prefer the types of cereals and other foods grown locally. Cracked or rolled cereals are usually preferred, and rodents seem to prefer clean and good quality baits, so it may be false economy to try to save on the type of bait used.

Bait shyness has caused many control operations to fail. Impurities in the rodenticide have caused bait shyness with such materials as zinc phosphide, warfarin, and red squill. With all rodent baits, the way they are formulated may also increase bait shyness. Some success has been reported for reducing the bait shyness of rodenticides through microencapsulation, but most attempts have failed.

Zinc phosphide (Zn_3P_2) has a fairly good safety record with people because of its black color, strong taste, and garlic-like odor, but care must be taken to protect pets, chickens, ducks, livestock, and other nontarget species. The odor of zinc phosphide initially attracts many species of rodents, but once they consume only a sublethal amount of bait they quickly learn to become

"bait shy" of zinc phosphide on any kind of bait. Poor quality zinc phosphide also causes bait-shyness to develop. To prevent bait-shy rodent populations from developing, prebaiting with nontoxic bait should be done before zinc phosphide baits are put out.

N. Water Baits

Rats will drink water daily if it is available. Where access to water is restricted or water is naturally limited, water baits can be very effective. Norway rats require more water than do roof rats.

Water baits can often be used advantageously in conjunction with dry baits. Water-soluble salts of anticoagulants are used most extensively in water baits. Many types of liquid dispensers are available and will do. Plastic chick-type fountains which hold 1 or 2 quarts of fluid are ideal for anticoagulant water bait stations, but some rodent species may gnaw the plastic. If so, use glass containers. Anticoagulant water baits can be placed in large bait boxes and maintained as permanent stations, if serviced regularly. Even plain water without poison can be used where other food is abundant and water scarce to attract rats to other types of toxicants such as tracking powder.

O. Pelleted Bait and Paraffin Bait Blocks

Pelletized rodent baits are rather common and have some advantages over loose-type ground cereal baits, for they permit the blending of grains into a single particle, which may be more easily manipulated by rodents. Pelletizing also prevents the settling out or separation of small particles from the larger ones, which is particularly important in shipment of quantity lots. Newer innovative formulating techniques are appearing on the market, or are currently being developed. This is most encouraging, for these provide a greater variety of available commercial bait. Examples include baits formed by extrusion, baking, and other more complex processes, and the manufacturing of these baits in quantities requires specialized and generally costly equipment. The end product, although possibly more expensive, may be more than justified for rodent control in the specific situations for which they are designed.

Anticoagulant baits embedded in paraffin to form solid bait blocks are used in substantial numbers, not only for rat control in sewers, buildings and warehouse, but also for rodents in the field. Anticoagulant cereal bait is mixed into melted paraffin, which is then permitted to solidify in containers of usable size, such as cardboard pint or quart containers of the ice-cream type, or large paper cups. These bait blocks are reasonably moistureproof, eliminating the need for bait stations and avoiding the problem of moldy bait to some degree. Acceptance by rats is relatively good in sewers or other situations where the amount of quality of other food is limited, but loose-type baits are invariably accepted more readily by rodents than are paraffin baits. Therefore, use of blocks should be limited to situations where loose cereal baits are not practical.

P. Tracking Powder

Rodents walking over a toxic powder pick it up on their feet and fur and later ingest the material during their normal grooming. DDT is an excellent tracking powder for mice, but is is banned in the United States. Poisonous tracking powders are more effective than baits where food is plentiful. Rodents are more likely to ingest a lethal dose of a poorly accepted rodenticide applied by this method than if it is placed in a bait material, and there is less likelihood of shyness developing. Both anticoagulant and acute rodenticides are used as tracking powders.

If such powders are placed strategically in burrows, along runways, behind boards along walls, adjacent to nontoxic water, or on the floor of bait stations, the rodents will soon be poisoned. Such powers should not be used where rodents might track the poison onto food less than 5-10 m away that is destined for consumption by man or other animals. The powders can be applied with various types of shakers or sifters. Blowers can be used to apply generous amounts of the powder in burrows. In general, most of the tracking powders are more effective indoors than outside.

Q. Ectoparasite Control

Ectoparasites can be a health threat to humans. Ectoparasites are quick to leave a dead rodent carcass to seek another suitable host. Consideration should be given to ectoparasites and their control if diseases have been detected or the rodent population to be poisoned or trapped is high, for then man and his pests may end up being the new host.

Because insecticides are constantly changing, as are their appropriate registered uses, I have deliberately avoided suggesting specific pesticides to control ectoparasites and suggest that when ectoparasite control is warranted, you obtain the most up-to-date recommendations from local health or agricultural authorities.

When ectoparasite control is to be conducted, it should be instigated before or in conjunction with large rodent-control operations, not after the rodents have been killed off. The homeowner, when picking up dead carcasses, to be on the safe side should use gloves, a pair of tongs, or two small sticks to reduce the chance of getting ectoparasites on his skin or clothing.

R. An Effective Control Program.

There is no best way to control rodents. The important points are:

1. Proper political support, have the necessary regulations, adequate funding, and availability of equipment and supplies.

2. Adequate publicity and thorough training of personnel.

3. Bait-acceptance tests and proper formulation of bait.

4. Do preliminary field tests, then conduct public demonstrations.

5. Coordinate an integrated pest management program over a wide area and strive for permanent, relatively rodent-free situations.

6. Establish effective inspection and enforcement methods so no rodent population is allowed to flourish.

7. Continuously monitor the program and investigate thoroughly any problems that develop.

8. Do back-up research and constantly strive to improve efficacy of program.

6. RESEARCH NEEDS

There probably always will be a need for improved rodent-control methods and for better techniques of application in controlling field and urban rodents. Especially needed are rodenticides that are safer and more selective for the target species. No rodent-control program can be improved very much, however, without sound basic and applied bioecological research, provided directly or cooperatively. To achieve these goals and to develop ways of using existing rodenticides more effectively and of applying them more efficiently, every national government and some larger local governments must have one or more individuals devoting full time to developing and testing new materials and methods. What may be an excellent material and control procedure in one area or country may not be satisfactory in another for biological, ecological, and political reasons.

7. CONCLUSION AND RECOMMENDATIONS

Remember, rodent control is largely a people problem. It is mostly political, but partly economic. If rodent control is based on any natural laws, one probably is that "no control program is going to be any better than the political support it received from the top leaders of government." Other important considerations are to insure that the rodent-control staff is well trained, the public well informed, and stive for as nearly rodent-free conditions as possible. It is usually too late to try and stop current crop losses; the control should be done earlier to prevent such damage from occurring. Another fact about rodent control is that it is not difficult to destroy rodents; the problem is in creating a truly effective control program that will maintain the rodents at a very low population level.

I suggest in conclusion that the United States Agency for International Development develop a health-agricultural USAID-Eastern Caribbean Animal Pest project. The newly developed Rodent

Control Unit in the Ministry of Health and National Insurance in Barbados could serve both focal point for training in an integrated program in animal pest control, which could serve both public health and agricultural needs. The main objective would be to develop a Training Delivery System (TDS) in each participating Eastern Caribbean country to help each of these countries produce a **Highly Practical, Countrywide, Permanent, Well-Integrated, Self-sustaining** and **Private Enterprise, Rodent (Rats and Mice) Control Program plus Knowledge and Methodology on the Management of the Mongoose, Monkey, Bats and Depredating Birds,** of which public health education would be a major component of the project.

There is an urgent need in this region, where tourism is growing rapidly as the primary industry, to eliminate a number of real and potential serious zoonoses, including **Leptospirosis, Salmonella, Rat-Bite Fever, Murine Typhus,** and **Plague,** and to materially reduce the considerable economic losses to goods and materials and the agricultural losses to such items as **Sugar Cane, Pineapple, Coconuts, Cocoa, Bananas, Nutmeg** and other **Spices.**

6. CURRENT PERSPECTIVES IN INSECT CONTROL IN THE COMMONWEALTH CARIBBEAN

S. PARASRAM and B.K. RAI

CONTENTS

		Page
1.	INTRODUCTION	76
2.	LOSSES CAUSED BY INSECTS	76
3.	CHEMICAL CONTROL OF INSECTS	77
4.	BIOLOGICAL CONTROL OF INSECTS	78
5.	OTHER METHODS OF INSECT CONTROL	79
6.	ORGANISATION OF PEST CONTROL	79
7.	TRAINING	80
		80

I. INTRODUCTION

Insects and related arthropods cause greater losses in the tropical and sub-tropical areas than in the temperate ones, largely due to year round favourable climate. The situation is worse for humid tropics. In addition to damaging crop plants, insects and related arthropods also affect men and domestic animals by sucking blood, acting as vectors of diseases and causing annoyance.

2. LOSSES CAUSED BY INSECTS

Only a few studies have been conducted to estimate losses caused by insects in the Caribbean region. Further, some data on extent of infestation of crops by insects are available which indicate the losses that the insects are capable of causing: examples include the following:-

Sugar Cane: The moth borers, *Diatraea saccharalis* and *D. centrella* cause up to 8 percent joint infestation in most of the sugar cane producing countries in the Caribbean (Alam 1980). It is estimated that 1.0 percent joint infestation by these borers reduces yield by 0.75 percent (Anon 1971). The losses can thus run into millions of dollars. In 1970, from one plot of 1,950 acres of cane in Trinidad, a loss of 500 to 700 tons costing $100,000 to $140,000 was estimated. Froghopper is another serious pest of sugar cane in Trinidad, Guyana and Belize.

Rice: Paddy bug, *Oebalus poecilus* causes both qualitative and quantitative losses. In 1970, the qualitative loss alone was estimated to be about 4 million dollars in Guyana (Rai 1974). Paddy bug is also a serious pest in Belize. The other important pest in both Guyana and Belize is the fall armyworm, *Spodoptera frugiperda.* Angoumois grain moth, *Sitotroga cerealella* and lesser grain borer, *Rhizopertha dominica* cause up to 8 percent loss.

Coconut: In Guyana a pest complex — ant *(Azteca* sp.*)*, mealybug *(Nipaecocus nipae)* and scale *(Aspidiotus destructor)*, infested about 1,000 ha of coconut palms and reduced yield by 3.7 million nuts valued at G$372,000 in 1974. Moth borer, *Lapaeumides dedalus* infested up to 40 percent palms and infested palms bore 32-46 percent fewer nuts than the uninfested palms (Rai 1973). These pests along with leaf defoliating caterpillar, *Brassolis sophorae* are estimated to reduce coconut yield by 20 percent on a national scale in Guyana.

Coffee: Termites *Nasutitermes costalis* and *N. ephrate* made nests on coffee plants; 2.3–3.8 percent plants died annually in 6-9 year old plantations in Guyana, due to termite infestation. Further, infested plants bore 37 percent fewer berries by weight than the uninfested ones (Rai et al. 1977).

Sweet potato: Root weevil, *Cylas formicarius* is a serious pest in Guyana and Montserrat: up to 76 percent of tubers were infested and thus lost. Some farmers harvest crop earlier to reduce infestation and get lower yield.

Cabbage: The two serious pests are the diamondback moth, *Plutella xylostella*, in all Caribbean countries and budworm, *Helulla phidilealis* in Guyana, Trinidad, Barbados and St. Vincent. Both pests can destroy the crop completely.

Cucumber: Pickle worm, *Diaphania nitidalis* infested up to 66 percent fruits and rendered them unmarketable, in Trinidad.

Peppers: Bud moth, *Symmetrischema capsicum* infested up to 100 percent flowers in St. Vincent and Antigua. This pest is also recorded from other countries in the region (Parasram (1973).

Pigeon pea: Jassid, *Empoasca* sp. curled up to 100 percent plants in St. Vincent, resulting in failure of crop. Pod borer *Ancylostomia* sp. spoiled 40 percent of grains in Trinidad.

3. CHEMICAL CONTROL OF INSECTS

Insecticides are being used to cope with perhaps 90% of current pest problems. Insecticidal use offers effective and economically feasible ways to deal with literally thousands of pest species. It is difficult to conceive how we can hope to develop alternative methods soon for controlling most insects with equal effectiveness, dependability, and cost. However, there are limitations such as toxicity hazards to applicators, consumers, non-target organisms; resurgence of the controlled or other pests and resistance in pest species. Because of the limitations, it is necessary that the insecticides should be used judiciously to reduce or eliminate some of the undesirable side effects. A serious problem today is that research in the proper use of chemical insecticides is being neglected, as was the case sometime back with alternative methods of pest control. This problem is catastrophic for countries where no information exists on chemical control of pests and the specialists are trained in ecology, biological control, host resistance, and novel methods of control.

Screening of a large number of commercially available insecticides against major pests, developing specific formulations and methods of application, determining minimum effective dosage in field and residues of insecticides in produce, with the objective of finding out an insecticide, formulation and technique of application which at a low dosage gives a good control of pest with least deleterious side effects, could lead to judicious use of insecticides. Utilisation of the level of specificity of action of insecticides in available products, injection of insecticides into plants, application of insecticidal baits, and placement of insecticide granules, could reduce hazards to non-target organisms.

Injection of monocrotophos into coconut palm controlled two major pests – leaf eating caterpillar *Brassolis sophorage*, moth borer, *Lapaeumides dedalus* (Rai 1973), and did not contaminate the coconuts, but the insect pollinators visiting inflorescence were affected within a few hours of treatment. However, the treatment became ineffective to honey-bees seven days later. Control of ant, *Azteca* sp., infesting coconut palm, with a meat bait containing mirex as toxicant, led to the elimination of a serious pest, the scale, *Aspidiotus destructor*, by naturally ocurring predators (Rai 1977a). Control of the ants tending pineapple mealybug with bait containing heptachlor as toxicant, led to development of sooty mold in mealybug colonies, and reduced mealybug population by approximately 75%. Screening of a large number of insecticides against pineapple mealybug revealed that dipping of pineapple planting material in 0.01% dimethoate and spraying 0.07% phoxim on field plants controlled the pest (Rai and Sinha 1980). These three operations have to be simultaneously conducted for the control of pineapple mealybug with minimal use of insecticides.

Screening and field testing of insecticides against paddy bug, *Oebalus poecilus*, indicated that monocrotophos was residually effective for the longest period against the pest on rice inflorescences (Rai 1971). Monocrotophos spray @ 285 g a.i./ha has replaced BHC and carbaryl applied at much higher dosages and also better control is obtained. Data on the amount of insecticides used per ha before and after the research work for judicious use (Table 1) indicated that the quantities of a.i. used reduced appreciably after the work. Such work may need to be

done for up to 10 major insect pests in each country to improve the pest control and to reduce the quantities of pesticides used.

Table 1 Amounts of Insecticides used in Guyana per hectare for the control of some pests, before and after specific research work

	Before specific research work		After specific research work		Ref.
	Treatment	g a.i./ha	Treatment	g a.i./ha	
Paddy bug, *Oebalus poecilus*	dust gamma BHC dust carbaryl	1,105 – 1,430 850 – 1,000	spray monocropophos spray carbaryl	,285 1,402	Rai 1971
Rice caterpillar, *Spodoptera frugiperda*	spray trichlorfon spray carbaryl	475 – 665 680 – 935	spray fenitrothion	170-225	Rai 1973
Paddy moth, *Sitotroga cerealella*			spray surface of stacks of bagged paddy with phoxim	1 g/7 tons paddy	Rai and Croal 1974
Coconut caterpillar, *Brassolis sophorae*	spray trichlorfon	1,000 – 1,500	inject monocrotophos into palms	72-180*	Rai 1973
Coconut moth borer, *Lapaeumides dedalus*	spray DDT, chlordane, aldrin or dieldrin	445 – 1,125	inject monocrotophos into palms		Rai 1973 Van Dinther 1960
Ant, *Azteca* sp. rears mealybug and scale insect on coconut	spray aldrin	2,400	in meat bait	7.5	Rai 1977
Ant, *Solenopsis* sp. protects mealybug on pineapple	spray aldrin on nest	32**	heptachlor in milk + flour	1.6**	Rai and Sinha 1980
Corn armyworm, *Spodoptera frugiperda*	spray trichlorfon	800 – 1,200	spray monocrotophos or fenitrothion with knapsack sprayer	200	Anon 1973
			spray monocrotophos with high clearance boom sprayer	200	Rai and Badrie 1977
Diamondback moth *Plutella xylostella* on cabbage	spray 0.05% pirimiphos methyl	270	spray 0.2015% permethrin	13.5	Lee 1973 Sinha and Rai (unpub.)

* when 20 – 50 palms/ha treated ** when 40 nests/ha treated

4. BIOLOGICAL CONTROL OF INSECT PESTS

Introduction and establishment of natural enemies and augmentation and conservation of native natural enemies, has been practised in the West Indies for several decades (Bennett 1974). During the period 1931-35, the Amazon fly, *Metagonistylum minense*, was introduced from Brazil into Guyana and from there into St. Lucia, and the Cuban fly *Lixophaga diatraeae* into Antigua and St. Kitts and control of sugar cane borer, *Diatraea saccharalis*, was obtained. In Barbados, following the very perservering work of introduction of more than 13 exotic species of parasites over 45 years, one introduced in 1965 finally proved successful, and currently a good control has been obtained with *Apanteles flavipes* and *L. diatraeae*, with joint infestation reduced to a low of 3.3% in 1976, from an average of over 15% per annum prior to 1965. Further, *A. flavipes* has been successfully introduced into St. Kitts and St. Vincent. In Jamaica, where *D. saccharalis* is parasitized by native parasites, 5.6% internodes were bored in 1977, indicating that no further augmentation of parasitism was necessary. *D. centrella* is another moth borer pest of sugar cane in many caribbean countries. Because of inadequacy of natural parasites, introduction of newer parasites was attempted without much success.

Vedalia beetle, *Rodolia cardinalis*, was successfully introduced into Barbados in 1945 for the control of cottony cushion scale, *Icerya purchasi*. In 1966, it was further introduced into St. Kitts and Montserrat and later into Antigua. It has provided a satisfactory control in Barbados, St. Kitts and Montserrat.

In 1952, citrus black fly, *Aleurocarithus woglumi*, was accidentally introduced in Barbados. To combat this *Eretmocerus serius* from Jamaica and *Prospaltella opulenta* from Mexico were introduced into Barbados in 1964. *P. opulenta* proved more competitive. Later, *P. opulenta* was also introduced into Jamaica. Further, in 1972 both these parasites were successfully introduced into Bahamas.

The above mentioned examples illustrate the classical approach to biological control i.e., the introduction of parasites from the homeland of the introduced pest. It is commonly held that chances of success of biological control are more for pests of perennial crops than for those of annual crops. The position is further complicated if a few pests of a crop need to be controlled simultaneously, as the insecticide applied to control one pest could eliminate the effective parasites of the other pests. A multiple approach comprising the introduction of more parasites, encouragement of native natural enemies, use of pathogens and possibly anti-feeding agents, has been suggested.

Permanent biological control once established has a very favourable cost/benefit ratio but it is frequently not possible to predict in advance the length of time required to establish natural enemies or the level of success which may be achieved. However, there is evidence that most successes have occurred in areas where most efforts and resources have been applied.

5. OTHER METHODS OF INSECT CONTROL

Cultural and other methods of control of insect pests have been neglected because of total reliance on effective insecticides. With the realisation of the limitations of chemical control, stress especially on cultural control is needed. It is a common observation that infested vegetative planting material is used by farmers and that infested vegetables unfit for marketing are left on the plants or in the field. International research institutions are doing monumental work in breeding plant varieties resistant to insects; most countries are testing those varieties, and retaining those useful to them. The technique of release of sterile insects for the control of a pest population, though highly suitable for islands, is very capital intensive, requires a large number of scientists and techniques, and is thus out of reach of many small countries.

6. ORGANISATION OF PEST CONTROL

Assistance to select and to make available pest control inputs may be provided by the Plant Protection service of the country or by specialised commodity production groups e.g., sugar, coconut and citrus producers' associations and rice marketing boards etc. In some other countries, no such assistance is provided. In Guyana, at the conclusion of a research project for the control of major pests of coconut which had reduced yields appreciably, another project was initiated to spread the new technology relatively quickly, to ensure that the pest control operations were carried out properly, and to reduce losses caused by the pests. Under that project, insecticides and insecticide application equipment were made available to producers at a subsidy, technicians were trained to demonstrate to and work with producers in all major coconut growing areas of the country. Because of the success of the approach, a similar project was initiated for the control of the mealybug of pineapple after research work was completed.

In the Commonwealth Caribbean some of the major crops are produced on small holdings belonging to a large number of farmers. Because of serious lossed caused by a certain pest, even though the pest did not appear in all fields at one time, aerial application of insecticides was recommended. Contamination of environment and deleterious side effects of insecticidal use are greater when insecticides are applied over large contiguous areas and by air. Thus an advantage due to small holdings was not realized. Further, the small producer who generally is underemployed, has to pay for spraying by air when he could have sprayed his field himself, and further his field might not have needed treatment at that time. In case of failure of a treatment farmers cannot know if the chemical applied was the recommended one and was applied at the proper dose.

Pesticides should be recommended by their common names, approved by the International Standards Institution, rather than by their proprietary names, as different proprietary products containing same a.i. and similar amounts of a.i. sell at different prices. Sale of older pesticides,

being manufactured by a large number of basic producers, are not much pushed and thus get neglected in newer markets as the users are not aware of them. Here is a responsibility to introduce older and cheaper pesticides, even though to the importer the profit may be less and use once developed may be subject to competition from other importers. The different proprietary formulations of a pesticide may have different amounts of a.i. The price of such products should be compared on the basis of a.i. content, other things being equal. Further, some of the newer pesticides are very expensive but may be required in much lesser amounts to control pests. Thus cost of various pesticides should be compared on the basis of cost of pesticides required to control pests per unit area.

7. TRAINING

At present there is a certain amount of emphasis on training of specialist and extension staff. The specialist staff should not only be able to generate new technology for pest control but should be able to cope with the many and varied problems of pest control at country level. The farmers, unfortunately, have been given little or no training to enable them to follow simple recommendations contained in farmers' bulletins. The result is that the farmer either cannot use or abuses the recommendations. A lot more resources need to be spent for farmers training. A start in this direction has been made at least by one country in the region.

8. CONCLUSION

Climatic and other conditions permit insects to inflict greater losses on crops in the tropics than in temperate climates, and also encourage more insect vectors of diseases of humans and animals. Data for crop losses presented in this paper indicate how serious these can be, and it is not surprising that recourse has been made to chemical insecticides to cope with perhaps 90% of insect pest problems – with varying degrees of success. However, biological control has been practised in the Caribbean for more than half a century, and with increasing awareness of the ecological hazards of chemical pesticides and their escalating costs, there has been an upsurge of interest in biological control techniques. Whatever approach is taken, however, cannot attain its full potential without training of both extension staff and farmers.

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7. CURRENT PERSPECTIVES IN PLANT DISEASE CONTROL IN THE CARIBBEAN

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CONTENTS

		Page
1.	INTRODUCTION – BACKGROUND	82
2.	PLANT QUARANTINE	83
3.	ERADICATION	83
4.	PROTECTION	83
5.	DISEASE RESISTANCE	85
6.	NEMATOLOGICAL PERSPECTIVES	85
7.	PERSPECTIVES IN VIROLOGY	85
8.	CONCLUSION	86

1. INTRODUCTION – BACKGROUND

A review of plant disease control in the Caribbean must take into consideration the widely varied levels of sophistication in the technology of production and the range in the size of enterprise that are so characteristic of the region's agriculture. Thus, it is possible to see, in close proximity within one country, Sigatoka control by aerial spraying and the application of a copper suspension of unknown concentration with a peice of leafy shrub to control tomato early blight. This is a region where there are plantations of sugar cane, coconut and banana, each occupying thousands of hectares, and holdings of less than one hectare carrying five or more different species of food crop. The extremes and contrasts are numerous – banana is shipped under refrigeration in carefully packed cartons, but avocado is moved in miscellaneous containers on the decks of sloops, or citrus bud wood is carefully selected from mother trees known to be virus free and grafted on root stocks growing in soil that is infested with the citrus nematode.

The traditional export crops – banana, cacao, coffee, sugar cane, coconut and citrus – have, for many years, been serviced by research, some conducted by the industries themselves, on a broad range of problems, including those caused by plant pathogens. Control measures have been developed for a number of important diseases such as Sigatoka, Moko and fruit rots of bananas, witches' broom of cacao and red ring of coconut. The well-coordinated, regional research activity on sugar cane has enabled the industry to meet the challenge posed by sugar cane smut. Within two years of the appearance of the disease in Trinidad, for example, it was possible to initiate a programme of replacement of highly susceptible varieties with more tolerant introductions. The recent appearance of rust into the region will further test the mettle of the research programme to provide varieties with resistance to both of these destructive diseases.

Research on the great majority of the fruit, food forest and ornamental crops grown in the region has been of more recent vintage and, largely, by no means comparable in range and intensity with the research on the traditional export crops. Where programmes do exist, phytopathological content may be non-existent or, at best, restricted to some aspect of an important disease. The major constraints to adequate study of the disease problems on most of our cultivated plants are a scarcity of funds and a critical lack of pathologists, plant breeders, plant physiologists, entomologists, indeed the range of expertise that is required to provide the armour with which to combat plant diseases satisfactorily. We are yet to determine the causal agents of the "burning disease" of aroids, nutmeg decline, onion "blast", canker of pommecythere, pomerac decline, die back of breadfruit and little leaf of coconut – the list is a long one. We are far from developing control procedures for the phanerogamic pathogens that take heavy toll of fruit and forest

trees. The conditions for the storage and transport of such lesser-known fruit and food crops as tannia *(Xanthosoma sagittifolium)*, dasheen *(Colocasia esculenta)*, mammee apple *(Mammea americana)* and soursop *(Annona muricata)* have not been developed. The shortages in research funds and expertise combined with the bewildering diversity of plant pathogenic organisms present a formidable challenge to those few pathologists who have to man the ramparts against the invading horde of plant diseases.

2. PLANT QUARANTINE

Plant quarantine services in the Caribbean offer a very porous defence against the entry of exotic diseases. In most countries, certainly of the Commonwealth Caribbean, staff are inadequate in number and in training, facilities for treatment and destruction of infected material are deficient, and post-entry stations almost non-existent. These defects are compounded by the fact that the public, on the whole, are unaware of the dangers posed to agriculture by plant pathogens. Surreptitious entry, particularly of ornamentals and fruits, is widespread and presents one of the greatest difficulties to overworked quarantine staff.

There are some dangerous diseases not yet reported from the Caribbean but important to our commercial crops. Bunchy top virus of banana, peanut rosette virus, stem and bud nematode and citrus canker are a few that deserve special mention in this regard. The need for strict quarantines against these and many others need not be over emphasised.

3. ERADICATION

Disease control by eradicative procedures is practised widely, though, in some instances improperly. Crop rotation is such a traditional measure that farmers at every level of sophistication use the method. However, in the intensive cultivation, say of vegetables, in small holdings, rotation may involve the movement of adjacent beds which are subject to contamination by surface run-off or spatter during torrential rains. Pruning of diseased limbs of trees is often done by cutlass which leaves jagged wounds that are easily invaded by wood-rotting and other fungi. Sanitation in markets and on vehicles and vessels used in the transport of perishable foods is one of the most neglected aspects of disease control. Losses incurred in the storage and transportation of vegetables, fruits and root crops are very high. They result from improper handling, packaging and storage conditions. Reference has already been made of the need to determine the proper storage conditions for some of the indigenous crops and there is an equal requirement to develop systems of refrigerated transport of perishables for the small vessels that ply between countries of the Caribbean. It is a striking inconsistency that, in a region accustomed to the use of precise methods in the handling of bananas, other perishables are moved with little regard to the risks of spoilage.

4. PROTECTION

The Caribbean region falls within the humid tropics in which, for approximately half the year, there are frequent rains, sometimes of great intensity. It is an area replete with leaf spots, blights, anthracnoses and mildews that attack the foliage of plants. Often the use of an efficacious fungicide is the only alternative to a ruined crop. It is not surprising, therefore that the ultra-low volume (ULV) system for the control of Sigatoka on banana was developed in this region, by pathologists in the French West Indies. The system benefitted, particularly, the small grower who was unable to use high-volume sprays to control the disease. The application of ULV sprays by aircraft is now an established procedure for the control of pests and diseases in sugar cane and banana.

One of the prime advantages in the use of low volume systems of pesticide application is that the dosage of pesticide can be reduced, as a result of the greater efficiency of deposition. The application of oil-based sprays by ULV methods allows for even greater reduction in chemical usage because of enhanced retention. Although low volume methods of application are in wide use in the Caribbean, the attendant possibilities for reduced dosage have not been as generally accepted by farmers accustomed to gauging the thoroughness of application by the visi-

bility of the chemical on the plant surface. The proper utilization of this system now requires effective education of the farming communities, large and small.

In the opening paragraph reference was made to an extreme in the lack of sophistication in fungicide use. In this region very many farmers are yet to be convinced of the importance of dosage rate in the application of pesticides. Some find it difficult to afford even the simplest machine. Clearly, assisting such farmers has less to do with pathology than it has with agricultural policy. However, these are real hurdles to be overcome in improving the procedures for disease control.

Pathological research in the Caribbean needs to examine more intensively the fundamental nature of host-parasite relationships under different environmental conditions. There is a need to determine the level of infection that can be tolerated without significantly affecting yield. This kind of information is necessary for refining procedures of control and, as it relates to fungicidal use, for determining the timing and frequency of application.

Considerable improvements need to be accomplished in controlling plant diseases through the use of clean planting material. There are real dangers, even for the traditional export crops, which are heightened because of the weaknesses in the quarantine systems and the free movement of produce among countries, often not through official ports of entry. For example, Moko disease of banana is now found in Grenada, 'Cedros wilt' of coconut has been discovered in Trinidad and sugar cane leaf scald is periodically intercepted in new setts at the quarantine station in Trinidad.

There is a likelihood of increased levels of disease particularly in root crops, legumes, cereals and ornamentals, where planting material is frequently maintained by the grower. It is not uncommon for the material retained for 'seed' to be that part of the harvest which cannot fetch the best price. Often the cost of the lower quality is pathological.

At the same time, the interaction of nematodes with other soil organisms in disease complexes has received little or no attention. An assessment of the destructive nematode diseases ih most countries is incomplete. Consequently, there is no way for the farmers to determine the level of nematodes in their fields and thereby make management decisions on crop rotation, nematicide application or varietal selection.

Knowledge about nematode pest control in the Caribbean is still fragmentary. There is an urgent need to broaden our knowledge about nematodes in the region. We need to develop training programmes for people interested in pest control and also for those who may be working in other scientific areas, e.g. agronomy, zoology etc.

Furthermore, there is a lack of educational materials for the Caribbean and this has greatly reduced the effectiveness of training programmes. There are currently only two or three text books in tropical nematology.

An educational programme is needed to make farmers aware of crop losses now occuring and to show them how adoption of simple and inexpensive control measures can increase their production and ultimately their quality of life.

Whilst developed nations are able to take advantage of new technological advances almost immediately, such technology is difficult to take advantage of in the Caribbean, where resources for research or development (laboratory and field equipment, library facilities, travel and technical assistance) are limited. In 1967, the Council of Ministers in the Commonwealth Caribbean expressed the view that more attention should be given to nematology and requested (1) an assessment of the nematological problems affecting crops in the region and (2) recommendations on control measures for nematodes which attack crops. However, because of the relatively slender resources available to territorial Departments of Agriculture in the region, the recruitment of a plant nematologist for each country was not possible.

Use of chemical pesticides, crop rotation and resistance, alone, will not be adequate for economic control of nematodes. Accordingly, the only feasible and even possible long-range, effective programme must be for integratory pesticide and/or non-pesticide methods of control. For example, root-knot nematode *(Meloidogyne incognita)* is widely distributed throughout the carrot growing region of St. Vincent. Nematicides have controlled the nematode and increased yields, but they have not proven to be economical. No resistant carrot variety is avail-

able. A pest management approach, using fertilizer, crop rotation, or inter-cropping appears the most practical solution to this problem on a commercial scale.

5. DISEASE RESISTANCE

The production of varieties of the various species of economic plants with resistance to the region's major disease has suffered severely from the lack of expertise in plant breeding and crop protection and especially from the shortage of funds. Crop improvement programmes which include the incorporation of resistance to important diseases require long-term funding that is not readily secured. The advent of the international research centres has considerably facilitated research on the improvement of a number of economic plants. Even these programmes have their limitations in that the varieties developed may succumb to different races of the pathogens in this region. A case in point is the experience with 'resistant' cowpea lines from IITA which were susceptible to Trinidad strains of cowpea mosaic virus. There remains, still, a wide range of species that are consumed in substantial quantities which await some kind of organised programme for their genetic improvement.

6. NEMATOLOGICAL PERSPECTIVES

The accepted, practical approach to phytonematode control has been by the use of resistant varieties, crop rotation and chemical pesticides. However, the use of chemical pesticides is beyond the financial means of most small farmers where a large segment of the population survives on subsistence-type agriculture. Such farmers must rely on effective, non-chemical methods for pest management. In addition, the impact of the environmental movement or reaction of Government regulatory agencies in banning the use of pesticides, proved or assumed to be hazardous to humans or environment, has curtailed the use of pesticides. Banning the use of the nematicide, Nemagon, for controlling nematodes in banana and other crops in the Caribbean is a case in point. However, the use of chemicals by the West Indian Tobacco Company and the Banana Industry in the Windward Islands serves to dramatise the damage caused by nematodes and bring to the forefront the benefits to be gained from their control. There is a vast amount of information on pesticides that is available from developed countries. However, little or no information is available on the behaviour of these chemicals in terms of their longevity under tropical conditions.

Phytonematology has been a neglected area of pathological research, especially with respect to food crops. The major nematode diseases in the Caribbean are Root-knot nematode in vegetables, Citrus nematode in citrus, Reniform nematode in many vegetables, root crops and pineapple, red ring nematode in coconut and the Cyst nematode. The destructiveness of this nematode is well known and the possibility of it becoming established in cultivated fields should be a matter of concern. Of equal importance is the need to determine the current status of the ectoparasitic nematodes, *Xiphinema* and *Trichodorus* which have been found in cacao.

7. PERSPECTIVES IN VIROLOGY

Caribbean agriculture, perhaps throughout its modern history, has lived with virus diseases, as with many other elements which depress the yield, but do not destroy the plants completely. Most plant virus diseases depress the yield to varying degrees depending on many factors but do not kill the plants. However, we in the Caribbean have been fortunate not to have faced the 'hurricane-like' effects of some virus diseases which have shaken the agricultural panorama in other countries from time to time. Tristeza virus destroyed seven (7) million orange trees in Brazil within a decade beginning 1936. The writers do not intend to dramatise the importance of virus diseases, but the fact remains that they should not be ignored. They are important yield reducers and yield destabilizers.

It is a matter of fact that we do not know all of our virus diseases, and those which we know, we do not know how bad they are. We need to know their strengths and weaknesses to rationalise our approach towards them. CARDI's Yam virus project sprang a pleasant surprise by discovering that, in an average year, Yam viruses could reduce yield by as much as 30-40%. The question may be asked as to what was pleasant in this surprise. The answer is simple. We had a lot at

stake to go in for. This emphasises the importance of assessment of losses due to virus diseases. Only the degree of loss can justify the level of investment, whether in research or actual control promotion. Just a few examples will elucidate how variable the effects of viruses are. A susceptible variety of cowpea may be almost entirely free of cowpea mosaic virus during the dry season, but during the rainy season the incidence may be as high as 80%. Tomato plants affected by the severe strain of TMV (Tobacco mosaic virus) may yield almost nothing, but a mild strain of the same virus may not reduce the yield at all. There exists a wide variability in the distribution, as well, of the viruses. Yam viruses are widespread throughout the Caribbean, but golden mosaic of bean is restricted to Jamaica and Belize. Information on the nature, distribution and effect of viruses would provide bases for reducing their adverse effects.

Control of virus diseases differs markedly from that of other diseases. Unlike fungicides, nematicides and bactericides, commercially suitable viricides have not been found so far. Therefore, virus diseases are mainly avoided by prevention rather than cure. Pesticides directed to the vectors have been used successfully for the control of only a few viruses. These are restricted to some viruses transmitted by nematodes and fungi, as well as by aphids requiring longer feeding times for transmission; such viruses have not yet been recorded in the Caribbean.

Avoidance or reduction of viruses, either temporarily or longlasting, offers tremendous scope for control of virus diseases in the Caribbean. This would, however, be a continuing battle. The strategy could consist of a combination of methods, depending on the particular crop disease situation. Selection and breeding for resistance and tolerance have provided some notable successes and there is need to pursue this approach. The development of Laura B, a variety of cowpea with commercially acceptable qualities and resistance to cowpea mosaic virus, deserves mention. The vast germplasm pool of many crop plants now developed at the International Institutes and other institutions offers promising scope for breeding and selection work.

Techniques for obtaining virus-free seed and vegetative stock for many crops are either available or easily possible to develop. There is an urgent need to exploit these in a planned programme. Investigations on Yam viruses in CARDI revealed that the entire Yam stock of the region was infected with viruses and even a single virus-free plant of *Dioscorea alata* could not be found. Using heat therapy and meristem tip-culture techniques, it was possible to develop virus-free clones of *D. alata* for commercial production of virus-tested stock. The three important viruses of citrus, namely, tristeza, psorosis and exocortis are known to exist in the region. A programme for the production of certified disease-free, budwood material and suitable resistant rootstocks would deserve prime consideration for protecting the future plantings of citrus.

Manipulation of agronomic practices, including changes in planting time and crop mixture, have been successfully exploited to reduce the adverse effects of virus diseases in several instances. This would seem to be particularly important in multiple cropping programmes using short-duration crops.

CONCLUSION

The importance of plant disease control is well appreciated in official circles and by the growers of the major export crops in the Caribbean, but implementation measures leave much room for improvement. Plant quarantine services in general, though existing in virtually all territories, are endangered by shortage of staff and lack of public awareness of the serious consequences to crops that may follow illegal importation of plant material. At the farmer and marketing levels sanitation practices are not well understood: preventive measures are virtually confined to the major export crops, e.g. bananas. Plant breeding for resistance is a costly long term approach, though the need is at least partially being filled by various international research centres. More attention to nematology and virology is urgently required.

8. WEED PROBLEMS AND WEED CONTROL IN THE COMMONWEALTH CARIBBEAN

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CONTENTS

		Page
1.	INTRODUCTION	87
2.	EFFECTS OF WEEDS	87
3.	LOSSES DUE TO WEEDS	88
4.	THE WEEDS	88
5.	CONTROL METHODS	92
6.	WEED CONTROL RESEARCH	95
7.	CONCLUSION	96

INTRODUCTION

That weeds can and do cause large losses of agricultural production, and increase the costs of production, is indisputable. This is generally recognized by farmers although their weed control practices may not be effective or timely enough to minimise losses in yield. Without any weed control, many crops will give negligible yields. Partial or delayed control will substantially increase yields, although they will be much less than those achievable with more complete and more timely control.

Nine years ago, Holm (1971) suggested that, worldwide, "more labour is expended for the weeding of man's crops than on any other human activity". This probably remains true today for many Caribbean farmers. A recent estimate suggests that 25% of actual expenditure on food crop production in the Eastern Caribbean goes on labour for weeding. In spite of developments in herbicide technology, hands, hoes and machetes (or cutlasses) remain the commonest methods of weed control in the Caribbean and in developing countries in general.

Weeds are best defined as "plants growing where they are not wanted". It follows that volunteer crop plants growing in the following crop can be regarded as weeds. In practice, many small farmers would not so regard them, and would not remove them.

Weeds may be annuals or perennials, herbs, grasses, sedges, shrubs, trees or vines in growth form, and autotrophic or partially or entirely parasitic. Love vine *(Cuscuta* spp.*)* is probably the most familiar parasitic weed of the Caribbean. *Striga* spp. are fortunately absent: these root parasites are serious weeds of sorghum and corn in Africa and Asia.

2. EFFECTS OF WEEDS

Weeds affect agricultural production in many ways. They compete with crop plants for light, water and nutrients, reducing yields and crop quality. They may harbour pests and diseases of crop plants. Poisonous weeds can cause ill-health, and even death, in domestic livestock and man. Black sage *(Lantan camara)* is probably the best known example of a poisonous weed. Livestock normally avoid poisonous plants, but may eat them in cut or wilted fodder. Spiny or prickly weeds can injure livestock and workers engaged in weeding or reaping. Indeed, workers may refuse to hand-weed if certain prickly weeds are present. Bur grass *(Cenchrus echinatus)* and spiny calalu *(Amaranthus spinosus)* are familiar Caribbean examples of such weeds. A luxuriant

growth of weeds, particularly of viny weeds, can severely hamper reaping and reduce the efficacy of crop protection sprays. Water weeds can impede water flow and interfere with navigation. Finally, certain weeds can cause allergies in both livestock and man, either on contact or by inhalation of pollen.

3. LOSSES DUE TO WEEDS

It is not easy to estimate, reliably, the quantitative impact of weeds on Caribbean agriculture. Parker & Fryer (1975) have estimated that the percentage loss of food attributable to weeds world-wide, varies from 5% in highly developed agricultural systems to 25% in the least developed systems, where production is mainly from small units with minimal modern inputs. They estimate the annual loss in the latter category to be 125 x 10^6 tonnes of food. Caribbean agriculture varies widely in its technological development: many sugar estates practice good weed control and would experience losses of perhaps only 5 - 10%, whereas many small farmers growing food crops would experience much greater losses. My own "guestimate" of the overall loss of food due to weeds in the Commonwealth Caribbean, would be 20%.

That Parker & Fryer's figure of 25% loss is not unreasonable, and may, for many crops, be optimistic, is evidenced by experimental data showing the losses that can occur when weeds are inadequately controlled. Data of Nieto, Brondo & Gonzalez (1968) from Mexico illustrate this effectively. Where weeds were not controlled until 30 or 40 days after crop emergence, but were adequately controlled thereafter, yields of corn were reduced by 25 and 51% respectively compared with the yield of plots kept weed-free from emergence until harvest. Dry bean yields in comparable experiments were reduced by 53 and 92% respectively. In contrast, when the crop was kept weed-free for the first 30 or 40 days, but no weed control was practiced thereafter, yield losses in corn were, respectively, 7 and 5%, and in dry beans 7 and 3%. These results illustrate, firstly, the importance of early weed control, which the farmer is often unable to practice because of pressure of other work, and secondly, the ability of the crop to suppress weed growth once it has been given a good start with early weed control.

Kasasian & Seeyave (1969) have presented data for other short-term crops grown in the Caribbean. They concluded that the critical period for weed competition and therefore for weed control, is approximately the first one-third of the crop's life span. It is in securing control during this period that pre-plant incorporated and pre-emergence herbicides can materially assist the small farmer. Even if the control from the herbicide is only partial, or not long-lasting, it can reduce the time needed for weeding and/or delay the need for weeding without adverse effects on yields (Hammerton, 1974 c).

4. THE WEEDS

Tables 1-3 list the most important weeds of the Commonwealth Caribbean. The selection is based largely on subjective estimates by experienced agronomists working with farmers (CARDI, 1980). Species are listed in (approximately) decreasing order of importance. Weeds in the "most serious" category (Table 1) were reported from most countries, and were assessed as particularly serious and/or difficult to control. Those in the "locally serious" category (Table 3) were reported as serious only from a few countries, but did have local importance. Detailed descriptions, accounts of the agricultural importance, and world-wide distribution maps for most of the species listed in Tables 1-3 are given by Holm, Plucknett, Pancho & Herberger (1977). A detailed listing of these weeds by distribution and relative importance is given by Holm, Pancho, Herberger & Plucknett (1979).

Table 1. The "most serious" weeds of the Commonwealth Caribbean

Botanical Name [1]	Common Name(s) [2]	Notes [3]
Cyperus rotundus	nut grass, purple nutsedge	Per. sedge
Cynodon dactylon	bahama-grass, bermuda-grass, devil-grass	Per. grass
Commelina spp.	water grass, french grass	Ann./Per. herb
Parthenium hysterophorus	white top, white head, bastard feverfew, mugwort	Ann. herb
Portulacea oleracea	purslane, pussley	Ann. herb
Cleome spp.	consumption weed, caia, sambo	Ann. herb
Amaranthus spp.	bhaji, calalu, calaloo, spinach	Ann. herb

[1] Botanical names follow Holm, Plucknelt, Pancho & Herberger (1977)

[2] The most widely used common names in the Commonwealth Caribbean

[3] Ann. = annual; Per. = perennial

* Source: CARDI (1980)

Nutgrass *(Cyperus rotundus)* is regarded as the world's worst weed (Holm, *et. al.*, 1977) and is evidently the most serious individual weed species in the Commonwealth Caribbean (Table 1). It is listed as serious in 52 countries around the world (Holm *et. al.*, 1977). Essentially a weed of intensive agricultural systems it is relatively unimportant in non-intensive systems. It is difficult and expensive to control and propagates vegatatively and regrows very rapidly (Hammerton, 1974 d). It can form almost pure stands, with a few thousand tubers – the main propagule – per m^2 of land, in situtions where control practices have eliminated other species.

Bahama grass *(Cynodon dactylon)* is rated second to nut grass in importance in the Caribbean, and world-wide (Holm, *et. al.*, 1977). It spreads in cultivated land principally by stolon fragments, but also by seed. Control is difficult.

Several species of water grass occur in the Caribbean, namely *Commelina elegans, C. diffusa* and *C. benghalensis.* The common names are misleading as these are not grasses. They are serious weeds of bananas and other crops in the Windward Islands, particularly in wetter locations where they can form large mounds. There are reports of resistance to paraquat (Gramoxone) (CARDI, 1980), but this may be due to paraquat sprays killing only the surface leaves and stems of these mounds, leaving the lower stems undamaged.

White top *(Parthenium hysterophorus)* has spread within the last few years to all Commonwealth Caribbean countries and to the Bahamas, and no doubt to other countries of the region. It is not documented how it came to be introduced to the region. It is resistant to paraquat, except when very young, and has become dominant in lands where this herbicide is regularly used. It is widespread in Inida where it causes severe skin allergies among the population, but this does not seem to be a problem in the West Indies.

Purslane *(Portulaea oleracea)* has become a serious weed of intensive vegetable production and of other crops intensively grown and fertilized. The succulent stem appears to tolerate desiccation and uprooted plants can often re-establish. It also appears able to recover from paraquat sprays although the leaves are usually killed. According to Kasasian (1967) the response

to phenoxy herbicides varies within the Caribbean. Purslane has been used as a pot herb and medicinally.

Caia *(Cleome viscosa)* is probably present in most, if not all, the countries of the Commonwealth Caribbean. It has yellow flowers and is almost entirely covered with sticky glandular hairs. It may grow to a metre or more in height, and when present in large numbers, can compete severely with crops. Consumption weed *(C. ciliata)* is a more delicate plant with trailing branches and white or purple flowers. It is probably absent from some Commonwealth Caribbean countries, but where present is an aggresive weed in vegetables and other short-term food crops.

Spiny calalu *(Amaranthus spinosus)* has stipular spines that make hand-weeding unpleasant. *A. dubius* and *A. viridus* are used as spinachs and are often left in the crop to grow in order to be reaped and used as food later. These species are common in intensive well-fertilized agricultural systems, but are susceptible to many herbicides. They are prolific seed producers, and the seed has varying levels of dormancy.

Table 2. The "serious" weeds of the Commonwealth Caribbean*

Botanical Name[1]	Common Name(s)[2]	Notes[3]
Eleusine indica	fowlfoot grass, goosegrass, yard grass iron grass	Ann. grass
Echinochloa colonum	jungle rice	Ann. grass
Euphorbia spp.	spurges, milkweeds	Ann. herb
Brachiaria mutica	para grass	Per. grass
Paspalum conjugatum	sour grass	Per. grass
Sporobolus indicus	drop seed, hay grass, tapia grass	Per. grass
Ipomoea tiliacea	wild slip, wild potato	Ann. herb

[1] Botanical names follow Holm, Plucknelt, Pancho & Herberger (1977)

[2] The most widely used common names in the Commonwealth Caribbean

[3] Ann. = annual; Per. = perennial

* Source: CARDI (1980)

The second category of weeds — "serious" — are listed in Table 2. Five of the species in this Table are grasses. Fowlfoot grass *(Eleusine indica)* occurs in many crops and is also a prolific seeder. Once established, plants are difficult to removed by hoeing and can reroot.

Jungle rice *(Echinochloa colonum)* is very responsive to rain or irrigation and rapid growth follows quite light showers of rain. It is a heavy seeder, and is common in rice, corn, sorghum and many other crops.

The spurges *(Euphorbia hirta, E. hypericifolia, E. prostrata* and others*)* are characterised by the copious milky sap produced from broken stems. They are found in many crops, both annual and perennial. Seed-under-the-leaf *(Phyllanthus amarus)* is another common weed closely related to *Euphorbia* spp.

Para grass *(Brachiaria mutica)* is a spreading perennial grass with stout culms that root at the nodes. A weed mainly of wetter areas it is important in sugar cane, citrus and bananas. It is spread by stolon fragments. Paraquat usually fails to kill the older culms so that regeneration occurs.

Sour grass *(Paspalum conjugatum)* is another creeping grass which may form pastures on poorer soils. When young, it provides useful grazing but becomes less nutritious with age. It is usually a weed of perennial crops such as cocoa, bananas and citrus.

Drop seed *(Sporobolus indica)* is a wiry-stemmed tufted grass common in pastures. It appears to be increasing in frequency in some countries. It is unproductive and low in nutritive quality. Control is largely a matter of management.

Wild slip *(Ipomoea tiliacaea)* is a relative of the sweet potato. Several other *Ipomoea* spp. occur as weeds also. They are viny weeds common on fences but may climb over fruit trees and invade and spread across cultivated land. There are indications that one or more species show resistance to paraquat.

Table 3. Some "locally serious" weeds of the Commonwealth Caribbean

Botanical Name[1]	Common Name(s)[2]	Notes[3]
Rottboelia exaltata	corn grass	Ann. grass
Digitaria sanguinalis	crab grass	Ann. grass
Mimosa pudica	dead and wake, sensitive plant, shame bush, ti marie	Per. herb
Scleria reflexa	razor grass	Per. sedge
Cenchrus echinatus	bur grass	Ann. grass

[1] Botanical names follow Holm, Plucknelt; Pancho & Herberger (1977)

[2] The most widely used common names in the Commonwealth Caribbean

[3] Ann. = annual, Per. = perennial

* Source: CARDI (1980)

Five species are listed as "locally serious" (Table 3). Corn grass *(Rottboelia exaltata)* appears to be spreading in some Commonwealth Caribbean countries, particularly in sugar cane, citrus and bananas, but also in some food crops. Leaf sheath bases have long irritating hairs that break on contact causing irritation and infections. These hairs can penetrate clothing. Workers may refuse to hand-weed or reap crops infested with this weed. Fallowing appears to be an effective control measure if diligently carried out.

Crab grass *(Digitaria sanguinalis)* can behave as a perennial, rooting at the nodes and forming large mats. It is very variable in habit, and its low structure may cause it to be underrated as a serious weed. It is a common weed in sugar cane and many food crops.

Shame lady *(Mimosa pudica)* is one of the best known weeds among non-agriculturists. "Pudica" derives from the latin for "bashful" or "modest" and refers to the closing of the

leaves when touched. It can form large cushions in pastures and in many perennial crops, but also occurs in cultivated land. Being spiny it is not popular with workers when reaping or hand-weeding.

Razor grass *(Scleria reflexa)* and two other *Scleria* spp. form large clumps of vegetation in damp places, particularly in some of the Windward Islands. It occurs in perennial crops and on newly-cleared land. The leaves are sharp-edged and it is therefore difficult and unpleasant to control by macheting.

Bur grass *(Cenchrus echinatus)* has spiny burs containing several spikelets. The barbed spines penetrate skin causing irritation, and the burs are carried and distributed on clothing and animal fur. It is widely distributed but rarely dominant, except in local patches.

Many other weed species are problem weeds in limited areas, or are widely distributed but of secondary or minor importance. Adams, Kasasian & Seeyave (1970) list the commoner weeds of the Caribbean, with illustrations and notes on their habitats and distribution. Belize has a rather different weed flora from those of the Caribbean Islands, due both to its geographical location and to the type of agriculture practiced by many farmers in that country. Kellman & Adams (1970) have listed the weeds of milpa (i.e. slash-and-burn) fields in one area of Belize. Weeds are considered the primary reason for abandonment of milpa lands in Belize, but these weeds also constitute the initial phase of the fallow succession, which is essential to the continuation of the system. Guyana also has a distinctive weed flora, particularly in the extensively farmed areas, as a result of its geographic location.

Many weeds in the Caribbean have been introduced, and some are escapes from cultivation (e.g. *Sorghum halepense*, which was introduced to Jamaica as a pasture grass).

Aquatic weeds are only very locally important, but the water hyacinth *(Eichornia crassipes)* is present in many waterways in the region. An *Elodea* spp. has apparently become prominent in a section of the Layou River in Dominica.

5. CONTROL METHODS

These vary widely from "high technology" methods, involving use of herbicides and modern tillage and herbicide application equipment, to "low technology" systems with minimal use of herbicides and reliance on manual methods of control. This contrast occurs within a single crop. Sugar cane, for example, may be treated with two or three herbicides annually on the large estates, but may receive no herbicides at all with weeds controlled by hoeing or macheting in small farmer plantings. A few estates have ventured into vegetables in recent years, using herbicides and other high technology inputs, but small farmers growing vegetables rely on hand weeding and hand hoeing.

Macheting is widely used in land preparation and in tree crops to control weeds. Tree crops may be ring-weeded by machete or a herbicide, with the remaining area cut by machete relatively infrequently. In some instances farmers may merely top the taller weeds to allow easier access for reaping. Tractor-mounted brush cutters are also used in tree-crops, and in pastures, for weed control. Cattle may be used as a form of weed control, in coconut groves for example.

In short term crops, particularly vegetables, hand weeding and hand hoeing are widely used, either as the sole means of weed control or to supplement and reinforce herbicide treatments which have given only partial control of weeds, or failed to control certain species. Hand weeding is almost invariably needed in onions, even if DCPA and/or nitrogen have been used. A consequence of the need to hand weed or to hoe is that crop rows or plants are often wide apart so as to allow access for weed control. Plant populations are therefore low, which itself restricts potential yields.

Tractor-mounted hoes and inter-row cultivators are uncommon, except on sugar estates where some cultivation would be done in ratoons. Walking, or two-wheeled, tractors with inter-row hoes or cultivators are also not common, but interest in these is increasing. Animal-drawn implements are rare, but there is interest in the use of animal power in some countries. Wheeled push hoes are used by a few farmers.

Mulching, usually with grass, is practised for some crops, such as pineapples and escallion, particularly in dry areas. Flooding of fallow land, to control weeds and soil pests, is practised in Guyana on the sugar estates. The flooding of rice paddies will eliminate many weeds, but an adapted weed flora will develop. Intercropping can help to suppress weeds, but may render weed control difficult unless the intercrop is a fast-establishing competitive species.

Weed fallows, usually only of a few months duration, are not uncommon. The weed growth is often slashed and burnt before land preparation for planting. The weed fallow can be criticised on the grounds that it allows perennial weeds to spread and annuals to set seed. However, some vegetative cover may be desirable to minimise soil erosion.

Table 4 lists the herbicides used in the Commonwealth Caribbean. Availability varies widely: in some countries a considerable range of herbicides is available whereas in others only a few will be available. The list is alphabetic except for paraquat which is the most commonly used herbicide. It is used in land preparation, for inter-row shielded or directed spraying, for ring weeding, and along paths and irrigation canal and ditch banks and around buildings. It is a broad-spectrum weed killer, non-residual, rapid-acting and relatively rain-fast: rain within 30 minutes of spraying has no effect on its efficiency. It is very commonly used in bananas, and many thousands of gallons of Gramoxone are, or have been imported into the Windward Islands for banana rehabilitation following Hurricane Allen. It is probably the most useful herbicide for small farmers (Hammerton, 1974c). The concentrate is extremely toxic to man, however.

The major use of herbicides is in sugar cane, and much of the acreage in Barbados, Belize, Guyana, Jamaica and Trinidad is treated with ametryne, asulam, atrazine, 2,4-D, diuron and ioxynil. Citrus groves may also be treated with herbicides, usually a soil-acting residual possibly mixed with paraquat. Weed control in many groves of citrus and other tree crops relies either partially or wholly on macheting or brush-cutting, however.

The herbicides listed in Table 4, with major uses in vegetables (or in specific vegetables), are used in relatively small quantities by the larger and more specialised vegetable growers.

Both 2,4-D and 2,4,5-T can cause epinastic damage to broad-leaved crops as a result of drift, either of spray or vapour, from sugar estates where 2,4-D is commonly used. Vapour drift can be avoided by use of low volatile formulations, but these are more expensive than the volatile esters.

EPTC, and the related herbicides vernolate, butylate, molinate, etc., are useful pre-plant incorporated herbicides for nutgrass control. Glyphosate is also effective against nutgrass and many other perennial weeds but does need several hours of dry weather after spraying to be effective. Propanil is used only in rice, post-emergence, and naptalam is almost solely used in cucurbits.

With the escalation of herbicide prices over the past few years, the economics of herbicides in small farm systems is dubious, particularly in the context of limited cash for the purchase of inputs and the availability of family labour for weeding. The versality of paraquat and the absence of residues, make it the only herbicide used by most small farmers.

The knapsack sprayer is the commonest method of applying herbicides, even on sugar estates, but tractor-mounted boom sprayers are used. The holdings of many small farmers are often remote from a water supply, so that granular herbicides would be preferable being easier to transport than water and requiring no application equipment. Ultra low volume applicators are another alternative to knapsack sprayers. They do not require water, but are expensive for the small farmer. Nevertheless their use is likely to increase.

Many weeds are attacked by insects, nematodes and diseases, but the role of these in controlling weed populations is not clear. Ocassionally a particular weed species is seen to be heavily infested or infected, so that its competitive vigour and capacity for propagation by seed or vegetative propagules is reduced. There are no successful cases of the biological control of major weeds in the Commonwealth Caribbean. The Commonwealth Institute of Biological Control is headquartered in Trinidad and does work, *inter alia*, on the biological control of weeds.

Cultivation and fallowing can prevent weeds shedding seeds or propagating vegetatively. However, rotavation in particular may be an effective means of disseminating weeds. Paraquat and glyphosate can be used to control weeds after reaping and before land preparation for the next crop.

Table 4 A listing of Herbicides used in the Commonwealth Caribbean

Common Name[1]	Proprietary Name[2]	Major Uses
Paraquat	Gramoxone	General, inter-row, ring weeding, non-crop.
Alachlor	Lasso	Corn, peanuts.
Ametryne	Gesapax	Sugar cane, cotton.
Asulam	Asulox	Sugar cane.
Atrazine	Gesaprim	Corn, Sugar cane, Citrus.
Bromacil	Hyvar-X	Pineapples, citrus.
Chlorbromuron	Maloran	Bananas.
Cyanazine	Bladex	Corn.
2, 4-D	"Numerous"	Sugar cane, corn rice, pastures.
Dalapon	Dowpon	General: for grass weeds only.
DCPA	Dacthal	Vegetables.
Diphenamid	Dymid	Vegetables.
Diquat	Reglone	General: used as a desiccant.
Diuron	Karmex	Bananas, citrus.
DSMA	Ansar	General non-crop.
EPTC	Eptam	Especially for nutgrass.
Glyphosate	Round up	General, non-crop: especially perennial weeds.
Ioxynil	Actril	Sugar cane.
Linuron	Lorox	Corn, carrots, potatoes.
Methazole	Probe	Onions, citrus.
MSMA	Daconate	General non-crop.
Naptalam	Alanap	Cucurbits.
Nitrofen	Tok	Onions, crucifers, carrots.
Picloram	Tordon	Pastures, non-crop.
Prometryne	Gesagard	Carrots, cotton, pigeon pea.
Pronamide	Kerb	Vegetables.
Propachlor	Ramrod	Corn, pulses.
Propanil	Stam	Rice.
Simazine	Gesatop	Non-crop, tree crops.
2, 4, 5-T	"Numerous"	Brush and shrub control.
Trifluralin	Treflan	Pulses, vegetables.

1. Common names follow Weed Sciences Society of America (1979).

2. The name given is the most familiar in the Commonwealth Caribbean. "Numerous" indicates that a large number of proprietary names exist.

Poor hygience has led to the spread of many weeds in planting material or on implements. For example, rhizomes of Johnson grass *(Sorghum halepense)* have been distributed on the roots of citrus plants, and rhizomes, stolons and tubers of weeds are often spread on implements.

Weed control should not be thought of as additional to the normal sequence of operations required for crop production. Land preparation, refining, ridging, moulding-up, thinning and supplying are all operations which assist in weed control. Maximum use should be made of these operations to achieve control of weeds, and herbicides should be used in the system in such a way as to give adequate duration of weed control and to reduce weed problems in subsequent crops.

6. WEED CONTROL RESEARCH

Without attempting a bibliography of weed control in the Commonwealth Caribbean, nor a definitive history, some mention of sources is necessary.

Before 1960 weed control research in the region was concerned almost solely with the traditional export crops (e.g. sugar, citrus, etc.). The work was done by the companies (e.g. Tate & Lyle Ltd.) or by Regional or National Commodity Associations, or by Statutory Boards. Some work was done also in the departments of Agriculture of the then colonial territories, though there was no specialist staff. The Regional Research Centre (RRC) was set up in the 1950's at the Imperial College of Tropical Agriculture (ICTA) to undertake research mainly on food crops. This work included some on weed control. The results of the work carried out by the institutions mentioned above were usually published in Annual Reports and/or in the journal "Tropical Agriculture".

ICTA later became the Faculty of Agriculture of the University of the West Indies (UWI) and RRC became a part of the Faculty. In 1975 RRC became CARDI, an autonomous institute.

A Herbicide Research Unit (HRU) was set up within RRC with L. Kasasian as Herbicide Agronomist. Initially based in Trinidad, Kasasian moved to Jamaica in 1965 and J. Seeyave became Herbicide Agronomist in Trinidad. Work was done throughout the region on a wide range of crops in conjunction with Ministries or Departments of Agriculture and other RRC staff. The HRU was disbanded in 1969 leaving behind a strong base for future work. It had trained and influenced many agriculturists now working on weed control.

The work of HRU was reported regularly in PANS(C)* between 1963 and 1969. Several sets of herbicide recommendations were produced, the last being published in 1968 (Kasasian and Seeyave, 1968). This need revising. An illustrated guide to West Indian weeds was published in 1970 (Adams, Kasasian & Seeyave, 1970) in collaboration with Dr. C.D. Adams of UWI. Many other papers and articles came from HRU and most of these are listed in Kasasian (1971).

Weed research continued in RRC after the disbanding of HRU, albeit at a lower intensity, primarily in Jamaica during the period 1970-76. Several papers, reports and bulletins were published as a result of this work (Hammerton 1974, a, b, c, d, e) and annual reports were published in PANS. CARDI continues to work on weed control, primarily within cropping systems. At the same time, weed control research was undertaken by organisations such as Caroni Ltd. (Trinidad), WINBAN (St. Lucia), the Coconut Industry Board (Jamaica), and by many other commodity organisations in the region.

Weed control work in the Ministries and Departments of Agriculture of the countries of the Commonwealth Caribbean increased greatly in the late 1960's and early 1970's, stimulated by the work of the HRU. Specialist officers were appointed in Barbados, Guyana and Jamaica. Excellent work was, and continues to be done. All the Ministries or Departments now have at least one officer with some training in, and responsibility for, weed control research and extension. Results of such work appear in Annual Reports, Extension Leaflets and other publications.

In the UWI weed control research is underway in the Department of Crop Science and in the Department of Biology at the Cave Hill Campus, Barbados.

It is probably true that this considerable body of weed control research has had little impact on the majority of farmers in the Commonwealth Caribbean. This is not the place to pursue the reasons for this, but the development of appropriate technologies for weed control in small farm systems is one of the challenges of the 1980's for Caribbean agriculturists.

*PANS(C) was "Pest Articles and News Summaries Section C. Weed Control". This later became just "PANS" and, in 1980, was renamed "Tropical Pest Management".

7. CONCLUSION

The overall loss of potential food due to weeds in the Caribbean is estimated at about 20%. A considerable amount of the farmers' total effort is spent on weed control, and a great deal of attention has been, and is being devoted by research institutions to developing control methods that are both less laborious and more effective than hard cultivation. Individual weeds have been studied in detail, so that their ecological and behavioural patterns are understood; herbicides are being carefully tested and suitable recommendations developed: a large number of herbicides is now available and substantial quantities are used, particularly on the major export crops. Biological control of weeds has not yet been successfully developed in the Caribbean, though work to this end is proceeding. It is emphasised, however, that herbicides are not the only, nor necessarily the major, tool in weed control; maximum use should be made of the several normal crop production operations – land preparation, refining, ridging, moulding up, thinning, supplying, mulching, which all assist in weed control, while herbicides should be used in such a way as to assist in giving adequate duration of weed control and to reduce weed problems in subsequent crops.

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9. PROBLEMS WITH EXTERNAL PARASITES OF LIVESTOCK IN THE CARIBBEAN

R.O. DRUMMOND

CONTENTS

		Page
1.	INTRODUCTION	98
2.	LIVESTOCK	98
3.	EXTERNAL PESTS	99
4.	PESTICIDE USE	100
5.	CONCLUSION	102

1. INTRODUCTION

It is appropriate that the scope of this workshop/seminar include pests of livestock as well as pests of plants. Just as the productivity of plants is affected by pests, so is the productivity of man's domesticated animals. The need for animal protein in the form of meat, milk, or eggs in the human diet has been well documented (Scrimshaw and Young 1976). Man's basic source of animal protein is his domesticated livestock – cattle, sheep, goats, swine, and poultry. Ruminant livestock, primarily cattle, sheep, and goats, can convert plants, plant products, plant and animal wastes, and other sources of cellulose into animal protein for human consumption. Because these animals can graze on marginal lands that can support grass and other plants, but are not used for cultivation, ruminant livestock need not compete directly with man for the natural resources of the earth. In fact, the use of grazing animals allows for the greater productivity of the land (Moore et al. 1967). In addition, in some countries domestic animals provide the mechanical power with which man cultivates the land to grow essential crops.

In order to examine the production of animal proteins from domesticated livestock, it is necessary to eliminate or reduce the effect of any factor that limits this production. The 3 factors that are needed for efficient animal production are (1) adequate food, including grass, water, minerals, and other elements of the environment, (2) a suitable breed of animals, and (3) sufficient management. The management factor includes a variety of animal husbandry practices such as pasture rotation, supplemental feeding (if needed), careful breeding, and attention to animal health. Animal health includes prevention of diseases and pests that can be and are important limiting factors in many areas of the world, including the Caribbean (Snelson 1975, Drummond et al. 1978). Oftentimes, there are plentiful, highly nutritious grasses and a favorable environment that are supportive of animal production, and there are superior, potentially highly productive breeds of livestock available, but animal production is severely curtailed or eliminated because of an animal health problem. An example is the loss of 7 million square kilometers of grazing land in central Africa due to the presence of tsetse flies and trypanosomiasis (Omerund 1976). A variety of diseases, internal parasites (such as parasitic helminths), and external parasites affect livestock production in the Caribbean. There is a considerable amount of information on the subject of diseases and internal parasites of domesticated livestock. But, because of limitations on space and on scope of knowledge and experience of the author, this paper will focus on the livestock, the kinds of external parasites of livestock, and the control of these parasites.

2. LIVESTOCK

In order to develop an understanding of the magnitude of the influence of livestock on the economy of the Caribbean, it is helpful to look at the numbers of livestock found in the area. Although actual livestock surveys have not been conducted in many countries, there are estimates of the numbers of livestock available (Table 1).

Table 1 Numbers of livestock (1000) in countries in the Caribbean (1974).[a/]

Country or group	Number				
	Cattle	Sheep	Goats	Swine	Poultry
CARICOM	700	220	190	510	19,900
Cuba	7,400	320	90	1,450	15,700
Puerto Rico	500	5	20	230	4,600
Others	2,700	200	1,730	2,570	14,200
Total	11,300	745	2,030	4,760	54,400

a/ Data taken from United Nations (1976).

These data show that there are large numbers of livestock in the Caribbean. Nevertheless, most countries have to import animals or animal products in order to meet local needs, and the need for increased livestock production has been recognized in most countries (Anon. 1980). Further investigation shows that the numbers of animals in the area can change from year to year; the trend can be down or up. Also, most livestock are raised by farmers who have only a few animals in a limited land area — a situation in which there is little input of money and time into management of the animals. Under these conditions, it is possible for diseases and pests to lower the production efficiency of the livestock.

3. EXTERNAL PESTS

External parasites affect the health and productivity of livestock in several ways. Ectoparasites transmit a variety of agents that cause diseases of livestock (Bram 1975). Of special importance to the Caribbean are babesiosis and anaplasmosis, which are diseases of cattle caused by protozoans transmitted by ticks. Often, native cattle are tolerant of these diseases, but cattle imported to improve the production of meat and milk are often highly susceptible to these diseases. If imported cattle do not die, they usually require extensive health care and may never realize their productive capability. Typical of the problem is that reported by Williams and Gonzales (1968) in which dairy cattle imported into Trinidad from Canada became infected with *Babesia* spp. and *Anaplasma marginale* as a result of placing the cattle on tick-infested pastures. Even after antibiotic therapy, the cattle suffered hemolytic crises for months. Animal disease organisms and their arthropod vectors are critical factors in the planning of the expansion of livestock production in the Caribbean (Smith 1974). It is important also to have sufficient surveillance and adequate quarantine facilities in order to prevent the introduction of exotic animal diseases and parasites into Caribbean countries (Anon. 1978).

Of special interest at this time is the presence of African swine fever (ASF) in the Dominican Republic. Depopulation of swine, the only known means of eradication of ASF, is almost complete, and new swine have been introduced onto the eastern portion of the island. Plans are now being discussed for eradication of ASF from Haiti. Cuba has reported eradication and is in the surveillance stage of operation. Soft ticks of the genus *Ornithodoros* are reservoirs and vectors of the virus of ASF.

External parasites also cause physical damage to their hosts. Massive infestations can cause loss of blood, injury to the hide, irritation, decreased feed intake, and decreased productivity. In addition, animals may become infected with bacteria, fungi, and other pathogens, and infestations with some parasites may lead to the death of the animal. An example of the last category is the invasion of living flesh by larvae of the screwworm fly, *Cochliomyia hominivorax* Coquerel. Wounds created by these larvae become so infested with larvae of the screwworm

fly and other myiasis-producing flies and with other pathogens that, if not treated, the infested animal may die.

Although external parasites are of importance to the efficiency of production of livestock in the Caribbean, the literature contains little information on their presence and less information on their prevalence or importance in specific countries of the area. Most papers do little more than list the species of ectoparasites found on livestock, although some (Drummond et. al. 1980, Smith 1974) attempt to determine more than presence of specific pests. More in-depth studies on the presence, distribution, and importance of ectoparasites are needed for all of the countries in the Caribbean. A summary listing of the lice and ticks of domestic animals reported in the literature for the Caribbean is presented in Table 2. Of special concern is the presence of *Amblyomma variegatum* F. in several countries. This large tick species causes considerable irritation to animals and is associated with the spread of a fatal dermatitis called streptothricosis caused by *Dermatophilus congolensis*. Also, *Boophilus microplus* Canestrini, the known vector of babesiosis and anaplasmosis, can also occur on livestock in numbers large enough to cause physical damage. The table also lists ectoparasites of horses for, although horses are not considered food-producing livestock, they are found in some numbers in all of the countries of the Caribbean and often occupy a significant socioeconomic role. *Anocentor nitens* Neumann, the tropical horse tick, is an important vector of the agent that causes babesiosis of horses. In addition to the lice and ticks in Table 2, there are other parasites such as *Oestrus ovais* L., the sheep bot fly, in sheep (Williams 1978), *C. hominivorax* and other myiasis-producing flies in livestock (Murray and Thompson 1976), and *Gasterophilus nasalis* L., the throat bot fly, in horses (Van Volkenberg 1938). Also undoubtedly most of the countries in the Caribbean have livestock or livestock facilities infested with *Haematobia irritans* L., the horn fly, *Stomoxys calcitrans* L., the stable fly, and *Musca domestica* L., the house fly.

The presence of these injury-causing, disease-transmitting arthropods is of concern to the owners of livestock in the Caribbean. The General response of owners has been to treat their animals with pesticides in order to lower populations of these external parasites below levels that create stresses and production problems in their livestock.

4. PESTICIDE USE

As with the information on arthropods affecting livestock, there is little published information available on the use of pesticides on livestock in the Caribbean. Many of the pesticides used on livestock throughout the world have been or are being used in the Caribbean; pesticides used to control ticks on cattle in Jamaica and Barbados are listed in Table 3. On Barbados, most of the cattle are lactating dairy cows, but none of these acaricides listed in Table 3 is suggested for application to lactating dairy cattle in the United States (USDA 1980). The use of pesticides on animals calls for special formulations that are specifically designed for use on livestock. Most formulations of pesticides are designed for use on plants and therefore may not be suitable for use on livestock. These formulations may contain the same active ingredient, but the solvents, diluents, and other ingredients are selected for use on plants and not animals. Also, special care must be exercised when applying pesticides to livestock so as to prevent the creation of harmful (or illegal) residues in meat and milk, the poisoning of animals and humans, and destruction or contamination of the environment (Bram 1978, Drummond 1976). In each Caribbean country there need to be special regulations regarding the sale and use of pesticides on livestock and special education of livestock owners on the use of these pesticides. Methods of application of pesticides to livestock range from hand dusting and hand-powered sprayers to power-driven sprayers, spray races, and dipping vats. Treatment frequencies range from "almost never" or "as needed" (when a problem is recognized by the owner) to a weekly or biweekly schedule.

Although some of the pesticides in Table 3 and others that are no longer in use have been used for a number of years in the Caribbean, there is little information on the incidence of resistance of livestock ectoparasites to pesticides. Recently, strains of *B. microplus* in Jamaica were found resistant to lindane (1, 2, 3, 4, 5, 6-hexachlorocyclohexane, *gamma* isomer of not less than 99% purity), and strains from several other countries had low levels of resistance to lindane and certain organophosphates (Rawlins and Mansingh 1977, 1978).

The Caribbean has been the site of the use of an integrated pest management technique to eradicate an arthropod pest of livestock, pets, and humans. In 1954, screwworms were eradicated from Curacao by use of the sterile insect technique (Baumhover et al. 1955). The island

became reinfested in 1975 (Snow et al. 1978). Through the use of a bait-toxicant system (Screwworm Adult Suppression System – SWASS) to reduce the population of native flies and the subsequent release of sterile males, the island was again freed of screwworms in 1977 (Coppedge et al. 1978). Also, screwworms were eradicated from Puerto Rico and the Virgin Islands (Williams et al. 1977). Eradication depends upon integration of treatment of wounds to kill larvae, use of SWASS to reduce native populations of flies, and the distribution of sterile male flies.

Table 2 Ticks and lice of livestock in the Caribbean.[a/]

Livestock host	Ectoparasite species
Cattle	*Amblyomma cajennense* F., *A. variegatum* F. *Boophilus microplus* Canestrini, *Haematopinus tuberculatus* Burmeister
Sheep and goats	*Amblyomma cajennense*, *A. variegatum*, *Boophilus microplus*, *Damalinia caprae* Gurlt, *D. ovis* Schrank, *Linognathus africanus* Kellogg & Paine
Swine	*Haematopinus suis* L.
Horses	*Amblyomma cajennense*, *A. variegatum*, *Anocentor nitens* Neumann, *Boophilus microplus*
Poultry	*Argas persicus* Oken, *Menopon gallinae* L., *Menacanthus stramineus* Nitzsch, *Lipeurus caponis* L., *Goniodes meleagridis* Nitzsch, *G. dissimilis* Denny, *Goniocotes hologaster* Nitzsch

a/ References: Van Volkenberg 1938; Clarkson and Owen 1959; Morel 1966; Anon. 1914; Thompson 1950.

Table 3 Acaricides used in Jamaica and Barbados to control ticks on cattle.[a/]

Acaricide	Jamaica	Barbados
Carbaryl (1-naphthyl methylcarbamate)		X
Chlorfenvinphos (2-chloro-1-(2,4-dichlorophenyl) vinyl diethyl phosphate)	X	X
Coumaphos (0-(3-chloro-4-methyl-2-oxo-2H-1-benzopyran-7-yl) 0, 0-diethyl phosphorothioate)	X	X
Diazinon (0, 0-diethyl 0-(2-isopropyl -4-methyl-6 pyrimidinyl) phosphorothioate)		X
Dioxathion (2,3-p-dioxanedithiol S,S-bis (0, 0-diethyl phosphorodithioate)	X	X
Lindane (1, 2, 3, 4, 5, 6-hexachlorocyclohexane, *gamma* isomer of not less than 99% purity)	X	
Malathion (0, 0-dimethyl phosphorodithioate of diethyl mercaptosuccinate)		X

a/ Data on Jamaica from Rawlins and Mansingh 1977 and on Barbados from Drummond et al. 1980.

5. CONCLUSION

From this brief presentation it can be seen that, although more study must be conducted on the magnitude of the problem, livestock in the Caribbean are hosts to a limited number of external parasites that transmit disease agents and are found in such high populations that they decrease the efficiency of production of essential animal protein for human consumption. Generally, small numbers of animals are owned by farmers who graze them on very limited pastures. Although the kinds of external parasites of livestock are limited, those found there, especially the ticks, transmit etiologic agents that cause diseases of livestock and cause injury and stress to the animals. In order to control these external parasites, livestock owners treat their animals with pesticides. The use of pesticides on livestock is very special in that only specific formulations should be used on specific animals. Particular problems are (1) the need for more information on the kinds and numbers of ectoparasites on livestock, (2) the prevention of the introduction of new diseases and pests, and (3) the regulation of the sale and use of pesticides on livestock. Lack of regulations and knowledge on pesticide use on livestock could lead to poisoned animals, harmful pesticide residues in meat and milk, and contamination of the environment.

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10. THE INTEGRATED PEST MANAGEMENT APPROACH

RAY F.D. SMITH

CONTENTS

1. INTRODUCTION 105

2. PRINCIPLES FOR APPLICATION OF IPM 106

(i) Indentification of Pests 106
(ii) Defining the Management Unit 106
(iii) Developing the Pest Management Strategy 106
(iv) Establishing Economic Injury Thresholds 107
(v) Development of Reliable Monitoring and Predictive Techniques 108
(vi) Evolving Descriptive and Predictive Models 108
(vii) Overcoming Socio-economic Barriers 108

3. CONCLUSION 109

1. INTRODUCTION

Integrated pest management is a broad ecological approach to pest control utilizing a variety of control technologies compatibly in a single pest management system. Some in this audience may have heard of "integrated pest management" under the name "integrated pest control." These two terms as used today are exactly synonymous. Whichever term we choose to use, the goal of integrated pest management is to manage the pest populations in such a manner that crops can be produced economically and in an ecologically sound way. It should be an integral part of the crop production process.

In integrated pest management, stress is placed on the importance of realistic economic injury levels which are used to determine the need for control actions. At the same time, all possible is done to protect and preserve naturally occurring biotic mortality agents such as parasites, predators and pathogens. When artificial controls are needed, for example, chemical pesticide applications, they are employed in as selective a manner as possible and only when their use is economically and ecologically justified. The ultimate objective of the integrated pest management system is to produce the optimum crop yield of high quality at minimum cost, taking into consideration the ecological and sociological constraints in that particular agro-ecosystem and the longterm preservation of the environment. This is the ideal of integrated pest management for which we should strive.

Integrated pest management (IPM) is of special importance to the countries in the less developed parts of the world for a number of reasons. (1) IPM has the potential to reduce heavy dependence on chemical pesticides and their high costs. (2) Agroecosystems of the tropical and subtropical parts of the world have been less disrupted by earlier uses of pesticides and these environments have greater potentials for utilization of natural enemies and other biological controls. (3) In many instances, the production patterns still have a strong traditional character, and these constitute a more favorable situation for the integrated approach than do highly intensified production systems. (4) The farmers are very closely involved with their crop development and spend much more time in their fields than large-scale farmers. They are therefore in a better position to provide information on pest incidence, and, with a certain amount of training, they can directly participate in the pest surveillance system. (5) In addition, there is the further incentive to reduce the severe ravages of pests in the subtropics and tropics. For example, a study by IRRI last year showed that next to water, pests and diseases have become the major constraint to rice production.

We at CICP and our colleagues in FAO and other international organisations, consider IPM capable of providing more permanent control and thus will lead to permanent improvements in crop well-being and it has the additional advantage of being environmentally safer. In its

broadest form, integrated pest management considers all the key pests in an agroecosystem; namely, insects, pathogens, weeds, and nematodes. In its most restricted form, integrated control may apply to a single major pest. Of major importance, however, is the application of the philosophy and ecological principles inherent in the concept.

2. PRINCIPLES FOR APPLICATION OF IPM

Over the years a number of principles have gradually emerged for the application of the integrated pest management philosophy. They are described in outline form below in a logical sequence of their application in developing an integrated pest management system. However, it must be remembered that these principles are closely interrelated and must be applied in the context of the pertinent agroecosystem.

(i) Identify the pests (diseases, insects, weeds, etc.) to be managed in the crop production system or agroecosystem.

A. An organism should not be called a pest until it is proven to be a pest. A particular organism may be a pest in some situations or areas and not in others or at certain times and not in others.

B. Identification of pest status should be coupled with the establishment of economic injury thresholds (see below).

C. Pests interact with one another and this interaction may compound or offset their effects on the crop plant. We should not assume their effects are additive.

D. **Categories of pest status.**

1. **Key Pests** are serious, perennially occurring, persistent species that require control measures to be taken regularly because in the absence of control they frequently occur at above economic injury thresholds. Usually there are only a few key pests (sometimes only one or two) in any agroecosystem. The key pests are the focal point of the pest management systems.

2. **Occasional or secondary pests** are relatively minor pests that rise to economically damaging levels only at certain times or in certain places. These occasional pests are especially susceptible to an integrated pest management approach aimed at preventing these occasional outbreaks. Prediction technology is especially useful for these "part-time" pests.

3. **Potential pests** cause no significant damage under the conditions currently prevailing in the agroecosystems. In attempts to manage key pests or occasional pests, care must be taken not to alter the conditions of the agroecosystem so that then potential pests erupt as severe pests.

4. **Migrant pests** are non-residents of the agroecosystems that enter periodically and which may cause severe economic damage, e.g. migratory locusts and armyworms. The ecological approach to the control of such pests is still valid but must be applied in the perspective of a very large geographic area.

5. Many other phytophagous forms may be present in the agroecosystem but are considered to be non-pests.

(ii) Define the management unit, i.e. the agroecosystem.

The limits of the agroecosystem are determined principally by the characteristics of the local cropping system and the characteristics of the pests (particularly their patterns of movements or vagility). The limits may circumscribe, for example, a tree, or an orchard, or a valley, or other large ecological unit.

(iii) Develop the pest management strategy.

A. The fundamental strategy of pest management is the coordinated use of multiple tactics in a single integrated system with the goal to hold pest numbers and damage to tolerable levels. It is a containment strategy rather than an eradication strategy.

B. The four fundamental tactics of integrated pest management are:

1. Utilization of indigenous natural control.
2. Management through cultural practices.
3. Use of inherent plant resistance and tolerance.
4. Selective use of chemical pesticides.

How these tactics are utilized will depend on the specific agroecosystem and the nature of its key pests.

C. Any pest control procedure must only be applied when economically and ecologically justified.

D. How does agroecosystem diversity relate to pest management strategy? It depends on the kind, or quality of diversity. This aspect of diversity must be understood in developing agroecosystem management strategy.

E. The pest management strategy for a particular agroecosystem can aim at:

1. Reducing level of original pest infestation or inoculum in the agroecosystem.

2. Modifying the rate at which the pest increases in the agroecosystem.

3. Reducing the influx of pest invaders into the agroecosystem.

4. Some combination of the above three. The exact combination will depend on the characteristics of the pest and the agroecosystem.

(iv) Establish economic injury thresholds.

A. The economic injury threshold is that pest population level or level of pest intensity that produces an incremental reduction in crop value greater than the cost of implementing a pest management action. (The level of pest intensity may be measured by various indices of presence, e.g. amount of potential inoculum present, as well as number of pest individuals per unit area.)

B. Often the economic injury thresholds are varied according to either phenological time or physiological state of the crop plants.

C. To establish an economic injury threshold something must be known of the following:

1. Methods of measuring plant response to pest injury or impact.

2. Methods of measuring directly or indirectly the pest abundance or intensity, i.e. sampling.

3. The crop loss from the anticipated level of pest intensity in terms of quantity and quality of the crop and its economic value.

4. A cost/benefit analysis of the proposed pest management action.

D. The establishment of an economic injury threshold is the most difficult research area facing the integrated pest management research worker.

E. Economic treatment threshold is a level at which action must be taken to prevent economic damage. It is a somewhat lower level of pest intensity than the economic injury level. At the economic treatment threshold, if a decision to take a pest management action is made, time is still sufficient, before the economic injury threshold will be reached, to permit the control actions to be carried out and for them to have their anticipated impact on the pest.

To establish an economic treatment threshold requires some knowledge of: (1) future patterns of pest intensity, (2) factors influencing the economic injury threshold, and (3) pest damage potential in the specific crop situation.

F. Not all pest control actions are based on direct response to levels of pest intensity. For example, preventive or prophylactic actions may be taken far in advance of the presence of the pest. They are aimed at (a) lowering the mean level of the pest, (b) altering the pest population distributions, or (c) altering the basic structure of the crop management system.

But many other actions must be taken during the course of the growing season in response to seasonal developments of crop pests or to the presence or absence of key elements in the management system, or changes in levels of pests. The in-season response is usually a temporary, suppressive action, e.g. a cultural practice or application of a pesticide.

G. In some situations, it may be possible to raise the economic injury threshold through appropriate manipulations of the components of the agroecosystem. This may be just as effective in changing the status of a pest as by reducing its mean population level.

H. The goal of an integrated pest managment system is to manage and manipulate the agroecosystem so that the incidence of the pests always remain below the economic injury threshold.

(v) Develop reliable monitoring and predictive techniques.

A. Develop a sufficient understanding of the crop production system and associated agroecosystem to forecast potential problems with both short- and long-term predictions so that it is possible to undertake the necessary measures to prevent these events from occurring.

B. The development of a sound predictive technique may be based on one or a combination of the following:

1. An understanding of the crop phenology and related pest correlatives.

2. An understanding of pest phenology.

3. Monitoring of pest incidence.

4. Monitoring of weather conditions.

(vi) Evolve descriptive and predictive models.

A. This is the ultimate goal in the more sophisticated pest management systems but is not an absolute requirement for the development of integrated pest management. Nevertheless, a sound understanding of the agroecosystem is always required for integrated pest management.

B. The usual steps in the systems analysis approach may be described as follows:

1. Qualitative analysis of the stucture and behavior of the agroecosystem. This usually results in a flow diagram with the several components identified together with their interactions.

2. Formulation of a mathematical model for the agroecosystem. This puts the flow diagram into mathematical terms.

3. Assessment of the adequacy of the model. The predictive capability is tested against the facts from the real agroecosystem. Gaps in information concerning the agroecosystem may be thus identified in this process.

4. Mathematical assessment and analysis of the behavior of the agroecosystem together with refinement of the mathematical model.

5. Optimization of the agroecosystem management decisions. The model is utilized as a tool in reaching a decision in the best procedure of obtaining the desired benefit at the lowest cost.

(vii) Overcoming the socio-economic barriers to the establishment of integrated pest management systems.

A. Overcome social, economic and political activities interfering with the development and establishment of integrated pest management.

B. Demonstrate that food crop production is everyone's business. Demonstrate that integrated pest control is a practical and sensible approach to dealing with pest problems.

C. Create a real awareness of the necessity for conserving the environment and resources of the biosphere. Plan a national utilization of the environment. Provide an environmental ethic.

D. Establish and maintain adequate communication systems.

E. Education is the key to this process.

3. CONCLUSION

Integrated pest management offers excellent possibilities for effective and permanent pest control at minimum cost. The technical aspects do not have to be a major obstacle to the introduction of this approach in developing countries. Certain conditions in the subtropics and tropics even favor integrated pest management more than in developed countries. It has the great advantage of making optimal use of natural resources and therefore fits well into the efforts to reduce reliance on external energy inputs. The gradual expansion of integrated pest management in developing countries should be carried out within the proper framework to ensure that proposed solutions really fit the needs and absorption capabilities of these countries.

11. SOME RECENTLY INTRODUCED PLANT PESTS OF IMPORTANCE

A.L. BROWN

CONTENTS

	Page
1. INTRODUCTION	110
2. SUGAR CANE	110
3. AVOCADO	111
4. COFFEE	111
5. MANGO	111
6. BANANA AND PLANTAIN	111
7. COCONUT	111
8. CASSAVA	112
9. LEGUMES	112
10. PLANT QUARANTINE	112
11. CONCLUSION	113

1. INTRODUCTION

During the past few years several economically important plant pests (and I use the term in the broad sense to include fungi, nematodes, etc.), have been introduced into the Caribbean. Some of these introductions were unavoidable, others were not. It would be an impossible task to keep out all foreign disease producing agents, especially those incited by air borne organisms. We shall see later, however, effective plant guarantine operation can still be of much benefit in early detection of harmful pests before they have a chance to become firmly established.

Considered first will be recent introductions into the Region followed by some serious pests already present in limited areas that have extended their geographic range and then concluding with some of those that pose an immediate threat. The latter pests are only a few of many on a worldwide basis, and in this paper will be restricted to those in continguous areas or those that may be introduced from outside the region on planting material presently being imported.

2. SUGAR CANE

Smut *(Ustilago scitaminea)* was first reported in the Caribbean about 1975. It has now spread to almost all Caribbean, Central and northern South American countries. In the Caribbean, variety HJ-5741 proved to be highly susceptible and was present in extensive holdings. Variety B-49119 also proved to be susceptible and was still being grown in certain areas although this same variety was attacked by the leafscald organism *(Xanthomonas albilineans)* in the late 1960's in certain Caribbean territories.

Rust *(Puccinia melanocephala)*, was first reported in July 1978 in the Dominican Republic but from the quick succession of reports from neighbouring islands an almost simultaneous infection of Cuba, Jamaica, Haiti and Puerto Rico must have occurred. It is possible that the entire region was infected at the same time although it was several months later that it was first found in Barbados.

I am pleased to report, however, that the situation is now looking better. During visits to the sugar producing islands the various sugar producers associations were called upon and all report

by the end of 1981 almost all susceptible varieties will have been replaced. This has been a tremendous task as in the case of one of the larger producers, almost 70% of the cane was variety B-4362. The rapid varietal replacement would not have been possible without the great service rendered the islands by the West Indies Sugar Cane Breeding Station and the Varietal Testing Station located in Barbados.

3. AVOCADO

Interception records of the Animal and Plant Health Inspection Service of the USDA indicate that the avocado seed moth *(Stenoma catenifer)* is probably present in the Caribbean. It must be kept in mind that using interception records injudiciously can often result in error. However, many interceptions of the same pest from the same place for an extended period of time is a good indication that the pest is present even though it hasn't been reported or acknowledged by that country. The avocado seed moth is a serious pest of the fruit, burrowing into the fruit and feeding on the flesh and the seed. There are no treatments, such as fumigation, effective against the insect in the fruit although irradiation treatments may prove successful in the future..

4. COFFEE

The coffee berry borer *(Hypothenemus hampei)* has been in Guatemala and Honduras and recently has been found in Jamaica and Mexico. The insect reproduces rapidly and all feeding stages are found in the berries, often in large numbers, and produces an unsaleable product. The viable coffee industries of Haiti and the Dominican Republic are severely threatened.

5. MANGO

Based again upon APHIS interception records up to the present time, there is a possibility that the mango seed weevil is also present in the Caribbean. This insect has not been reported in the western hemisphere and is a serious pest of mangoes where present. Again, treatment of the fruit to kill the insect is difficult.

6. BANANA AND PLANTAIN

Moko disease, caused by a strain of *Pseudomonas solanacearum*, has long been present in Trinidad, northern South American and Central America. Recently it has been found in the northern banana growing area of Grenada, the southern peninsula of Haiti close to Port-au-Prince and in a small area on Andros Island in the Bahamas. The infection in Andros was limited to one plot which was removed. In Haiti, they hope to supply the sugar cane workers on whose plots infections were present, with resistant varieties. The Grenada Government has received some assistance from FAO eradicate or control the infection there.

Black Sigatoka, caused by *Mycosphaerella fijiensis* var. *difformis*, although not yet present in the Caribbean, is now reported in Belize, Costa Rica, Guatemala and Honduras. The disease is more difficult to control than the common sigatoka and poses a real threat to the banana industries of the Caribbean.

Also of regional interest are reports of varieties, formerly considered as resistant, now succumbing to Panama disease. At present, these reports have been restricted to the Greater Antilles and should be more critically investigated before any conclusions are drawn.

7. COCONUT

Lethal yellowing has recently been reported to have crossed the Gulf of Mexico and is now present in Texas on date and ornamental palms. It has not been reported in the Region east of

the Dominican Republic. Latest studies indicate that the vector responsible for transmitting the mycoplasma has been identified.

Phytomonas disease of coconut and oil palm will be studied in detail in Suriname by the Government with the assistance of U.S. universities. The disease, reported as Heart Rot in Suriname and Cedros Wilt in Trinidad, is capable of rapidly killing mature palms, but as yet little is known of how it is transmitted.

Red ring disease, incited by the nematodes *Rhadinaphelenghus cocophilus*, has long been a serious pest in the lower Caribbean and Central America. No recent reports of the extension of its geographical range are recorded and the most northern extension of its range in the Lesser Antilles is St. Vincent. It should be noted however, that *Rhyncophorus palmarum*, the palm weevil that can carry the nematodes from tree to tree, is present on several islands where the disease is not present.

8. CASSAVA

Two very serious diseases of cassava, bacterial blight caused by *Xanthomonas manihotis* and cassava mosaic disease, while not known to be present in the region, are a direct threat to us. The international exchange of cassava planting material is vast and all such material should be at least grown in isolation until it can be determined that they appear disease-free.

9. LEGUMES

There will probably be a great increase in food legume production in the Caribbean and the indiscriminate importation of legume seed should be avoided. Importations should be screened, if possible, or at the very least, grown in strict isolation because there are many bacterial and virus diseases of legumes that are seed-borne. Post-entry plant quarantine facilities are the ideal as far as being able to assure the release of pathogen-free seed and other planting material but they are expensive to construct, equip, staff and maintain; and few developing countries can afford to finance one on their own. Regional Stations could very well serve the same purpose but here too, financing or alloting shares to the countries involved can be an insurmountable problem.

10. PLANT QUARANTINE

The constraints to effective plant quarantine service in the Caribbean are many but only a few will be discussed here:

1. Lack of adequate legislation – very few Caribbean countries have legislation that authorizes the plant quarantine inspector to do the tasks necessary for good plant quarantine enforcement. For example, at the present time inspectors are not authorized to board arriving carriers and they have no knowledge of what fruits, vegetables or other plant materials are present in ships' stores, dining halls, kitchens, quarters or other areas. Serious pests such as Khapra beetle may be present in the holds and landed with non-plant cargo as well as possibly escape from infested dry stores. There is a real need for enactment of adequate, up-to-date legislation throughout the region.

2. Failure to recognize the importance of plant quarantine – preventing the entry of foreign pests or at least, delaying their entry, cannot be over-emphasized as it is an essential building block of a successful agricultural system. The lack of support given plant quarantine is readily apparent in the lack of personnel and facilities in the Region.

3. Lack of trained inspectors – there are many inspectors in the region that have little knowledge of what they are supposed to be doing. They don't know what to look for – or even how to look. This is readily evident in the quality of interceptions made. Most interceptions at present are of common cosmopolitan storage pests. There is also lack of continuing pest surveys by inspectors, especially in areas immediately surrounding ports of entry. Many lack

knowledge of local pests present and hence would not recognize an introduced pest. If an introduced pest is discovered early enough it would be a relatively easy job to eradicate it before it becomes firmly established and covers a large area. Without continuing pest surveys, it cannot be accomplished.

4. Lack of public information programmes – from time to time in the past some countries have prepared a brochure for distribution or prepared a chart or display at the international airport but there has been no continuing efforts in this direction. Regulatory agencies usually meet with rejection from the public and the only way plant quarantine services can be effective is to show the public why and how their services are necessary to the country.

11. CONCLUSION

An alarmingly large number of both fungal and insect pests, some potentially very serious, has appeared in the Caribbean in recent years. Some have presumably arrived by natural causes, but others have undoubtedly entered as a result of inadequate or inefficient quarantine services. Ignorance by the public has also played a part. Constant monitoring of the pest situation, quick action to combat the condition, proper training of inspectors and public alike, and strengthening of the quarantine services in the several territories, must all be on-going procedures in the fight against serious outbreaks of introduced diseases and pests.

III
BACKGROUND ON PESTICIDES

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12. IMPLICATIONS OF THE DEVELOPMENT OF RESISTANCE TO PESTICIDES: BASIC PRINCIPLES AND CONSIDERATION OF COUNTERMEASURES

G.P. GEORGHIOU

CONTENTS

		Page
1.	INTRODUCTION	116
2.	STATUS OF RESISTANCE	116
3.	RESISTANCE MANAGEMENT	122
4.	CONCLUSION	128

1. INTRODUCTION

During the past few years, two important developments have rekindled interest in research on countermeasures for resistance and have raised hopes that some practical breakthroughs might be forthcoming: These developments are:

(1) the discovery of new insecticides with new modes of action, and

(2) the conceptualization of "integrated pest management" (IPM) and its broad acceptance among applied entomologists.

Among the new insecticides that have been discovered are the juevnile hormone mimics, the chitin synthesis inhibitors, a number of derivatized organophosphates and carbamates, several synthetic pyrethroids, and certain new strains of bacterial toxins. These discoveries are very significant in that they provide us with some diversification in available chemicals, and enable us to avoid an overreliance on one specific compound. However, these new chemicals in themselves do not offer solutions, since none has been shown to be immune to the development of resistance or to reverse already existing resistance. Since additional new chemicals may not be forthcoming for some time, there is great interest both in agriculture and in public health to safeguard these available chemicals against the development of resistance.

The second development, integrated pest management, is also significant since in advocating the integration of chemical with non-chemical control, it contributes to a reduction in chemical selection pressure and thus to a delay in the evolution of resistance. IPM may in fact be the most important enemy of resistance, and vice versa. It is becoming increasingly evident that for an IPM program to remain viable, it must ensure that resistance does not evolve: an imposed change to a different insecticide is usually so disruptive to the biological control component of IPM that an entirely new control program must then be formulated. As we know, such programs require prolonged and costly experimentation.

Thus, interest in research on resistance has increased substantially in recent years, but with a sensibly different orientation: whereas in the past the challenge of continued effective pest control rested almost solely with the synthetic chemist, now it is shared at least equally by the pest management specialist who must ensure that resistance itself does not evolve or that it is sensibly delayed.

The question that is now being asked therefore is: What knowledge and what technological innovations are still needed to enable the effective use of new chemicals without exposing them to the risk of resistance?

2. STATUS OF RESISTANCE

Before I proceed with the status of research on countermeasures, I believe it is essential that I highlight some relevant aspects of resistance. As we all know, resistance is not limited to insects.

It occurs in such relatively simple forms as bacteria and sporozoa, as well as in such advanced forms as mammals and plants. It affects a variety of toxicants, including antibiotics, antimalarials, coccidiostats, insecticides, rodenticides, etc. It is also evident, however, that while the capacity to develop resistance to chemicals is universal, it is those compounds that are employed as insecticides that have exceeded their targets and have selected for resistance in practically every type of organism, from bacteria to mammals. Since resistance cannot be induced by any other means except by lethal action, this undoubtedly implies a special responsibility for the pest control professional.

With regard to forms that we more commonly consider as pests, our records to date indicate that resistance to one or more chemicals has appeared in 432 species of arthropods, 50 or so species of plant pathogens, five species of weeds, and two species of nematodes. Such resistance is of importance both in agriculture and in public health: of the 432 arthropod species known to be resistant, 261 (or 60%) are injurious to agriculture, and 171 (40%) are pests of man and animals (Tables 1, 2) (Georghiou 1980).

Table 1. Chronological increase in numbers of species of insects and mites resistant to insecticides

Year	Agricultural Pests	Medical/Veterinary Pests	Total
1908	1	-	1
1918	3	-	3
1928	5	-	5
1938	5	2	7
1948	9	5	14
1955	13	12	25
1960	65	72	137
1967	127	97	224
1976	225	139	364
1978	246	146	392
1980	261	171	432

Table 2 Taxonomic distribution of Arthropoda with reported cases of resistance to pesticides*

Taxa	Pesticide Group									
	DDT	Cyclod.	OP	Carb.	Pyrethr.	Fumigant	Other	Med.	Agr.	Total
Acarina	17	15	43	6			14	15	38	53
Anoplura	4	3	2	1				5		5
Coleoptera	24	53	26	9	3	8	5		64	64
Dermaptera	1								1	1
Diptera	107	111	58	9	3		2	132	25	157
Ephemeroptera	2								2	2
Hemipt./Het.	7	15	5					5	13	18
Hemipt./Hom.	13	12	29	8	2	3	1		43	43
Hymenoptera	1	2							3	3
Lepidoptera	41	40	31	15	7		2		65	65
Mallophaga		3						3		3
Orthoptera	2	3	1	1	1			3		3
Siphonaptera	7	5	2					8		6
Thysanoptera	3	5	1				2		7	7
Totals	229	267	198	49	16	11	26	171	261	432

*G.P. Georghiou, Resistance Documentation Center, University of California, Riverside, California. Updated July 1980.

Of course, the number of species that show resistance is only a partial indicator of the gravity of resistance problems. Other indicators that must be considered are:

(1) the number of different chemicals that can be resisted by a population;

(2) the frequency of the resistant genes, and

(3) the geographical extent of resistance.

It is well established that a given pest population can accumulate several mechanisms of resistance and thus may resist several types of insecticides at the same time. The number of such cases of so-called "multiresistance" has progressively increased so that of the 432 arthropod species known to be resistant, at least 25 species can resist the four principal classes of insecticides: DDT, cyclodienes, phosphates and carbamates (Table 3). In addition, a higher stage of multiresistance has recently been reached: at least ten species of insect pests have also developed resistance to the relatively new class of insecticides, the synthetic pyrethroids (Table 4).

Table 3. Development of multiple resistance to insecticides

Year	All Resistant Species	Stages of Multiresistance*				
		I	II	III	IV	V
1948	14	13	1	0	-	-
1955	25	4	18	3	0	-
1969	224	155	42	23	4	0
1976	364	221	70	44	22	7
1980	432	249	95	53	25	10

*Species in stage I-IV can resist insecticides belonging to 1,2,3,4, and 5 chemical classes, respectively (DDT, cyclodienes, organophosphates, carbamates and pyrethroids).

Table 4. Reported cases of resistance to pyrethroids in field populations of major pests.

Species	Host	Country	Compound	Resistance Level
Myzus persicae	Peach	N.S.W., Australia	Permethrin	15x (CR)[a/]
Scrobipalpula obsoluta	Tomato	Peru	Decamethrin	10x (R)[b/]
Spodoptera exigua	Cotton	El Salvador Nicaragua, Guatamala	Decamethrin	400x (R)
Plutella xylostella	Cabbage	Thailand, Malaysia	Decamethrin	500x (R)
Aedes aegypti		Guyana	Permethrin	30x (CR)
Musca domestica		England, Middle East Denmark	Permethrin Permethrin Bioresmethrin Tetramethrin	100x (R) 100x (R) 191x (R) 171x (R)
Leptinotarsa decemlineata	Potato	U.S.A.	Permethrin	100x (CR)

a/ CR = Cross-Resistance

b/ R = Resistance

Data on the georgraphic extent of resistant populations and on the frequency of resistant genes often reveal some surprising situations. For example, resistance to dimethoate in the green peach aphid in Britain was found to be so generally distributed that of 258 collections that were examined, only 3 did not contain resistant individuals. With 196 collections, more than 76% of the aphids were resistant (Sawicki et al. 1978). The frequency of DDT-resistance genes in *Anopheles culicifacies* in India during 1970-71 was calculated to have been 0.34. In *Anopheles albimanus* in certain areas of El Salvador, the frequency of DDT-and propoxur-resistance genes during 1970-72 was found to be 0.80 and 0.48, respectively, (Georghiou and Taylor 1976). Such extremely high frequency of resistance genes in mosquitoes is usually encountered in intensely agricultural environments where the mosquito population is exposed to indirect selection by sprays applied to crops.

Mechanism and dynamics of resistance

There are three principal types of mechanisms of resistance (Table 5). The first involves increased detoxification of the insecticide by means of specific enzymes or enzyme groups, such as dehydrochlorinases (e.g., for DDT), microsomal oxidases (for OPs, carbamates, pyrethroids), glutathione transferases (for various OPs) and hydrolases and esterases (chiefly for OPs). The second type of mechanism confers decreased sensitivity of the target site toward the toxicant. Such decreased sensitivity may concern the acetylcholinesterase enzyme that is the target of OP and carbamate insecticides, or it may involve a reduction in the sensitivity of the nervous system, as is the case with one of the mechanisms of DDT resistance. The latter also provides a high degree of resistance to pyrethroids. Finally, many cases of resistance involve a slower rate of penetration of the chemical through the integument. Such decreased penetration by itself confers only negligible resistance, but in combination with a detoxification mechanism, it produces a multiplicative rather than an additive resistance.

Table 5. Primary mechanisms of resistance to insecticides

Mechanism	Insecticide Affected
1. Increased detoxification	
– Dehydrochlorinase	DDT ⟶ DDE
– Microsomal oxidase	Phosphorothioates Carbamates Pyrethroids
– Glutathione transferase	Organophosphates (O-dimethyl)
– Hydrolases, Esterases	Organophosphates
2. Decreased sensitivity of target site	
– Decreased sensitivity of acetylcholinesterase	Organophosphates, carbamates
– Decreased nerve sensitivity (Kdr)	DDT, pyrethroids
– Cyclodiene resistance genes	Cyclodienes
3. Decreased cuticular penetration	
– pen	Most insecticides

Thus, in searching for specific chemical countermeasures, one must be cognizant of the fact that a given insecticide may be resisted by a number of different mechanisms, depending on the genes present in a population, as illustrated by the mechanisms of resistance known for DDT (Fig. 1).

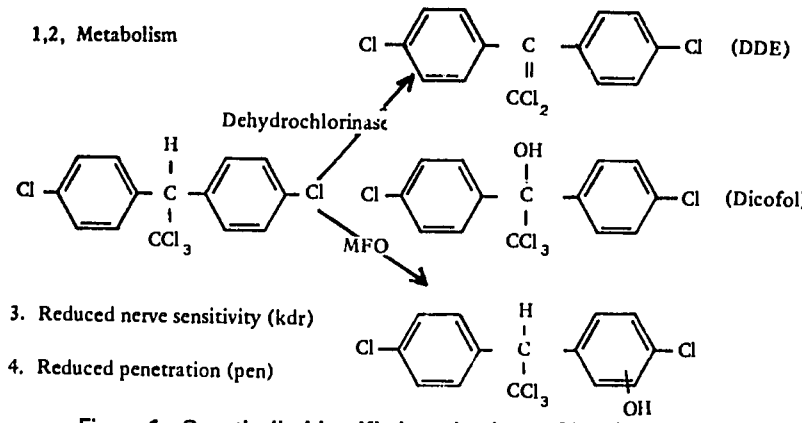

Figure 1. Genetically identified mechanisms of DDT resistence

One must also be aware that a given mechanism may protect an insect against more than one class of insecticide, as is the case with the gene kdr, which protects against both DDT and pyrethoids. For example, the selection of the gene kdr by the pyrethoid permethrin in the mosquito *Culex quinquefasciatus* not only increased resistance to pyrethroids, but also to DDT (Fig. 2) (Priester and Georghiou 1980).

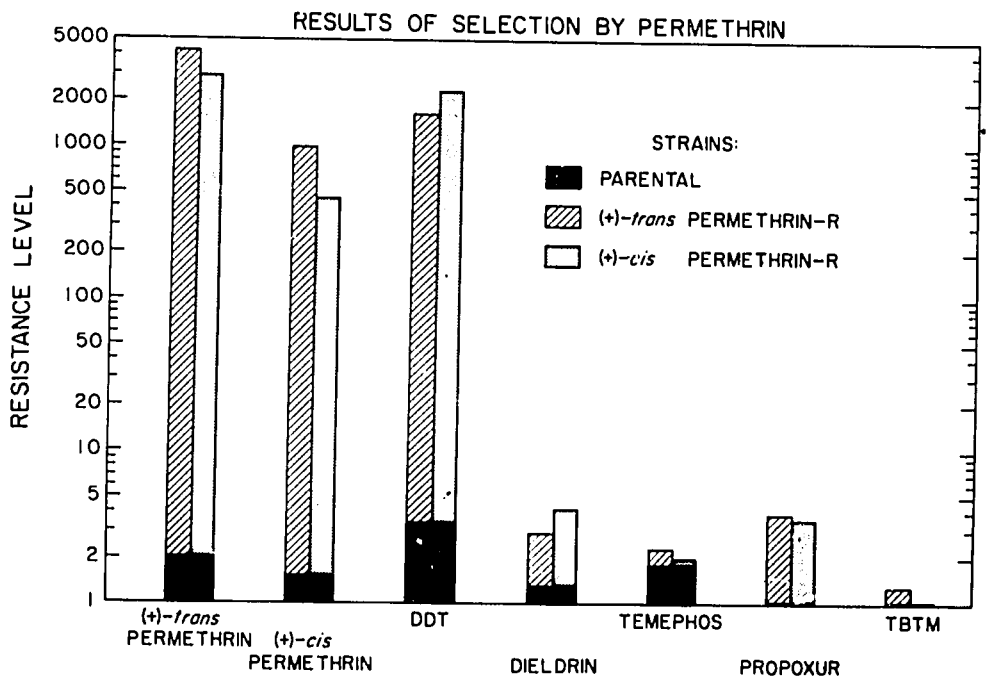

Figure 2. Effect of selection by permethrin on resistance to non-pyrethroid insecticides in Culex quinquefasciatus larvae (Data in Priester and Georghiou 1980).

Likewise, selection of *Anopheles stephensi* by DDT increased resistance to pyrethroids as well as to DDT (Fig. 3) (Omer et al. 1980). Similar observations were reported with house flies (Farnham 1977, Farnham and Sawicki 1976).

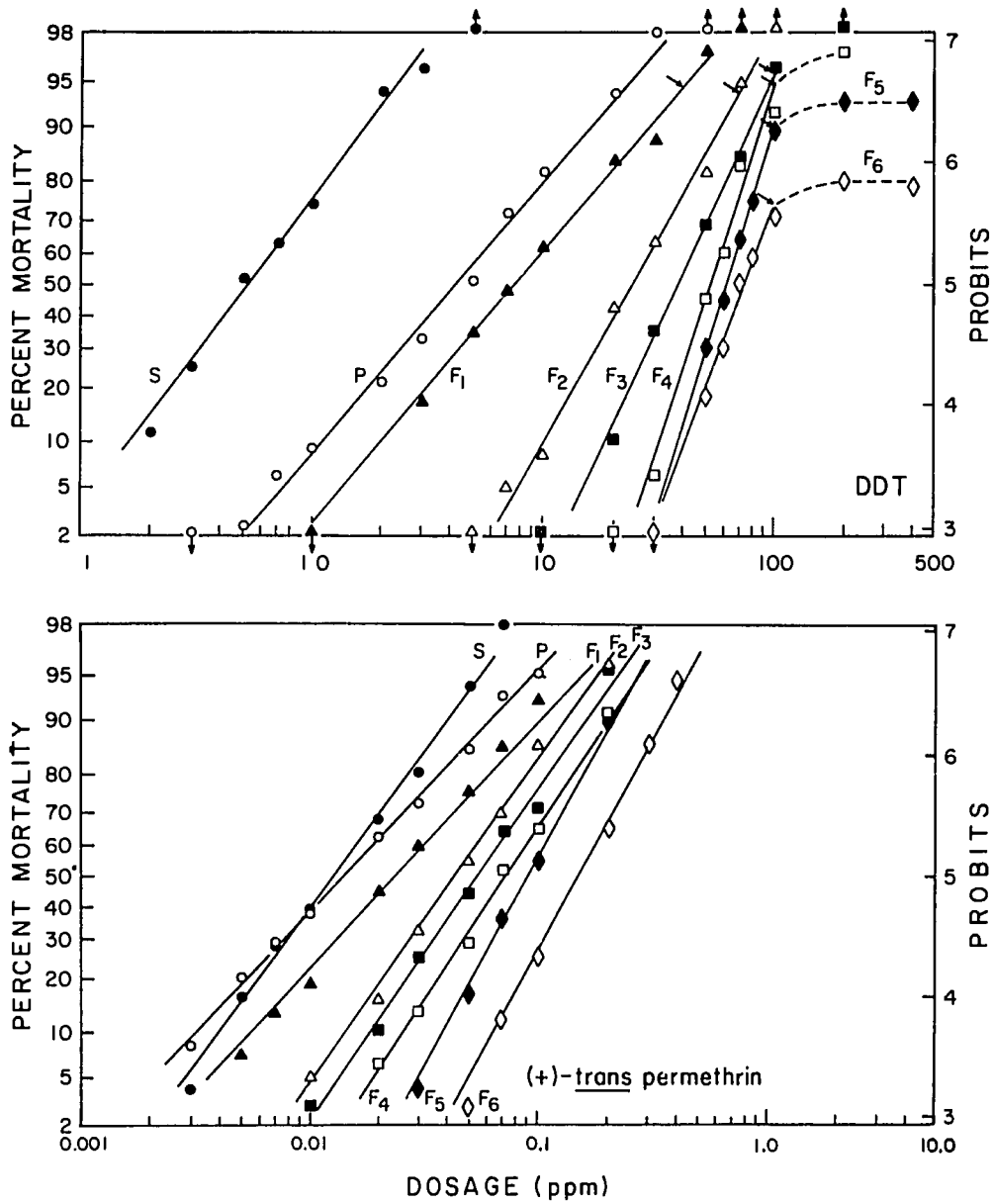

Figure 3. Development of resistance to DDT and cross resistance to (+)-trans-permethrin in *Anopheles stephensi* during selection of DDT. (Adapted from Omer et al. 1980).

My purpose in providing these seemingly specialized details is to stress that a thorough understanding of the mechanisms of resistance is vital in any attempt to devise effective chemical countermeasures.

There is, however, another type of information that is also vital, namely the dynamics of resistance in populations. It is an established fact that the rate of development of resistance is extremely variable: it has arisen slowly in some species and faster in others. It is also a fact that even in the same species, resistance has developed rapidly under one set of circumstances and slowly or not at all under different circumstances. What are these factors and circumstances, and how do they influence the evolution of resistance?

We have classified these influences into three groups: genetic, biological and operational (Table 6) (Georghiou and Taylor 1976, 1977a, 1977b). Factors in the genetic and biological categories are inherent qualities of the population; therefore, they are beyond our control, but their assessment is essential in determining the "risk for resistance" in the target population. The operational factors, on the other hand, are man-made and are thus within our control. These factors can be altered to any extent necessary, depending on the risk for resistance that is revealed by the genetic and biological factors.

Table 6. Factors influencing the evolution of resistance

Genetic	Biological	Operational
Frequency of R alleles	Biotic	The Chemical
Number of R alleles	Generation turn-over	Nature of pesticide Earlier used chemicals Persistence of residues Formulation
Dominance of R alleles	Offspring per generation	
Interactions of R alleles	Monogamy/polygamy	The Application
Pest selection by other chemicals	Behavioral	Application threshold Selection threshold Life stage(s) selected Mode of application Space-limited selection Alternating selection
Integration of R with fitness factors	Mobility; isolation	
	Monophagy/polyphagy	
	Fortuitous survival	

Adapted from Georghiou and Taylor 1976.

3. RESISTANCE MANAGEMENT

There are three types of approach to management of resistance by chemical means: management by "moderation," by "saturation," and by "multiple attack" (Table 7).

Table 7. Chemical strategies of resistance management

- Management by moderation
  - Reduction of selection pressure
    - Lower dosages
    - Less frequent applications
    - Observance of "refugia"
- Management by saturation
  - Rendering R gene "functionally" recessive
    - Higher dosages on target
  - Suppression of R genes
    - Synergists

Management by multiple attack

Multidirectional selection
Mixtures of toxicants
Alternation of toxicants

Management of resistance by "moderation"

This approach recognizes that susceptible genes are a valuable resource that must be conserved, and it attempts to accomplish this through reduction of the selection pressure.

Consideration of the operational factors listed in Table 6 leads to the obvious conclusion that resistance can be delayed the most or avoided entirely if the following conditions are fulfilled:

(a) the insecticide has short environmental stability;
(b) the mode of action or metabolism of the insecticide is not related to that of a chemical used previously;
(c) the formulation does not provide prolonged release of the chemical into the environment;
(d) the selection threshold is relatively low;
(e) selection is directed mainly against adults;
(f) the application is localized rather than areawide, and
(g) certain generations are left untreated.

These measures may appear to be extreme, and *in toto* they may be impracticable, but it should be remembered that the extent to which one or more of these measures may be necessary would depend on the "resistance risk" that has been ascribed to the target population through consideration of the genetic and biological factors.

The process of selection may be illustrated by frequency distribution curves for susceptible, hybird and resistant individuals (Fig. 4). Initially the susceptible genotypes are by far the most common, with only rare occurrence of an individual that is heterorzygous for resistance. Insecticides are usually applied at dosages that are lethal to the susceptible individuals but spare the heterozygotes and the homozygous resistant insects, thus progressively shifting the relative frequency of genotypes in favor of the resistant.

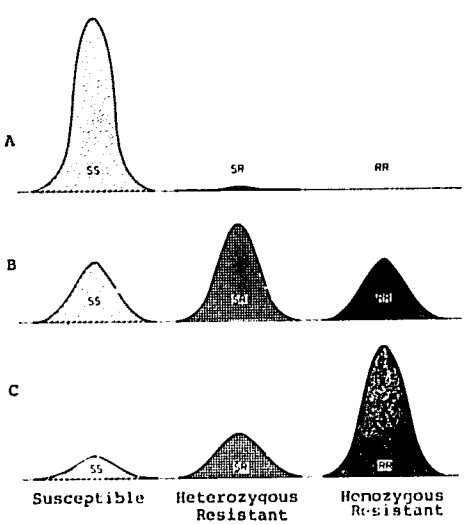

Figure 4. Digrammatic representation of progressive changes in frequency of susceptible (SS), heterozygous resistant (SR) and homozygous resistant (RR) individuals with continued selection pressure (A-C).

By applying a lower dose than that which kills all susceptible individuals, say LD_{90} or less, sufficient susceptible genes are preserved in the population to delay the onset of resistance. Likewise, incomplete coverage allows susceptible individuals to survive in untreated pockets (called "refugia") (Georghiou and Taylor 1977a, b). Furthermore, if a higher population density threshold is set for insecticide application, this results in fewer treatments, and hence in lower overall selection pressure.

Management by saturation

While management by moderation comes close to meeting environmental standards and is less destructive to biological controls, it may not be appealing where pests of high-value crops are involved or where insect vectors of disease must be kept at very low densities. For these situations, a different approach to resistance management may be considered, namely "management by saturation." The term saturation here does not imply saturation of the environment by pesticides, but rather indicates the saturation of the defense mechanisms of the insect by dosages that can overcome resistance.

This approach is based on the premise that resistance develops rapidly if the R gene is dominant, but it is slowed considerably if the R gene is recessive (Georghiou and Taylor gene functionally recessive by applying dosages sufficiently high to be lethal to heterozygotes as well as homozygous susceptible individuals (Curtis et al. 1978, Taylor and Georghiou 1979). It should be stated that homozygous resistant genotypes are unlikely to exist in an untreated population due to the extremely low initial frequency of the R gene (ca. 0.001-0.00001).

When the heterozygotes are killed, the R genes are eliminated and resistance does not evolve. However, this approach may be applicable only where a high dose of a rapidly decaying pesticide is possible, as with fumigants, or if technological innovation eventually enables the application of sufficiently high doses only to the target pest through microencapsulation, systemic uptake, or some other process.

Under management by saturation we could also include the use of synergists, i.e., compounds that act by inhibiting specific detoxication enzymes and thus eliminate the selective advantage of individuals possessing such enzymes. An important consideration is that there should be no alternative resistance pathway available in the population.

Recently, we demonstrated the application of this principle in the mosquito *Culex quinquefasciatus*, using a strain that possessed high resistance to several organophosphates. The use of the oxidase inhibitor piperonyl butoxide (PB) in combination with any of these insecticides failed to produce synergism, thus indicating that this resistance was not due to an oxidase (Table 8). In contrast, treatment in combination with the esterase inhibitor DEF reduced resistance almost to the level found in the susceptible strain (Georghiou et al. 1975). Having thus shown that the strain possessed only esterases and not oxidases as mechanisms of resistance, we then showed by selection with temephos during 12 consecutive generations that resistance will not evolve if the insecticide is used jointly with DEF but that it can advance to higher levels when the insecticide is used alone or in combination with PB (Table 9) (Ranasinghe and Georghiou 1979).

Table 8. Effect of synergists PB (oxidase inhibitor) and DEF (esterase inhibitor) on resistance to organophpsphates in *Culex quinquefasciatus* 1/

Insecticide	Resistance Factor		
	Insecticide	+PB	+DEF
chlorpyrifos	52.2	47.0	0.5
methyl parathion	24.0	25.0	1.3
methyl paraoxon	16.0	12.9	1.2

1/ Hanford field strain. (adapted from Georghiou et et. 1975)

Table 9. Effect of selection by temephos + synergist on evolution of organophosphate resistance[1/]

Insecticide	Resistance Factor				
	Parental strain	temephos-selected (F_{12})	temephos + PB-selected (F_{12})	temephos + DEF-selected (F_{12})	Not selected (F_{12})
temephos	117	322	122	3.1	3.1
chlorpyrifos	52	52	52	2.8	2.5
parathion	14	33	17	3.7	1.4
methyl parathion	24	36	28	1.3	2.8

1/ Adapted from Ransinghe and Georghiou 1979.

The difficulty with synergists is that none of those that are presently available can be used under field conditions: DEF is a defoliant and PB is unstable in sunlight. However, the principle is promising and we should see more progress in this direction in the future.

Management by multiple attack

A third group of countermeasures utilizes the principle of "multiple attack." This requires that control he achieved through the action of several independent selecting forces through a program in which the selection pressure on any single mechanism would be below that required for the development of resistance. A good example of such selection are the multisite toxicants employed in earlier years for the control of insects and plant diseases, such as arsenicals, sulfur, copper sulfate, etc. These chemicals proved exceedingly capable of withstanding the development of resistance since they attacked several vital functions within the target organism. Of course we cannot return to the arsenicals, but the principle of multisite attack has given considerable food for thought to both synthetic chemists and toxicologists.

One artificial means of achieving multisite attack is by the use of insecticides in mixtures or in rotations. The principle of mixtures is not new; it is practiced widely in medicine, as in the simultaneous administration of three different drugs for the treatment of TB.

The concept of mixtures assumes that the mechanisms for resistance to each member chemical exist at such low frequencies that they do not occur together in any single individual within a given population. Thus, insects that survive one of the chemicals are killed by the other.

The concept of rotation assumes additionally that individuals that are resistant to one chemical have substantially lower biotic fitness than susceptible individuals, suggesting that their frequency would decline during the intervals between applications of the compound in question.

The possible oscillations in susceptibility of a population that is exposed to four chemicals used in rotation are presented diagrammatically in Fig. 5. Resistance to compound A rises slightly in the generation in which it is applied and then declines during the subsequent three generations during which it is not applied. It rises in the 5th generation when the compound is again applied, but drops in generations 6, 7 and 8. The same pattern is anticipated for compounds B, C, and D, each chemical oscillating one step behind its predecessor in the treatment sequence.

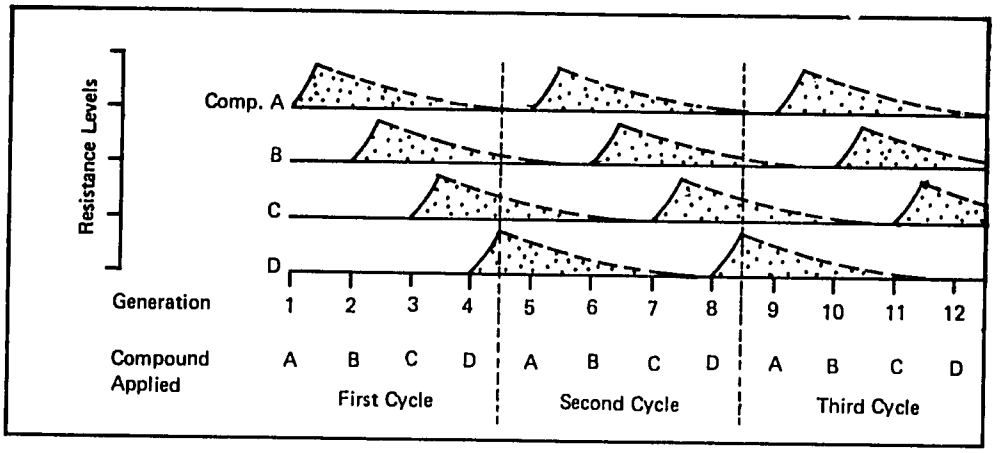

Figure 5. Diagrammatic representation of expected oscillations in susceptibility of a population that is exposed to four unrelated chemicals (A-D) used in rotation against succeeding generations (1-12) (Georghiou 1980b).

If one chemical is applied repeatedly and is not replaced until resistance begins to develop, the system may be referred to as "sequential use," rather than rotation. The challenge in either case is to determine the optimal sequence of use of the chemicals and the stage at which a change must be made.

Recent discoveries of new toxic agents of disparate structures and modes of action, such as juvenile hormone mimics, chitin inhibitors, *Bacillus thuringiensis* toxin, pyrethroids, and certain "derivatized" carbamates and organophosphates, have prompted us to re-examine the validity of these approaches. We should stress that this is long-term research, and that certain aspects, especially rotations and sequential use, require selection for several generations before definitive conclusions can be reached. Rearrangement of the sequence of chemicals may also be required.

In our laboratory, we have tested these approaches using three compounds: temephos, propoxur and permethrin. Each of these is known to induce high resistance to itself, but little or no cross resistance to the other compounds. A strain of *Cx. quinquefasciatus* was synthesized by incorporating 2% of the genome of three resistant strains, Temephos-R, Propoxur-R and Permethrin-R, into a susceptible strain. Subcolonies of this synthetic strain were selected with each insecticide applied either singly or jointly, as well as in various rotational sequences.

Although this study is still incomplete, the following trends are emerging (Georghiou *et al.* 1980, Lagunes 1980):

Each strain that was selected with a single chemical promptly developed resistance toward that chemical, thus confirming that the factors for resistance from strains Temephos-R, Propoxur-R and Permethrin-R had indeed been incorporated in the synthetic strain. There was no cross resistance evident toward the other two chemicals (Fig. 6).

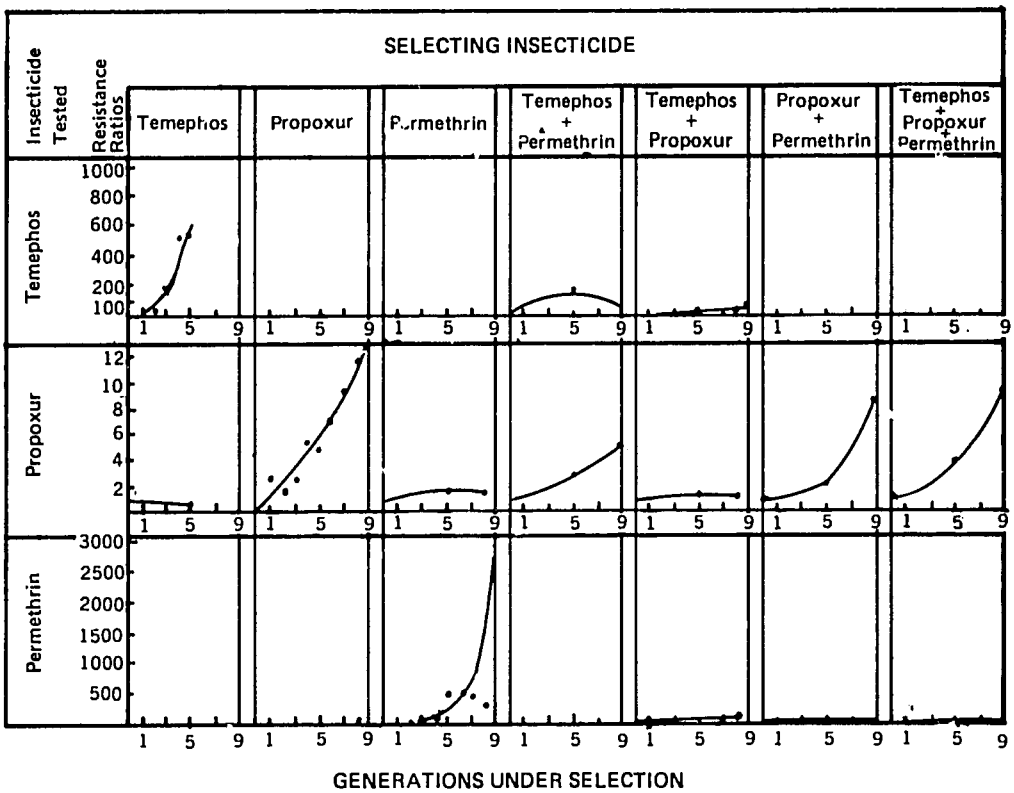

Figure 6. Changes in susceptiability to temephos, propoxur, and permethrin in sibling strains of Culex quinquefasciatus in the course of selection by these insecticides singly or in various combinations (Data by Lagunes 1980, by permission).

Upon suspension of selection pressure, the level of resistance began to decline. This regression was faster in the temephos-selected strain, less so in the permethrin strain, and least in the propoxur strain.

Selection by combinations involved temephos + propoxur, temephos + permethrin, propoxur + permethrin, and temephos + propoxur + permethrin. After selection for nine consecutive generations, a significant degree of resistance to propoxur evolved in all strains in which propoxur was included as a selecting insecticide; however, resistance to temephos and permethrin was inhibited by the combinations and dosages used.

Sequential usage consisted of selection of a strain by one chemical until significant resistance had appeared, at which time it was replaced by a second chemical. After resistance to this had also appeared, it was substituted by the third chemical. The following sequences were studied:

temephos – propoxur – permethrin
temephos – permethrin – propoxur
propoxur – temephos – permethrin
propoxur – permethrin – temephos
permethrin – temephos – propoxur
permethrin – propoxur – temephos

The most interesting observation emerging from the results to sequential usage was the rapid regression of resistance to temephos or permethrin when selection by one of these two chemicals was followed by selection by the other. Thus, temephos resistance regressed rapidly when temephos was replaced by permethrin as the selecting agent, and vice versa, and this regression appeared to be somewhat faster than was observed in strains that were removed completely from selection pressure. This reciprocal relationship did not appear to exist between propoxur and permethrin or between propoxur and temephos. Genetic tests are currently underway to elucidate the observed relationship.

The concept of use of insecticides in mixtures, rotations or in optimal sequences may be limited in many instances by economic or practical considerations. However where control practices are applied on a large scale and are centrally coordinated, this concept might present a distinct advantage as a means of delaying or averting the evolution of resistance.

It was concluded from these results that a system of rotation has merits when the compounds involved are neutral toward each other with respect to cross resistance, and when the rotation interval is sufficiently long to avoid the cumulative effects of selection by the same chemical.

The approaches to management of resistance as discussed under the three general categories of moderation, saturation and multiple attack present alternatives that can meet the needs and feasibilities existing in a variety of situations. The applicability of each approach, or of their combinations, requires individual appraisal depending on the particular pest involved and on the prevailing environmental conditions. I believe the groundwork for future reseach has been laid and that we are bound to see progress in this area in the years ahead.

4. CONCLUSION

The phenomenon of resistance to pesticides has continued to increase in terms of numbers of resistant species, frequency of resistant genes, and geographic extent of resistant populations. More than 432 species of insects and mites are known to have developed resistance to one or more pesticides.

Integrated pest management programs contribute to a reduction in chemical selection pressure and thus in the rate of evolution of resistance. But where chemicals must continue to be relied upon for adequate pest control, or are an important component of IPM programs, knowledge of the mechanisms and dynamics of resistance is vital to proper planning of successful countermeasures.

The paper summarizes the status, mechanisms and dynamics of resistance and present the rationale and examples of measures for management of resistance under three categories: management by "moderation," "saturation" and "multiple attack."

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13. CLASSIFICATION AND TOXICOLOGY OF PESTICIDES

PART I. CLASSIFICATION, CHEMISTRY AND TOXICOLOGY OF PESTICIDES

BY

VIRGIL H. FREED, Ph.D.

AND

PART II. TOXICOLOGY AND HUMAN HEALTH CONSIDERATIONS OF PESTICIDES AND THEIR LIMITATIONS TO USE

BY

JOHN E. DAVIES, M.D., M.P.H.

CONTENTS

	Page
PART I	131
1. INTRODUCTION	131
2. CLASSIFICATION OF PESTICIDES	132
3. SPECIFIC CHEMICAL GROUPS	132
4. ORGANOHALOGENS	132
5. ORGANOPHOSPHATES	133
6. CARBAMATES	133
7. HETEROCYCLIC COMPOUNDS	134
8. AROMATIC ACIDS	134
9. UREAS	134
10. STRUCTURE OF PESTICIDES	134
11. PROPERTIES OF COMPOUNDS IN RELATION TO TOXICOLOGY	142
PART II	147
1. INTRODUCTION	147
2. CATEGORIES OF HUMAN PESTICIDE EXPOSURE	147
3. TOXICITY OF INSECTICIDES	148
4. TOXICITY vs. HAZARD	148
5. HOW EXPOSURE OCCURS	149
6. APPLICATOR POISONING	149
7. PICKER POISONING	149
8. CHILD POISONINGS	150
9. FIRST AID MEASURES	150
10. MANAGEMENT AND TREATMENT OF ACUTE ORGANOPHOSPHATE POISONING	150

11. CHRONIC EXPOSURES 150

12. INCIDENTAL EXPOSURE 151

13. TOXICOLOGICAL CONCERNS FOR QUANTITATIVE ESTIMATES OF EXPOSURE 151

14. TOXICOLOGICAL CONCERNS FOR EXPOSURE ASSESSMENT 151

15. LIMITATIONS AS TO USE 151

REFERENCES 153

APPENDIX: PESTICIDE PROTECTION – A TRAINING MANUAL FOR HEALTH PERSONNEL
US. ENVIRONMENTAL PROTECTION AGENCY 156

PART I
CLASSIFICATION AND TOXICOLOGY OF PESTICIDES

PART I. CLASSIFICATION AND CHEMISTRY OF PESTICIDES

I. INTRODUCTION

Since 1945 some 900 to 1,000 individual compounds have come into use as pesticides. These chemicals have been offered for sale and application in about 35 to 40,000 different formulations. To be sure, only about 150 of those chemicals are very widely used. The remainder are used in smaller quantities or used selectively on specialized problems.

In looking at the large number of chemicals available, and the even more confusing number of different formulations, it would only be natural for one to ask first, 'why do we have so many chemicals', and then secondly 'how does one keep them all straight?' It is to the second question that this presentation is primarily directed, but a few moments spend in answering the first question is well worthwhile.

Since man first essayed the agricultural enterprise some ten thousand years ago, he has been in competition with other organisms that destroyed his crops, afflicted his livestock and otherwise wrought great destruction to his food supply. There was little that could be done to stem a plague of locusts, or control outbreaks of fungal disease, and only with backbreaking labor could weeds be prevented from smothering the family's food supply. Domestication and utilization of draft animals enabled mankind to enlarge the agricultural enterprise to accomodate to a growing population and of course the inevitable losses to pests. However, the continuing loss accuring through production and storage proved to be an onerous situation. It is little wonder, then, that we find that several hundred years B.C. people in China, Greece, Rome and elsewhere, attempted the control of pests through using various concoctions of chemicals. Their successes were small, and not widely accepted, but the fact that it was attempted gives us an insight into the seriousness of the problem even in those days.

Gradually, agriculture evolved a number of practices intended to abate the problem of the insects, plant disease, weeds and other organisms, that took their toll of crop production and caused animal losses. These practices included among other things cultivation, crop rotation, field sanitation, and ultimately improved crop varieties having a resistance to disease and insects and a variety of regulations to provide clean seed and restrict the movement of pests from one area to another.

Up to the middle of the 19th Century only a few interested individuals continued trying different chemicals or mixtures for pest control. Little systematic effort was devoted in this direction despite the enormity of the problem. The demonstration that simple inorganic and organic chemicals might control insects and fungi in the mid 19th century resulted in greater efforts being directed to the discovery and utilization of chemicals for pest control. The success achieved in those early days was sufficiently dramatic to demonstrate that tremendous benefits

in crop production could ensue from use of chemicals. Copper salts were effective in reducing plant diseases, and such things as lead arsenate and paris green could dimish the devestation of an insect outbreak.

Even greater benefits were derived from the organic chemicals introduced in the 1940's. Substances like DDT, 2,4-D and the dithiocarbamates gave outstanding pest control with a resulting large increase in yield. The value of chemicals increasing crop production was established. Equally good results were being attained in the field of health protection where these chemical effectively controlled vectors of disease.

The outstanding results with chemicals unfortunately led many to discard the cultural and other practices that are equally essential to a pest management program. The consequence was an over-use of chemicals and in many instances a misuse. We are, therefore, confronted today with a concern as to the impact of these materials on human health.

2. CLASSIFICATION OF PESTICIDES

With some 900 compounds and a multitude of different formulations, it is necessary to have some system of ordering the array of chemicals in order to properly identify those we wish to use. One scheme is to classify the chemicals by biological use. For example, those used to control insects will be termed insecticides, and so on. However, this does not give us sufficient identification since a variety of different chemicals may be used for insect control and vary greatly in their composition, manner of use, and biological and chemcial properties. Moreover, we will find certain classes of chemicals that may be used as not only as an insecticide, but also as a fungicide, and a herbicide as is the case with some of the highly volatile materials that we call fumigants.

Another system of classifying the chemicals is by chemical group. This is somewhat more informative, at least to the chemist, but leaves us without the initial clue as to where the chemical is used. Thus, we can talk about hydrocarbons that are substituted with chlorine, bormine or iodine or aliphatic, alicyclic, heterocyclic, and aromatic compounds, and then further categorize them by substituent groups as carbamic acid esters, phosphates or phosphonates, nitriles, carboxylic acid esters and so on.

The scheme of categorization of pesticides that has evolved is a hybrid between the biological and the chemical classifications. Thus, we talk of organohalogen insecticides, organohalogen herbicides or fungicides and so on. Such a scheme of classification enables us to identify the chemicals in a generic way and even to some extent in a specific way and speak of them in, as it were, shorthand terms. Thus, if we refer to an OP compound, most pesticide control biologists recognize this as referring to an organic chemical that contains a phosphorous atom somewhere in the molecule. It also immediately tells them that this is likely to be a cholinesterase inhibiting substance that should be used with considerable caution.

3. SPECIFIC CHEMICAL GROUPS

It was easier at an earler time to categorize chemicals and speak of them as belonging to a particular class, for we had fewer chemicals and their structures were such to make the classification less equivocal. Thus, we could speak of chlorinated hydrocarbons or organohalogen compounds, and generally refer to substances containing carbon, hydrogen and a halogen. As the number and complexity of the compounds increased, the lines of demarcation became less well defined. For purpose of sharper definition of the compounds we are forced to refine the system and utilize subcategories. For example, both DDT and 2,4-D contain carbon, hydrogen, and chlorine, but in addition the 2,4-D has three atoms of oxygen. We can refer to both compounds as organohalogens, but the DDT is a hydrocarbon, and the 2,4-D an aromatic acid. Even more confusing might be the case of something like Ronnel, an organophosphate containing three chlorine atoms.

Just as there is a continuum in structures of compounds that make some of the classification arbitrary, so there is a continuum in the chemical and physical properties of the compounds. It cannot be assumed, for example, that one particular property is peculiar to a certain class of

compounds since it may be found in varying degree in compounds representative of a different organic class. To illustrate, in the generalized reaction with water, that is hydrolysis, one might deduce that the chlorinated hydrocarbons are resistant to hydrolysis compared to the organophosphates if one considers only DDT. On the other hand, the chlorinated hydrocarbon methyl chloride hydrolyzes quite readily also. Or yet, again, because of the high fat solubility of many of the halogenated compounds, one might expect that a high partition coefficient would be characteristic of the group. In contrast, the relatively poor solubility of the alkyl phosphates such as dimethoate or malathion might lead one to characterize the OP's as having a low partition coefficient and hence, lacking propensity to biocumulate. This does not turn out to be the case, since some of the OP's such as dichlofenthion and leptothos have rather substantial partition coefficients and as a result partition into fat.

With these caveats then, we will then try to give a general description of some of the more familiar classes of pesticides and follow that with specific examples of each class drawn from the insecticide, herbicide, and fungicide group.

4. ORGANOHALOGENS

The organohalogen, that is compounds containing fluroine, chlorine, bromine or iodine, probably constitutes the largest groups of biologically active organic chemicals known. One finds high biological activity in the halogenated methanes, e.g., chloroform, and carbontetrachloride, which are used as solvents or fumigants, as well as in polychlorinated aromatic compounds with melting points up to almost 200°C, and very low vapor pressures. It should be noted that the organohalogen compounds are not exclusively man-made chemicals. The carbon halogen bond in aliphatic and aromatic compounds occurs extensively in nature. Not only are such compounds found in living organisms, as for example thyroxine, an iodine-containing hormone, but it is believed that natural processes of the sea result in the formation of methyl iodide (40 million tons annually), and carbontetrachloride (1.7 million tons annually). Even more complex organohalogen compounds have been identified from natural sources.

The organohalogens among pesticides may include such simple compounds as carbon tetrachloride, or dichloropropene, and range up to more complex chemicals as DDT, dieldrin, phenoxy acids, and substituted ureas. As would be expected, there is a range of both biological and chemcial properties among these different materials. Accordingly, it becomes easier to classify some of the materials according to functional group rather than on the basis of their containing a halogen. Thus, we have the halogenated hydrocarbons represented by such things as carbon tetrachloride, dichloropropene, a soil fumigant, DDT, toxaphene, and dieldrin. A substance such as Ronell that contains three chlorine atoms is classified by the functional groups as a phosphorothionate derivative and hence is labeled an organophosphate.

5. ORGANOPHOSPHATES

These chemicals — for the most part insecticides although a few show activity as herbicides — are esters of one of the phosphorous acids. TEPP, for example, one of the first of the phosphate insecticides, is a simple ester of pyrophosphoric acid, while dichlorvos is 'an ester of orthophosphoric acid. The more widely used organophosphates are usually derivatives of thiophosphoric acid in which one of the oxygen atoms has been replaced by a sulfur atom. Malathion, on the other hand, is a dithiophosphate in which two oxygen atoms have been replaced by sulfur.

The phosphate esters, like any other ester, hydrolyze readily to yield phosphoric acid derivatives, and the corresponding phenol, or alcohol. In contrast to the chlorinated hydrocarbons, the organophosphates breakdown somewhat more readily, though some, such as parathion, are known to have considerable persistence.

6. CARBAMATES

The carbamates are derivatives of carbamic acid, a nitrogen-containing acid. The carbamate pesticides are usually esters except in the cases of a few dithiocarbamates which are sufficiently stable to be used as metal salts. The oxygen-containing carbamate pesticides are esters in which

either an aromatic or alkyl substitution has been made on the nitrogen atom. For the most part, those with the alkyl substitution on the nitrogen are insecticides and those with the aromatic substitution are herbicides, although in the case of aldicarb, the substituent on both the oxygen and the nitrogen are aliphatic.

Like the organophosphates, the carbamates hydrolyse readily and thus degrade fairly rapidly. The carbamates containing aromatic rings will have relatively low water solubilities (in the one to 100 ppm range), while the alkyl substituted carbamates will have solubilities more in the range of 100 to 2000 ppm.

7. HETEROCYCLIC COMPOUNDS

The heterocyclic compounds are materials containing rings made up of 4 to 6 atoms of which one or more atoms will be other than carbon. There may be more than one ring in the compounds, either in a condensed form or joined by a single bond. The atoms other than carbon going to make up the ring may consist of nitrogen (triazines, diazinon), sulfur (phosfolan), or oxygen (coumaphos). As might be expected from the divergent structures found in this group, the biological and chemical properties of the compounds vary widely. Some have high activity as insecticides, others herbicides and yet others as fungicides, rodenticides, etc.

8. AROMATIC ACIDS

A number of aromatic acids are used as herbicides. Among them the phenoxy acids and benzoic acids and their derivatives. The aromatic portion of the molecule influences the biological and chemical properties of the compound, but the carboxylic acid portion determines in a large measure the physical behavior of the compound. Most are relatively strong acids that readily form salts and amides and can be esterified. Salts, for the most part, are water soluble, and the esters fat soluble. The volatility of the ester is markedly influenced by the molecular weight of the alcohol used to prepare the ester.

9. UREAS

For the most part, the ureas are considered to be herbicides, but recently the benzoylphenyl ureas have been shown to be effective as larvicides. The ureas are derivatives of organically substituted urea, a common fertilizer. These compounds can have low water solubilities, and low mammalian toxicity.

There are a number of other organic classes represented among the various pesticides and growth regulators. Among these would be included phenols, organometallic compounds, nitrilies, quinones, and others. In addition to the insecticides derived from botanical origins such as pyreforum, derris, and rotenone. There are, of course, also a number of compounds based on the chemistry of pyrethum. Finally, there is developing a class of insecticides called the "biorational" exemplified by the various pathogenic insect viruses, such as polyhedrosis virus.

10. STRUCTURE OF PESTICIDES

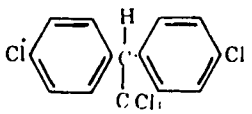
In the following material the structures of some of these various classes of pesticides are illustrated.

FIG. 1. CLASSIFICATION AND STRUCTURE OF PESTICIDES

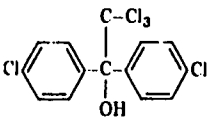
A. INSECTICIDES

1. Chlorinated Hydrocarbons

a. Diphenyl Alkanes

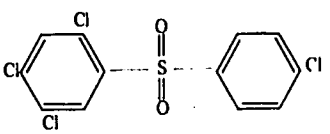


DDT



Kelthane

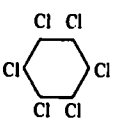
b. Diphenyl Thioates



Tedion

c. Polychloro Alicyclics

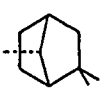
Monocyclic



99% gamma isomer

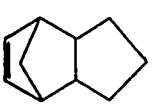
Lindane

Bicyclic



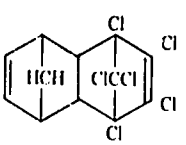
Toxaphene

Tricyclic



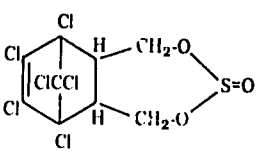
Chlordane

Tetracyclic



Aldrin

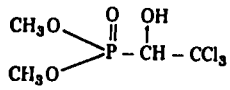
Hexacyclic



Thiodan

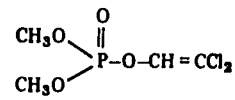
2. Organic Phosphorous Esters

a. Phosphonate



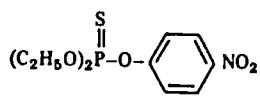
Dipterex

Phosphate



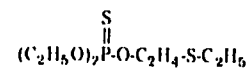
DDVP

b. Thionophosphate



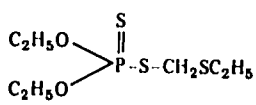
Parathion

Thiol phosphate



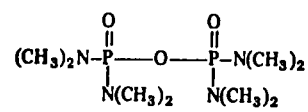
Systox (thiol isomer)

c. Dithiophosphate



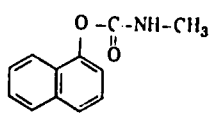
Thimet

Amido phosphate



Schradan

3. Carbamates



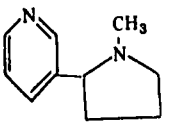
Sevin

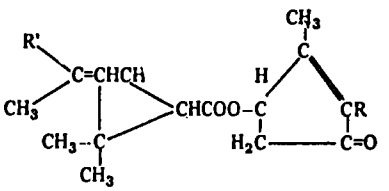
Generalized Structure: None

Examples:

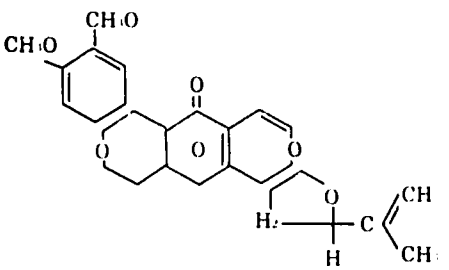
(a) Natural

Nicotine





Pyrethrum



Rotenone

Ryania

$C_{25}H_{35}NO_9$

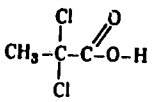
Sebadilla

$C_{36}H_{57}O_{11}N$

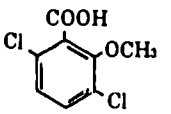
B. HERBICIDES

1. Chloro organic acids

Chloro aliphatic Acids

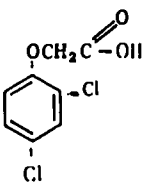


Dalapon



Dicamba

Chlorophenoxy acids

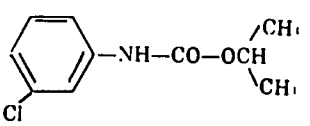


2,4-D

2. Nitrogen Compounds

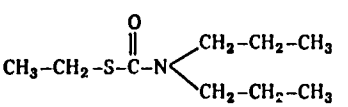
Mono-N aliphatics

Carbamates



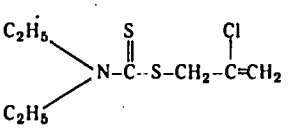
CIPC

Thio carbamates



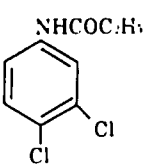
Eptam

Dithio carbamate



CDEC

Amides

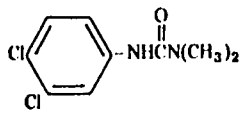


Propanil

Di-N aliphatics

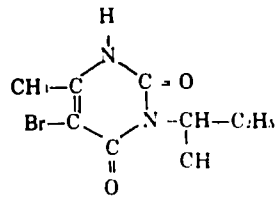
Di-N heterocyclics

Ureas



Diuron

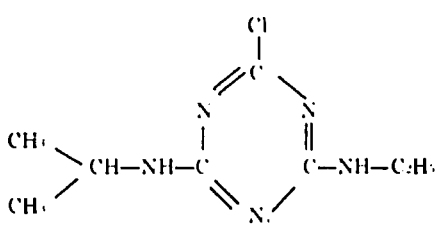
Uracils



Bromacil

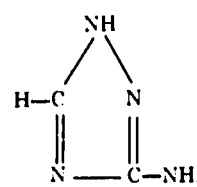
Tri-N heterocyclics

Triazines



Atrazine

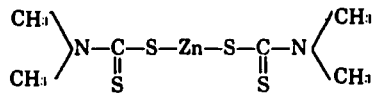
Triazoles



Aminotriazole

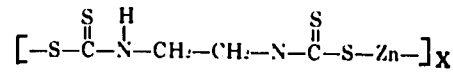
C. FUNGICIDES

Dithio carbamates



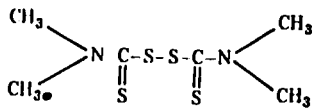
Ziram

Dis di thio carbamates



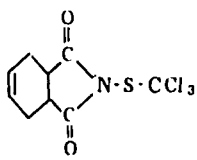
Zineb

Thiurams



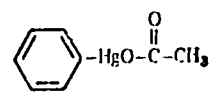
Thiram

Tetrahydro phthalimides



Captan

Organo mecurials



PMA

D. NEMATICIDES

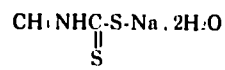
Halo alkanes

CH = CH = CH2

Cl Cl

DD

Di thio carbamates



Vapam

FOR FURTHER READING

GREEN, M.B., HARTLEY, G.S., and WEST, T.F. (1977). Chemicals for Crop Protection and Pest Control. Pergamon Press, New York.

PLIMMER, J.R. (editor). (1977). Pesticide Chemistry in the 20th Century. ACS Symposium series #37. ACS, Washington D.C.

FARM CHEMICALS HANDBOOK. (1980). Meister

FARM CHEMICALS HANDBOOK. (1980). Meister Publishing Co. Willoughby, OH.

11. PROPERTIES OF COMPOUNDS IN RELATION TO TOXICOLOGY

The intrinsic toxicity of a chemical depends on:

a. the atomic composition and molecular arrangement of the compound, and

b. the physical properties of the compound.

In broad terms there is a commonality among living systems so far as their biochemistry is concerned. Thus, a compound that is an effective pesticide, for example a herbicide, if administered in a sufficiently high dose, will also affect a mammalian system. The difference in susceptibility between the plant and the animal is due to rather subtle differences in their biochemistry, and how the compound is distributed in the living body whether plant or animal.

Whether a given dosage of a chemical will be toxic to a particular organism depends in some measure on route of exposure. If there is an effective barrier, whether physical or chemical, the organism may be relatively unaffected. Thus, the human skin effectively prevents the entry of the ester form of 2,4,5-T into the human body, whereas the cuticle of the plant is a much less effective barrier, resulting in a high rate of absorbtion. Thus, the human is quite immune to the relatively small amount of 2,4,5-T used in weed control, whereas, many broad leaf plants are destroyed by it. Similarly, there are organophosphate insecticides that are poorly absorbed by human skin, and others that are readily absorbed, as for example is the case with parathion.

One of the properties that has been found to be quite important in absorption of a compound and also in subsequent toxic action is the partition coefficient. This is a term that describes the relative distribution of a compound between a lipid or fat-like layer and water. The most commonly reported partition coefficient is that between octanol and water. Octanol is chosen in part because of its similarity in properties to fats. Compounds with high octanol water partition coefficients are likely to bioaccumulate, that is, deposit in fat at concentrations above the ingestion level. If, at the same time, the compound is refractory to breakdown by enzymatic, or purely chemical means, it may persist in the body for some period of time.

The following diagram (Fig.2) demonstrates the relationship between the partition coefficient and bioaccumulation: from this diagram and Tables 1 and 2 it is seen that there is an inverse relationship between solubility in water and the partition coefficient (also see fig. 3). It is clear that the compounds having higher partition coefficients gain entry and accumulate in the organism.

While these data are based on bioaccumulation in fish, it has also been shown that when the partition coefficient lies within certain values, the compound will also penetrate human skin very readily. However, such penetration is a complex phenomenon, and does not relate exclusively to one physical property. Thus, some highly water-soluble compounds such as the alkyal substituted organophosphates, and carbamates penetrate very readily.

In concluding the section on classification and chemistry of pesticides, it may be of interest to note the partition coefficients of some commonly used organophosphate pesticides (Table 3), and also to note some of the relationships between the molecular properties of compounds and aspects of their biological activity (Table 4).

It is hoped that what has been presented here in Classification and Chemistry of Pesticides, albeit a very sketchy overview, has laid a better foundation for consideration of the toxicology of their compounds and their limitations as to use.

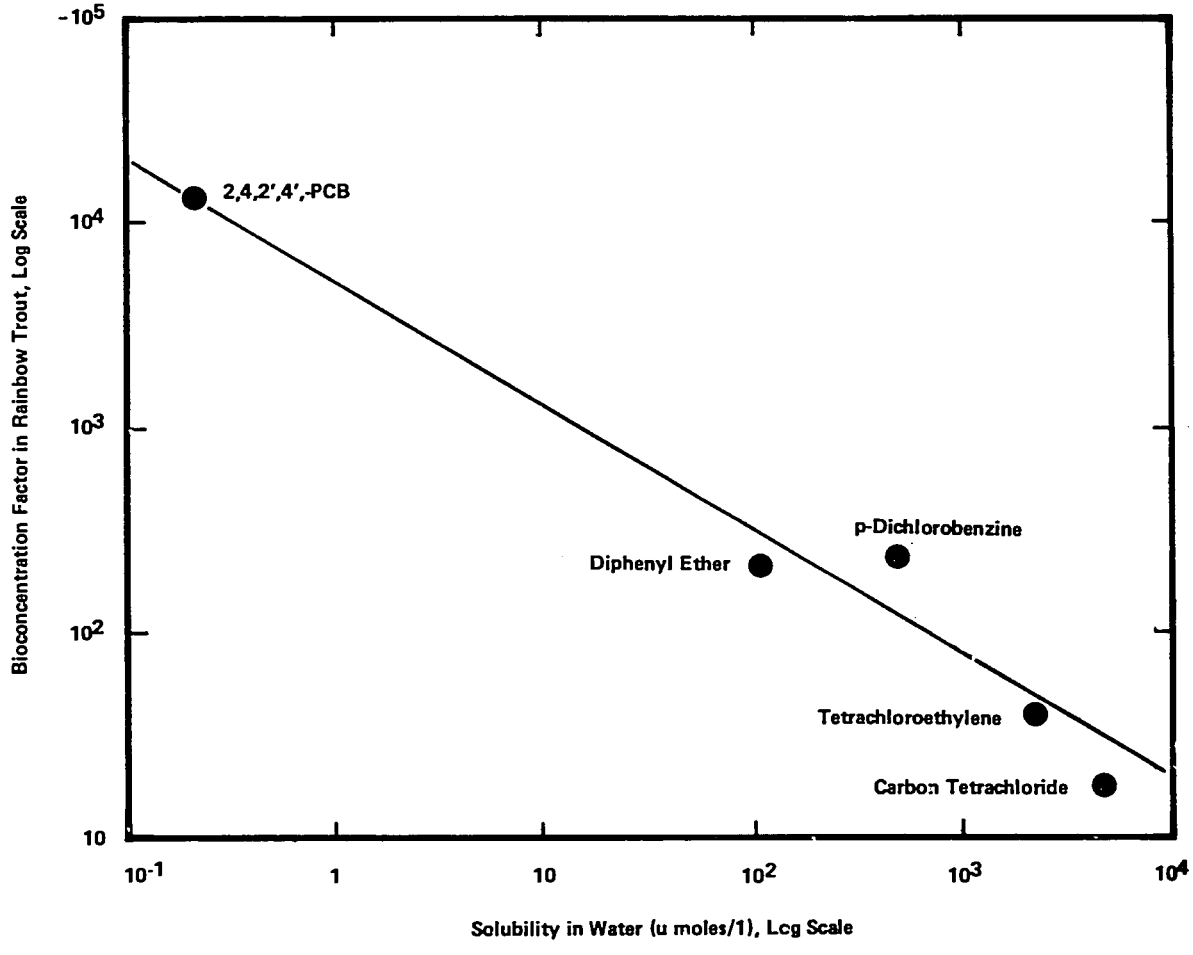


Fig. 2. Solubility in Water and Bioaccumulation Factor of Selected Compounds in Rainbow Trout

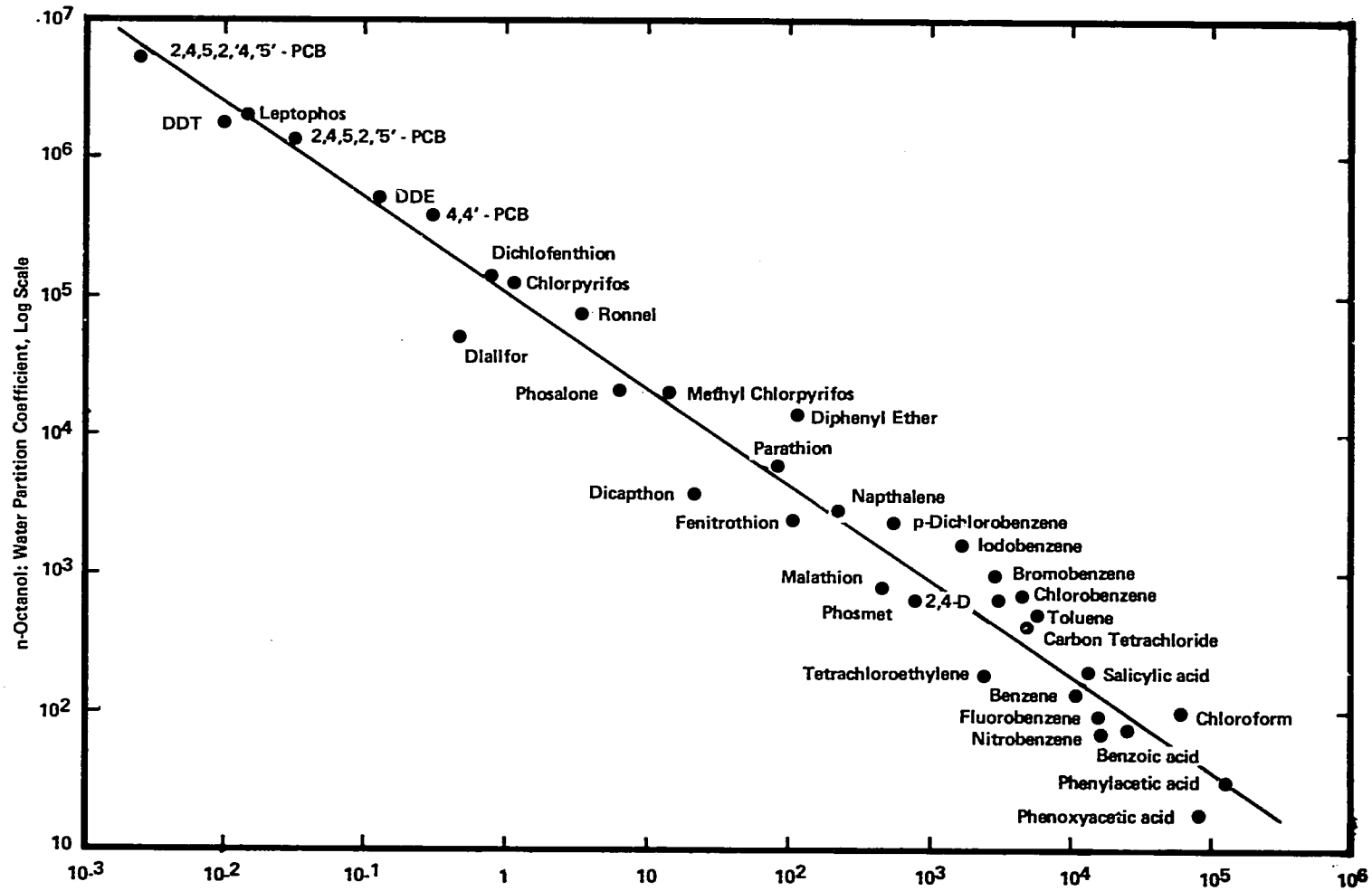


Fig. 3. Solubility In Water And n-Octane/Water Partition Coefficient of Selected Compounds

Table 1 Relationship of solubilities and bioconcentration

Compound	Solubility in Water (ppm)	Bioconcentration Factor
Carbon tetrachloride	800	17
Tetrachloroethylene	400 (25°)	39
p-Dichlorobenzene	79 (25°)	230
Diphenyl ether	21 (25°)	200
2, 4, 2', 4' - PCB	0.065-0.070	12,300

Table 2 Solubilities and Partition Coefficients of Various Compounds

Compound	Solubility in Water (ppm)	Log (n-Octanol/H_2O Partition Coefficient)
Benzene	820 (22°C)[a]	2.13[d]
Toluene	470 (16°)[a]	2.69[d]
Fluorobenzene	1540 (30°)[a]	2.27[d]
Chlorobenzene	448 (30°)[a]	2.84[d]
Bromobenzene	446 (30°)[a]	2.99[d]
Iodobenzene	340 (30°)[a]	3.25[e]
p-Dichlorobenzene	79 (25°)[a]	3.38[b]
Naphthalene	30[a]	3.37[c]
Diphenyl ether	21 (25°)[b]	4.20[b]
Tetrachloroethylene	400 (25°)[b]	2.60[b]
Chloroform	7950 (25°)[b]	1.97[f]
Carbon tetrachloride	800[a]	2.64[g]
p,p'-DDT	0.0031[i] - 0.0034[j]	6.19[h]
p,p'-DDE	0.040 (20°)	5.69[h]
Benzoic acide	2700 (18°)[a]	1.87[d]
Salicylic acid	1800 (20°)[a]	2.26[f]
Phenylacetic acid	16600 (20°)[a]	1.41[d]
Phenoxyacetic acid	12000 (10°)[a]	1.26[d]
2,4-D	890 (25°)[b]	2.81[d]
2,4,5,2',5'-PCB	0.010 (24°)	6.11
2,4,5,2',4',5'-PCB	0.00095 (24°)	6.72
4,4'-PCB	0.062 (20°)	4.30
Phosalone	2.12 (20°)	4.30
Methyl Chlorpyrifos	4.76 (20°)	4.31

[a]Handbook of Chemistry and Physics, 34th Ed., Chemical Rubber Pub. Co.

[b]Kenaga, E.E., Partitioning and Uptake in Biological Systems, In Env. Dynamics of Pesticides, Plenum Press, New York, 1975.

[c]Hansch, C., and T. Fujita, J. Am. Chem. Soc. 86:1616 (1964).

[d]Fujita, R., J. Iwasa, and C. Hansch, J. Am. Chem. Soc. 86:51775 (1964).

[e]Leo, A., C. Hansch, D. Elkins, Chem. Rev., 71:525 (1971).

[f]Hansch, C., S. Anderson, J. Org. Chem., 32:2583 (1967).

[g]Macy, R., J. Ind. Hyg. Toxicol. 30:140 (1948).

[h]O'Brien, R.D., "Environmental Dynamics of Pesticides", p. 336, R. Haque and V.H. Freed (eds.), Plenum Press, New York (1975).

[i]Bowman, M.C., F. Acree, Jr., M.K. Corbett, J. Agr. Food Chem., 8(5):406 (1960).

[j]Biggar, J.W., G.R. Dutt, R.L. Riggs, Bull. Environ. Contam. Toxicol. 2(2):90 (1967).

Table 3 Solubilities and Partition Coefficient (Octanol/Water) of Organophosphates

Compound	Solubility in water (ppm)	log P[1]
Phosmet	miscible	2.83
Fenitrothion	30	3.38
Dicapthon	62.5	3.58
Parathion	11.9	3.81
Phosalone	2.15	4.30
Methyl Chlropyrifos	4.76	4.31
Dialifor	0.18	4.69
Ronnel	1.08	4.88
Chlropyrifos	0.4	5.11
Dichlofenthion	0.245	5.14
Leptophos	0.0047	6.31

(1) P = Partition Coefficient.

Table 4 Processes and Molecular Properties in Relation to Biological Activity

Site	Process	Molecular Properties Implicated
Environment	Transport	Solubility Vapor pressure ΔH (solution)
	Interaction	Partition Coefficient Molar Polarization Dimensions & Spatial Geometry Reactivity Photochemical Hydrolysis Oxidation/Reduction Complexation
Boundary of Organism	Interaction	Dipole, Van der Waal, and Chemical Binding Reactivity
	Passage Through	Partial molar volume Fugacity Symmetry/size Partition Coefficient
Inter- and Intracellular	Transport	Solubility/Partitioning Polarizability Dipole Differsivity Molal volumes
	Interaction	Dimension/Geometry Bond energies/reactivity Composition
"Active Site"	Interaction	Hydrogen bonding, polarizability, Partition Coefficient Reactivity/bond energies "activation" Covalent bonds Size, geometry, orientation, dimension between bonding sites, exclusion volume

PART II

TOXICOLOGIC AND HUMAN HEALTH CONSIDERATIONS OF PESTICIDES AND THEIR LIMITATIONS TO USE

1. INTRODUCTION

Consideration of the toxicological aspects of pesticides and their limitations to use are greatly simplified if one has a background understanding of the methods of human pesticide exposure and the related health outcomes.

2. CATEGORIES OF HUMAN PESTICIDE EXPOSURE

Modern pesticides and pest management practices result in three categories of different exposure situations, each with different outcomes. The three categories of exposure are: acute, chronic high (occupational), and chronic low (incidental exposure), producing a wide range of different health outcomes, some of which are summarized in Figure 1. With single and excessive exposures, the outcome will be either a systemic poisoning or a topical lesion frequently observed on the skin or in the eyes. Since today most acute intoxications are from organophosphate and carbamate insecticides, these systemic manifestations are cholinergic and are due to inhibition of acetylcholinesterase and the buildup of the neurotransmitter, acetylcholine, at the synaptic sites. In contrast, the topical effects are either the result of the irritancy of the chemical or have an allergic basis for their occurrence.

There are three routes of exposure from these cholinesterase pesticides. They are:

(i) Ingestion – the result of accidental, suicidal or homicidal attempts – absorption via this route usually causes the most serious illness;

(ii) Inhalation – this usually occurs in confined spaces and exposures have most frequently occurred when pesticide tanks and warehouses are being cleaned out or during a fire in a formulating plant or storage area;

(3) Dermal absorption – this is the most common route for occupational illness. Most worker poisonings are the result of dermal absorption and almost all can be prevented by the wearing of appropriate and acceptable protective clothing especially if this is changed frequently and is appropriately laundered.

The organophosphates and carbamate insecticides inhibit the enzyme cholinesterase. This enzyme normally terminates the action of acetylcholine which is the chemical transmitter for the following components of the nervous system:

1. The preganglionic neurons of the sympathetic and parasympathetic fibers;
2. The post-ganlionic parasympathetic fibers, and
3. The central nervous system.

When the enzyme cholinesterase is bound up in the body by the organophosphate insecticides acetylcholine builds up and predominately parasympathetic manifestations occur. These are called muscarinic effects and the organ involved, the effects seen, and the physical findings are shown in Table 1. Acetylcholine is also excreted at the skeletel nerve endings where it produces weakness and paralysis. These neuromuscular effects are called nicotinic effects. Acetylcholine is also the chemical mediator between the sympathetic nerve fibers and the sweat glands, which is why excessive sweating is commonly found in cholinergic poisoning.

Atropine sulphate which is the specific antidote for cholinergic poisoning, acts by blocking the effects of acetylcholine. Atropine, however, has no effect on the neuromuscular nerve endings. This is where the use of oximes, the second group of antidotes, are beneficial. The oximes break up the chemical binding between the pesticide and the cholinesterase enzyme, thus freeing

cholinesterase to terminate acetylcholine action at the neuromuscular junction. If given early, the paralytic effects, which in the case of respiratory muscles are life-threatening, are overcome.

3. TOXICITY OF INSECTICIDES

Insecticides vary greatly in their toxicity to man, from highly toxic materials such as paration and dieldrin, to relatively safe compounds such as methoxychlor and Abate. Hayes wrote, "The hazard of a given compound is the danger which it presents; the toxicity of a compound as its inherent ability to injure living organisms. Hazard may be measured only in relation to practical conditions, although it can be predicted to a considerable extent, from toxicity. Conversely, toxicity can be guessed from the results of accidents; toxicity can be measured only under standardized experimental conditions." (Haynes 1960).

The acute toxicity of a chemical may be measured as: (1) oral toxicity, the reaction following ingestion of the material by mouth; and (2) dermal toxicity, the reaction cause by absorption of the chemical through the skin or other tissues. Acute toxicity data are ordinarily obtained through experimentation with laboratory rats, monkeys and other mammals. A variety of chronic toxicity tests are used to estimate the risk of carcinogenicity, feto-toxicity, birth defects, mutagenicity and neurotoxicity. A variety of invivo and invitro tests are used as presumptive tests for mutagenicity and, if positive, for carcinogenic risk.

Acute toxicity is ordinarily measured in milligrams of the insecticide per kilogram of body weight of the test animal that produces a 50 percent mortality (LD50) in laboratory tests. Since a milligram is 1/1000 gram and a kilogram is 1,000 grams, the toxicity is actually expressed in parts per million. As the toxicity rating is based upon only the amount of basic insecticide in a mixture, it follows that the dilute insecticide creates a much smaller toxic hazard than the full strength concentrate.

4. TOXICITY VERSUS HAZARD

The hazard of a pesticide, or its potential for producing injury, depends on:

a) the inherent toxicity of the active ingredient,

b) the dose and/or concentration of the pesticide,

c) the physical and chemical properties of the material,

d) the route of absorption of the chemical, and

e) the duration of exposure.

The dose (amount) of pesticide taken into the body is the most important factor in determining the hazard of a chemical. A small amount of some pesticides may cause severe illness; large doses of others may be fairly harmless. Pesticide concentrates are the most hazardous form. People working with them are at the greatest risk of getting a harmful dose.

The physical and chemical properties of some pesticides make them more hazardous in certain situations. Parathion, for example, changes to a more toxic chemical (paraoxon) at high temperatures.

The duration of exposure helps determine the dose absorbed. Brief exposure to a concentrate could produce effects similar to longer exposure to the dilute pesticide.

5. HOW EXPOSURE OCCURS

There is some degree of hazard to each step of pesticide manufacture and use. Because they work with pesticide concentrates, workers in pesticide manufacturing and formulating plants are

in positions with a high potential hazard. Most manufacturing plants, however, use a closed system which does not expose the worker to the pesticide. Safe occupational practices and a good industrial hygiene program help to minimize the danger at both stages of pesticide production.

Health personnel are most likely to encounter pesticide poisonings in three main groups of people: applicators, pickers, and children. Each is clinically different and each must be recognized at once.

6. APPLICATOR POISONING

The hazard to applicators results from the dilution and application of the pesticide concentrate. Hazards exist, therefore, in both mixing and applying the pesticide. The toxicity and concentration of pesticides varies in different applicator situations. Every applicator, however, is at risk of exposure to varying degrees of pesticide concentrate, and therefore, is in danger of poisoning. The further down a person is in the chain of pesticide handling and use, the less training he usually has and the greater is his risk of poisoning.

Workers associated with aerial application of pesticides are especially highly exposed. It is unwise for a pilot to mix and load chemicals. The normal procedure is to employ aircraft loaders and mixers. They dilute the material and load the aircraft before each run. This is done on the airstrip with fixed-wing aircraft. Helicopters are often loaded from an accompanying trailer at the scene of application. Loaders are one of the most highly exposed occupational groups in the entire spraying process.

7. PICKER POISONING

Once a pesticide has been diluted to its final concentration and is applied to the crop, the pesticide residue remaining on the fruit and leaves becomes a new source of exposure. The concentrations of these residues are high at first. They decline with time as a result of biodegradation and exposure to light. The rate of dissipation of foliar residues varies considerably with different pesticides and with different concentrations of pesticides. Weather factors also affect the rate of dissipation. Rain removes pesticides more rapidly, and the high temperatures favor the changing of some pesticides to more toxic forms.

Too early a re-entry to a treated site creates a hazard for the worker. The worker is at risk during the process of thinning and harvesting the crop.

The type of human illness is sometimes called "picker poisoning." It occurs most frequently with exposure to plants with large leaf surfaces as citrus, peaches, grapes and tobacco.

Cotton is a crop with a large surface, but it is almost entirely machine harvested in the United States, so that residue is not a serious threat with this crop. This is not the case, however, for Central America, where hand harvesting is still practised and hundreds of cases of "picker poisoning" have been reported. Because pesticide poisoning from residues may be milder, it may be overlooked in the health clinic. Health personnel should take special care to be on the lookout for this syndrome with people working in high-exposure groups, especially when the weather is hot.

A nurse may be confronted by a picker who has been picking beans or citrus or working in a field with high foliar crops and suddenly becomes dizzy, develops a headache and becomes progressively weak. He would probably complain of sweating profusely. She may soon find that other members of the crew have developed the same symptoms and are waiting outside the clinic or have gone to another doctor. The clue is that residue poisoning cases are: (1) usually multiple, (2) mild, and (3) require only small doses of antidotes.

8. CHILD POISONINGS

Children are the group at the greatest risk of accidental poisoning from pesticides which have not been stored or disposed of properly. Prompt action is especially important in these poisonings. The nurse must always be on the lookout for these dire emergencies. In this type of case, the nurse is usually confronted with a very sick child who is semi-comatose, vomiting profusely, and has diarrhea and pinpoint pupils.

The child is the most frequent victim and although recent U.S. Environmental Protection Agency legislation on child packaging requirements for pesticides should help prevent this type of poisoning most cases give a history that the child acquired the poison because the pesticides, particularly the concentrate, were placed and stored in unlabelled bottles and jars, and were within easy reach of the child.

9. FIRST AID MEASURES

The essentials of treatment are: 1) removal from exposure, 2) decontamination, 3) hospitalization, 4) oxygenation and 5) antidotal therapy. It will be clear from what already has been said that speed is of the utmost importance in serious organophosphate poisoning. The victim must be removed from further exposure, stripped if the exposure has been dermal, the ambulance called, and the patient should be thoroughly washed with soap and water. If there appears to be some difficulty in breathing a search for dentures should be made and removed from the mouth with a finger. The chin should be kept forward to prevent the tongue from slipping back and likewise, the head turned to the side so that vomitus is not aspirated. If oxygen is available, it should be administered and the patient should be removed to the hospital as soon as possible.

If the symptoms suggest cholinergic poisoning the patient should be accompanied to the hospital and never sent there alone. If the pesticides has gotten into the eyes, these should be irrigated for 15 minutes in clean water.

The question has often been asked, "Should employers or workers carry atropine?" Workers should not carry atropine. Oral atropine has no place in a real poisoning emergency. The dose is much too small, and the victim cannot take oral medication if he is vomiting or stuporous. The most that atropine tablets can do is temporarily mask or delay early symptoms of poisoning, which can be deterimental in two ways. The victim may go back to work and thereby sustain further exposure, or if he is taken to a physician who is unaware that atropine has been administered, he may fail to recognize that pesticide poisoning has occurred. In California, a young worker died of phosphate ester poisoning several hours after he complained to his employer that he was ill. The employer sent him back to work when his condition temporarily improved after giving him 2 atropine tablets. Two atropine tablets are not very toxic to an adult, but they do give a false sense of security; they delay or prevent medical treatment, and they cause neglect of important first aid measures. Atropine and 2-PAM should never be taken as prophylactic measures; they will not prevent poisoning.

10. MANAGEMENT AND TREATMENT OF ACUTE ORGANOPHOSPHATE POISONING

This type of poisoning presents the primary care physician with a potential life-threatening situation, the outcome of which is largely dependent upon the early diagnosis and the prompt and vigorous administration of the appropriate antidotal regimen. Cholinergic illness can mimic a variety of commonly occurring conditions such as stroke, gastro-enteritis, pneumonia, diabetic coma, epilepsy and other causes of coma. Diagnosis should be made on clinical lines for time does not permit waiting for confirmatory laboratory analysis. The essential features of organophosphate intoxication are described in the manual attached. Other chemical groups of insecticides which are of medical toxicological significance are the organochlorine pesticides, the bipyridil herbicides and miscellaneous groups of other pesticides. The essential clinical features are also discussed in the attached manual.

11. CHRONIC EXPOSURES

With chronic and sustained exposures, such as occurs with occupational pesticide exposures, the populations at risk are those who may receive repetitive exposures during the manufacture, formulation, mixing, application or disposal of pesticides, and those whose exposure is acquired in the field from foliar and soil residues during the picking and thinning of fruits, vegetables or cotton. The outcome can be any one of a variety of different diseases which have been described in most organs of the body.

Over the last decade, however, numerous epidemiologic studies, chiefly case control but also including some retrospective cohort studies, have demonstrated causal relationships of occupational exposures to individual pesticides, with a wide variety of diseases ranging in diversity and severity from chloracne to cancer. Thus, both hypertension and hyperlipoproteinemia in pesticide workers were positively associated with elevated serum organochlorline levels (Carlson and Kolmodin Hedman 1972). Soft tissue sarcomas and histocytic lymphomas with phenoxy acetic acide and chlorophenol in Swedish railroad workers, neurologic and behavioral abnormalities with occupational exposures to chlordecone (KeponeR), delayed neurotoxicity with leptophos (PhosvelR) (Hardell and Sanstrom 1978, Taylor et al 1976, Xintaras et al 1978), and male sterility with dibromochloropropane (DBCP) (Shafik et al 1973) have been described.

12. INCIDENTAL EXPOSURE

With the small chronic incidental exposure that the public sustains from trace amounts of pesticide residues in the air, food, water, and housedust of our 20th Century environment, disease is not usually an outcome but rather a pollution profile or a pesticide exposure profile is acquired. These are the chemical expressions of incidental exposures to the several persistent and non-persistent pesticides and their metabolites, and they are traditionally measured in serum, fat, urine or breast milk.

Findings such as these have prompted the recognition of the adverse health potential of chronic as well as acute pesticide exposures, and the need for additional research on human exposure assessment itself, and the efficacy of exposure reduction modalities.

13. TOXICOLOGICAL CONCERNS FOR QUANTITATIVE ESTIMATES OF EXPOSURE

Toxicology has been defined as "the qualitative and especially the quantitative study of the injurious effects of chemical and physical agents, as observed in the alterations of structure and response in living systems; it includes the application of the findings of these studies to the evaluation of safety and to the prevention of injury to man and all useful forms of life."

Toxicology is concerned with untoward effects, but the toxicologist must base his judgements on a broad understanding of medicine. He must know the range of normal in order to identify correctly the abnormal. He must consider intended use in "judging what is adverse." The dosage response relationship is of such importance that it must be considered a part of the definition of toxicology. In fact, it is mainly this principle that is signified by the word "quantitative" in the definition above. In the case of pesticides, a variety of exposure assessments have been used to quantify this.

14. TOXICOLOGICAL CONCERNS FOR EXPOSURE ASSESSMENT

The recognition that the diseases associated with pesticide exposure is greatly simplified when the pesticide exposure is single, can be readily measured, when the life-style characteristics of the exposed are known and when the induction period of the disease in question is relatively short. Some epidemiological considerations which are specifically concerned with exposure assessment and reduction studies include:

a. Precision of exposure estimates.

b. Mixed versus single exposures.

c. Biological indices to exposure — Urinary metabolites

a) **Precision** — The Spectrum of Exposure Assessments — In the past, epidemiologists working in the field of pesticide epidemiology have had to use exposure instruments whose precision and specificity has varied enormously. Thus, at one extreme disease outcomes have been related to pesticide exposures measured in terms of occupational categories, geographical differences (e.g., urban vs. rural), temporal differences, the use of surrogate pesticide exposures and person years of the worker in the pesticide industry. At the other end of the spectrum, pesticide exposure has been quantified on the basis of very precise estimates based upon what is known of the pharmacokinetics of the pesticide in man or total dose estimated, based on the summation of exposures in the immediate environment of the subject acquired as a result of his occupation and home environment, which includes estimates of incidental exposure from food, air, water, and even from the proverbial flea collar on the household pet. A variety of circumstances, many of which are uncontrollable, would influence the selection of exposure instruments to be used in the epidemiologic study. Sometimes one has to go along with very broad descriptive estimates of exposure, as was the case with Kepone where attack rates by job categories exhibited a dose effect of this pesticide; these are perfectly satisfactory when the exposure is to a single pesticide.

In the broad area of environmental epidemiology, Sarracci (1978) pointed out that "suspect illness due to environmental factors should be assessed as to possible causal realtionships to an environmental insult based on a biological index of exposure rather than on crude proxy indicators." Pesticide exposure means different things to different people. When precision and specificity are the issues of concern, exposure which is based upon the absolute laboratory quantification of the chemical in and/or excreted by the exposed individual, or which can be measured in the immediate ambient environment of the study subject, offers the most unequivocal approach for validating the individual's pesticide exposure.

In the case of pesticide epidemiology, the quantitation of the residue stored or excreted from the body may represent the sort of biologic index to which Sarracci (1978) is referring, though utility of these indices with the exception of DDE and certain other lipophilic pesticides is of limited value for the epidemiologic study of long induction time diseases. In the case of single pesticide exposure studies, however, and as expressions of exposure for the study of short induction time diseases, these biologic indices are powerful estimates of exposure.

b) **Mixed Exposure Situations** — Etiologic association of disease with chemicals is relativley simple when the exposure is single, as is often the case in pesticide manufacturing. Much more complex is the assessment of a specific pesticide etiology when exposures are multiple. Chemicals interact with one another in a very complex fashion with some potentiating each other in their mixture, and others inhibiting one another. Thus, DDT and dieldrin are strong liver microsomal enzyme inducers whereas malathion and piperonyl butoxide are liver microsomal enzyme inhibitors. In these mixed exposure situations the validation of exposure by metabolite screeing often provide specificity and quantitation of the more significant ingredients of the mixture.

c) **Biologic Indices of Exposure** — Urinary Metabolites. Examples of some of the biological indices of exposure which have been used in epidemiologic studies are shown in Table 2. They have both clinical and epidemiologic significance and since the urinary metabolites are the most recent to be used only these will be discussed in more detail.

The urinary metabolites have long been recognized as useful sources of pesticide exposure estimates in the worker, the poisoned victim and the incidental exposure sustained by the population at large. Surveillance of the parathion worker was one of the earliest examples; the data were highly reliable and the findings endorsed this approach for the study of human parathion exposures. Since then, several reports of occupational health studies of pesticide workers by metabolite surveillance have been published.

The development of practical analytical methodologies for both the alkyl phosphates and phenolic metabolites by Shafik et al (1973 (a) and (b)) have accelerated exposure assessments for both the organophosphate and carbamate insecticides. Two types of metabolites are identified; these are the alkyl phosphate and phenolic metabolites and both are excreted rapidly in the urine following exposure. The major urinary alkyl phosphate metabolites which can be identified following human exposure to organophosphate insecticides are: DMTP and DEP (diethylphosphate). For malathion the mono-acid and di-acid metabolites are the major urinary

metabolites and superior to the alkyl phosphates which are the minor metabolites.

15. LIMITATIONS AS TO USE

We have attempted to provide a concise overview of the chemical nature of pesticides, their classification and uses in modern agriculture and public health.

We have also tried to review some of the very real and potential human and environmental hazards which can arise as a result of their indiscriminate use in pesticide programs.

Smith (1976) has defined pesticide management as "technology concerned with the safe, efficient and economic use and handling of pesticides from time of manufacture to the final utilization and disposal. Included in this process are formulation, packaging transfer, storage, official registration, labelling for use and sale, selection for use, application and the disposal of containers and unwanted materials. In addition, pesticide management is concerned with the problem of residues in food and in the environment and the total impact of these on man."

Such a broad definition implies responsibility for safety within the domain of several different organizational groups. The groups concerned have the in-country responsibilities for importation, in-country production, formulation, distribution, application and disposal. The limitations for use within an individual country are dependent upon multiple considerations. The first step in responding to these needs must surely be the development of an interdisciplinary pesticide advisory group. This group would be charged with advising the government as to importation regulations which are best for the local conditions. It would ensure an importation policy which meets the needs of both agriculture and public health, and which recognizes the capabilities of training the pesticide infrastructure.

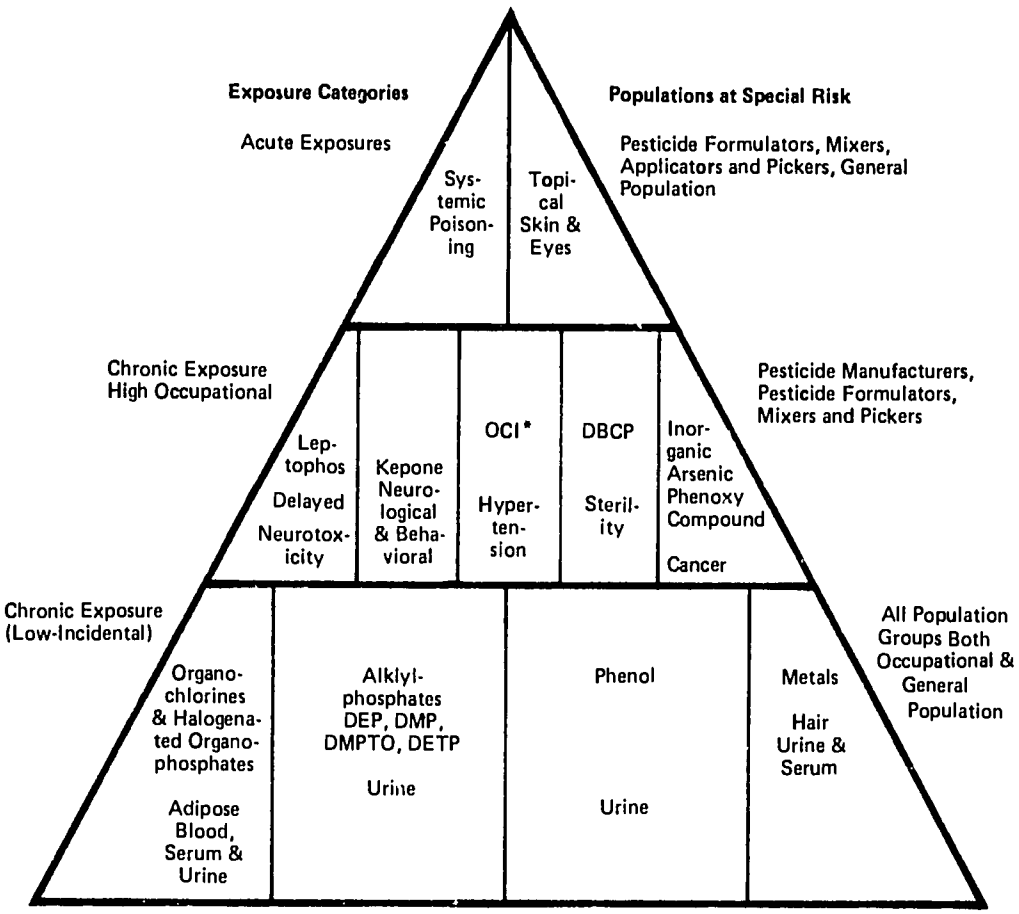
If one looks at the policies which some Third World countries have already utilized with regard to importation of pesticides, the final decisions have ranged from programs which have been almost completely supportive upon the agricultural needs for pesticides, to the other end of the spectrum wherein acute pesticide toxicity and hazard for man and the environment have been the over-riding constraints and limitations for pesticide use.

In the latter situations, the acute oral and dermal toxicity has been the major consideration for use. Little consideration has been given in importation decisions for the growing concern or to the significance of chronic exposure and the environmental impact of persistent pesticides.

Another limitation for use rests in the area of training and understanding the necessary ingredients necessary for health and environmental protection in all the areas described by Dr. Smith in his definition of pesticide management.

Much needs to be done in all parts of the world in these areas and in the philosophies of integrated pest control. Almost certainly it is this recognition of these several unmet needs for safe pesticide management which has prompted this Caribbean conference in order that we may collectively have a simultaneous look at pests and pest management problems.

Figure 1 Categories of Pesticide Exposure and Related Health Effects



*Organochlorine insecticides

Table 1 Muscarinic Effects caused by Anticholinesterase Poisoning

Organ	Effects	Physical Findings
Eyes — Pupil	Constricted	Miosis
Ciliary Muscle	Stimulated	Blurred Vision
Glands — Lacrimal	Stimulated	Tearing
Salivary	"	Salivation
Gastric	"	Increased Secretions
Heart — Muscle	Slow Rate	Bradycardia
Lungs — Bronchi	Constricted	Bronchospasm
Intestines — Lumen	Stimulated	Increased Peristalsis
Sphincters	Relaxation	Evacuation
Bladder — Detrusor Muscle	Stimulated	Increased Peristalsis
Trigone	Inhibition	Evacuation

Table 2 Biological Indices of Pesticide Exposure

TYPES	USES
Cholinesterase Determinations	Verification of Cholinergic Illnesses and Monitoring of the Worker's Exposure to Organophosphate Pesticides
Skin and Hair Residues	Verification of Exposures to Trace Metals (Hg, Arsenic)
Urinary Metabolites (Alkyl Phosphate and Phenols)	Verification of Exposure to the Organophosphate and Carbamate Insecticides and Confirmation of Acute, Chronic, and Incidental Exposures
Adipose and Serum Pesticide Residues	Verification of Acute, Chronic and Incidental Exposures to the Organochlorine Pesticides Verification of Acute and Chronic Exposures to Certain Lipophylic Organophosphate Pesticides

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CONTENTS

	Page
ACKNOWLEDGEMENTS	157
INTRODUCTION	158
CHAPTER I – Pesticides	159
CHAPTER II – Pesticide Hazards and How Exposure Occurs	163
CHAPTER III – Systemic Organophosphate and Carbamate Poisoning	168
CHAPTER IV – Miscellaneous Poisonings	175
CHAPTER V – Topical Effects	179
CHAPTER VI – Pesticide Epidemiology	181
CHAPTER VII – Methods of Prevention	184
CHAPTER VIII – Acute Pesticide Poisoning Verification	186
Appendix 1 Pesticide List	188
Appendix 2 Toxicity	195
Appendix 3 Screening Test	198
Appendix 4 Laboratory Methods	199
Appendix 5 Chemtree	201
Appendix 6 Communications Check List	204
Appendix 7 Notification Locations	205
Appendix 8 Reporting Form	207

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INTRODUCTION

This manual is for all health personnel involved in the prevention, recognition, and treatment of pesticide poisoning. However, the information should be of particular interest to nurses[1], especially those working in rural clinics, hospital emergency rooms, and departments of public health. They are the personnel most intimately involved with the care of patients suffering from pesticide poisoning.

Nurses are concerned not only with treatment, but also with prevention. If they understand the nature and use of pesticides, they can work with their public health personnel and community health workers toward the development of safety measures. They can contribute to improved case finding and the followup of illness due to pesticide exposure. They are also ideally suited to educate agricultural workers and their families.

2

In the primary care setting nurses in the clinic are in a strategic position to recognize cases early and to rapidly implement necessary treatment measures. In this situation, therefore, they must know the signs and symptoms of pesticide poisoning, and the emergency room measures which save lives and decrease morbidity.

In the intensive care unit, the nurse's ability to recognize the reappearance of cholinesterase signs or to detect evidence of atropine excesses can significantly contribute to the successful management of this medical emergency.

Ambulance attendants and other health personnel also need this information so they can begin the rapid treatment which is necessary for lifesaving before the patient arrives at the hospital.

There is an urgent need for accurate and verified data on acute pesticide poisonings. Present reporting is incomplete, and the potential of the laboratory to verify possible pesticide illness is poorly understood. This book describes the steps necessary to confirm suspected pesticide illnesses.

This book deals mainly with two major types of pesticide illness:

- acute systemic poisoning
  - severe
  - mild
- topical (local) effects
  - eyes
  - skin.

Actual case examples of pesticide poisoning are used to illustrate:

- the essential diagnostic and management needs of the patient, and
- the potential of the laboratory in verifying the event.

[1]There is no intention by the author to stereotype by sex any health personnel or workers. To avoid a cumbersome text, the words "he" and "she" have been used interchangeably.

CHAPTER I

PESTICIDES

What Are Pesticides?

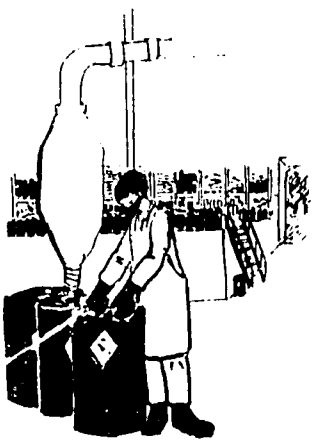
Pesticides are a diverse group of chemicals which have been developed to kill, prevent, or suppress a wide variety of pests. Six of the most common types are:

- insecticides (insects)
- herbicides (weeds)
- fungicides (fungi)
- molluscicides (snails and slugs)
- nematicides (nematodes)
- rodenticides (rodents).

Others include miticides (mites), defoliants (remove unwanted plant growth), repellants (keep pests away), attractants (lure pests), and plant growth regulators (stop, speed up, or otherwise change normal plant processes).

The essential component of a pesticide is the active ingredient. This is the material that actually controls the pest. It is produced in a manufacturing plant.

Following manufacture, the active ingredient usually goes to a formulating plant, where it is mixed with other chemicals and a carrier for effective delivery. These are the inert ingredients. They may include such materials as tales, oils, kerosene, and binding agents (to increase adherence).

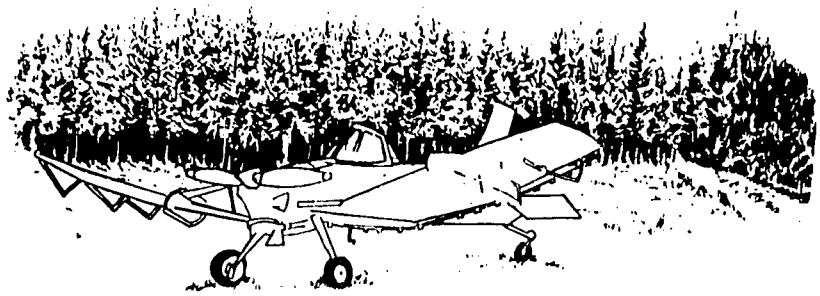


These formulated products are sold in many forms, the most common of which are liquids, wettable powders, granules, and dusts. Each form is available in several concentrations.

From the formulating plant, the products move to a wide variety of users, including farmers, commercial pesticide applicators, and the general public.

Application is by various types of ground equipment, hand equipment, or aircraft. It is estimated that aircraft supply about 65 percent of all pesticides used by agriculture.

3



Registration

More than 1 billion pounds of pesticides are produced each year in the United States. Before any pesticide product can be sold, the manufacturer must register it with the Environmental Protection Agency (EPA). The manufacturer must provide EPA the results of many kinds of tests on the product before it can be registered.

Labeling

EPA requires certain information to be on every pesticide label. Much of this information can be of help to health personnel in diagnosis and treatment of pesticide poisonings. When you know or suspect that a pesticide is involved in an illness, try to get the product label or a copy of it as soon as possible.

Information which must be on a pesticide label includes:

- brand name
- common name (simplified chemical name)
- active ingredients (chemical or common name, plus percent of the contents they make up)
- inert ingredients (need not be named, but label must tell what percent of contents they make up)
- net contents
- name and address of manufacturer
- registration number (shows that the product has been registered with EPA)
- establishment number (identifies the factory which made the product)
- signal words (one of the following)

Signal Words	Toxicity	Approximate amount needed to kill the average person
DANGER	Highly toxic	a taste to a teaspoonful
WARNING	Moderately toxic	a teaspoonful to a tablespoonful
CAUTION	Low toxicity or Comparatively free from danger	an ounce to more than a pint
All products must bear the statement "Keep out of reach of children."		

- skull and crossbones (must appear, with the word "poison", on all highly toxic materials)
- hazards to humans and animals (includes ways in which the product may be poisonous and protective equipment needed)
- environmental hazards
- physical and chemical hazards (special fire, chemical, or explosion hazards)
- statement of practical treatment (emergency first aid measures and information for physicians on the treatment of poisoning)
- statement of use classification (tells whether the pesticide is restricted to use by certified applicators)
- directions for use (may include reentry times, storage and disposal instructions).

Chemical Groups and Mode of Action

Because most pesticides kill unwanted organisms, they are obviously toxic materials. Their mode of action depends on the chemical group to which they belong. The five major chemical groups are:

- organophosphates and carbamates
- organochlorines
- nitro and chloro phenols
- anticoagulants
- bipyridyls.

The *organophosphate and carbamate* group is the greatest public health problem. It contains many widely used insecticides. In the United States, severe organophosphate poisoning results more often from ethyl parathion and phosdrin. Carbamates commonly used include carbaryl (Sevin), propoxur (Baygon), and methomyl (Lannate or Nudrin).

Organophosphates and carbamates inhibit the enzyme cholinesterase (ChE). This inhibition causes a buildup of acetylcholine in the body. Acetylcholine is the primary chemical transmitter for:

- the preganglionic neurons of the sympathetic and parasympathetic fibers
- the postganglionic parasympathetic fibers
- the central nervous system.

These nerve fibers are called cholinergic fibers. Anticholinesterase poisoning causes parasympathetic effects in the organs they supply. Some of these *muscarinic effects* are shown in the following table.

Organ	Effects	Physical Findings
Eyes - Pupil Ciliary Muscle	Constricted Stimulated	Miosis Blurred Vision
Glands - Lacrimal Salivary Gastric	Stimulated Stimulated Stimulated	Tearing Salivation Increased Secretions
Heart - Muscle	Slow Rate	Bradycardia
Lungs - Bronchi	Constricted	Bronchospasm
Intestines - Lumen Sphincters	Stimulated Relaxation	Increased Peristalsis Evacuation
Bladder - Detrusor muscle Trigone	Stimulated Inhibition	Increased Peristalsis Evacuation

6

Acetylcholine is also secreted at the skeletal nerve endings, where, in excess, it produces weakness and paralysis. These neuromuscular effects are called *nicotinic effects*. Acetylcholine is also the chemical mediator between the sympathetic nerve fibers and the sweat glands. This is the reason for excessive sweating in poisonings with these cholinergic chemicals.

Atropine is the specific antidote for cholinergic poisoning. It blocks the effects of acetylcholine. Atropine has no effect on the neuromuscular nerve endings, however. This is where the oxime drugs are beneficial. They break up the chemical binding between the pesticide and the cholinesterase enzymes. This frees cholinesterase to stop the acetylcholine action at the neuromuscular junction and thus end the paralytic effects. Oximes are contraindicated, however, in cases of carbamate poisoning.

The effects of this group of chemicals are both systemic and topical. If there is a topical eye exposure, the effects are those of topical effects of acetylcholine on the eye:

- the pupils are constricted
- the ciliary muscles are stimulated, causing blurring of vision and an eyebrow headache.

The *organochlorine* pesticides are powerful nervous system stimulators, but their modes of action are not completely known. These chemicals are soluble in fat, accumulate in the human body, and are very persistent in the environment. Most uses of these pesticides (such as DDT, aldrin, dieldrin) are prohibited in the United States, so acute poisonings are not frequent. Systemic poisonings occur most often with endrin, which is one of the most toxic members of this group.

The *nitro and chloro phenols* are strong metabolic stimulators causing increased metabolism and hyperthermia. These are widely used as fungicides and herbicides.

The *anticoagulants* are rodenticides, such as Warfarin. They produce their effects by inhibiting prothrombin and causing capillary damage.

The *bipyridyls* include paraquat and diquat, which are widely used in agriculture for weed control and defoliation. These chemicals produce proliferative changes in a variety of tissues.

CHAPTER II
PESTICIDE HAZARDS AND HOW EXPOSURE OCCURS

Hazards of Pesticide Use

The hazard of a pesticide its potential for producing injury depends on:

- the inherent toxicity of the active ingredient (see Appendix 2)
- the dose and/or concentration of the pesticide
- the physical and chemical properties of the material
- the route of absorption of the chemical
- the duration of exposure.

The *dose* (amount) of pesticide taken into the body is the most important factor in determining the hazard of a chemical. A small amount of some pesticides may cause severe illness; large doses of others may be fairly harmless. Pesticide concentrates are the most hazardous form. Persons working with them are at the greatest risk of getting a harmful dose.

The *physical and chemical properties* of some pesticides make them more hazardous in certain situations. Parathion, for example, changes to a more toxic chemical (paraoxon) at high temperatures.

The three possible *routes of absorption* are:

- ingestion–the result of accidents or suicide or homicide attempts; usually causes the most serious effects.
- inhalation–occurs mainly in confined spaces (warehouses, pesticide tanks); usually causes less serious effects than ingestion.
- dermal absorption–most common method of occupational exposure; causes the least severe effects.

The *duration of exposure* helps determine the dose absorbed. Brief exposure to a concentrate could produce effects similar to longer exposure to the dilute pesticide.

How Exposure Occurs

There is some degree of hazard at each step of pesticide manufacture and use. Because they work with pesticide concentrates, workers in pesticide manufacturing and formulating plants are in positions with a high potential hazard. Most manufacturing plants, however, use a closed system which does not expose the workers to the pesticide. Safe occupational practices and good industrial hygiene help to minimize the danger at both these stages of pesticide production.

Health personnel are most likely to encounter pesticide poisonings in three main groups of people:

- applicators
- pickers
- children.

Each is clinically different and each must be recognized at once.

Applicator Poisoning

The hazard to applicators results from the dilution and application of the pesticide concentrate. Hazards exist, therefore, in both mixing and applying the pesticide. The toxicity and concentration of pesticides varies in different applicator situations. Every applicator, however, is at risk of exposure to varying degrees of pesticide concentrate, and therefore is in danger of poisoning. The further down a person is in the chain of pesticide handling and use, the less training he usually has and the greater is his risk of poisoning.

Workers associated with the aerial application of pesticides are especially highly exposed.

It is unwise for a pilot to mix and load chemicals. The normal procedure is to employ aircraft loaders and swampers. They dilute the material and load the aircraft before each run. This is done on the airstrip with fixed wing aircraft. Helicopters are often loaded from an accompanying trailer at the scene of application. Loaders are one of the most highly exposed occupational groups in the entire application process.

8

An example of applicator poisoning was Tony B., who was employed as a pesticide mixer and loader for a fixed-wing crop dusting firm. He had started loading the aircraft at 6 a.m. with a mixture of parathion 6-3 and toxaphene. Rubber gloves were the only protective clothing worn, and he was a heavy smoker.

He soon began to feel unwell. He was admitted at 11:35 a.m. to the emergency room of a local hospital. He complained of nausea, vomiting, weakness, and blurring of vision. His pupils were constricted and there was profuse perspiration.

A screening cholinesterase test revealed severe inhibition. After being put in a shower and scrubbed all over, he was given a total of 12 mg of atropine intravenously in the emergency room over a brief period of time. The oxime 2-PAM was also administered in a one gram dose in 1,000 cc of D5W. Atropine therapy was continued after his transfer to the medical ward and he proceeded to improve over the next few days.

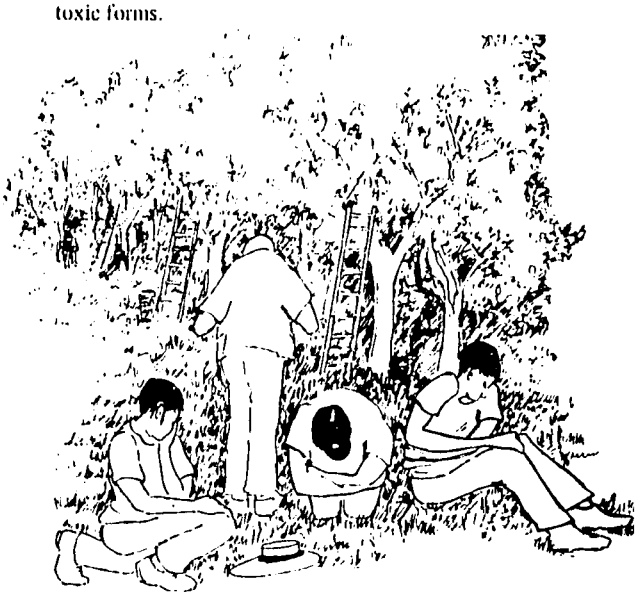
Subsequent blood and urine metabolite studies by the laboratory confirmed that the poisoning was due to an exposure to ethyl and methyl-parathion.

The special lessons of this case are:

- the illness was severe
- no protective clothing was worn
- there was no positive history of an accidental spill
- only one applicator was affected.

Picker Poisoning

Once a pesticide has been diluted to its final concentration and is applied to the crop, the pesticide residue remaining on the fruit and leaves becomes a new source of exposure. The concentrations of these residues are high at first. They decline with time as a result of biodegradation and exposure to light. The rate of dissipation of foliar residues varies considerably with different pesticides and with different concentrations of pesticides. Weather factors also affect the rate of dissipation. Rain removes pesticides more rapidly, and high temperatures favor the changing of some pesticides to more toxic forms.



Too early a reentry to a treated site creates a hazard for the worker. The worker is at risk during the process of thinning and harvesting the crop.

One type of pesticide worker who is at special risk of intoxication is called a "scout." This person goes into the fields regularly to count the number of pests on the plants. Since the job often involves going into the field shortly after application, there is a special risk of residue intoxication.

This type of human illness is sometimes called "picker poisoning." It occurs most frequently with exposures to plants with large leaf surfaces such as citrus, peaches, grapes and tobacco.

Cotton is a crop with a large leaf surface, but it is almost entirely machine-harvested in the United States, so that except for scouts residue poisoning is not a serious threat with this crop. This is not the case, however, for Central America, where hand harvesting is still practiced and hundreds of cases of "picker poisoning" have been reported.

Because pesticide poisoning from re[illegible] may be milder, it may be overlooked [illegible] health clinic. Health personnel sh[illegible] take special care to be on the lookout for this syndrome with people working in high-exposure crops, especially when the weather is hot.

A nurse may be confronted by a picker who was picking beans or citrus or working in a field with high foliar crops and suddenly became dizzy, developed a headache, and became progressively weak. He would probably complain of sweating profusely. She may soon find that other members of the crew have developed the same symptoms and are waiting outside the clinic or have gone to another doctor.

The clue is that residue poisoning cases:

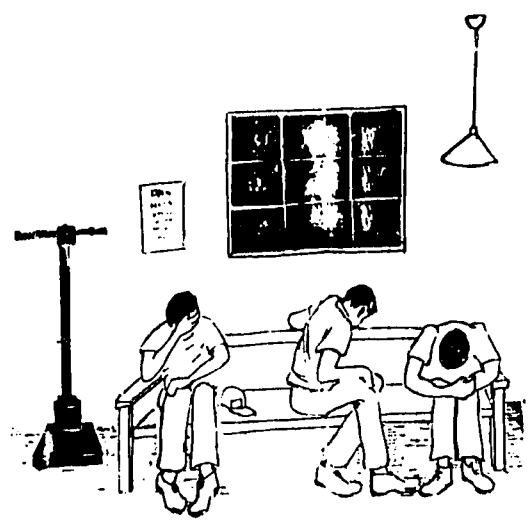
- are usually multiple
- are mild
- require only small doses of antidotes.

The following outbreak is a typical example:

An emergency room nurse had three patients with mild symptoms resembling those seen in organophosphate poisonings.

Three other patients were in the waiting room with similar symptoms, and four more were on their way to the hospital. All were weak, sweating and complaining of abdominal cramps, nausea, and vomiting. Some had difficulty with breathing. Others had diarrhea as well as vomiting. Most had miotic pupils.

By the end of the evening, 10 of a crew of 17 migrant workers who had been detasseling corn that morning had been admitted to the hospital. They received atropine intravenously and were beginning to respond after decontamination and intravenous fluids.



The epidemic was clearly due to an anticholinesterase pesticide, a fact that was later confirmed when 64 mg of a carbamate insecticide called methomyl was identified from a methylene chloride extraction from the shirt of one of the exposed victims.

At 7 a.m. they had entered a cornfield where an airplane had sprayed the field with methomyl. Their clothes and canvas shoes had become moistened from the dew on the ground and from the moisture on the leaves.

Child Poisonings

Children are the group at the greatest risk of accidental poisoning from pesticides which have not been stored or disposed of properly. Prompt action is especially important in these poisonings.

The nurse must always be on the lookout for these dire emergencies. In this type of case, the nurse is usually confronted with a *very sick* child who is semicomatose, vomiting profusely, and has diarrhea and pinpoint pupils. For example:

A 4-1/2-year-old boy who was playing in his grandfather's barn spilled some liquid over his pants at about 1 p.m. When he returned home at 6 p.m. he was not feeling well and he looked pale and listless. He was put to bed. At 9 p.m., his parents noted that he was drowsy and that his respirations were labored. His father rushed him from his home to the emergency room of a nearby hospital. His mother checked his clothes and noticed they had an insecticide smell. The grandfather checked the barn and found a bottle of ethyl parathion.

By the time the boy reached the emergency room, he was moribund, in deep coma with his eyes rolled back, and barely breathing. His respirations soon ceased and he had to be kept alive by artificial respiration and endotracheal intubation. When the mother reported that parathion had been spilled on the child, he was stripped, washed all over, and oxygenated. Atropine was administered intravenously every 10 minutes through the night, and 2-PAM was given. By 5:30 a.m. he was much improved and continued to recover over the next 2 days.

Here, the point is that exposure might not be recognized. Children get extremely ill very rapidly and treatment must be prompt and vigorous.

There is a high incidence of pica among migrant families. This is a situation where the ingestion of a pesticide might not be realized. Geophagia is not uncommon.

A 3-year-old child was taken to a local migrant clinic with extreme miosis, foaming at the mouth and nose, and diffuse rales throughout both lung fields. An exposure history revealed that the child had been playing in a strawberry field which had been heavily treated within the last three days with phosdrin, Kelthane, and parathion. Pesticide analyses showed total inhibition of cholinesterase. Parathion was identified in the gastric content. It was later determined that the intoxication was the result of ingestion of soil containing parathion.

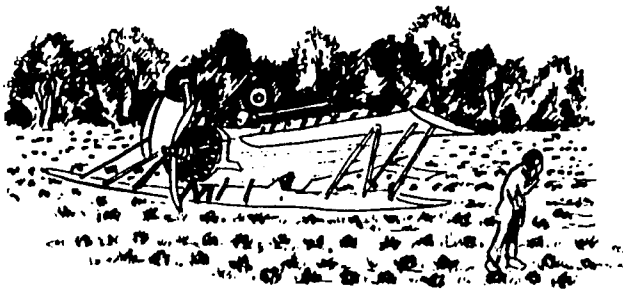
This case illustrates the point that children eat dirt—which is not commonly recognized. It exemplifies the real possibility of this mechanism of poisoning when a toddler is playing in the fields where the mother is working.

Emergency Personnel

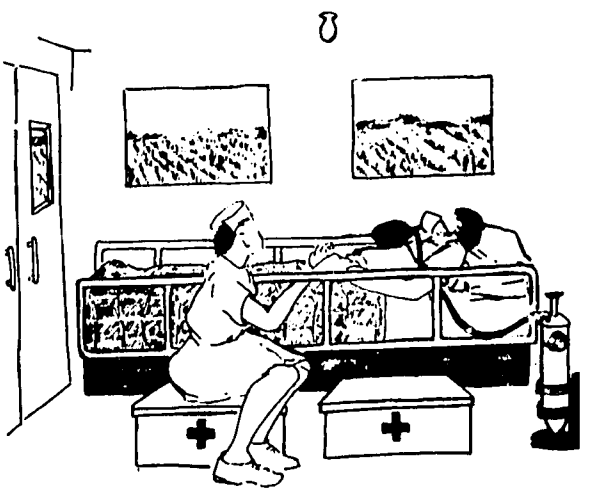
In a rural area, the emergency personnel in the ambulance can expect to encounter anticholinesterase poisonings. Recognition and early treatment are of vital importance.

A migrant worker might fall off a ladder while picking citrus which had been treated with parathion. His pesticide exposure might not be recognized while the patient is being transported to the hospital, particularly if he appears dazed. The diagnosis may be clouded by other evidence of trauma which he may have sustained during his fall. The questions which should be asked are, "Why did the worker fall?" and, "Was the fall due to pesticides?"

Pesticide poisoning might also go unrecognized in a pilot who has had an aircraft accident. The possibility of injury is likely to be of greater concern than the possibility of chemical intoxication which may have been the result of a spill before, during, or after the accident. It is essential to evaluate whether the pilot has sustained a serious pesticide exposure. If the exposure is allowed to pass unrecognized, it could cost him his life.



Emergency personnel who are transporting suspected cases to the hospital should always be in radio contact with the hospital. The patient's condition might suddenly deteriorate in transit, requiring immediate therapy. If the physician is alerted ahead of time, he can communicate with the emergency personnel to prescribe whatever is necessary.



CHAPTER III

SYSTEMIC ORGANOPHOSPHATE AND CARBAMATE POISONING

Symptoms and Signs

Symptoms and signs of systemic organophosphate and carbamate poisonings are almost entirely due to cholinergic manifestations. They include both muscarinic and nicotinic effects and are the result of acetylcholine accumulation.

Early symptoms depend on the route of absorption and the severity of the intoxication.

- Gastric symptoms appear earlier if the material has been ingested.
- Shortness of breath, salivation, and excessive bronchial secretions occur if the material has been inhaled.
- With dermal exposure, gastrointestinal and respiratory symptoms appear at the same time.
- In children, a convulsion may be the first symptom.
- In serious intoxication, both muscarinic and nicotinic symptoms and signs begin shortly after exposure.

12

Muscarinic effects, which usually precede nicotinic effects, include:

- anorexia
- nausea
- vomiting
- abdominal cramps
- diarrhea
- involuntary defecation and urination
- sweating
- salivation
- lacrimation
- pain in the chest
- excessive bronchial secretions
- blurring of vision due to miosis.

Nicotinic effects include:

- muscle twitching
- fasciculations
- weakness
- flaccid paralysis.

With involvement of the muscles of respiration, further respiratory failure occurs from bronchial constriction, blockage by secretions, and depression of the respiratory center.

Central nervous signs and symptoms include anxiety, restlessness, giddiness, headache, drowsiness, convulsions, and coma.

In the advanced state, the patient is pale, sweating, and frothing at the mouth. The pupils usually are miotic and non-responsive to light. Pupils will sometimes be dilated if the patient is in extremis. They will then become miotic with initial treatment.

The most important neurological findings are:

- Fasciculations—localized and generalized involuntary twitching may be elicited by tapping the muscles over the cheekbone, over the thorax, or on the arms.
- Sometimes generalized clonic seizures may be observed The plantar reflex is extensor and electroencephalographic changes may be noted.
- Miosis—the pupil is small, usually less than 5 mm. The diameter of the pupil in millimeters should be recorded.

Metabolic signs and symptoms include the following:

- Blood sugar may be elevated at first, and glycosuria may be observed. The level of hyperglycemia is much less than levels observed with diabetic coma. Ketoacidosis is not seen.
- Serum electrolytes are usually normal, though hypokalemia may occur and be aggravated by diuretic therapy. Serum K levels should be checked early.
- Fever is not a constant finding. The patient's temperature usually is normal or subnormal, though severe dehydration may occasionally cause fever.
- Polymorphonuclear leukocytosis is common.

Clinical Diagnosis

In severe poisoning, the initial diagnosis and institution of appropriate treatment must be made on clinical grounds alone, since there is not enough time to wait for confirmatory laboratory results.

The most important factors in the clinical diagnosis of organophosphate poisoning are:

- a pesticide exposure history
- symptoms and signs typical of an anticholinesterase illness
- the presence of atropine refractoriness.

Pesticide Exposure History

The first prerequisite to diagnosis is to determine whether the patient has been exposed to any of the anticholinesterase pesticides. Symptoms begin shortly after exposure. They are seen especially early after ingestion or inhalation.

With few exceptions the patient will begin to feel ill within 15 minutes to an hour after ingestion.

If a patient has ingested a pesticide, this is usually known or admitted, except in the case of a toddler. Ingestion of a pesticide as a result of pica might not be realized.

Dermal exposure may be obvious and the patient may recall spilling the pesticide on his skin and clothing. On the other hand, he may not be aware that pesticides can be absorbed in this way. He may not mention that his shirt, pants, or shoes were wet from the pesticide or from moist residue on leaves. In arid areas, dermal exposure occurs from dry, dusty residues on the leaves of the plant and there is no sensation of wetness. In all suspected cases, however, diagnosis is materially helped if the attending health personnel are made aware that the patient has sustained a pesticide exposure. Use the exposure history form in Appendix 8.

Symptoms and Signs

Symptoms and signs compatible with cholinergic excess are the second most important variables contributing to the clinical diagnosis of anticholinesterase poisoning.

Although symptoms of cholinergic poisoning may be easily confused with those of other conditions, a pesticide cause should always be considered. Physical signs are less subject to misinterpretation. Miosis is a rare condition in the clinic setting. It should always lead to first consideration of exposure to anticholinesterase pesticides. Miosis is doubly significant if it is accompanied by nicotinic and muscarinic symptoms and muscle fasciculations. These signs, together with the general appearance of the patient, should prompt the nurse and the physician to a diagnosis of organophosphate poisoning.

Atropine Refractoriness

This is the third important clinical observation which helps substantiate the diagnosis of an anticholinesterase illness. When a physician prescribes a larger than normal dose of atropine in a person *not* exposed to anticholinesterase pesticides, the early signs of atropine toxicity soon become apparent. These signs include:

- dry mouth
- flushed skin
- increased heart rate
- dilated pupils.

If the patient has anticholinesterase poisoning, large doses of atropine are required to produce these normal reactions.

Differential Diagnosis

Mild anticholinesterase poisoning causes such symptoms as:

- headache
- fatigue
- dizziness
- blurred vision
- excessive sweating
- nausea and vomiting
- stomach cramps
- diarrhea
- salivation.

These symptoms are shared by many illnesses not related to pesticides, such as influenza, heat stroke or heat exhaustion, and gastroenteritis.

Moderately severe poisoning causes all of the symptoms found in mild poisoning, but in addition, the patient:

- is unable to walk
- often complains of chest discomfort and tightness
- exhibits marked miosis
- exhibits muscle twitching.

These symptoms might be reasonably mistaken for such conditions as pneumonia, myocardial infarction, and encephalitis.

Severe poisoning results in:

- unconsciousness
- local or generalized seizures
- the manifestation of a florid cholinergic crisis.

In these cases, several alternative causes of coma enter into the differential diagnosis.

If there is glycosuria, diabetic coma might be considered. The miosis might lead to consideration of a cerebrovascular accident, particularly a pontine hemorrhage.

Screening Tests

At all three levels of clinical severity, a screening cholinesterase test can help confirm a cholinergic poisoning diagnosis. These are colorimetric procedures using filter paper impregnated with a color reagent which is sensitive to pH change. The time taken for the color to change is a crude index of the degree of cholinesterase inhibition. The severity of inhibition is categorized as none, suspicious, or severe.

Although these tests have several limitations, they offer the most immediate confirmation which is within the laboratory expertise in any hospital or clinic. The Acholest test is the most reliable of the several available screening methods for plasma cholinesterase determinations. It can detect inhibition as low as 20 percent of plasma cholinesterase. The results correlate well with more quantitative procedures.

14

The test should be administered:

- to any patient who claims to have been exposed to a pesticide
- to any worker having regular and heavy pesticide exposure, such as spraying chemicals or loading aircraft (see Chapter VII–PREVENTION)
- to any patient complaining of three or more of the previously cited symptoms
- to any patient with any one of the following physical signs:
  –miosis (less than 5 mm in size)
  –muscle fasciculations
  –bronchial exudation
  –bradycardia (pulse rate of 50 or less per minute).

To prepare a blood sample for the Acholest or other qualitative screening test, collect 1 cc of blood in a *green stoppered* vacutainer tube (heparin-lined) and separate the plasma by centrifugation.

(See Appendix 3 for complete description of the test.)

No further laboratory confirmation is needed in the clinical setting.

Definitive verification and validation of the poisoning episode, however, calls for:

- quantitative measurements of the plasma and red cell cholinesterase
- specific analysis of the intact pesticide and/or urinary pesticide metabolites to help identify the specific offending pesticide.

Laboratory Diagnosis

Three types of laboratory investigations can help confirm a clinical diagnosis of cholinergic poisoning:

- cholinesterase determination
- urinary metabolite studies
- intact pesticide studies.

Cholinesterase Determination

The levels of cholinesterase in the red blood cells and in the plasma are used to confirm human poisoning. They correlate well with nervous system cholinesterase inhibition. It is believed that ChE values of 0.5 or less (Michel method) for either red blood cell or plasma represent abnormal depressions for most individuals.

The four laboratory techniques most commonly used for quantitative expressions of these enzyme activities are the electrometric (Michel), the titrimetric (pH stat), the colorimetric (Ellman) and gas chromatographic (Cranmer) methods (see Appendix 4).

In two instances, laboratory tests may not show low levels of cholinesterase enzymes, even though cholinergic poisoning is present. These are:

- overexposure to carbamate pesticides–With this group of chemicals, cholinesterase reactivation is rapid. In vitro reactivation often occurs before the blood reaches the laboratory. Normal red cell and plasma levels may be reported even in the presence of obvious cholinergic illness.
- red cell cholinesterase determinations made after the administration of 2-PAM–if this oxime is given early in the case, red cell cholinesterase reactivates rapidly, even in the presence of continued cholinergic symptoms.

Low plasma cholinesterase levels may sometimes be due to other causes including:

- liver diseases, malnutrition, hyperpyrexia, myocardial infarction, dermatomyositis
- after certain drugs
- as a result of genetically determined low plasma cholinesterase. This condition may lead to respiratory arrest after being anesthetized with succinylcholine. The defect occurs in about 3 percent of the population. Recognition of this defect is primarily of medico-legal importance. Special laboratory procedures permit differentiation of pesticide exposure from this phenotypic mechanism.

Low red blood cell cholinesterase is found:

- in paroxysmal hemoglobinuria
- in the newborn after complicated delivery
- with disseminated sclerosis.

Urinary Metabolite Studies

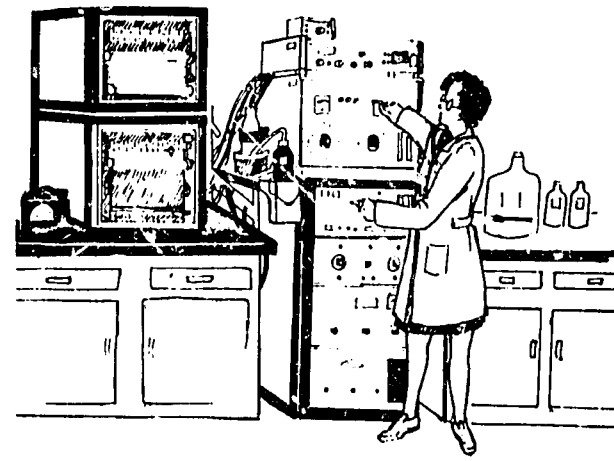
These breakdown products are excellent measures of exposure. Qualitatively they often provide valuable information on the exact type of pesticide which has caused the illness. Quantitatively, their concentrations in urine can be used as a measure of:

- the severity of the poisoning
- its probable duration.

The analysis of these breakdown products, therefore, is the second laboratory technique which will assist in the confirmation of the illness. (See Appendix 4)

Intact Pesticide Studies

The identification of the intact pesticide is the third way in which the laboratory can confirm an anticholinesterase pesticide poisoning. In the case of ingestion of the material, the intact pesticide can be identified by gas chromatographic studies of the gastric contents. In severe exposures, the intact pesticides may even be identified in the blood and other tissues. (See Appendix 4)



Collecting Specimens

Confirmatory tests must be done by a special pesticide analytical laboratory. When confirmatory tests are required, specimens should be handled in specific ways:

Blood—If the Acholest test is positive, collect an additional 8 cc of blood for definitive red blood cell and plasma cholinesterase determination. A 10 ml *green stoppered* vacutainer tube (heparin-lined) is the best method of collection. Invert the tube gently once or twice to insure proper mixing. Take care to avoid hemolysis. Label the tube to show:

- the name of the patient
- the time and date of collection,
- whether a sample was obtained before or after 2-PAM administration.

Cover the label with transparent tape.

Refrigerate (do not freeze) the tube before transferring it to the laboratory. If the specimen must be sent to another laboratory, it should be airshipped. Pack it with crushed ice in a styrofoam container.

Urine and other tissues—In cases of suspected organophosphate and carbamate poisonings, collect 20 ml of urine as soon as possible. Place the urine in a hexane-washed glass bottle with an aluminum foil lined metal screw top. The label should contain:

- patient identification
- the time and date of voiding.

Cover the label with transparent tape and close the lid securely. Freeze the bottle and its contents and airship it with the blood as soon as possible.

In special circumstances, other tissues may be collected for laboratory analysis. Handle them the same way as urine.

Gastric contents—Gastric washings should be labeled and frozen before sending to the laboratory. Collect the first washing for toxicological studies.

Treatment

The five basic steps in emergency treatment are:

- airway clearance
- oxygenation
- antidotal therapy
- decontamination, including gastric lavage
- collection of appropriate biological materials.

Time is of the utmost importance. The prompt action required in a serious intoxication, particularly with a child, is similar to that required by a patient with ventricular fibrillation with cardiac arrest.

What a nurse may or may not do in such circumstances depends on:

- her previous training and experience in the necessary resuscitative procedures
- whether there is a written protocol.

In both the rural health clinic and the emergency room, standing orders should be drawn up ahead of time to cover pesticide emergency situations. The nurse and physician should agree on procedures involved in all five of the steps of emergency treatment.

16

Airway Clearance and Oxygenation

Remove dentures and use a finger or, preferably, suction to clean mucus and debris from the mouth and pharynx. Introduce an oropharyngeal or nasopharyngeal airway, and administer 50 percent oxygen by mask or nasal catheter. Draw serial blood gases to monitor respiratory and metabolic dynamics.

Antidotal Therapy

Atropine–Atropine sulphate is lifesaving and should be given as soon as possible. It should not be withheld while efforts are being made to overcome any respiratory embarrassment.

The nurse should be instructed by protocol to administer atropine when the patient is first seen. Under no circumstances should such a patient be transferred to the emergency room without having had atropine therapy.

For an adult, the physician will order 2 to 4 mg of atropine sulphate intramuscularly or intravenously every 10 minutes during the early phase of treatment. Doses for children should be proportionate to weight–0.05 mg per kg of body weight.

The pulse rate, pupil size, and amount of bronchial exudate are important variables which influence the frequency of atropine administration. Large doses may be required. In a severe poisoning case, a man was unconscious for 14 days and required atropine continuously for 18 days. The therapeutic goals are to reach and maintain atropinization during the period of poisoning. Dilation of the pupils and a pulse rate of 140 per minute are the indications that atropinization has been reached.

With certain types of organophosphate pesticides, the intoxication period may be prolonged. The signs of cholinesterase inhibition reappear as the effects of atropine wear off. These periods may be followed by periods of atropine excesses with the pulse rate exceeding 140/min and the pupils becoming fully dilated. It is thus very important for the nurse to continuously monitor:

- the pulse rate
- the degree of bronchial secretions
- rate of respiration
- changes in pupil size.

This information helps the physician decide when it is necessary to readminister atropine or when there are signs of atropine toxicity. As recovery occurs, the intervals between atropine administration get longer until there is no further need to continue this treatment. When no further treatment is necessary, the patient should be observed in the hospital for another 24 hours.

Even if the poisoning appears mild and atropinization is reached after only a single dose, observe the patient for 24 hours. The atropine may have produced only temporary relief of symptoms in what may prove to be a serious case of poisoning.

Oxime–The only oxime available in the United States is N-Methyl 2 formylpyridinium oxime, used as the chloride (2 PAM-Cl) or Protopam Chloride. This should be available in any health clinic or emergency room likely to have to treat cholinergic poisonings. Give 2-PAM as early as possible and always in conjunction with atropine. The two drugs are complementary in their action.

The oximes are not recommended for use in cases of carbamate poisoning -in fact, they are contraindicated - but more research is needed in this area. Therefore, the physician faces a dilemma when it is not known whether the poisoning has been caused by an organophosphate or a carbamate. Make every possible effort immediately to find out the specific pesticide involved.

The oximes are not active against all, of the organophosphates. Depending upon the particular organophosphate, "aging" of the phosphorylated enzyme occurs, at which time the inhibited enzyme can no longer be reactivated by 2-PAM.

With parathion, aging does not occur for 2 days after exposure, so 2-PAM may be used up to that time. With malathion, aging is early. Effects of oxime therapy in this intoxication are generally disappointing.

The usual adult dose is 1 gm intravenously, preferably as an infusion in 250 ml of saline given over 30 minutes. If this is not practicable, give it in not less than 2 minutes. A second dose of 1 gm can be given in 1 hour. In children, 20 to 50 mg per kg is given intravenously in 250 ml of saline over 30 minutes.

If convulsions are troublesome, trimethadione or thiopental may be used. Respiratory embarrassment is usually due to excessive bronchial secretions rather than pulmonary edema. For this reason, opiates, aminophylline, reserpine, phenothiazine, tranquilizers, succinylcholine, and furosemide are contraindicated.

Decontamination

The first step should be to remove the patient from further exposure. Bring him out of the exposure area and try to limit further absorption of the pesticide.

The attendant should strip the patient and place all clothing in a plastic bag. The patient must be thoroughly washed. If he is conscious, place him in a shower and wash him all over with large amounts of soap and water. Be sure to rinse the hair thoroughly and remove any residue from under the nails.

Decontamination also includes the removal of the ingested pesticide. Vomiting should not be induced:

- in stuporous or unconscious patients, or
- if petroleum distillates are part of the pesticide formulation.

In these instances, or if there is doubt about what pesticide is involved, gastric lavage is preferable to the use of an emetic. Place the patient head down and on his side to avoid aspiration of vomitus. Wash out the stomach with large amounts of water.

The use of an esophageal obturator is the best way to avoid aspiration of stomach contents, if the nurse has had previous training in inserting the obturator.

Collection of Biological Materials

(See instructions in previous section, "Laboratory Diagnosis.")

Carbamate Poisoning

Carbamate pesticides, like the organophosphates, are powerful cholinesterase inhibitors. Special considerations in the diagnosis and treatment of carbamate poisonings include the following:

- Cholinesterase reactivates rapidly after carbamate poisoning. Laboratory cholinesterase determination tests may be misleading.
- Since blood tests may not be reliable, identification of the nonhalogenated phenols—the urinary metabolites of carbamates—becomes more significant.
- The oxime 2-PAM should not be used to treat carbamate intoxications.

Interprofessional Communication

A systemic pesticide poisoning involves a wide variety of health professionals. Good communication among these professionals is essential.

If the clinic nurse is the first point of patient contact, she should contact the attending physician as soon as possible, as well as the patient's next of kin and his employer.

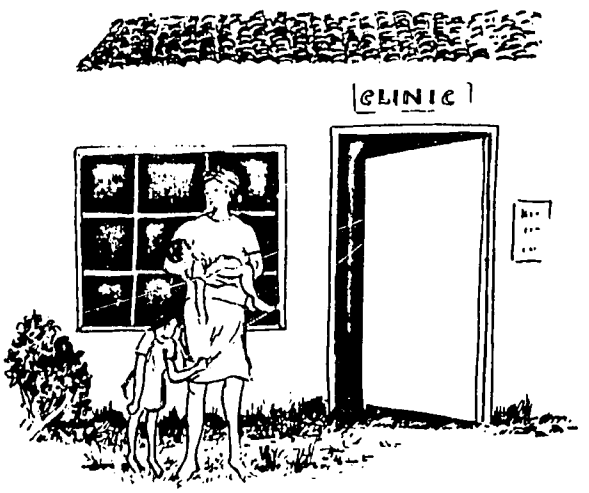
If the physician is not immediately available, the nurse will have to communicate with an ambulance service and the nearest hospital emergency room to arrange for the transfer of the patient. Meanwhile, she must begin emergency treatment to stabilize the patient's condition.

If there is an epidemic of poisonings, the

health department must be informed. These are usually "picker poisoning" incidents. If there is a massive chemical spill with a potential community hazard, the nurse should communicate with CHEMTREC (See Appendix 5).

If a sick child has been brought in from the home and the source of the pesticide has not been identified or removed, other children in the home may be at immediate risk of poisoning. The police should be contacted. The nurse should also contact the regional pesticide analytical laboratory for poisoning verification.

The implementation of these communication needs are best insured by working through a checklist of persons who should be contacted. This is shown in Appendix 6.



18

If the patient comes straight from the field or the home to the hospital, the emergency room nurse is primarily concerned with reporting significant changes in her patient's condition to the attending physician. She should contact the immediate family, employer, police, or health department if this has not already been done.

EMT personnel should be in constant radio contact with the emergency room while transporting the poisoned patient to the hospital. If the patient suddenly collapses, the attendant can apply the appropriate treatment while in transit.

The public health nurse or the community health worker will encounter special risk factors when investigating the scene of the accident. These must be reported to the employer or landowner and local health and environmental resources so that further poisonings can be prevented.

CHAPTER IV
MISCELLANEOUS POISONINGS

Organochlorine Insecticides

These pesticides:

- are soluble in fat
- build up in the human body
- are persistent (break down slowly and remain unchanged in the environment for a long time)
- are powerful nervous system stimulators. Organochlorine poisoning causes excitation. Convulsions are the most important symptom.

Applicator poisonings and residue intoxication are not common with these pesticides, since most of their uses are prohibited. Most systemic poisonings are caused by accidental oral ingestion of endrin.

Acute poisonings may be caused by the organochlorine pesticides which are no longer sold but still remain in some homes.

A 2-year-old boy was brought to the emergency room of a local hospital. On arrival, he had a convulsive seizure. The parents reported that the child had ingested an unknown amount of an insecticide. The child was hyperactive, ataxic, and unsteady. He fell down when he tried to walk. Pupils were 2 to 3 mm in size. There was no vomiting, sweating, or increased bronchial secretions. The chest was clear. He was given diphenylhydantoin and a large intravenous dose of phenobarbital. He was admitted to the Pediatric Intensive Care Unit for observation. Both heparinized and whole blood were collected. By the Michel method the RBC ChE was 0.69 Δph/hr, and the plasma ChE was 0.90 Δph/hr which are normal enzyme levels with this method. Blood tests for intact pesticide, however, identified dieldrin in a concentration of 407 ppb. This confirmed an organochlorine pesticide poisoning due to dieldrin.

Nursing care for organochlorine poisoning is the same as that for other convulsive disorders. There are no specific antidotes. Sodium phenobarbital and diphenylhydantoin are the drugs most often used to control the convulsive seizures. Trimethadione or thiopental may also be used.

Diagnosis can be confirmed by identifying the intact pesticide in the serum. In a case of suspected organochlorine pesticide poisoning, draw 10 cc into a *red stoppered* vacutainer tube. Label the sample and allow it to clot. Separate the serum and freeze it. If the specimen must be sent to another laboratory, it should be airshipped. Pack it with crushed ice in a styrofoam container.

Dieldrin seldom causes convulsions when blood levels are less than 200 ppb. With blood levels greater than 200 ppb, convulsive seizures may be seen. The worker should be taken off his work with levels of this magnitude.

Bipyridyls

Paraquat is more toxic than diquat and produces proliferative changes in the lung, cornea, lens, nasal mucosa, skin, and fingernails. Diquat affects the lens and gastrointestinal mucosa. It does not produce the lung changes characteristic of paraquat.

Except for eye lesion, illness due to occupational exposure is usually mild and is the result of topical exposure. Epistaxis occurs in workers following droplet inhalation. Conjunctival changes occur with accidental spills.

The clinical picture following accidental or suicidal ingestion is very different. Paraquat ingestions are frequently fatal. Their management is unsatisfactory and largely symptomatic. Three clinical stages follow ingestion of as little as an ounce of paraquat:

- The first is a gastrointestinal phase with burning in the mouth and throat, nausea, vomiting, and abdominal pain with diarrhea.
- Several days after exposure, signs of hepatic and renal toxicity appear. These are due to central zone necrosis in the liver and acute tubular necrosis of the kidney.
- Ten to 20 days after ingestion, progressive proliferative changes develop in the lungs. Hyperplastic changes in the terminal bronchioles occur with alveolar fibroblastic proliferation. Loss of lung surfactant has been demon-

strated. Within a few days, death from respiratory failure occurs.

Urine studies have indicated that 90 percent of the ingested paraquat is excreted in the first 24 hours. Delayed pulmonary effects appear to be the result of an irreversible process that develops long after the initial stimuli has gone.

Paraquat is poorly absorbed from the gut. Excretion data suggest that only 1 to 5 percent of the ingested material is absorbed in man. Maximal blood concentrations are reached within 4 to 6 hours after ingestion. Treatment, therefore, is primarily concerned with:

- decreasing the amount of paraquat absorbed
- perfusion of the circulating blood through charcoal columns.

Steps to decrease the amount of the paraquat absorbed include:

- gastric lavage with every precaution to avoid aspiration of gastric contents
- repeated administration of large amounts of adsorbents together with the administration of purgatives.

The ability of Bentonite, Fuller's earth and other clays to absorb bipyridyls has been studied. Fuller's earth was more effective than Bentonite. 500 ml. of a 30 percent suspension of Fuller's earth together with 5 percent magnesium sulphate should be administered after lavage.

Perfusion of the blood through charcoal columns has been advocated.[2] In addition to hemoperfusion, forced diuresis with Mannitol, hemodialysis, and corticosteroid and immunosuppresant therapy have also been recommended.[3]

Although steroids and alkaloids are given for pulmonary complications, no treatment has shown to be effective at this stage of the intoxication.

There is a simple urine test for paraquat that can provide presumptive evidence of paraquat poisonings in suspected cases exhibiting early symptomatology.[4]

[2]Smith, L.L., Wright, A., Wyatt, I., Rose, M.S. Brit. Med. J. 1974, (4):569.
[3]The Lancet Editorial, 1976, (1):1057.
[4]Goulding, R., Volans, G.N., Crome, P., Widdop, B. Brit. Med. J. 1976, (1):42.

Rodenticides

These are not particularly hazardous, but they are widely used. Children often accidentally ingest rodent tablets or baits—an event which leads to much anxiety, questions, and the need for reassurance.

Fumigants

Fumigants can present serious health hazards resulting in human illnesses and, occasionally, death. Methyl bromide, acrylonitrile, calcium cyanide, and carbon tetrachloride are the fumigants most likely to cause death if overexposure occurs. Others which can cause skin and eye injury and systemic illness include:

- sulfuryl fluoride (Vikane)
- 1,3 dichloropropene (Telone)
- 1,2 dibromo 3 chloropropane (Nemagon)
- ethylene dibromide
- formaldehyde
- chloropicrin
- phosphine
- sodium methyl dithiocarbamate (Vapam).

Methyl bromide is sold as a liquid under pressure. At atmospheric pressure, it vaporizes at 40°F to a colorless and odorless gas. Because of this property, methyl bromide should always be used in formulations which contain chloropicrin (tear gas), which serves as a warning agent. A worker who is exposed to enough of this mixture to cause tearing has also been exposed to dangerous quantities of methyl bromide.

Methyl bromide is absorbed through the lungs, skin, and mucous membranes. It can cause:

- acute poisoning, either topical or systemic, and
- chronic effects.

Acute Poisoning

Topical effects—Skin contact with the liquid or high concentrations of the vapor produces itching and prickling of the skin. This is followed by reddening and formation of vesicles and slow-healing blisters. Getting the liquid in the eyes may cause corneal ulceration.

Systemic poisoning—Symptoms usually develop 3 to 12 hours after inhalation of the vapor. Early symptoms include nausea, vomiting, dizziness, headache, blurring of

vision, and changing taste of food. These are followed by listlessness, weakness, staggering gait, and slurring of speech. In addition, the patient may complain of double vision and even temporary blindness.

In severe poisoning, the victim becomes comatose and has a high fever and respiratory embarrassment. Death is usually the result of either respiratory failure or cardiovascular collapse. Death is preceded by cyanosis, pulmonary edema, and renal failure. Muscle twitching and convulsion are not uncommon.

Chronic Effects

A papular pustular rash, not unlike acne, may develop on the face, arms, back, and chest. This is the result of repeated dermal exposures. All the symptoms and signs listed under acute effects may also appear as a result of chronic exposure. Fatigability and loss of appetite are frequent complaints. More severe chronic manifestations include a change of personality, a chronic central nervous system effect which may persist for years. Visual disturbances and locomotor impairment are common.

Treatment

First, quickly get the patient out of the contaminated atmosphere and remove all contaminated clothing. Methyl bromide can penetrate rubber gloves. Wash skin burns carefully with water. Administer a therapeutic trial with dimercaprol (BAL). If there is severe respiratory depression, give oxygen under positive pressure. Artificial respiration may be necessary. Keep the patient under observation for at least 48 hours after symptoms have subsided.

No simple laboratory tests are available for confirmation, but blood levels of bromine correlate well with the severity of the exposure.

Prevention

Methyl bromide must be applied by a closed-delivery system. All State and local requirements concerning the use of plastic sheets or tarpaulins must be followed. Guards and warning signs should be posted. The application should be done at a safe distance from inhabited structures, and under appropriate weather conditions. Animals and humans must be removed from the area to be treated.

Methyl bromide must be kept under lock except when the applicator or other responsible persons are present. The material should be stored in a cool, dry, well-ventilated building in order to avoid an explosion hazard and the possible buildup of toxic concentrations of vapors caused by leaking containers. The storage sites should be at a safe distance from populated areas and inhabited buildings.

Dinitrophenol and Pentachlorophenol

These materials are used as insecticide sprays, fungicides, and wood preservatives. They are rapidly absorbed by the gastrointestinal and respiratory tracts and the skin. They are profound stimulators, stimulating all the cells of the body by blocking oxidative phosphorylation. Body fat is the major, if not exclusive, fuel for this extra metabolism.[5] The body temperature becomes elevated and the breathing and heart rate increase rapidly. Because respiratory and cardiac stimulation do not accelerate in proportion to the increased metabolism, anoxia and acidosis develop rapidly.

Acute and Subacute Poisoning

The patient complains of marked fatigability, excessive thirst, and profuse sweating. His face is flushed. These are the result of the higher metabolic state, as is the exceptionally high fever, which may reach 110°F. The higher the fever, the more serious is the intoxication.

In such cases, tachycardia, hyperpnea, cyanosis, and muscle cramps will occur. Death, which is usually the result of respiratory or circulatory collapse, occurs within 24 hours.

In mild or subacute cases, most workers will complain of lassitude, headache, and malaise. Some, however, may have an alarming sense of excessive energy, drive, and hyperactivity. They should be warned of the dangers of overheating, because the metabolic activities of these compounds are exaggerated by heat.

[5] Shils, M.E. and Goldwater, L.J. Effect of diet on the susceptibility of the rat to poisoning by 2,4-dinitrotoluene. Arch Environ Health 8:262, 1953.

Treatment

The essential goals of treatment are:

- prompt elimination of the material and curtailment of all possible further sources of exposure,
- symptomatic treatment designed to control the high fever and its secondary consequences, such as anoxia, dehydration, and acidosis.

Gastric lavage with large amounts of sodium bicarbonate solution should be followed by saline catharsis using 15 to 30 grams of sodium or magnesium sulphate in water. To control the fever, use cold packs and alcohol sponges. Cold water enemas may be needed.

Supportive measures include:

- intravenous fluids to control dehydration and acidosis,
- oxygen and artificial respiration as required.

Following the acute phase of the intoxication, liver and renal complications may develop. These are the result of the toxic action of these materials on the renal tubules and on the liver cells.

22

Laboratory Confirmation

Laboratory confirmation of the intoxication is provided by the detection of high levels of dinitrophenols or pentachlorophenol in the urine and blood of the victim.

CHAPTER V
TOPICAL EFFECTS

Skin Problems Among Agricultural Workers

Skin problems accounted for 62 percent of all occupational diseases reported in the United States in 1973. The agricultural worker who is exposed to pesticides is four times more likely to develop a skin rash than the average industrial worker.

Diagnosis

Because the agricultural worker is exposed to a wide variety of agents besides pesticides, determining the cause of dermatitis is highly complex.

Dermatitis from pesticides can result from:

- exposure to primary irritants, or
- contact with contact sensitizers (allergens).

The first diagnostic consideration is to differentiate between these two types of skin rash.

Primary Irritants—Primary irritants are either absolute or relative.

Absolute irritants are usually chemicals which can cause a chemical burn or severe irritation on almost anyone's skin. The reaction occurs immediately or within an hour or so. It usually does not present a diagnostic problem.

Relative irritants are agents which can cause varying degrees of dermatitis (inflammation of the skin) according to environmental conditions. Some, like kerosene or turpentine, are more likely to cause problems on sweating skin, or under occlusive clothing and boots. All are more damaging to skin which is already abnormal (sunburn, eczema, and atopic dermatitis).

Some areas of the body are more susceptible than others. The genitalia, scrotum, and eyelids are particularly vulnerable. Thus, a worker might have dermatitis on the penis and eyelids due to contamination by materials on the hands.

The primary irritants usually produce a short term dermatitis which goes away and can be related to a known definite exposure.

The rash caused by primary irritants is more likely to be confined to the areas of the skin actually exposed to the chemical. Irritants in solution often are confined to the hands and the forearms, but relative irritants may be absorbed in clothing and boots. The rash will appear where the clothing is in closest contact with the skin—buttocks, knees, and dorsum of the feet.

Irritants dispersed in sprays or aerosols more often affect the face and neck. Powders tend to accumulate at the waistline, the collar, and tops of boots.

A primary irritant is likely to be the cause if several workers experience a rash on exposed surfaces at the same time, especially if burning or itching occurs soon after exposure. It is useful to ask the patient if he knows whether any other workers in the same area have the same problem.

When multiple cases of dermatitis follow the application of an agricultural chemical, the material or its carrier is clearly too irritating for continued use. The nurse should notify the physician as soon as possible.

Treatment—When the person is removed from further exposure, this type of dermatitis usually clears up, especially if a topical steroid cream is applied to the affected areas.

Contact Sensitizers-Substances which cause allergic contact dermatitis may affect only a few individuals who have become "sensitized" or "allergic" to the material. Even then, there may be marked differences between individuals in the degree of cutaneous reaction or severity of the clinical dermatitis.

A new product occasionally has a high potential for producing allergic skin conditions. These usually are soon recognized and taken off the market, but it is still worthwhile to ask whether a new product has been used. First reports of a hazardous substance often come from nurses or other medical personnel who are closest to actual field conditions.

Depending on the patient's sensitization, the reaction may occur within a few hours of contact to as long as a week. Most occur within 48 hours. Redness, itching, swelling (especially around the eyes), and "water blisters" are the clues to this type of dermatitis.

Having a basic knowledge of the principal sensitizers, reading the ingredients on the labels, or checking the Physicians' Desk Reference will often help in diagnosis. Plant dermatitis is common and must be considered as a cause of allergic contact dermatitis.

Some chemicals may be both primary irritants and contact sensitizers. In addition, many agricultural compounds are dissolved in solvents such as kerosene or xylene. This creates a perfect mechanism for both primary skin damage and an allergic reaction.

Treatment—The treatment of allergic contact dermatitis includes:

- using cool compresses
- treating infections
- identifying the offending agent.

It may be necessary to refer the patient to a facility which performs patch testing.

Topical steroid creams, gels, or lotions are beneficial. Severe or extensive cases may require a short course of systemic steroids. Systemic steroid therapy should always be under the direction of a physician. It should never be given to patients who may have undetected tuberculosis or are at risk of tuberculosis.

Apart from the highly specialized area of patch testing, the laboratory has no place in the verification of topical skin effects from pesticides.

The illnesses are often a sensitivity phenomenon and are therefore not strictly dose related. Cholinesterase determinations and urinary metabolite studies are not necessary.

Effects of Pesticides on the Eyes

Eye injuries are common in agricultural workers. Topical effects can occur as the result of exposure to any of the pesticides in common use today. In addition, xylene and petroleum distillates in common use as pesticide carriers are very irritating materials. They produce a severe inflammatory response when they get into the eyes.

Eye injuries can result from:

- accidentally splashing or spilling the material into the eye
- exposure to pesticide drift
- rubbing the eyes with contaminated hands.

Sulphur, paraquat, Omite, parathion, and dieldrin are some of the most common causes of eye injuries.

Eye injuries are most common in pesticide mixers, loaders, and applicators because of their risk of exposure to the pesticide concentrate.

Damage is the result of:

- a direct irritating effect of the chemical or the vehicle
- an allergic reaction
- direct pharmacologic action on the eye, as is the case with anticholinesterase pesticides.

Conjunctivitis, corneal ulceration, uveitis and lenticular opacities are some of the lesions which occur. These chemicals have a delayed effect on visual accommodation and diminish the peripheral fields of vision.

Treatment

If there is a conjunctival infection, irrigate the eyes from the inside to the outside with large amounts of water or sterile normal saline solution. After the eyes have been thoroughly irrigated, evert first the upper and then the lower lid and clean them with a moist cotton tip to remove any debris. Then irrigate the eyes once more. Apply an eye shield and make an appointment for the patient to see the attending physician for definitive diagnosis and treatment.

CHAPTER VI
PESTICIDE EPIDEMIOLOGY

The possible effects of pesticide exposure can be divided into three categories:

- acute exposure, which produces acute poisoning and topical injuries
- chronic high exposure, which is concerned with long term effects of pesticides
- chronic low exposure or incidental exposure, which is concerned with human pesticide residue and the public's concern for the possible risks of carcinogenesis.

Those at risk in the first category are:

- pesticide workers
- members of the general public who become accidentally poisoned in the home or garden.

In the second category is the occupationally exposed worker. The third category includes the general public, who are exposed to small amounts of pesticides in water, air, food, and clothing.

The nurse is primarily concerned with the first and second categories. She is most likely to encounter acute pesticide poisoning in the clinic and hospital. She has an important role in preventing both acute and unnecessary chronic exposure to the workers in the second category.

As an individual she is probably also concerned with the third level of exposure for her own and her community's sake.

Acute Poisonings

Acute pesticide poisonings are a serious health problem in many areas of the world. The World Health Organization estimates that there are approximately 500,000 cases annually, with about a 1 percent fatality rate.

No accurate statistics exist for the United States as a whole, but reports from selected populations suggest the size of the problem.

In California in 1975, there were 503 systemic pesticide poisonings in persons employed in agriculture. Some authors, however, believe that these reported statistics represent no more than 1 percent of the number.

Incidence data is equally incomplete in Florida, a state second only to California in the amount of pesticides used. Between 1970 and 1975, pesticides were listed as a

PESTICIDE EXPOSURES, HEALTH CONCERNS AND NURSING GOALS

Pesticide Dose	Types of Exposure	Health Concerns	Nursing Goals
High	Acute Overexposure	Pesticide Poisonings Topical Injuries (Skin and Eyes)	Prevention Early Diagnosis
Intermediate	Occupational	Occupational Safety	Industrial Hygiene Occupational Health Health Education Surveillance Safety Standards
Low	Incidental	Human and Environmental Pesticide Residues	Monitoring

cause of death in 26 persons in Florida.

- Ten deaths (35 percent) were children under the age of 10.
- Males accounted for 19 cases (73 percent).
- Fifteen ingested the toxicants (57 percent).
- Three inhaled the agent (11 percent).
- Two persons died from dermal contact.

These statistics, however, tell nothing of the occupational hazards of pesticides or why these materials were in the home. The total picture is still incomplete. Information on the acute morbidity of pesticides is of extreme importance, for it is only with this knowledge that decisions can be made on future pesticide management, policies, and regulations.

26

Applicator and Picker Poisoning

These two syndromes have distinct clinical, epidemiologic, and public health features.

Clinically, because residues are much less toxic than pesticide concentrates, picker poisoning is of shorter duration. Cases are often multiple and the case fatality rate is low.

Illness which is the result of exposure to the concentrate is usually more severe and protracted. The case fatality rate is high.

Epidemiologically, too, there are differences. Residue intoxications occur primarily in the agricultural worker and the migrant worker through dermal exposure to the foliar residues. In this situation, the worker is not aware of the potential hazard, because he does not know that the residues are there. Occasionally, exposure may occur when workers are accidentally sprayed or come in contact with pesticide drift.

The applicator, on the other hand, should be aware of the potential hazard of the chemical which he is applying or mixing. Such persons should be acquainted with the hazards of spills and should have been taught to wear protective clothing. They are generally more informed and better trained.

Applicator poisonings occur wherever application is done. Residue poisonings occur mainly in hot, arid areas.

Preventive strategies also differ. With residue poisoning the preventive goal is to make the place of work safe. The federal government has established reentry times for different pesticides. These are the time intervals which must elapse after a crop has been treated before it is safe for an agricultural worker to enter the field. The preventive approach is very different for applicators. It focuses on the preventive potential of worker education, personal hygiene, and the wearing of protective clothing. These are skills for which the nurse is ideally suited.

Child Poisoning

Children are the group at greatest risk of accidental poisoning from pesticides which have not been securely stored or correctly

disposed of, although adults, too, are at risk if chemicals are stored in improper bottles. The home, the garden, and the local refuse dump are often the scene for the other category of acute accidental pesticide poisoning. The toddler is the person at greatest risk.

When water is added to a pesticide, the liquid often becomes milky. If this is stored in a bottle, there is a real danger that the poison will be inadvertently given to a baby.

Incorrect disposal of pesticide containers causes many fatal cases.

> *A 2½-year-old Mexican child died after being sprayed with what seemed to be a harmless fluid in a simple spray gun. Her father, who could speak no English, could not understand the label on the container which he brought home from the field where he had been working. There were remnants of the pesticide concentrate at the bottom of the drum. He knew that the liquid was effective against the pests in the fields, so he told his 14-year-old daughter to spray the home because of heavy roach infestation. She did this, but tragically also sprayed her younger sister who was asleep in the crib.*

Transportation and storage also can be hazardous. If there is a large spill, such as might occur with a tanker collision or train crash, a highly dangerous situation can arise. In this event, a telephone call (collect) can be made to CHEMTREC, which is a special service to assist in such cases. A description of CHEMTREC service is in Appendix 5.

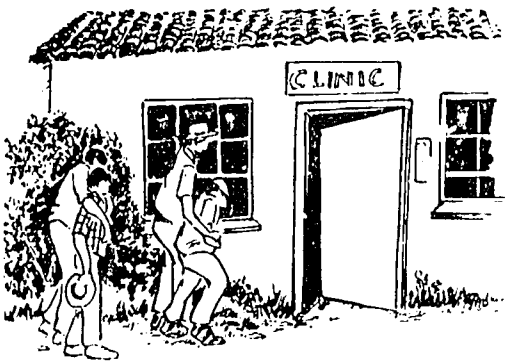
Careless unloading of pesticides can cause leaking containers. If these are stored in warehouses close to food, accidental contamination of food may occur. This is especially true during storms and floods. The general upkeep and waste disposal practices of the pesticide storehouse should be inspected regularly.

It is apparent that pesticide poisonings are a problem area for several agencies and institutions. A cooperative effort is needed to insure human safety through improved pesticide management.

CHAPTER VII
METHODS OF PREVENTION

The rural health clinic nurse and the public health nurse are in key positions to prevent pesticide poisoning.

These nurses are often the first to learn about a case. They are usually the first contact of the patient and his family. This gives them the opportunity to follow up the case.



28

The nurse can go to the site of the poisoning to try to retrace how the episode came about. She can visit the home to discuss safety and explain to the worker and his family how poisonings happen. Since other members of the camp will be interested, the nurse can use the incident as a teaching point.

She should also meet with crew chiefs and employers to promote pesticide safety. The nurse can meet with workers, employers, and even local government groups, civic clubs, and labor groups to explain how the occupational health hazards of the worker can be minimized with sound pesticide management. Her visibility at the place of work and in the home will facilitate her acceptance greatly. It also will allow her to see for herself the whole chain of pesticide formulation, application, and exposure.

Applicator Safety

The nurse should check for the correct use of protective clothing. She should find out whether goggles, masks, coveralls, rubber gloves and boots are provided and if they are in good repair. She should also watch for skin conditions in the workers. When abrasions in the skin occur through cuts or dermatitis, the skin loses its natural protective barrier and chemical absorption is greatly increased.

She should discuss with the operator such issues as the availability to the worker of showers at the end of the day and the opportunities for a wash and change of clothing.

She also should discuss procedures for rinsing and disposing of empty pesticide containers. Too often, they are left in the fields or are picked up and dumped into an empty lot or garbage pit, where they continue to present a poisoning potential.

She should make sure the employer knows the name of the nearest physician and hospital. She might leave her own card and tell him about the pesticide poisoning program at the clinic.

Routine cholinesterase testing is necessary for highly exposed workers such as formulators, spray rig operators, pilots, and aircraft mixers and loaders. The nurse and the employer should explore ways in which a program can be organized. Pre-employ-

ment cholinesterase determination can be built into the pre-employment physical examination.

It is customary to advise the withdrawal of the worker from continued anticholinesterase exposure if there is a 20 percent decline in these enzymes.

If a baseline level is not available, the worker should be temporarily changed to a job away from anticholinesterase pesticides if the red blood cell cholinesterase is less than 0.4 Δph/hr (Michel method).

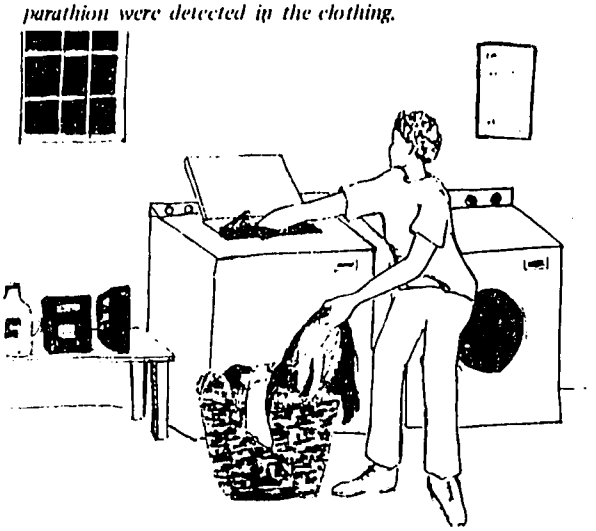
Picker Safety

In the education of the agricultural laborer whose pesticide risk is from plant residues, field reentry regulations are most important. In addition, the nurse can help the migrant worker understand the need for:

- changing clothing
- showering after work
- laundering the clothes correctly
- keeping contaminated clothes away from living areas
- washing hands and face before smoking or eating while working in treated fields.

Parathion has been identified in the house dust of workers' homes. This is probably due to the dusty residues dropping off the workers' clothing or shoes.

One worker was hospitalized with parathion poisoning. When he went back to work a few days later, he became sick a second time after putting the same clothes on again. High concentrations of parathion were detected in the clothing.



The nurse can discuss laundering with the worker's wife. The worker's clothing should be laundered separately and subjected to several washes. Laundering of contaminated fabric three times is not effective in removing all of the residues of some pesticides (such as parathion and toxaphene).

Child Safety

The nurse should inform families about correct storage of chemicals in the home. She also should warn them about taking the child into the fields. Often it is impossible to leave the child at home because there are no day nurseries nearby. If one is available and the mother agrees to use it, the risk that occurs from a child playing in the field while her father and mother are working would be removed.

One 5-year-old girl, for example, was hospitalized for organophosphate poisoning which she sustained while playing in the fields where her parents worked. She was poisoned as a result of eating tomatoes which had been treated earlier with phosdrin, methomyl, dimethioate and monocrotophos. The mother recognized the condition because five of her eight children had been hospitalized for parathion poisoning several years earlier.

CHAPTER VIII

ACUTE PESTICIDE POISONING VERIFICATION

Verification of acute pesticide poisonings has two aspects:

- the confirmation of diagnosis, using clinical and laboratory procedures, and
- collecting and tabulating data on confirmed pesticide poisonings to gain a fuller understanding of the problem.

Diagnosing a full-blown organophosphate illness usually poses no real problem. It appears, however, that many milder intoxications of agricultural laborers and migrant workers pass unrecognized or are not reported or satisfactorily investigated in the field. Even in the more obvious cases, laboratory confirmation is insufficiently practiced. The specific pesticide involved is rarely identified.

The verification and chemical confirmation of an acute pesticide poisoning is important to many people:

- The agricultural worker is interested, for within the process rests his assurance for just consideration and compensation for any job-related poisoning.
- Farmers are vitally interested in having safe products to use.
- Chemical manufacturers and formulators want to make a safe product and to insure that an alleged pesticide illness attributed to their product is correctly investigated and verified.

Jurisdictions, legislators, law enforcers, and insurance organizations are also served by verification of pesticide-related illnesses. The attending physician also has a professional interest, having often proceeded with vigorous treatment measures without initial laboratory confirmation.

Steps in Poisoning Verification

The four ingredients of poisoning verification are:

- a pesticide exposure history in which the symptoms complained of are compatible in time and with a known toxicity of a pesticide
- physical signs which reflect the known toxicity of the pesticide
- demonstration of significant red blood cell and plasma cholinesterase inhibition in acute organophosphate poisoning
- identification of the specific urinary pesticide metabolites and/or the intact pesticides in certain tissues of the body.

(See Chapter III for information on clinical and laboratory tests and instructions for collecting laboratory specimens.)

Many of the symptoms of acute pesticide poisoning are common to a wide variety of more frequently occurring illnesses not related to pesticides. Some of the diseases included in this list are influenza, gastroenteritis, heat exhaustion, diseases of the heart and lung, and central nervous system disorders. To distinguish mild or subacute cases of pesticide illnesses from these other conditions, an arbitrary and reasonable selection process is necessary. The following guidelines are suggested.

Apply a simple cholinesterase screening test such as the Acholest:

- to any patient who complains of having sustained a pesticide exposure
- to any worker having regular and heavy pesticide exposure
- to any patient who has three or more of the following symptoms: weakness, sweating, headache, nausea and vomiting, diarrhea, abdominal cramps, excessive tearing, salivation, bronchial secretions, shortness of breath, pains in the chest, blurring of vision, and convulsions
- to any patient with either miosis (less than 5 mm in size), muscle twitching or fasciculations, or clinical evidence of bronchial spasm or bronchial exudation
- to any patient with a pulse rate of 50 or less.

In the event of a convulsion, serum should not only be analyzed for cholinesterase inhibition but it should also be sent to a special pesticide analytical laboratory for electron capture and mass spectrometry gas chromatographic studies for organochlorine poisonings.

If the screening test is positive, the nursing and medical staff should be informed at once. The following additional steps are necessary:

- Collect 8 cc of blood in a heparinized tube for quantitation of red cell and plasma cholinesterase determinations.

- Collect 20 cc of urine for urinary pesticide studies.
- Ship both as soon as possible to a specialized pesticide analytical laboratory for more specific and precise analyses.
- Send a resume of the pertinent clinical findings and exposure history with the specimens. (Use form in Appendix 8.)
- Inform the local community health worker and public health nurse so that a field visit can be made as soon as possible.

Shipping and Notification

Even in the verification process, speed is of the utmost importance. Inform the special pesticide laboratory by telephone of the time of shipment and the expected time of arrival of the specimens and enclosures. The laboratory should complete the analyses quickly. Results should be communicated to the referral center first by telephone and then by written confirmation.

Farm worker clinics may send specimens, together with background information, to the appropriate laboratory as listed in Appendix 7.

Notice: Clinics forwarding specimens via air shipment should notify the laboratory via telephone so the shipment can be met at the airport. Flight number and date should be provided (if known) together with names and telephone numbers to be used in calling back results.

County hospitals, private clinics, industry health units and emergency rooms wishing to have samples analyzed may do so, if cost reimbursement conditions are acceptable.

If suspected cases of poisoning are being treated in rural areas distant from possible air connections to the verification laboratory, consult state departments of health or agriculture for nearby laboratory facilities which can provide blood and urine analyses.

Collection of Data

For administrative purposes, reports on pesticide poisoning should contain the following information:

1. Name of patient or patient identification number (Patient identification is needed so that followup studies can be done. Because this form is a medical record, the information will remain confidential.)
2. Sex and age of patient
3. Time and date of occurrence
4. Location of occurrence
5. Route of exposure
6. Symptoms and signs
7. Type of pesticide used:
   a) name (copy or original of label, if possible)
   b) active ingredients
   c) EPA registration number
8. Crop pesticide was applied to and target pest
9. Means by which pesticide was applied—plane, spray rig, etc.
10. Immediate first aid measures taken, medical attention provided
11. Any other facts which could be useful in analyzing the causes and effects of the poisoning.

To provide this information, duplicate the form in Appendix 8, fill it in, and furnish it with medical specimens to be analyzed. Locally used forms providing the above data may be substituted.

APPENDIX I

SELECTED CHOLINESTERASE-INHIBITING ORGANIC PHOSPHORUS PESTICIDES

Common or Trade Name	*Chemical Name*
Acephate	O,S-Dimethyl acetyl phosphoramidothioate
Acethion	O,O-Diethyl S-carboethoxymethyl phosphorodithioate
Acetoxon	O,O-Diethyl O-carboethoxymethyl phosphorothioate
Akton* or Axiom*	O,O-Diethyl O-(2-chloro-1-(2,5-dichlorophenyl) (vinyl) phosphorothioate
Alamos* or Azothoate* or Slam*	O-(p-chlorophenylazo) O,O-dimethyl phosphorothioate
Amidithion	O,O-Dimethyl-S-[[2-methoxyethyl) carbamoyl] methyl] phosphorodithioate
Amiton	O,O-Diethyl-S-(2-diethylamino) ethyl phosphorodithioate
Aphidan*	O,O-Diisopropyl-S-ethylsulfinyl methyl dithiophosphate
Aspon*	O,O,O,O-Tetra-n-propyl dithiopyrophosphate
Azethion	O,O-Diethyl S-(carbomethoxymethyl) phosphorothioate
Azinphosmethyl	O,O-Dimethyl S-[(4-oxo-1,2,3-benzotriazin-3(4H)-yl)-methyl] phosphorodithioate
Bensulide	S-(O,O-Diisopropyl phosphorodithioate) ester of N-(2-mercaptoethyl) benzenesulfonamide
Bomyl*	Dimethyl 3-hydroxyglutaconate dimethylphosphate
Bromophos ethyl	O,O-Diethyl-O(4-bromo-2,5-dichlorophenyl) phosphorothioate
Butonate	O,O-Dimethyl-(2,2,2-trichloro-1-n-butyryloxyethyl phosphonate
Carbophenothion	O,O-Diethyl-S-[[(p-chlorophenyl)thio] methyl] phosphorodithioate
Chlorfenvinphos	2-Chloro-1-(2,4-dichlorophenyl) vinyl diethyl phosphate
Chlormephos	S-Chlormethyl-O,O-diethyl phosphorothiolothionate
Chlorthion	O,O-Dimethyl 0-(3-chloro-4-nitrophenyl) phosphorothioate
Conen*	O-Butyl-S-benzyl-S-ethyl phosphorodithioate
Coroxon	O,O-Diethyl-O-(3-chloro-4-methylcoumarin-7-yl) phosphate
Coumaphos	O,O-Diethyl O-(3-chloro-4-methyl-2 oxo (2H)-1-benzopyran-7-yl) phosphorothioate
Crufomate	4-tert-Butyl-2-chlorophenyl methyl methyl-phosphoramidate
Cyanthoate	S-[[(1-Cyano-1-methylethyl)carbamoyl] methyl] O,O-diethyl phosphorothioate
Cythioate	O,O-Dimethyl O-p-sulfanoylphenyl phosphorothioate
DAEP	O,O-Dimethyl-S-2-(acetylamino)ethyl dithiophosphate
DEF*	S,S,S,-Tributyl phosphorotrithioate
Demeton	O,O-Diethyl O-(and S)-[2-(ethylthio)ethyl] phosphorothioate
Demeton methyl	O,O-Dimethyl-S-[2(ethylthio)ethyl] phosphorothioate
Diazinon	O,O-Diethyl-O-(2-isopropyl-6-methyl-4-pyrimidinyl) phosphorothioate

*Trade name.

32

Common or Trade Name	*Chemical Name*
Dicapthon	O-(2-Chloro-4-nitrophenyl) O,O-dimethyl phosphorothioate
Dichlorvos	2,2-Dichlorovinyl O,O-dimethyl phosphate
Dicrotophos	Dimethyl phosphate of 3-hydroxy-N,N-dimethyl-cis-crotonamide
Diethquinalphione	O,O-Diethyl-O-(2-chinoralyl)-phosphorothioate
Dimethoate	O,O-Dimethyl S-(N-methyl carbamoyl methyl) phosphorodithioate
Dioxathion	2,3-p-Dioxanedithiol S,S-bis(O,O-diethyl phosphorodithioate)
Disulfoton	O,O-Diethyl S-[2-(ethylthio)ethyl] phosphorodithioate
DMCP	S-(p-Chlorophenyl) O,O-dimethyl phosphorothioate
Dursban*	O,O-Diethyl O-(3,5,6-trichloro-2-pyridyl) phosphorothioate
Dyfonate*	O-Ethyl-S-phenylethylphosphonodithioate
EPN	O-Ethyl O-(p-nitrophenyl) phenylphosphonothioate
Ethion	O,O,O',O'-Tetraethyl S,S'-methylene bisphosphorodithioate
Fenitrothion	O,O-Dimethyl O-(4-nitro-m-tolyl) phosphorothioate
Fensulfothion	O,O-Diethyl O-[p-(methylsulfinyl)phenyl] phosphorothioate
Fenthion	O,O-Dimethyl O-[4-(methylthio(-m-toly] phosphorothioate
Folex*	Tributyl] phosphorotrithioite
Formothion	O,O-Dimethyl S-(N-formyl-N-methylcarbomylmethyl) phosphorodithioate
Forstenon	Diethyl carbethoxydichloromethyl-phosphonate
Fostion*	O,O-Diethyl-S-(N-isopropylcarbamolymethyl) phosphorodithioate
Gardona*	2-Chloro-1-(2,4,5-trichlorophenyl) vinyl dimethyl phosphate
Hosdon*	O,O-Dimethyl-S-2(isopropylthio) ethyl phosphorodithioate
Imidan*	N-(Mercaptomethyl) phthalimide S-(O,O-dimethyl phosphorodithioate)
Inezin*	O-Ethyl-S-benzylphenylphosphonothiolate
Iodofenphos	O,O-Dimethyl-O-(2,5-dichloro-4-iodophenyl) thiophosphate
Ketothion	O,O-Diethyl S-acetonyl phosphorodithioate
Leptophos	O-(4-Bromo-2,5-dichlorophenyl) O-methyl phenylphosphonothioate
Malathion	O,O-Dimethyl dithiophosphate of diethyl mercaptosuccinate
Mecarbam	O,O-Diethyl S-[[(ethoxycarbonyl)methylcarbamoyl]-methyl] phosphorodithioate
Mecarpon	S-(N-Methoxycarbonyl-N-methylcarbamonylmethyl) dimethyl phosphonothiolothionate
Metasystox-S*+	O,O-Dimethyl S-[(2-ethylsulfinyl) isopropyl] phosphorothioate
Methyl mercaptophos	O-Methyl-O-ethyl-2-ethylmercaptoethyl thiophosphate
Methyl parathion	O,O-Dimethyl O-p-nitrophenyl phosphorothioate
Methyl phencapton	O,O-Dimethyl S-(2,5-dichlorophenylthio)methyl phosphorodithioate
Methyl potasan*	O,O-Dimethyl O-(4-methylumbelliferone) phosphorothioate

*Trade name.

33

Common or Trade Name	*Chemical Name*
Methyl trithion	S-(((p-Chlorophenyl)thio)methyl) O,O-dimethyl phosphorodithioate
Mevinphos	2-Carbomethoxy-l-methylvinyl dimethyl phosphate
Monitor*	O,S-Dimethylphosphoramidothioate
Monocrotophos	Dimethyl phosphate of 3-hydroxy-N-methyl-cis-crotonamide
Morphothion	O,O-Dimethyl S-(morpholinocarbonylmethyl) phosphorodithioate
Naled	1,2-Dibromo-2,2-dichloroethyl dimethyl phosphate
Naphthalaphos	N-Hydroxynaphthalimide diethylphosphate
Orthene*	O,S-Dimethyl N-acetyl phosphoramidothioate
Oxydemetonmethyl	O,O-Dimethyl S[2-(ethylsulfinyl)ethyl] phosphorothioate
Oxydisulfoton	O,O-Diethyl S-(2-(ethylsulfinyl)ethyl) phosphorodithioate
Paraoxon	O,O-Diethyl O-p-nitrophenyl phosphate
Parathion	O,O-Diethyl O-p-nitrophenyl phosphorothioate
Phencapton	O,O-Diethyl S-[[(2,5 dichlorophenyl)thio] methyl] phosphorodithioate
Phenthoate	O,O-Dimethyl S-(a-ethoxycarbonylbenzyl) phosphorodithioate
Phorate	O,O-Diethyl S-(ethylthio)methyl phosphorodithioate
Phosalone	O,O-Diethyl S-[(6-chloro-3(mercaptomethyl)-2-benzoxazolinone] phosphorodithioate
Phosphamidon	2-Chloro-2-diethylcarbamoyl-1-methylvinyl dimethyl phosphate
Phosphinon	O,O-Diethyl O-(1-(2-chloroethoxy)-2,2-dichlorovinyl) phosphate
Phosvel*	O-(2,5-Dichloro-4-bromophenyl) O-methyl phenylthiophosphate
Phoxim	Phenylglyoxyonitrile oxime O,O-diethyl phosphorothioate
Pirazinon*	O,O-Diethyl O-(6-methyl-2-propyl-4-pyrimidyl) phosphorothioate
Potasan	O,O-Diethyl O-(4-methylumbelliferone) phosphorothioate
Prophos	O-Ethyl S,S-dipropyl phosphorodithioate
Propoxon	O,O-Diethyl-S-carboethoxyethyl-phosphorothioate
Prothion	O,O-Diethyl S-carboethoxyethyl phosphorodithioate
Pyrazoxon*	O,O-Diethyl O-(3-methylpyrazol-5-yl) phosphate
Pyrazothion*	O,O-Diethyl O-(3-methylpyrazol-5-yl) phosphorothioate
Ronnel	O,O-Dimethyl O-(2,4,5-trichlorophenyl) phosphorothioate
Schradan	Octamethylphosphoramide
S-Seven*	O-Ethyl-O-(2,4-dichlorophenyl)-phosphonothionate
Sulfotepp	O,O,O,O-Tetraethyl dithiopyrophosphate
TEPP	Tetraethyl pyrophosphate
Thiometon	O,O-Dimethyl-S-[2-(ethylthio)ethyl] phosphorodithioate
Trichlorfon	Dimethyl (2,2,2-trichloro-1-hydroxyethyl) phosphonate
Trichloronate	O-Ethyl O-(2,4,5-trichlorophenyl) ethylphosphonothioate
VC-13 Nemacide	O-2,4-Dichlorophenyl O, O-diethyl phosphorothioate
Zytron	O-(2,4-Dichlorophenyl) O-methyl N-isopropylophosphoroamidothioate

*Trade name.

34

CROSS REFERENCE FOR SOME OF THE CHOLINESTERASE-INHIBITING ORGANIC PHOSPHORUS PESTICIDE TRADE NAMES

Aflix* ..... see formothion
Afos* ..... see mecarbam
Agrisil* ..... see trichloronate
Agritox* ..... see trichloronate
Agrothion* ..... see fenitrothion
Alkron* ..... see parathion
Alleron* ..... see parathion
Amiphos* ..... see DAEP
Anthio* ..... see formothion
Anthon* ..... see trichlorfon
Appex* ..... see Gardona+
Asuntol* ..... see coumaphos
Azodrin* ..... see monocrotophos
Basudin* ..... see diazinon
Baymix* ..... see coumaphos
Bayrusil* ..... see diethquinalphione
Baytex* ..... see fenthion
Baythion* ..... see phoxim
Betasan* ..... see bensulide
Bidrin* ..... see dicrotophos
Bilobran* ..... see monocrotophos
Birlane* ..... see chlorfenvinphos
Bladafume* ..... see sulfotepp
Bladen* ..... see parathion
Borinox* ..... see trichlorfon
Bromex* ..... see naled
Carbicron* ..... see dicrotophos
Carfene* ..... see azinphos-methyl
Cidial* ..... see phenthoate
Citram* ..... see amiton
Co-Ral* ..... see coumaphos
Corothion* ..... see parathion
Cygon* ..... see dimethoate
Cythion* ..... see malathion
Dagadip* ..... see carbophenothion
Dalf* ..... see methyl parathion
Dasanit* ..... see fensulfothion
Daphene* ..... see dimethoate
Dazzel* ..... see diazinon
Dedevap* ..... see dichlorvos
De-Fend* ..... see dimethoate
De-Green* ..... see DEF*
Delnav* ..... see dioxathion
Diazajet* ..... see diazinon
Diazide* ..... see diazinon
Diazol* ..... see diazinon
Dibrom* ..... see naled
Di-Captan* ..... see dicapthon
Dimecron* ..... see phosphamidon
Dimethogen* .... see dimethoate
Dipterex* ..... see trichlorfon
Di-Syston* ..... see disulfoton
Disyston S* ..... see oxydisulfoton
Dithione* ..... see sulfotepp
Dylox* ..... see trichlorfon
E-605* ..... see parathion
Easy Off-D* ..... see Folex*
Ectoral* ..... see ronnel
Ekatin* ..... see thiometon
Ekatin M* ..... see morphothion
Ektafos* ..... see dicrotophos
Elsan* ..... see phenthoate
Emmatos* ..... see malathion
Entex* ..... see fenthion
Equino-Aid* ..... see trichlorfon
Ethyl Parathion* . see parathion
Etilon* ..... see parathion
Etrolene* ..... see ronnel
Exothion* ..... see endothion
Filariol* ..... see bromophos ethyl
Folidol E-605* .. see parathion
Folidol M* ..... see methyl parathion
Folithion* ..... see fenitrothion
Fostion MM* .... see dimethoate
Frumin Al* ..... see disulfoton
Fujithion* ..... see DMCP
Fyfanon* ..... see malathion
Gardentox* ..... see diazinon
Garrathion* ..... see carbophenothion
Gusathion M* .... see azinphos-methyl
Guthion* ..... see azinphos-methyl
Hercules AC527* . see dioxathion
Karbofos* ..... see malathion
Klimite 40* ..... see TEPP
Korlan* ..... see ronnel
Lebaycide* ..... see fenthion
Malamar* ..... see malathion
Malaspray* ..... see malathion
Maretin* ..... see naphthalaphos
Meldane* ..... see coumaphos
Menite* ..... see mevinphos
Metasystox* ..... see demeton methyl
Metasystox-R* ... see oxydemeton-methyl
Metron* ..... see methyl parathion
Mintacol* ..... see paraoxon
MLT* ..... see malathion
Mocap* ..... see prophos
Morphotox* ..... see morphothion

*Trade name.

35

Murfotox* ..... see mecarbam
Muscatox* ..... see coumaphos
N 2790* ..... see dyfonate
Nankor* ..... see ronnel
Neragan* ..... see bromophos ethyl
Neguvon* ..... see trichlorfon
Nialate* ..... see ethion
Niram* ..... see parathion
Nitrox* ..... see methyl parathion
No Pest* ..... see dichlorvos
Novathion* ..... see fenitrothion
Nuvacron* ..... see monocrotophos
Nuvanol* ..... see fenitrothion
Orthophos* ..... see parathion
Ortho Phosphate
Defoliant* .... see DEF*
Panthion* ..... see parathion
Parathene* ..... see parathion
Parawet* ..... see parathion
Partron M* ..... see methyl parathion
Perfekthion* ..... see dimethoate
Pestan* ..... see mecarbam
Pestox III* ..... see schradan
Phosdrin* ..... see mevinphos
Phosfene* ..... see mevinphos
Phoskit* ..... see parathion
Phosphopyran* ... see endothion
Phosvit* ..... see dichlorvos
Phytosol* ..... see trichloronate
Prolate* ..... see imidan
Rabon* ..... see Gardona+
Rampart* ..... see phorate
Rawetin* ..... see naphthalaphos
Resistox* ..... see coumaphos
Rhodiatox* ..... see parathion
Rogor* ..... see dimethoate
Roxion* ..... see dimethoate
Ruelene* ..... see crufomate
Ruphos* ..... see dioxathion
Sapecron* ..... see chlorfenvinphos
Solverex* ..... see disulfoton
Soprathion* ..... see parathion
Spectracide* ..... see diazinon
Stathion* ..... see parathion
Sumithion* ..... see fenitrothion
Supona* ..... see chlorfenvinphos
Systox* ..... see demeton
Sytam* ..... see schradan
Tamaron ..... see Monitor*
Tanone* ..... see phenthoate
Tartan* ..... see cyanthoate
Task* ..... see dichlorvos
Tekwaisa* ..... see methyl parathion
Terracur P* ..... see fensulfothion
Tetrachlorvinphos . see Gardona*
Tetraethyl
Pyrophosphate . see TEPP
Tetram* ..... see amiton
Tetron* ..... see TEPP
Thimet* ..... see phorate
Thiocron* ..... see amidthion
Thiodemeton .... see disulfoton
Thiophos ..... see parathion
Thiotepp ..... see sulfotepp
Tiguvon* ..... see fenthion
Timet ..... see phorate
Trichlorphon .... see trichlorfon
Trimetion* ..... see dimethoate
Trinox* ..... see trichlorfon
Trithion* ..... see carbophenothion
Trolene* ..... see ronnel
Tugon ..... see trichlorfon
Valexon* ..... see phoxim
Vapona* ..... see dichlorvos
Vaponite* ..... see dichlorvos
Vapotone* ..... see TEPP
Viozene* ..... see ronnel
Volaton* ..... see phoxim
Zithiol* ..... see malathion
Zolone* ..... see phosalone

36

SELECTED CHOLINESTERASE-INHIBITNG CARBAMATE PESTICIDES

Common or Trade Name	*Chemical Name*
Aldicarb	2-Methyl-2-(methylthio) propionaldehyde 0-(methylcarbamoyl) oxime
Banol	6-Chloro-3,4-xylyl methylcarbamate
Baygon	0-Isopropoxyphenyl methylcarbamate
Bufencarb	3-(1-Methylbutyl) phenyl methylcarbamate and 3-(1-Ethylpropyl) phenyl methylcarbamate (3:1)
Butacarb	3,5 Di-tert-butylphenyl methylcarbamate
Carbaryl	1-Naphthyl N-methylcarbamate
Carbofuran	2,3-dihydro-2,2-dimethyl-7-benzofuranyl methylcarbamate
Dichlormate	3,4-and 2,3-Dichlorobenzyl methylcarbamate
Dimetilan	3-Hyrdroxy-N,N, 5-trimethylpyrazole-1-carboxamide dimethylcarbamate
Dioxacarb	0-1,3-Dioxolan-2-ylphenyl methylcarbamate
Ficam	2,2-Dimethyl-1,3-benzodioxol-4-yl-methylcarbamate
Formetanate (hydrochloride)	M-[((Dimethylamino)methylene) amino phenyl methylcarbamate] (hydrochloride)
Landrin	3,4,5-Trimethylphenyl methylcarbamate and 2,3,5-Trimethylphenyl methylcarbamate
Matacil	4-(Dimethylamino)-m-tolyl methylcarbamate
Mesurol	4-(Methylthio)-3,5-xylyl methylcarbamate
Methomyl	5-Methyl N-[(methylcarbamoyl) oxyl] thioacetimidate
Mexacarbate	4-(Dimethylamino)-3,5-xylyl methylcarbamate
Mobam	4-Benzothienyl methylcarbamate
Oxamyl	Methyl N',N'-dimethyl-N-[(methylcarbamoyl)oxy]-1-thiooxamidate
Pirimicarb	2-(Dimethylamino)-5, 6-dimethyl-4-pyrimidinyl dimethylcarbamate
Promecarb	3-methyl-5-isopropylphenyl methylcarbamate
Thiofanox	3,3-Dimethyl-1-(methylthio)-2-butanone 0-[(methylamino)carbonyl] oxime

37

CROSS REFERENCE FOR SOME OF THE CHOLINESTERASE-INHIBITING CARBAMATE PESTICIDE TRADE NAMES

A 363 ..... see Matacil
Ambush ..... see Aldicarb
Aminocarb ..... see Matacil
Aphox ..... see Pirimicarb
Arprocarb ..... see Baygon
Bay 9010 ..... see Baygon
B-37344 ..... see Mesurol
Bay 39007 ..... see Baygon
Bay 44646 ..... see Matacil
Bay 70142 ..... see Carbofuran
Bendiocarb ..... see Ficam
Blattenex ..... see Baygon
Bux ..... see Bufencarb
Carbamult ..... see Promecarb
Carbanolate ..... see Banol
Carpolin ..... see Carbaryl
Carzol ..... see Formetanate (Hydrochloride)
CIBA 8353 ..... see Dioxacarbe
Curaterr ..... see Carbofuran
D-1221 ..... see Formetanate (Hydrochloride)
D-1410 ..... see Oxamyl
Dicarol ..... see Formetanate (Hydrochloride)
Dowco 139 ..... see Mexacarbate
Draza ..... see Mesurol
Elocron ..... see Dioxacarb
ENT 27164 ..... see Carbofuran
ENT 27300 ..... see Promecarb
EP 316 ..... see Promecarb
EP 332 ..... see Formetanate (Hydrochloride)
Famid ..... see Dioxacarb
FMC 10242 ..... see Carbofuran
Furadan ..... see Carbofuran
G-22870 ..... see Dimetilan
G-13332 ..... see Dimetilan
Hexavin ..... see Carbaryl
IPMC ..... see Baygon
Karbaspray ..... see Carbaryl
Lannate ..... see Methomyl
Maz ..... see Mexacarbate
MCA-600 ..... see Mobam
Mercaptodimethur see Mesurol
Metalkamate ..... see Bufencarb
Methiocarb ..... see Mesurol
Metmercaptron ... see Mesurol
Minacide ..... see Promecarb
Mos 78 ..... see Mobam
MXMC ..... see Mesurol
NC 6897 ..... see Ficam
NIA 10242 ..... see Carbofuran
Nudrin ..... see Methomyl
OMS 716 ..... see Promecarb
Ortho 5353 ..... see Bufencarb
PHC ..... see Baygon
Pirimor ..... see Pirimicarb
PP 062 ..... see Pirimicarb
Propoxur ..... see Baygon
Ravyon ..... see Carbaryl
Romate ..... see Dichlormate
Rowmate ..... see Dichlormate
Schering 34615 ... see Promecarb
Schering 36056 ... see Formetanate (Hydrochloride)
Sendran ..... see Baygon
Septene ..... see Carbaryl
Sevin ..... see Carbaryl
Sirmate ..... see Dichlormate
Snip ..... see Dimetilan
Sok ..... see Banol
Suncide ..... see Baygon
Temik ..... see Aldicarb
Tendex ..... see Baygon
Tricarnam ..... see Carbaryl
UC 9880 ..... see Promecarb
UC 21149 ..... see Aldicarb
UC 22463 ..... see Dichlormate
UC 7744 ..... see Carbaryl
Unden ..... see Baygon
Vydate ..... see Oxamyl
Yaltox ..... see Carbofuran
Zectron ..... see Mexacarbate

APPENDIX 2

PESTICIDE TOXICITY

Because most pesticides destroy unwanted organisms, they obviously are toxic materials. Some pesticides are much more toxic than others. Severe illness may result when only a small amount of one type of pesticide has been ingested; with another type, a large amount may be ingested with no serious effects.

Toxicologists use a simple animal toxicity test to rank pesticides according to their inherent toxicity. Before any pesticide can be registered, the manufacturer must provide the results of these tests to EPA. The LD_{50} (the dosage level of a toxic chemical which is lethal to 50 percent of a population of test animals) is measured in terms of:

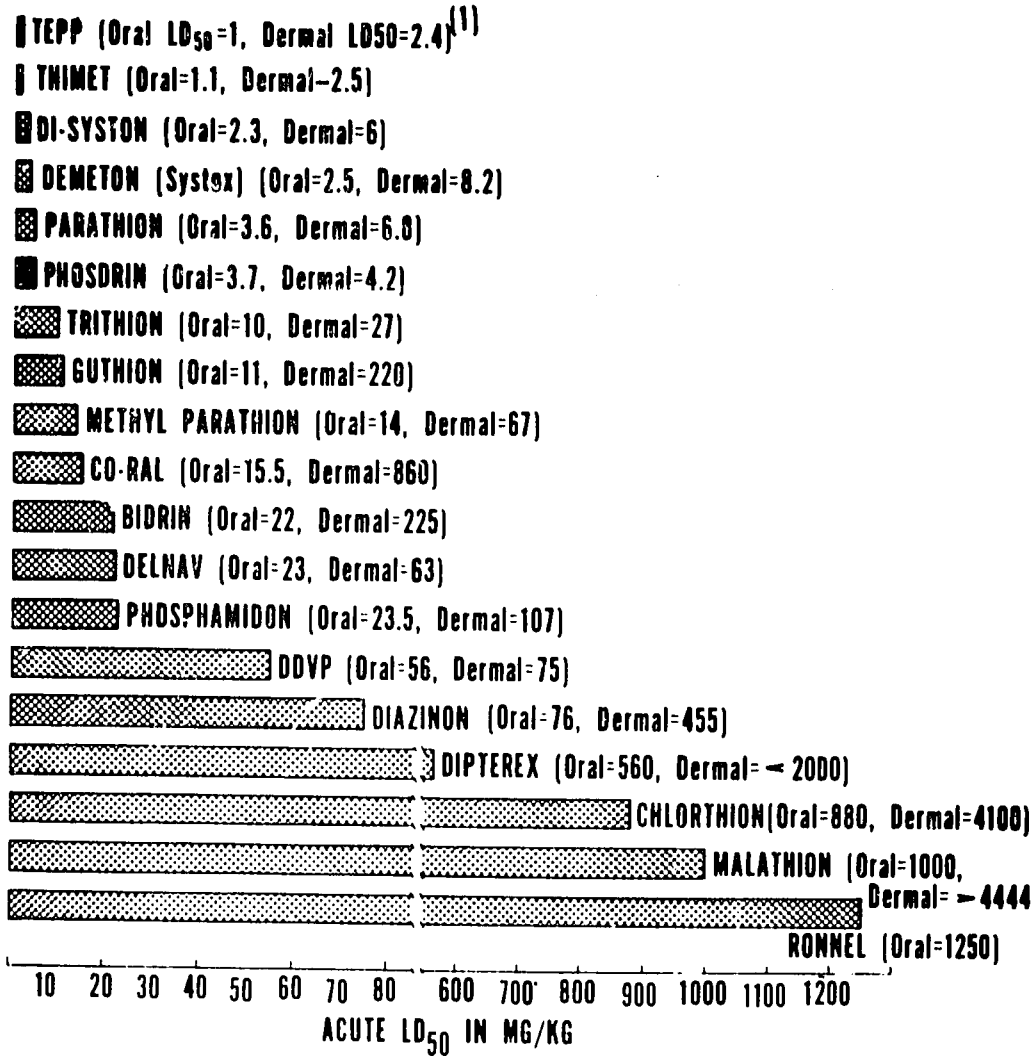
- oral toxicity (material is fed to rats)
- dermal toxicity (material is applied to the skin of rats)
- respiratory toxicity (material is inhaled).

In this way an arbitrary toxicologic ranking has been obtained for the organophosphate and organochlorine pesticides. The materials on the top of the list are the most toxic, and those at the bottom are the least toxic. The size of the dose is the most important single item in determining the safety of a given chemical. Actual statistics of human poisonings correlate reasonably well with these toxicity ratings. Health personnel will be able to get some idea of the probable severity of the poisoning being treated by referring to these figures.

The amount of pesticide required to kill an adult male can be correlated with LD_{50}:

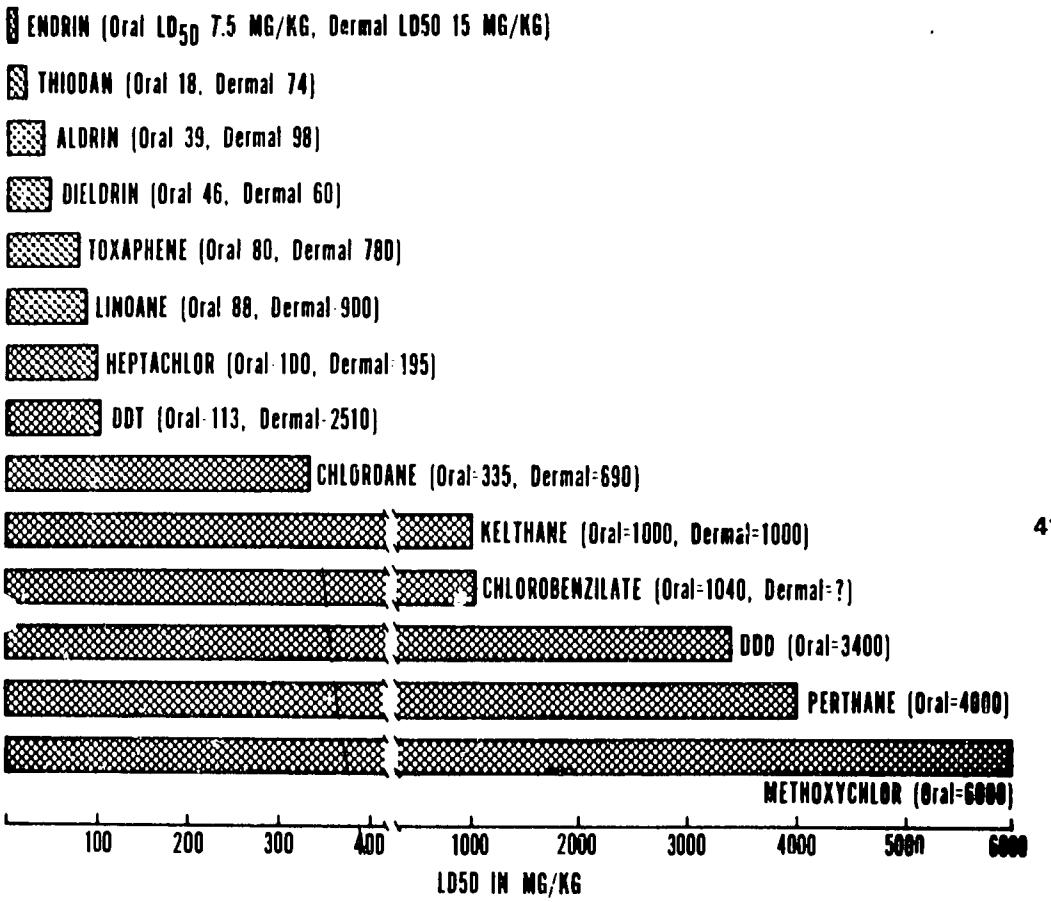
Acute Oral LD_{50}	Material which will kill an adult male
5	a few drops
5 - 50	a pinch to a teaspoonful
50 - 500	a teaspoonful to a tablespoonful
500 - 5,000	a 1 ounce to 1 pint
5,000 - 15,000	1 pint to 1 quart

Oral ingestions are more toxic than respiratory inhalations and these are more toxic than dermal absorptions. In addition, there are individual physical and chemical differences in a chemical which render the material more likely to produce poisoning. Thus, parathion changes to the more toxic "paraoxon" with high temperatures. Ethyl parathion is more toxic than methyl parathion, yet there is no great difference in their oral toxicity. Work exposure is usually dermal and that is why many more illnesses are seen in workers exposed to ethyl parathion than those exposed to methyl parathion.



Acute Oral and Dermal Toxicity Values for Some Organophosphate Pesticides.

(Prepared by the Bureau of Occupational Health, State of California Department of Public Health. Copied with permission.)



41

Acute Oral and Dermal Toxicity Values for Some Chlorinated Hydrocarbon Pesticides.

(Prepared by the Bureau of Occupational Health, State of California Department of Public Health. Copied with permission.)

APPENDIX 3

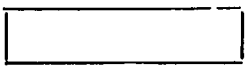
ACHOLEST™

(Cholinesterase Test-Paper)

METHOD FOR USING ACHOLEST TEST PAPER

Equipment

1. ACHOLEST Cholinesterase Test-Paper, Bottle I



Test Strip

2. Four slides.
3. 0.1 ml. pipette (0.01 ml. graduations)
4. Comparative color strips, Bottle II.

Comparative Strip

5. Watch or stop-watch.

42

Procedure: Place 0.05 ml. of non-hemolyzed plasma* on each of two thoroughly cleaned slides (avoid traces of acid or alkali). The plasma is to be quickly separated from the blood sample inasmuch as blood cells present in the plasma interfere with the reaction. With a pair of clean, dry scissors, cut one-half of a strip (2 x 1 cm.) of Acholest Test Paper from Bottle I, and one-half of a strip of control paper from Bottle II. Using tweezers, place the untouched half of each strip on each slide containing the plasma and cover with a second thoroughly cleaned slide, using gentle, even pressure several times in order to ensure complete saturation of the test and control papers and prevent mottling. To prevent evaporation of fluid, do not separate the slides until the test has been completed. Record the moment of contact of the test and control papers with the plasma as the beginning of the test.

* Heparinized, not citrated or oxalated tubes may be used for collection.

The Acholest Test Paper and the control paper, when dry, are similarly egg yolk colored. When exposed to the plasma, the Acholest Test Paper turns green, gradually developing into a yellowish color, after passing through various tones of green-yellow. The control paper, however, upon contact with the blood plasma, turns immediately yellowish with no further change in color. The plasma cholinesterase activity is measured by the time required for the Acholest Test Paper to reach the color of the control paper. For accurate comparison of the color, it is recommended that the test be performed on a white background with diffused light.

From the moment of contact of the plasma and Acholest Test Paper to the point when the comparative tone of color has been reached, the following time values have been established:

Minutes	Activity of Plasma Cholinesterase
Below 5	"increased"
5 - 20	"normal"
20 - 30	"suspicious"
30 and longer	"decreased"

Precaution: Acholest Test Paper should be stored away from light in tightly closed containers to protect it from moisture and chemical vapors. **Avoid contact with fingers. Plasma to be used should be free of cellular components. Always place Acholest Test Paper on the plasma, never drip plasma on the Test Paper; this similarly applies to the control strip.**

Readings should always be carried out under the same light conditions and room temperature. (Room temperature differences in the range from 68° F (19° C) to 75° F (25° C) do not influence the reliability and accuracy of Acholest Test Paper). Also hemolysis of a minor degree does not affect the accuracy of Acholest Test Paper. **It is important, however, to note that pH changes of the plasma might interfere with the accuracy of Acholest Test Paper independent of the plasma cholinesterase activity.** Such pH changes might be the result of alkali or acid cleansing materials on test equipment or of undue storage of plasma which might have led to degradation or decay (e.g. protein fractions). However, as a rule, storage of the plasma up to seven days at a temperature of 20° C or below (refrigeration of plasma is desirable), does not interfere with the accuracy of Acholest Test Paper.

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HICKSVILLE, NEW YORK 11802

APPENDIX 4

LABORATORY METHODS

Cholinesterase Determination

The four laboratory techniques most commonly used for quantitative expressions of these enzyme activities are the electrometric (Michel), the titrimetric (pH stat), the colorimetric (Ellman) and gas chromatographic (Cranmer) methods.

1. Michel method (pH meter)—Plasma and red cells are incubated with acetylcholine for one hour. The drop of the pH is due to the formation of acetic acid and is directly proportional to the cholinesterase activity. Normal values: Plasma 0.53 - 1.24 ΔpH units and Red Blood Cells 0.57 - 0.98 ΔpH units.

2. pH Stat (titrimetric)—The plasma and red cells are incubated with acetylcholine for 3 minutes and the acid formed is titrated with a base. The amount of base used is directly proportional to the cholinesterase activity in the blood sample. Normal values: Plasma 3.6 - 6.8 μM/ml/min and Red Blood Cells 11.1 - 16.0 μM/ml/min.

3. Ellman method (colorimetric)—Plasma and red cells are incubated for 10 minutes with acetyl thiocholine and the resultant thiocholine produces a yellow color in the presence of 5:5-dithiobis-(2-nitrobenzoic acid). The concentration of the yellow complex is directly proportional to the amount of cholinesterase present. Normal values: Plasma 5.8 - 16.6 M-SH/ml/3 min.

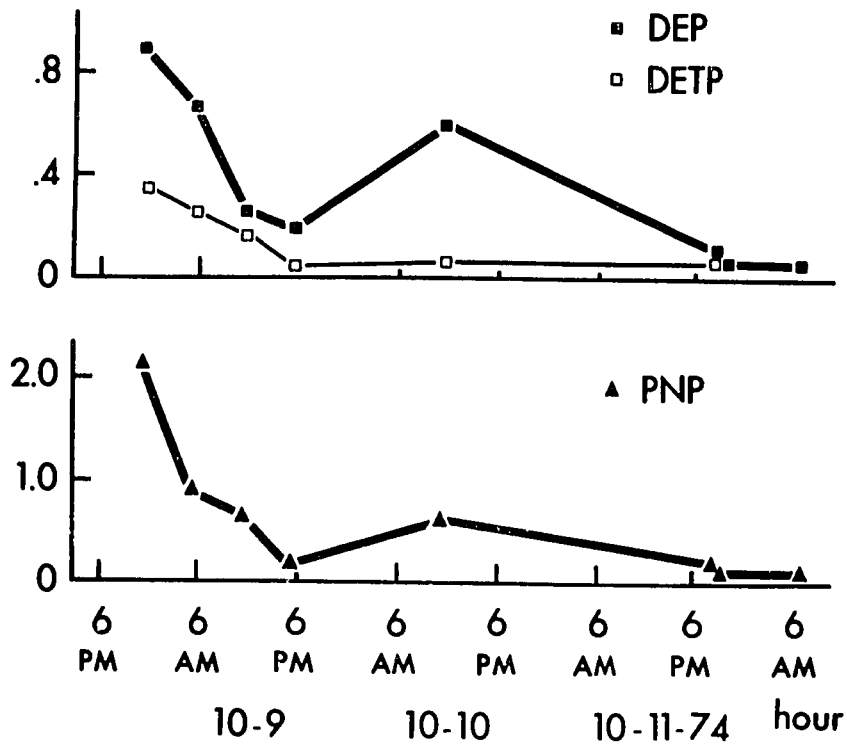
4. GLC method (chromatographic)—Plasma and red cells are reacted for 30 minutes with a compound that is similar to acetylcholine. The product formed, dimethyl butanol, is quantitated using a gas chromatograph. Normal values: Plasma 2.1 - 4.6 μM/ml/min and Red Blood Cells 8.2 - 11.8 μM/ml/min.

Urinary Pesticide Metabolite Data

The organophosphates are metabolized in man to produce two major types of pesticide metabolites in urine. These are the phenolic metabolites (e.g. nitrophenols and halogenated phenols) and the alkyl phosphate metabolites (namely, diethyl thiophosphate (DETP), diethyl phosphate (DEP), dimethyl thiophosphate (DMTP) and dimethyl phosphate (DMP). The carbamates, the other major group of anticholinesterase pesticides, are metabolized to non-halogenated phenols which are excreted in urine.

In poisoning cases the information from both types of metabolites is informative. Take ethyl parathion as an example. This is a diethyl thiophosphate pesticide and the excretion of the diethyl phosphate moiety in the urine is related to the parent compound. Parathion is oxidized to the more toxic product paraoxon, and it is this which is largely responsible for illness. Paraoxon is reflected by the excretion of diethyl phosphate (DEP) so that high concentrations of the oxon derivative are seen in the urine in poisoned victims. Paranitrophenol is the phenolic moiety and the identification of this in urine facilitates the specific diagnosis of the pesticide involved in the exposure, for paranitrophenol is only found in the urine following exposure to parathion and two other pesticides being used today (EPN and chlorthion).

Both the alkyl phosphate and phenolic metabolites have been found to be excellent indices of exposure if this exposure is a significant one, such as occurs in occupational and accidental exposure. The following chart illustrates the sequential excretion of these metabolites expressed as concentrations of the metabolites per milliliter in a parathion poisoning case.



Intact Pesticide Studies

The intact pesticide may be identified in blood, in other body tissues, and in gastric washing by electron capture gas chromatography using a flame photometric detector.

APPENDIX 5

CHEMTREC

CHEMICAL TRANSPORTATION EMERGENCY CENTER

For assistance in any transportation emergency involving chemicals (in the continental U.S.)

PHONE: Day or Night—Toll-Free

***800—424-9300**

* Add long-distance access number if required

483-7616 in District of Columbia

For calls originating outside the continental U.S.: 202—483-7616—Washington, D. C.

45

CHEMTREC

WHAT IT IS

CHEMTREC stands for Chemical Transportation Emergency Center, a public service of the Manufacturing Chemists Association at its offices in Washington, D. C.

CHEMTREC provides immediate advice for those at the scene of emergencies, then promptly contacts the shipper of the chemicals involved for more detailed assistance and appropriate follow-up.

CHEMTREC operates around the clock—24 hours a day, seven days a week—to receive direct-dial toll-free calls from any point in the continental United States through a wide area telephone service (WATS) number, 800-424-9300 (483-7616 for calls originating within the District of Columbia; 202-483-7616 for calls originating outside the continental U.S.).

Shippers, including MCA members and non-members, are notified through pre-established phone contacts providing 24-hour accessibility, via information operators, or through cooperation of fire and police services.

As circumstances warrant, the National Transportation Safety Board or appropriate offices of other agencies may be notified.

46

CHEMTREC's capabilities have been recognized by the Department of Transportation, and a close and continuing relationship is maintained between CHEMTREC and the Department.

WHAT IT IS NOT

Because chemicals find so many uses and have such a wide range of characteristics, there is much need for information about them—composition and purity, physical and chemical properties, effects on people and the environment, sources of supply, etc. It is important to understand that CHEMTREC *is not* intended and *is not* equipped to function as a general information source, but by design is confined to dealing with chemical transportation emergencies. Drivers should not call CHEMTREC on problems other than chemical cargo emergencies.

MODE OF OPERATION

CHEMTREC's number has been widely circulated in professional literature distributed to emergency service personnel, carriers, and the chemical industry, and has been further circulated in bulletins of governmental agencies, trade associations, etc.

Shipping documents of participating companies are requested to include the following: "For help in chemical emergencies involving spill, leak, fire or exposure, call toll-free 800-424-9300 day or night."

An emergency reported to CHEMTREC is received by the Communicator on duty, who records details in writing and by tape recorder. The Communicator then attempts to determine the essentials of the problem (as detailed on the left column of this page under "USER GUIDANCE"). This is to enable him to provide the best available information on the chemical(s) reported to be involved, thereby giving specific indication of the hazards and what to do (as well as what not to do) in case of spills, fire, or exposure as the immediate first steps in controlling the emergency. Information on the various chemicals, as furnished by the producers, is within easy reach. Trade names and synonyms of chemical names are cross-referenced for ready identification by whatever name is given.

CHEMTREC's Communicators are not scientists. They are chosen for their ability to remain calm under emergency stresses. To preclude unfounded personal speculation regarding a reported emergency, they are under instructions to abide strictly by the information prepared by technical experts for their use.

Having advised the caller, the Communicator proceeds immediately to notify the shipper by phone. The known particulars of the emergency thus relayed, responsibility for further guidance—including dispatching personnel to the scene or whatever seems warranted—passes to the shipper.

Although proceeding to the second stage of assistance becomes more difficult where the shipper is unknown, the Communicator is armed with other resources to fall back on. For example: Concerning radioactive materials, CHEMTREC can call on the Energy Research and Development Administration (ERDA). (Formerly Atomic Energy Commission).

Identification of product and shipper is important. Shipping papers are carried by truck drivers, and in engine or caboose of trains. Car and truck numbers and carrier names can be useful in tracing unknown cargoes.

Mutual aid programs exist for some products, whereby one producer will service field emergencies involving another producer's product. In such ceses, initial referral may be in accord with the applicable mutual aid plan rather than direct to the shipper. Arrangements of this sort are established on chlorine through the Chlorine Institute and on pesticides through the National Agricultural Chemicals Association.

The former has CHLOREP, the Chlorine Emergency Plan, in which the nearest producer responds to a problem. NACA has a Pesticide Safety Team Network of some 40 emergency teams distributed throughout the country. CHEMTREC serves as the communication link for both programs.

In Canada, the Canadian Chemical Producers' Association operates a Transportation Emergency Assistance Program (TEAP) through regional teams prepared to give phone and field response.

Many individual companies have well organized response capabilities, for their own products, some of which preceded CHEMTREC by several years. This program does not seek to displace these, but rather collaborates with them and enhances their effectiveness. CHEMTREC's single telephone number affords this opportunity.

BACKGROUND

MCA is a trade association of chemical manufacturers, large and small, representing more than 90% of the production capacity for basic industrial chemicals in the United States and Canada. It has long been active in programs to improve the safety of chemical shipping containers, both package and bulk units, and their reliability in handling and shipment, thereby minimizing failures and leakage of contents under extraordinary stress. Such efforts continue unabated.

Nevertheless, despite precautions taken, train derailments, truck upsets and collisions, and barge accidents, do occur. Such emergencies deserve to be handled as well as possible to minimize the consequences to life and property.

Emergency services—fire and police—are normally well prepared to cope with common materials, including certain flammables such as fuel oil and gasoline. Too often they are at a disadvantage when chemicals are encountered, espepecially since "what should be done"—and of equal importance, "what should *not* be done"—in the early stages may bear so heavily on the outcome. They need accurate and clearly understandable information to help them evaluate the situation and act with proper precautions for their own safety, as well as for the protection of the general public.

Realizing that personnel of chemical producers possessed the necessary expertise, officials of concerned Federal departments approached MCA. A study was undertaken by industry safety, packaging, and transportation specialists. After thorough consideration, it was concluded that a single center, nationwide in coverage and accessible to all through a single telephone number, would be the most expeditious arrangement—for contact with it and for feedback from it. Following review and confirmation by the industrial specialists of MCA's technical committees, CHEMTREC as now in operation was authorized.

CHEMTREC was established and continues as a voluntary project of the chemical manufacturing industry, wholly supported through the Manufacturing Chemists Association. It became operational on September 5, 1971.

USER GUIDANCE

CHEMTREC can usually provide hazard information warnings and guidance when given only the NAME OF THE PRODUCT and the NATURE OF THE PROBLEM. For more detailed information and/or assistance, or if product is unknown, attempt to provide as much of the following information as possible:

Name of caller and call back number
Location of problem
Shipper or manufacturer
Container type
Rail car or truck number
Carrier name
Consignee
Local conditions

FOR MORE INFORMATION

Questions regarding the operation of CHEMTREC should be directed to: Manager, Chemical Transportation Emergency Center, 1825 Connecticut Avenue, N.W., Washington, D. C. 20009. Phone: 202—483-6126.

APPENDIX 6

COMMUNICATIONS CHECKLIST FOR HEALTH PROFESSIONALS

- √ Attending Physician
- √ Family Members
- √ Employers
- √ Hospital Emergency Room
- √ Ambulance Service
- √ Health Department
- √ Local, County or State Police
- √ Landowner
- √ Pesticide Analytical Resource Laboratory
- √ EPA Resource (if necessary)
- √ Chemtrec (if necessary)

APPENDIX 7

LABORATORY AND EPA REGIONAL OFFICE LOCATIONS

Pesticide Verification Laboratory	State Service Area	EPA Region	EPA Regional Pesticide Branch Chief
Robert Altman, M.D., M.P.H. Project Director Epidemiologic Studies Program New Jersey State Dept. of Health John Fitch Plaza P. O. Box 1540 Trenton, New Jersey 08625 (609) 292-7608 Off-hour number: (609) 392-2020	ME VT NH MA RI CT	I	A. Charles Lincoln, Chief EPA, Pesticide Branch John F. Kennedy Bldg. Boston, Massachusetts 02203 (617) 223-5126
	NJ NY PR VI	II	Stanley Fenichel, Chief EPA, Pesticide Branch 26 Federal Plaza, Room 1005 New York, New York 10007 (212) 264-8356
	DE DC MD PA VA WV	III	Nelson Davis, Chief EPA, Pesticide Branch Curtis Building 6th and Walnut Streets Philadelphia, Pa 19106 (215) 597-9869
Dr. Ana Barquet Dept. of Epidemiology and Public Health University of Miami School of Medicine P. O. Box 0160669 Miami, Florida 33101 (305) 547-6972 Off-hour number: (305) 235-6280	AL FL GA KY MS NC SC TN	IV	Roy Clark, Chief EPA, Pesticide Branch 345 Courtland Street, N.E. Room 204 Atlanta, Georgia 30308 (404) 257-3222
E. Gomes 152 E. Stenger San Benito, Texas 78586 (512) 399-5352 Off-hour number: (512) 399:3455	AR LA NM OK TX	VI	Norman E. Dyer, Chief EPA, Pesticide Branch 1201 Elm Street 1st International Bldg. Dallas, TX 75270 (214) 749-7126

	IL IN MI MN OH WI	V	Mitchell Wrich, Chief EPA, Pesticide Branch 230 S. Dearborn St. Chicago, IL. 60604 (312) 353-2192
Donald P. Morgan, M.D., Ph.D. Project Director Epidemiologic Studies Program University of Iowa Oakdale Campus, AMRF Oakdale, IA 52319 (319) 353-5558 Off-hour number: (319) 338-8474	IA KS MO NE	VII	John Wicklund, Chief EPA, Pesticide Branch 1735 Baltimore Ave. Room 249 Kansas City, MO 64108 (816) 374-3036
	CO MT ND SD UT WY	VIII	Ivan Dodson, Chief EPA, Pesticide Branch Lincoln Tower Building 1860 Lincoln Street Suite 900 Denver, CO 80203 (303) 837-3926
Dr. Darrell Brock Acting Project Director Epidemiologic Studies Program Bureau of Laboratories Department of Health & Welfare Statehouse Boise, Idaho 83707 (208) 384-2233	AZ CA GU HI NV	IX	Jake McKenzie, Chief EPA, Pesticide Branch 100 California Street Room 340 San Francisco, CA. 94111 (415) 556-3352
	AK ID OR WA	X	Robert Poss, Chief EPA, Pesticide Branch 1200 6th Avenue Room 11-C Seattle, WA 98101 (206) 442-1090

50

APPENDIX 8

PESTICIDE POISONING EXPOSURE HISTORY
(MEDICAL RECORD)

Name of Patient _____
Age _____ Race _____ Sex _____
Address _____
Date of incident _____ Location of incident _____
Taken to _____ Hospital or Clinic
Date of Admission _____
Address _____
Person to contact with results _____ Telephone No. _____

EXPOSURE HISTORY: (Circle Appropriate Information)
Type of pesticide exposure: Ingestion Dermal Inhalation
Was this episode due to: Accidental Exposure Suicide Occupational Exposure
Name of pesticide involved _____
EPA Registration No. _____
Active ingredients _____
Crop pesticide was applied to and target pest _____
Time of last pesticide exposure of patient: Hour _____ Date _____

If Occupational Exposure patient was: (Circle)
Applying Pesticides:
Aerially Ground spray (hand) Spray rig (mechanical)
Or:
Loading Picking crops Mixing Thinning crops
Other _____

SYMPTOMATOLOGY DATA (Please Circle Appropriate Information if Present)
Weakness Sweating Nausea Vomiting Diarrhea
Abdominal Cramps Excessive Tearing Excessive Salivation
Excessive Bronchial Secretions Shortness of Breath Pains in Chest
Blurring of Vision Convulsions Other _____

SIGNS (Please circle appropriate information if present)
Miosis (less than 5 mm) Muscle twitching Muscle fasciculations
Bronchial spasms Bronchial exudation
Cholinesterase Screening Test: Positive Negative
Other _____

SPECIMEN COLLECTION

	Date	Time	
1. Heparinized blood			Collected before 2-PAM Administration? YES NO Atropine Administration? YES NO
2. Urine			
3. Other			

51

ADDITIONAL COMMENTS: Such as--

- important details relating to victim's pesticide exposure
- others affected and how
- other damage caused by occurrence.

52

SHIPPING

Send specimens and this form to one of the following laboratories:

Robert Altman, M.D., M.P.H.
Project Director
Epidemiologic Studies Program
New Jersey State Dep.. of Health
John Fitch Plaza
P. O. Box 1540
Trenton, New Jersey 08625
(609) 292-7608

Dr. Ana Barquet
Dept. of Epidemiology and Public Health
University of Miami School of Medicine
P. O. Box 016069
Miami, Florida 33101
(305) 547-6972

E. Gomes
152 E. Stenger
San Benito, Texas 78586
(512) 399-5352

Donald P. Morgan, M.D., Ph.D.
Project Director
Epidemiologic Studies Program
University of Iowa
Oakdale Campus, AMRF
Oakdale, Iowa 52319
(319) 353-5558

D. Darrell Brock
Acting Project Director
Epidemiologic Studies Program
Bureau of Laboratories
Dept. of Health and Welfare
Statehouse
Boise, Idaho 83707
(208) 384-2233

14. MOVEMENT OF PESTICIDES AND THEIR BREAKDOWN PRODUCTS IN THE ENVIRONMENT

VIRGIL H. FREED

CONTENTS

		Page
1.	INTRODUCTION	210
2.	THE ECOSYSTEM AND CHEMICAL MOVEMENT	210
3.	ENVIRONMENTAL PROCESSES IN TRANSPORT	213
(a)	General Considerations	213
(b)	Adsorption	216
(c)	Transport in Soil	216
(d)	Vaporization in Transport	217
(e)	Solution Behavior	217
(f)	Bioaccumulation	218
4.	TRANSPORT AND DISTRIBUTION	222
(a)	Water Transport	222
(b)	Wind	223
(c)	Biotic Transport	223
(d)	Degradation	223
5.	SUMMARY AND CONCLUSION	225
7.	APPENDIX – SOME METABOLIC REACTIONS COMMON TO PESTICIDES	226

1. INTRODUCTION

In recent years much public concern and controversy has arisen over the use of chemicals for pest control. In some nations, particularly the more affluent, there have been various attempts to suspend the use of a number of these chemicals. The concern and controversy stems in part from the rapid growth in number and amounts of pesticides used in the last three decades and the occasional adverse impact from their use. The environmental movement giving rise to residues in untreated areas and the biological affects produced in laboratories with doses far in excess of environmental exposure underlies much of this concern.

Pesticides have specific use on clearly identified target organisms and sites. However, we frequently do find that pesticides and their degradation products may be found outside of the target area. It is important that we know more about how this comes about and whether we can minimize such movement through the application of appropriate technology and use patterns.

2. THE ECOSYSTEM AND CHEMICAL MOVEMENT

We have come to recognize that the use of pesticides is a sophisticated high technology. Chemicals used as pesticides are released into a complex "system" having many components and a variety of forces acting in this system. As regards the agroecosystem into which the chemical is introduced, the boundaries are illdefined, thus affording no real containment of the chemical. We, therefore, find that indeed the chemical is transported from our desired target area and responding to the forces of work in this system become distributed in the different environmental compartments (Fig. 1).

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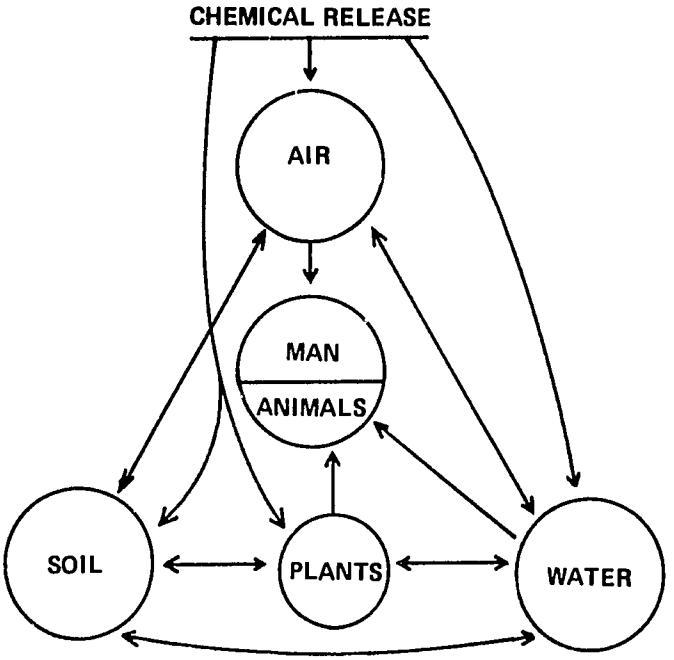


Figure 1 Man's exposure to a chemical through cycling of residues in the environment.

Note, however, that simply because the system and its operations and interactions are complex does not mean that we do not understand transport and behavior in the system. In any rational system we recognize that for a given effect there is a cause or set of causes and that given the appropriate study, these causes and the relationships can be understood. In dealing with pesticides in this system, we have three major concerns. They are: transport and distribution, effect on target and nontarget organisms, and finally the fate of the material, i.e. its persistence and breakdown. In each instance, we know that there are a number of processes and interacting factors that influence transport, the biological effect, and the ultimate fate of the material.

While the three major transport mechanisms are wind, water, and biota, the interaction of the chemical in adsorption, leaching, vaporization, and bioaccumulation modify availability for these processes. It is desirable, therefore, to consider these subprocesses in evaluating the overall transport of pesticides and their metabolites.

In order to begin to understand the transport and distribution of a chemical when it is introduced into the environment, one must have an appreciation of the nature of the environment itself. The basic compartments of the environment are: land (lithosphere), water (hydrosphere), air (atmosphere), and biota (biosphere). A rough estimate of the masses of the various phases yields the following: (1) air 5.3×10^{18} kg, (2) soil to six-inch depth 1.1×10^{17} kg, (3) water 1.3×10^{21} kg, (4) animals 2.0×10^{13} kg, and (5) plants 1.1×10^{15} kg. When a chemical is released into the environment it will be transported (partitioned) between the various phases with the concentration in any phase being a function of the properties of both the chemical and the phase. Applying the simple law of Boltzmann distribution to this complex system we have the following equation:

$$N_{ij} = N_o e^{-\varepsilon_{ij}/KT}$$

If we assume that $N_{ij} = N_{ji}$, $J_{ij} = 0$ when $i = j$ and $N_0 = N_1 + N_2 + N_3 + N_4 + N_5$, where N_o is the number of molecules of the chemical initially introduced and $N1 \ldots N_5$ are the number of molecules (i) in respective phases (j) of the environment. In the above equation, ε represents the energy barrier between two phases, k represents the Boltzmann constant, and T represents the absolute temperature. To understand the behavior of the chemical in the above five components one must have a detailed knowledge of the physical and chemical properties of the chemical.

First, let us observe that each of the some four million known to us possess a unique set or profile of properties, both chemical and physical. Thus, if we range over solubilities, vapor pressure, molar refractions, reaction rates, and so on, each chemical is found to be distinctive. It is on this basis that we as chemists are able to identify and characterize the materials.

Other physical-chemical properties relating to adsorption include partition coefficient and latent heat of solution. Of course these latter two are also related to water solubility.

Similarly, it is intuitively recognized that vapor pressure should be related to rates of volatilization. More recently, the studies of Spencer and his colleagues and others have developed more quantitative insight into evaporation of chemicals from soils and the work of McKay, et al (1973, 1979), the evaporation from water.

Based on these different characteristics of properties, we find that we can separate chemicals by distillation (differences in boiling point), solubility, and so on. This means that in the small systems in the laboratory, the chemicals behave differently because of their different properties, and we take advantage of this. Thus, that these varying physical and chemical properties should influence the potential for transport and istribution would seem to be self-evident. Consider now the very simple case of evaporization of hydrocarbons in the environment. Here, we know from much experience that there is a relationship between the vapor pressure and rate of evaporation. Hence, benzene evaporates much more readily than napthalene, or gasoline than motor lubricating oil. We are well aware that even in this simple illustration there are such factors as adsorption, air movement, and temperature that may modify this rate of evaporation, but this does provide us a basis then for asserting that in the processes responsible for transport and distribution, the physical and chemical properties of the compound will play an important role in modifying both a quantitative and qualitative aspects of the process.

The types of chemicals used range from simple aliphatics to high molecular weight polynuclear compounds. Also used are a few inorganic and organometallic compounds of widely different properties. Table 1 gives the production of some of the pesticides used and Table 2 illustrates the variability of properties of a number of common pesticides.

Table 1 Pesticide Production Volumes

Class	Common Name	Production (10^6 lb A.I.)*
Insecticides	Methyl parathion	45
	Toxaphene	50
	Carbaryl	45
	Malathion	35
	Chlordane	25
	Parathion	15
	Methoxychlor	10
	Diazinon	10
	Carbofuran	8
	Disulfoton	8
	Phorate	8
Herbicides	Atrazine	90
	2,4-D	45
	MSMA-DSMA	35
	Sodium Chlorate	30
	Trifluralin	25
	Propachlor	23
	Chloramben	20
	Alachlor	20
	CDAA	10
	2,4,5-T	6
Fungicides	PCP and salts	46a
	Dithio-carbamates	40b
	TCP and salts	20
	Captan	18
	FCNB	3
	Dodine	3

a Includes use as herbicide, desiccant, molluscicide, and for termite control.

b Includes CDEC, Dithane M-45, Dithane S-31, Ferbam, Maneb, Metham, Nabam, Niacide, Polyram, Thiram, Zineb, and Ziram

* Active Ingredient

(From Lawless, et al., 1972)

Table 2 Properties of Some Commonly Used Chemicals

Compound	Molecular Weight	mp(°C)	bp(°C)	Solubility in H_2O ppm (temp, °C)	Vapour Pressure	Partition Coefficient Octanol/H_2O
DDT	354.5	108-5		0.0034 (25)	1.9×10^{-7} (20)	1.55×10^{6}
Dieldrin	381	175-176		0.25 (25)	1.9×10^{-6} (20) 2.6×10^{-6} (20) 2.0×10^{-6} (20)	
1,2-dibramoethane (EDB)	187.872	9.97	131.65	3520 (20)	7.69 (20) 10.83 (25.1)	98.8
1,2-dichloroethane	98.960	-35.4	83.483	8450 (20)	62.1 (20.21)	25.0
2,4,-D (acid)	221	140.5		522 (25)	0.4 (160)	5.4×10^{2}
Malathion	330	2.85		145 (20) 300 (30)	0.55×10^{-5} (20)	781
Parathion	291	6.1		11.9 (20) 11 (40)	3.78×10^{-5} (20) 1.96×10^{-5} (20) 4.39×10^{-6} (20) 5.7×10^{-6} (20)	6.4×10^{3}
Leptophos	412	70.2-70.6 71.5-72.0		.0047 (20) .03 (25)		2.0×10^{6}
Chlorpyrifos	350.5	42-43.5		.4 (23)	1.87×10^{-5} (25)	1.29×10^{5}
Phosalone	368	48		10 2.15 (20)		2.0×10^{4}
Carbaryl (Sevin)	201	142		114 (24)	< 0.005 (26)	
Propoxur (Baygon)	209	91.5		≈ 2000 (20)	3×10^{-6} (20)	
Chlorpropham (CIPC)	213.7	41.4	247	102,3 (25)		
EPTC (Eptam)	189		235	375 (25)	1.55×10^{-1} (25) 1.62×10^{-2} (23) 1.97×10^{-2} (24)	
Atrazine	215.7	173-175		33 + 3.4 (25)	3.0×10^{-7} (20)	
Monuron	199	174-175		262 (25)	5×10^{-7} (25) 5.7×10^{-7} (25) 9×10^{-8} (27)	

3. ENVIRONMENTAL PROCESSES IN TRANSPORT

(a) General Considerations

Upon release of a chemical into the environment, the material immediately becomes subject to a number of processes (Freed, et al, 1977). These processes are the natural forces such as heating from the sun, dissolution in water, adsorption on surfaces, and a variety of degradative action. The rate and extent which the processes effect the chemical, its persistence, mobility, and biological action is modified and limited by the physical-chemical properties of the compound.

There are envisioned four steps or events leading to the biological action which in this case is control of pests of a chemical. These four steps are:

1. Interaction of the chemical with the environment prior to contact with the boundary of the organism;
2. Interaction with the boundary of the organism;
3. Passage through the boundary;
4. Intercelluar action leading to the biological effect.

Analysis of these four steps reveals the relationship between the properties of the chemical, persistence, transport and fate in the environment, and an indication of the ultimate effect on biota. At each of the four steps a number of different process and reactions can occur. These processes or reactions are dependent on both the properties of the chemical and its immediate surroundings, particularly the nature and properties of the specific component of the environ-

mental system with which it may be interacting or subjected to a process. In this context then, the physical-chemical properties of a compound permit prediction of the probable environmental behavior. The following table (Table 3) identifies the different processes that may be associated with the different steps described above.

Table 3 Processes involved in Chemical Action

Steps	Processes
Interaction with the environment	Adsorption on surafaces Vaporization Photochemical breakdown Autochemical breakdown Dissolution Partitioning
Interaction with barrier of organisms	Adsorption Destructive reactions Rejection
Intercellular transport	Adsorption Metabolic binding Metabolism Partitioning
Reaction with critical site	Adsorption Reaction

Over the years, a considerable body of information has built up relating physical-chemical properties and reactivity to the behavior and fate of chemicals in the environment (Kenaga, 1975; Freed, Chiou, and Haque, 1977). From this information it is possible to develop models of transport and behavior of chemicals in the environment. The important specific properties which are necessary to predict such behavior are water solubility, heats of solution, molar refraction, vapor pressure, partition coefficients, rates and types of reactivity and where applicable, ionic behavior.

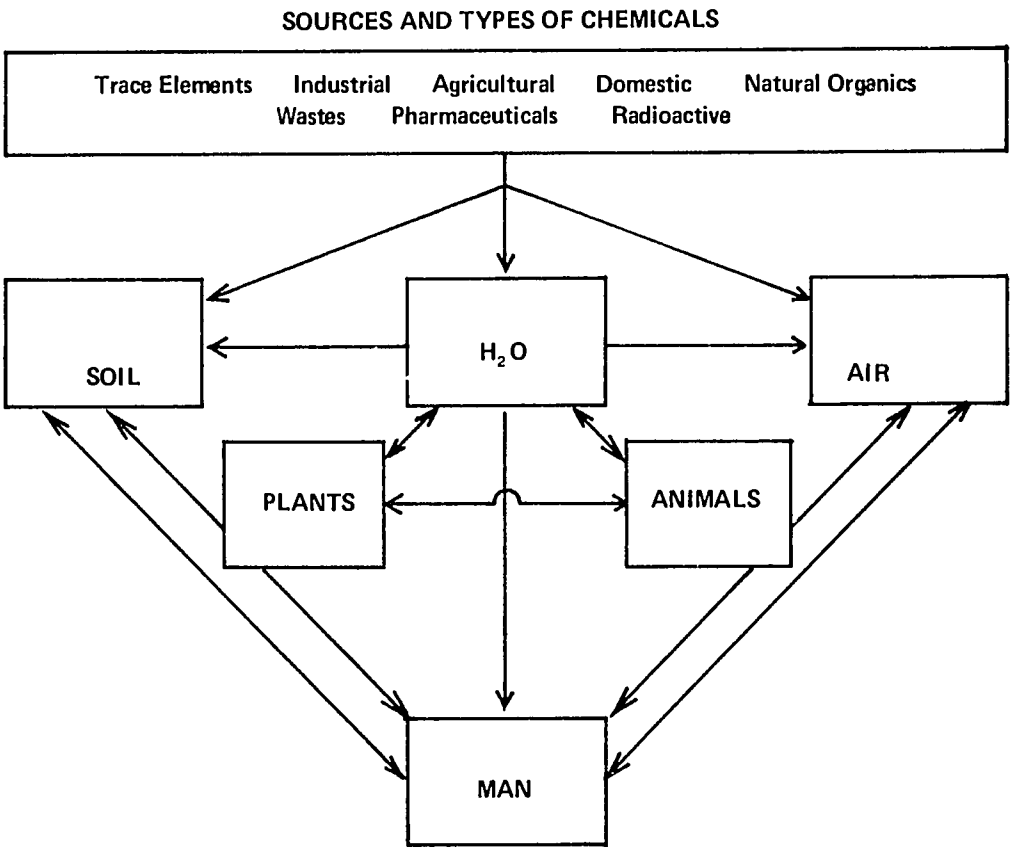
Interaction of a chemical with surfaces such as soil, organic matter, living vegetation is the result of the attractive forces between the surface and the chemical. The properties which indicate the extent and strength of the interaction or adsorption include water solubility, polarity and spatial orientation. These are indicated by the latent heat of solution, molar refraction, and to an extent, partition coefficient. In the adsorbed state, the chemical is much less mobile except for the transport of the sorbing surface and is also much less readily available for biological action. It may, however, be available for photochemical breakdown if exposed to sunlight or to microbiological attack if in the soil. Adsorption also attenuates other behavior patterns, as for example, volatility (Spencer and Cliath, 1975).

Aerial transport is one of the two ways of moving the chemical from where placed. The aerial transport may be during the application procedure or it may be through the movement of vapor or contaminated particles. Of specific interest is the movement of vapors which entails evaporation of the chemical from the surface. The rate of evaporation or volatilization is related to the vapor pressure at the ambient temperature and may be modified by variations in temperature, presence of moisture and air movement. The propensity for a compound to vaporize is related to the vapor pressure through the square root of its molecular weight and certain physical constants.

The partition coefficient, another important physical-chemical parameter, indicates the tendency of the chemical to distribute between polar and non-polar substrates. From the partition coefficient, one can predict whether the chemical will bioaccumulate, adsorb on organic matter, or partition into some other sink of the environment.

The reactivity of the chemical is also an important item of information in assessing environmental behavior. The susceptibility of the chemical to certain common reactions such as oxidation, reduction conjugation and so on may indicate not only its propensity to breakdown in the environment, but also the probability of its ready metabolism and excretion by organisms. An

additional reaction of considerable environmental importance is that of photochemical degradation. While chemicals generally absorb light energy in either the ultraviolet or visible range, not all are equally susceptible to photochemical breakdown. The strength of various chemical bonds in relationship to the quanta of energy received at a given length determines this reactivity. Figure 2 illustrates some of the interrelationships involved.



Transport	Processes	Reactions (Alterations)
Long Range	Sorption	Photochemical
Wind	Solution	Catalysis
Water	Vaporization	Chemical
Biota	Partitioning	Redox
	Biomagnification	Hydrolysis
Short Range	"Recycling between compartments"	Biologically mediated
Diffusion	Complexation	e.g., metabolism
Vaporization		
Sublimation		
Codistillation		
Leaching		

Figure 2 Interaction of chemicals with the environment

(b) **Adsorption**

The two major processes controlling the behavior of chemicals in a soil matrix are adsorption and leaching-diffusion. A change in the moisture content of the soil-chemical system and of temperature will greatly influence both processes.

A soil matrix represents a hetrogeneous mixture of various constituents, namely organic matter, sand, clays, and inorganic salts. These sometimes present a large surface area with a number of sites on which adsorption can occur. Although the bulk of the adsorption may be from solution, adsorption to a certain extent also occurs from the chemicals present in the vapor state.

The equilibrium in a chemical-soil system can be represented:

$$P(H_2O)_x + S(H_2O)_y - P(H_2O)_zS$$

where P and S represent the compound and soil matrix, respectively. With sufficient water present, both the chemical molecule and the soil matrix will be in the hydrated form. The symbols x, y, and z in the above equations denote the hydration numbers of the chemical, the soil, and the complex, respectively. The equilibrium constant K_E for the reaction is :

$$K_E = \frac{[P(H_2O)zS]}{[P(H_2O)x]\ [S(H_2O)y]}$$

Here the quantity in brackets [ ] represents the activity of the compound. An exact determination of K_E is difficult since an estimate of the exact volume occupied by the adsorbed species is nearly unattainable. Usually the adsorption for a soil-chemical system are represented with a Freundlich isotherm:

$$\frac{x}{m} = KC^n$$

where x/m is the amount of chemical sorbed per weight of the absorbent, C is the quilibrium concentration of the chemical, and K and n are constants. For dilute solutions of many compounds, the value of n approaches unity. The constant n throws much light on the nature of the adsorption whereas K represents the extent of adsorption and is related to the free-energy changes in the adsorption.

The adsorption also depends upon the nature of the chemical under investigation. Inorganic salts and organic cations adsorb on the clay portion of the soil through an exchange reaction. Most neutral organic molecules follow a physical type adsorption and the amount of chemical sorbed in many cases follows an inverse relation to its solubility.

Adsorption of chemicals from aqueous solution is in most instances an exothermic process. Usually a lowering in temperature means an increase in the adsorption. In general, for neutral adsorption of neutral organic compounds, the heat of adsorption ranges only a few kcal/mole, indicating a physical type adsorption or in some cases weak hydrogen bonding between adsorbate and the surface. Formation of a chemical bond or chemisorption has rarely been observed in neutral pesticide-soil system. For most of the neutral organic molecules the adsorption is of the physical type, in which there is first the formation of a monolayer on the surface followed by a build-up of multilayers. Hence, by analogy to the adsorption of gases on solids, the heat of adsorption for aqueous solution of a pesticide should be in the range of heat of solution.

(c) Transport in Soil

Another important process which controls the transport of a chemical in a matrix is its movement with water, a process termed leaching. The leaching may take place in three directions: downward, since this is the usual direction of water movement, but the lateral movement of the chemical in the soil with water and even upward movement are sometimes significant. The upward movement, which is a result of mass transfer of water upward under the influence of evaporation from the surface, may concentrate a chemical at the soil surface, thus effectively removing it from the root zone.

The movement of water downward in soil is thought to be in the form of film and is produced by combined effects of capillary and gravitational forces. The chemicals are usually applied

to the surface of the soil; as water arriving at the surface penetrates, it encounters the chemical, dissolving and carrying the chemical with it as it percolates through the soil.

The displacement of the chemical under rapid percolation of water is predominantly with the bulk of the water solution. Counteracting this downward movement is the tendency of iosdiametric diffusion of the chemical in solution. Where the water percolation is rapid, the bulk movement of the chemical will be in the direction of water flow, but as water percolation becomes slower and slower, diffusion becomes a greater factor in determining the distribution of chemical. In other words, there is a dynamic equilibrium between the free chemical and the chemical in the adsorbed phase as the chemical is carried through the soil profile by the movement and the adsorbed phase. As a consequence, a chemical which is tightly adsorbed should be leached slowly and vice versa. Thus, the ΔH of solution gives an indication of a chemical's mobility in leaching.

In practice the important factors controlling leaching are (1) water solubility of the chemical, (2) adsorption, (3) soil type, and (4) moisture and percolation velocity. A highly soluble chemical having a low enthalpy of adsorption will be leached soon because of its tendency to go into solution. As a consequence the amount of chemical carried in the soil will be proportional to the amount of water available to dissolve the chemical. Temperature will play an important role in the leaching since it affects the solubility.

(d) Vaporization in Transport

The vapor pressure of organic chemicals vary over a wide range from the highly volatile substances such as fluorocarbons, chloroform, and vinyl chloride through the moderately volatile compounds like parathion, to the low volatile materials such as DDT, PCBs, and polymers. An expression relating vapor pressure to quantity evaporating is found in the Langmuir equation:

$$Q = \beta P \sqrt{\frac{M}{2\pi RT}}$$

where β is an evaporation constant of a chemical under a given atmospheric condition.

The presence of suspended dust of aerosol particles may result in sorption of some of the vapors and consequently will increase the partition function of the chemical between the atmospheric phase and other elements of the environment. The sorbed chemical may then be transported some distance with the particulate. This may explain the finding of pesticides where they have never been used. Since the vaporization of a chemical from a surface is related to its diffusion in the air, air currents can increase the rate of vaporization.

Many chemicals in an aqueous system will evaporate simultaneously with the water. Vapor loss of a pesticide from the soil system for example, is accelerated by the presence of moisture. This has been shown with such diverse materials as 2,4-D esters, thiolcarbamates, triazines, N-phenyl carbamates, and the organochlorine insecticide aldrin.

Although vapor pressure of a chemical to a great extent determines the entry of the chemical into the atmosphere, caution must be exercised in interpreting the data. The vapor pressure of a chemical can give a good estimate of air transport as long as the chemical is in the free state or is evaporating from an inert surface. However, when the chemical is bound to a surface, the vapor pressure cannot be used as an index for vapor transport. It must be pointed out that while studying the vapor loss of a soil surface other factors which may control the release of the chemical may include temperature, initial concentration of the chemical, moisture, and pH.

(e) Solution Behavior

The major factors contributing to the partitioning of a chemical into the aquatic environment are its water solubility and the latent heat of solution. Many organic compounds in use today evidence a dydrophobic character having water solubilities in the parts-per-million (ppm or even partsperbillion [ppb]) range. This makes exact determinations of their solubilities quite difficult.

The alkalinity or acidity of the solution is thought to influence the stability and the solubility of certain pesticides. For example, the solubility of triazine molecules (a class of pesticides) usually increases with lowering pH and this is attributed to protonation of nitrogen with the formation of cationic species. The presence of salts in an aqueous solution of pesticide may cause ion-association or ion-pair formation.

As would be expected, temperature significantly influences the behavior of organic chemicals in aqueous solution. Though the exact mechanisms of the solubilization of some of the sparingly soluble chemicals is not known, solubility usually increases with temperature. The question still remains whether or not they form ideal solutions. However, by substituting the solubility of the compound at two temperatures in the Van't Hoff equation, an enthalpy of solution value [ΔH] can be obtained. The enthalphy value may be used as an approximate index of the tendency of a chemical to transport to the aqueous phase from the solid state, or dissolve. The ΔH values thus derived for a solution approximate the heat of adsorption for a physical-type adsorption.

Thiolcarbamate herbicides show reversal in the effect of temperature on solubility; solubility decreases with an increase in temperature. It has been suggested that this behavior is due to hydrogen-bond formation between water and the thiolcarbamates.

Other factors which may contribute to the transport and the persistence of chemicals in an aquatic environment are (1) the presence of clay or soil particles or proteins and lipids, and (2) effects of ultra-violet or other high-energy radiation causing a decomposition of the molecule. The presence in water of soil particles of any nature (soil, clay, sand, or biocolloid) will reduce the concentration of dissolved chemical by adsorption. The extent of adsorption will depend on the nature of the suspended particles and the temperature.

(f) Bioaccumulation

The accumulation of certain compounds in living organisms (bioaccumulation) has led to problems for populations of organisms. Many of the compounds that do this have a low water solubility and a high solubility in nonpolar solvents (lipophilic). The relation between water solubility and partition coefficient for a number of compounds is seen in Figure 3 and Table 4 The partition coefficient of such compounds provides a good measure of their tendency to accumulate in living organisms (see Figure 4). This coupled with a refractoriness toward reaction gives an indication not only of accumulation but transmission from one trophic level to another. The determination of the partitioning between an aqueous phase and a solvent phase can utilize a variety of organic solvents. The most desirable solvent, however, is one that more nearly resembles the adipose tissue of the living organisms. Such solvents as olive oil and corn oil have been used but while they may satisfactorily represent some system the solvent most nearly meeting the criteria of representation and convenience is n-octanol. Accordingly, the n-octanol water partition coefficient is the more widely reported.

The behavior of chemicals described in the foregoing has dealt primarily with the different components of sub-systems of the total environment. What is desired is a more comprehensive picture of the movement and behavior in the total environment system taking into account the interactions of the different sub-systems. Perhaps the most intensive attempt to model behavior of a pesticide in the total environment has been done with DDT. Harrison et al., (1970), provided one of the early detailed models of the behavior of this chemical in an attempt to estimate transport through various trophic levels and possible persistence of the chemical. Woodwell (1971), in assessing a global model for transport and persistence of DDT, found the concentration much lower in certain compartments than would be predicted on the basis of the model utilizing the parameters available to him. The most recent attempt to give a quantitative description or model of the circulation of DDT was done by Kramer (1973). He pointed out that rates of degradation, transfer, and adsorption by plankton are critical factors in such a model. Recent monitoring data would appear to suggest the rate of disappearance of DDT may be more rapid in the general environment than had been previously estimated. Others have given some attention to modeling behavior of pesticides other than the organochlorines in the atmosphere, soil, and water. As yet, insufficient data has been accumulated to facilitate further development of these models.

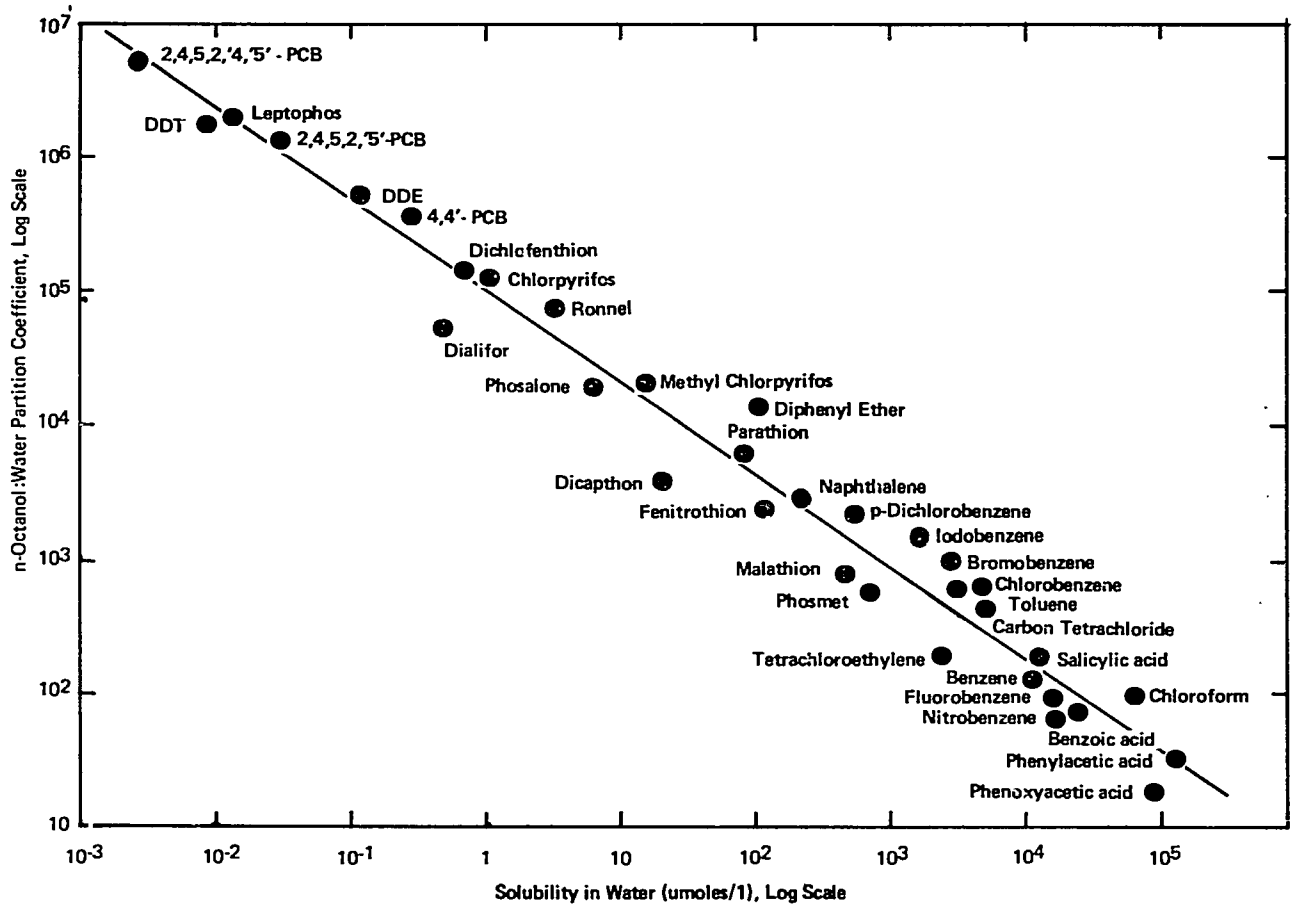


Figure 3 Relation between water solubility and partition coefficient

Table 4 Solubilities and Partition Coefficients of Various Compounds

Compound	Solubility in Water (ppm)	Log (n-Octanol/H_2O Partition Coefficient)
Benzene	820 (22°C)[a]	2.13[d]
Toluene	470 (16°)[a]	2.69[d]
Fluorobenzene	1540 (30°)[a]	2.27[d]
Chlorobenzene	448 (30°)[a]	2.84[d]
Bromobenzene	446 (30°)[a]	2.99[d]
Iodobenzene	340 (30°)[a]	3.25[e]
p-Dichlorobenzene	79 (25°)[a]	3.38[b]
Naphthalene	30[a]	3.37[c]
Diphenyl ether	21 (25°)[b]	4.20[b]
Tetrachloroethylene	400 (25°)[b]	2.60[b]
Chloroform	7950 (25°)[b]	1.97[f]
Carbon tetrachloride	800[a]	2.64[g]
p,p'-DDT	0.0031[i]-0.0034[j]	6.19[h]
p,p'-DDE	0.040 (20°)	5.69[h]
Benzoic acid	2700 (18°)[a]	1.87[d]
Salicylic acid	1800 (20°)[a]	2.26[f]
Phenylacetic acid	16600 (20°)[a]	1.41[d]
Phenoxyacetic acid	12000 (10°)[a]	1.26[d]
2,4-D	890 (25°)[b]	2.81[d]
2,4,5,2',5'-PCB	0.010 (24°)	6.11
2,4,5,2',4',5'-PCB	0.00095 (24°)	6.72
4,4'-PCB	0.062 (20°)	5.58
Phosalone	2.12 (20°)	4.30
Methyl Chlorpyrifos	4.76 (20°)	4.31

[a]Handbook of Chemistry and Physics, 34th Ed., Chemical Rubber Pub. Co.

[b]Kenaga, E.E., Partitioning and Uptake in Biological Systems, *In Env. Dynamics of Pesticides*, Plenum Press, New York, 1975.

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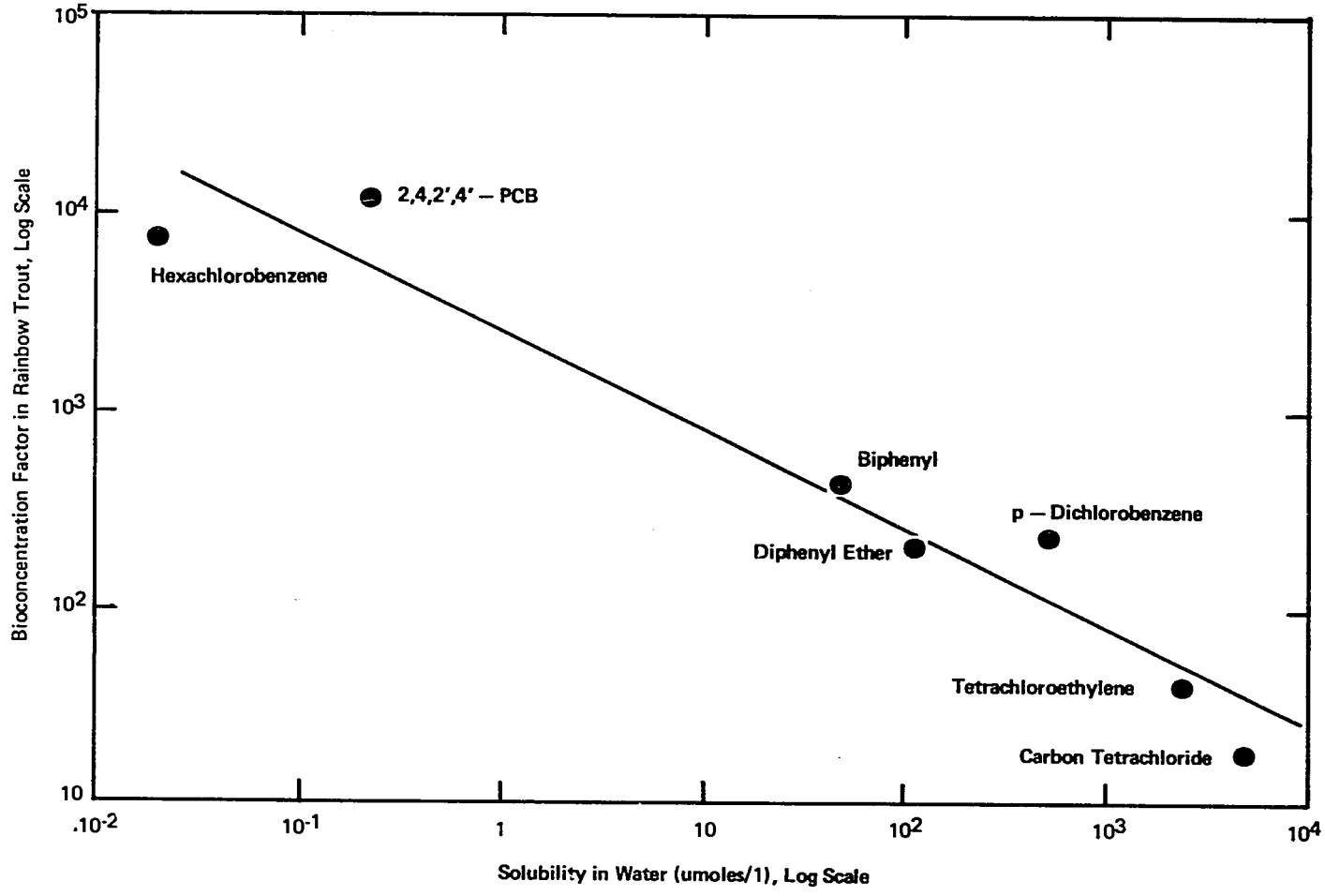


Fig. 4. Water Solubility vs. Bioconcentration based on the data of Neely, W.B., Dr. Branson, and G.E. Blau (1974) Environ. Sci. Technol. 8:1113.

4. TRANSPORT AND DISTRIBUTION

As indicated previously, the principle mechanisms of transport are wind, water, and biota. After introduction into the environment the chemical may become available for one of these transport processes by one or more of the sub-processes described. Thus, in wind transport it may become available during spraying as the carrier evaporates and leaves small droplets or particles of the pesticide suspended in air. On the other hand, the chemical may evaporate either from the droplet or a surface, thus becoming available for transport or just by air movement. Yet again, wind erosion of soil and dust contaminated by the chemical may result in transport as demonstrated by Cohen and Pinkerton (1966). Similarly, water transport may be as a result of soil erosion, leaching, or direct entry into the waterway. Biotic transport may be by migrating population of organisms, e.g. birds, fish, contaminated with the chemical at some distance point through food, and more importantly by man's transport activity.

(a) Water Transport

More attention is being given today to the problems of water transport, particularly that rising from runoff wherein the chemical and/or contaminated particulate matter is carried into bodies of water. It has been found that the solubility and adsorption characteristics of the chemical are very important in this process. Thus, as would be anticipated, the higher the water solubility the greater the proportion of chemical that will be found in the runoff water. The chemicals of greater adsorption and lower water solubility when found in runoff water are usually associated with particulate matter. In this case, the distribution coefficient such as used extensively by Hamaker (1972) and others determines the relative distribution of the chemical between the aqueous and the particulate phases as shown in Table 5.

Table 5 Relationship of K_{oc} and Soil Mobility

Compound	K_{oc}	Soil TLC R_f Calc.	Value Meas.
2,4-D	32	0.60	0.69
Monuron	83	0.37	0.48
Atrazine	172	0.22	0.47
Ametryne	380	0.11	0.44
Diuron	485	0.09	0.24
DDT	242,000	0.0002	0.00

Adapted from Hamaker 1975, (in Environmental Dynamics of Pesticides)

Wauchope (1978), has recently reviewed the percentage losses of a number of pesticides from runoff. He finds in analyses of the data differences due to water solubility, formulation, and in addition of course, to soil characteristics, slope, and intensity of rainfall event. Table 6 is an adaptation of some of the information presented in Wauchopes review.

Table 6 Seasonal runoff losses of Pesticides*
("Edge of Field Losses")

Compound	Location	Crop	Application Rate kg/ha	Period of Record (mo)	Total Runoff Cm H_2O	% of Chemical Lost
Atrazine	Ohio	Corn	1.12	3		4.7
	Pennsylvania	Corn	0.6	4	28	1.7
			9.0	4	28	3.0
Carbaryl	Ohio	Corn	5.03	3	1.5	0.15
Carbofuran		Corn	5.41	8	2.7	0.87
			3.11	6	4.1	1.9
2,4-D (NA)	Georgia	Corn	0.56	5	8.2	0.33
DDT	Mississippi	Cotton	7.8	30	16.2	1.6
Dieldrin	Ohio	Corn	5.4	27	29	0.007
Endrin	Louisiana	Sugarcane	0.34	10	13.3	0.11
Methyl Parathion	North Carolina	Cotton	13.4	4	5.3	0.13
Picloram	Ohio	Grass	2.24	11	0.7	0.007
Toxaphene	North Carolina	Cotton	26.9	3	7.3	0.51
Trifluralin	Georgia	Soybean	1.12	2	9.2	0.20

*Adapted from Wauchope, Jnl. Env'l. Qual., 7:459-472, 1978.

(b) **Wind**

Mass air movement is probably an important means of transport of low levels of chemicals to distant points. This is a subject that has engaged the interest of a number of meterologists and air pollution people for many years. From their studies, we can learn much that is applicable to the problem of transport of pesticides.

Factors relating to air transport include inter alia rates of vaporization, surface area exposed, quantity of chemicals available, rate of photodecomposition, fallout, and rainout. The residence time in the atmosphere of a number of chemicals has been determined. With many of the organics, the residence time will be in the order of a few nours to a few weeks depending on their refractoriness toward decomposition. The limited evidence available would suggest that many of the pesticides will have a rather short term residence in the atmosphere.

As would be anticipated in any rational analyses, the concentration of the chemical in the atmosphere and to be found subsequently on the surface decreases with the distance from the source. Dilution and decomposition as well as fallout are the factors contributing to the declining concentration.

(c) Biotic Transport

As suggested earlier, there are probably three routes of biotic transport. The first, that of transport by a migrating population probably does not involve large quantities of chemical. If, however, the migrating population is in the food chain of another organism, the chemical may be concentrated in a few organisms at a distant point. But for purposes of putting the matter in perspective, if one considered a migrating population of one million kg and carrying 10 ppm of residue, this might be bioaccumulated in a population having a mass of 100,000 kg giving a 10 fold increase in apparent concentration. I should say that this is a very idealized assumption since we know of no transfer mechanism that is 100% efficient. It is more likely that this would be on the order of 25% efficient and give only 2.5 fold factor. Transport of chemical through food is in part illustrated in the above example, but in the case of man the food may be transported in other ways. Thus, a chemical used as a pesticide at Point X can be transported to Point Y. However, in most instances the residue level is significantly reduced in the processing and preparation stages.

That man is a factor in biotic transport is self evident. We move technical chemicals from one point to another for use. It is in this transport that we can exercise appropriate precautions to avoid accidents and adverse effects. Obviously, here is a case where rational regulations based on scientific knowledge will be beneficial.

(d) Degradation

One of the important considerations of fate and behavior of a chemical in the environment and its effectiveness as a pesticide is the manner and rate at which it breaks down. All organic pesticides, when introduced into the environment, are subjected to physical and biological forces. The action of these forces results in breakdown of the chemical. This explains why wood rots, metals corrode and rust, or plastics break down.

For some compounds the breakdown or degradation is principally biological; that is, the compound is destroyed by metaoolism of plants and microorganisms. The degradation of the compound is brought about by the action of the various enzymes secreted by the organisms. Other compounds are susceptible to ordinary chemical attacks, such as hydrolysis, or they may be subject to photochemical breakdown.

Practically all chemicals will absorb light of one wavelength or another depending on the nature of the chemical. At an appropriate wavelength of light, the energy is great enough to result in modification or breakdown of the compound. This is illustrated by the following.

$$\text{Chemical} + \text{light} \longrightarrow \text{products}$$

Even though the shorter wavelengths at the ultraviolet are absorbed by the ezone layer, the wavelength of sunlight reaching the earth's surface, particularly at higher altitudes and in the tropics, will be sufficient to bring about a reaction of most compounds. If in addition, there are present hydrogen donors such as certain oils or water, the rate of photochemical decomposition increases. Moreover, if the compound is particularly unstable, the wavelengths may be sufficient to produce free radicals that lead on to decomposition.

Adsorption on surfaces may either increase or decrease the rate of photochemical decomposition. The decomposition can occur in solution and most probably does occur in the gaseous state. Photochemical decomposition is probably one of the reasons for the relatively short residual life of many chemicals.

Ordinary chemical reactions such as oxidation, reduction, and hydrolysis can also occur in the environment. With many chemicals, there is no need for biological intervention for these reactions to occur. Many organophosphates, for example, are readily hydrolyzed at the pH's commonly found in soil. This is illustrated by the following reaction; parathion + water to para-nitrophenol + phosphate. The adsorbtion on clays or organic matter increases the rate of breakdown of some chemicals by fostering either hydrolysis or some other chemical reaction.

Table 7 Hydrolysis of Organophosphates at Ph 7.4

Compound	Half-life
Parathion	130 days
Phosmet	7.1 hours
Dialafor	14 hours
Chloropyrifos	53 days
Malathion	10.5 days
Dicapthon	29 days

The biological reactions resulting in degradation of chemicals cover the range of oxidation, reduction, hydrolysis, dealkylation, and so on. These reactions are mediated by the different enzymes secreted by the organisms or free enzymes in the medium.

Of concern to us is the rate at which the chemical is degraded. This influences the length of time the chemical persists to give control of the pest or result in undersired residues. Rates of decomposition of various pesticides has been most extensively studied in soils. In many instances, the soil decomposition appears to follow a pseudo-first order kinetics as illustrated in the following equation:

$$c_x = c_o e^{-kt}$$

c_x = concentration at time x; c_o = initial concentration; t = time; k = reaction constant; and e = base of natural logarithms.

However, a more generalized equation has been proposed, called the "power rate model,' 'as illustrated in the following equation:

$$c_x = kc^n$$

c_x = concentration at time x; k = reaction constant; and, n = "power' 'constant.

The rate of decomposition in the soil has been found to be influenced by moisture, temperature, soil type, adsorption, and of course the level of nutrients and biological activity. Temperature has proven to be an important factor up to the temperature critical for the organism. If one were desirous of estimating the length of time a chemical persists at a given temperature knowing its rate or its energy of activation, persistence at another temperature may be estimated by applying the Arrhenius equation:

$$\frac{\log k_2}{k_1} \times \frac{\Delta h}{2.3R} \times \frac{\Delta T}{T_2 \times T_1}$$

k_1 k_2 = reaction constants at temperatures T_1, T_2 (Kelvin); ΔH = enthalpy of reaction; R = molar constant, 1.987 cal mole $^{-1}$; and, $\Delta t = T_2 - T_1$.

Many of the pesticides studied have been shown to break down at a rate that can be described by the first-order rate law. This has given rise to the terminology of half-life based on the so-called half-life calculated from the first-order kinetic equation. Actually what is being described in this instance is the time required for one half of the chemical to disappear. While not completely accurate, it is nonetheless a useful concept and a reasonable way of comparing the persistence of one chemical to that of another. The following table (Table 8) gives information on the half-life of certain chemicals.

Table 8 Soil Persistence of some Pesticides

Chemical	Half-Life
Parathion	175 days Lab study-soil
Parathion	55 days Field study
Phosmet	51 days Lab study-soil
Dialifor	151 days Lab study-soil
Chlorpyrifos	125 days Lab study-soil
DDT-aerobic	3000 days Field study
DDT-anaerobic	33 days Lab study
2,4-D	9.5 days Lab
Atrazine	130 days Lab
Diuron	212 days Lab

Not infrequently the layman, in expressing concern about pesticides or chemicals in general, speaks of the continuing accumulation of these products in soil. There is an apparent misconception that many of these chemicals undergo no degradation and continue to accumulate in subsequent applications. This obviously is not the case since the chemicals do undergo a degradation, and even with successive applications the concentration will decline. To illustrate this point let us take a chemical having a 12-month half-life that is applied in annual applications at the rate of 2 lbs/acre. The following graph then illustrates what we can readily calculate; namely that the maximum concentration that will ever be achieved is twice the annual application of two lbs/acre or approximately 2 kg/hectare (Fig. 4).

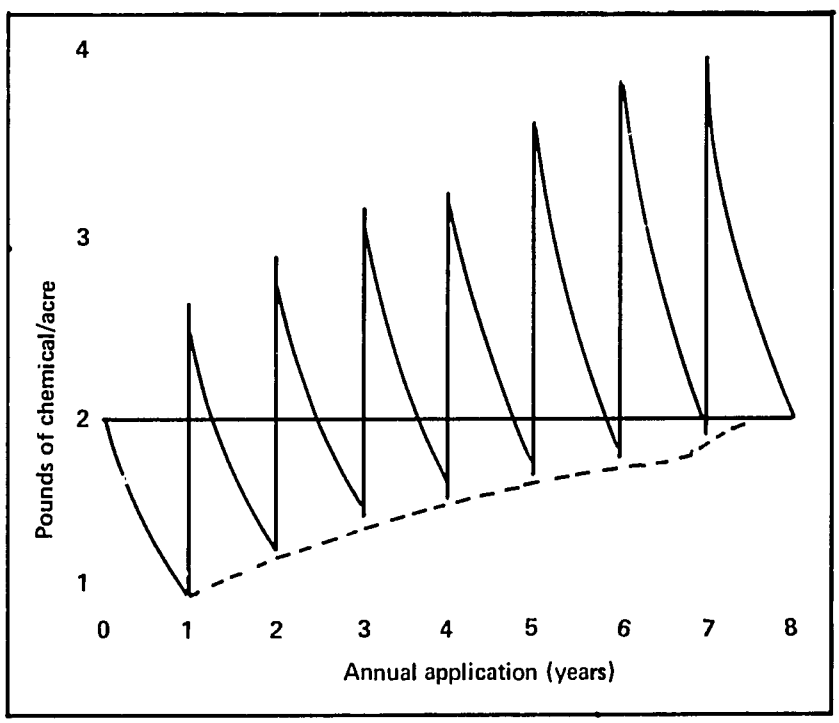
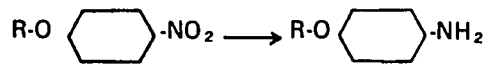
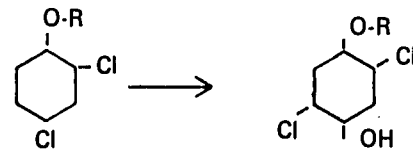
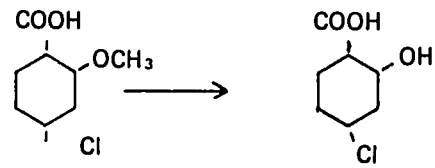


Figure 5 Trends in Soil Residue Level with 2 Pound Annual Application of Chemical with 12 Month Half-life

5. SUMMARY AND CONCLUSION

It is impossible at least for me to do justice to the large body of scientific information relating to transport and distribution in this short time. Of necessity, I have had to treat the topic lightly if not somewhat superfically in areas. I hope, however, that I have made a convincing case that extensive scientific knowledge does exist and if applied could result in safer use of our chemicals.

Common Metabolic and Environmental Reactions of Pesticides

Reaction	Illustrative Case
Hydrolysis	$R' - OC(=O)NHR'' + H_2O \rightarrow R'OH + CO_2 + R''NH_2$ Carbamate
Oxidation	$R\text{-}O\,CH_2\,CH_2\,CH_2\,COOH \rightarrow R\text{-}OCH_2\,COOH$ 2,4 D B → 2, 4-D
Reduction	 Parathion Nitrophenols Trifluralin
Hydroxylation	 2,4-D
Ether Cleavage	 Dicamba
Dehydrohalogenation	$CHCl_3 \longrightarrow R_2\,C{=}Cl_2$
Conjugation	$NH_2 \longrightarrow$ Amide $R\,COOH \longrightarrow$ Ester salt amide $OH \longrightarrow$ Glucoside Sulfate

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15. THE IMPORTANCE OF A PROPER PESTICIDE MONITORING PROGRAMME

AZIZ ALI

CONTENTS

		Page
1.	INTRODUCTION	228
2.	DANGERS OF PESTICIDES	228
3.	INCREASING USE OF PESTICIDES	229
4.	NECESSITY FOR ASSESSMENT AND CONTROL	229
5.	CONCLUSION	230

I. INTRODUCTION

From the dawn of civilization mankind's primary concern has been with the struggle for assistance for the improvement of his living conditions, especially with the provision of food. The continued and accelerating rate of increase in world population, together with the concomitant increase in available arable land has necessitated attempts to exercise control over the natural environment. The present widespread use of agricultural chemicals is but one of the latest facets of this constant battle.

Of the many control mechanisms presently in use, pesticides may be regarded as of critical importance. That there is a need for pest control is not in doubt; with the domestication of food plants and animals and the growth of organized agriculture the stage is set for the debut of insects in pest proportions. The problem was soon appreciated, but the cause has long defied man's ingenuity. Many chemicals are now used to kill insects, weeds, fungi, mites, etc. but their use also brings other problems into train.

With the increased use of pesticides, there has been an increasing awareness of the importance of soil colloids in the absorption, movement, persistence, degradation and bioactivity of pesticides. The fate and behaviour of pesticides in the environment are generally dependent on the following factors: chemicals, photochemical and microbial decomposition, volatilization, movement, plant uptake and adsorption.

2. DANGERS OF PESTICIDES

By their very nature pesticides must be toxic to some form of life, hence, the potential environmental pollution they can cause, and the dangers of toxic residues remaining on crops at harvest time, must be kept under close observation and control. To justify the use of such chemicals it may be necessary to show:

(a) that no better alternative method of control exists

(b) that toxicological effects are understood

(c) that such regulations as may be made can be properly enforced and

(d) that adequate chemical or biological methods are available to provide the evidence required in support or denial of (a), (b) (c) above.

Agriculture and horticultural application of pesticides have continued to increase as their benefits in terms of increased yields and cleaner harvests are observed. It is an unfortunate fact that these most useful pesticides, essential to the agricultural industries of the world if nutritional

levels are to be observed and maintained, are found as residues on the harvested crops. This is especially so in the case of the organochlorine pesticides which persist or are converted into stable, often toxic substances. The organophosphorus pesticides break down to toxic metabolites but many of these metabolites themselves break down into non toxic residues.

3. INCREASING USE OF PESTICIDES

The use of herbicides and insecticides have increased significantly over the last decade. In the United States alone over 300 million pounds of herbicides were sold and more than 120 million acres of agricultural lands were treated. The CARICOM Caribbean, though small by standards addressed to larger land masses, consists of 100,000 square miles and holds a population of about 5 million. With the emphasis on agriculture, tourism and industry, the question of environmental quality and management is taking on greater prominence. At the present time, no serious attempts have been documented towards the monitoring of pesticides.

There is limited information regarding the toxicity of most pesticides to all forms of life and the possible shift in the oxygen/carbon dioxide balance in the environment. This imbalance (if any) could result in the use of streams and lakes as impossible sources of potable water supply.

In the Commonwealth Caribbean more than 150 different pesticides are available to the public. Included are some chemicals which are highly toxic and are banned in other Countries. Most of these toxic chemicals are used by members of the farming community and it has been recognized that, in the past, insufficient attention has been given to ensuring that pesticides be applied at the recommended rates and that, while useful for the purposes for which they are intended, if misused they pose a threat to man and his environment. As a result, enabling legislation has been passed in several territories to control the use of pesticides.

4. NECESSITY FOR ASSESSMENT AND CONTROL

In recognition of the limited experience in the area of pesticide management, there is an urgent need to assess the situation and make recommendations for both national and regional demands. The urgency exists for each country to be guided by enabling legislation to control if necessary the excessive uses of fertilizers and other plant and animal protective chemicals. Each country ought to be guided as to the impact of industrial and agricultural development by the use of chemicals etc. on the quality of the environment and hence the quality of life.

Taking into consideration that the farming communities are wholly dependent on pesticides, that these chemicals and their metabolites are a potential threat to our environment and our health, (to name but a few, the pesticides aldrin, dieldrin, heptachlor, chlordane and mirex are suspected carcinogens), it is important that we understand the scope of the problem in order that we may begin to deal with it effectively. In this respect, it is imperative that the notification of important changes in and development of pesticides and regulations elsewhere in the world be heeded.

It has been recognized in developed countries that there should be uninhibited cooperation between the authorities concerned viz: Ministry of Health/Ministry of Agriculture etc. in order that they may begin to deal with the problem effectively.

The strategies for limiting the introduction of toxic pollutants into the environment are of two general types: control of products and their uses and control of agricultural/industrial effluents.

In the Caribbean control of products can be accomplished by reducing the input of toxic materials, that is, by using less of the chemical or by finding a less dangerous substitute for it. If for some reason a substitute is not suitable or effective, some control might be gained by limiting the use to closed systems thereby regulating disposal problems.

5. CONCLUSION

It is important, therefore, that the more toxic chemicals be identified and strict regulations be set regarding their uses, storage and handling, transportation and disposal. A strategy to control these chemicals must address other media such as air, water, foods and wastes. Furthermore, since increasing attention is being paid to the human health effects in relation to other environmental effects of toxic substances, priority now is clearly to determine human health effects and to protect human health, although protection for other species must also be provided.

16. GUIDELINES FOR PROPER STORAGE, HANDLING AND DISPOSAL OF PESTICIDES

S. PARASRAM, B.K. RAI AND J.R. SUAH

CONTENTS

		Page
1.	INTRODUCTION	231
2.	ENVIRONMENTAL IMPACT POTENTIAL OF PESTICIDES	232
3.	CONSIDERATIONS IN STORAGE OF CHEMICALS	233
4.	CONSIDERATIONS IN HANDLING OF PESTICIDES	234
5.	DISPOSAL OF CHEMICAL PESTICIDES	235
6.	DISPOSAL OF CONTAINERS	235
7.	EXTENSION WORK ON PESTICIDES	235
8.	CONCLUSION	235

I. INTRODUCTION

Developing countries in the tropics are making use of greater quantities of chemical pesticides in their agriculture, public health and industry, as they are becoming more and more sophisticated. In the production, distribution and use of pesticides some contamination of environment is inherent but misuses and accidents can lead to a larger scale contamination of the environment. Further, because of contamination or deterioration of pesticides, pesticides may have to be disposed.

Although there are not much data of poisoning from agricultural chemicals in the Commonwealth Caribbean, recent occurrences in Jamaica should serve to demonstrate the seriousness of this possibility. In 1976 there was a serious outbreak of poisoning caused by wheat flour contaminated with parathion in a warehouse before shipment to Jamaica. Twenty people including five from one family died. During the next two years, 22 cases of food poisoning were investigated, many of which were suspected to be due to the improper use of Gramoxone against head lice, *Pediculus humanus capitata*. In 1979 19 cases were investigated, of which 2 children died of organophosphorus poisoning. Up to August, 1980, 52 cases of chemical poisoning have been reported, 11 of which were suspected to be due to organophosphosphates through contaminated wheat flour, and one from Gramoxone used for the control of head lice.

2. ENVIRONMENTAL IMPACT POTENTIAL OF PESTICIDES

Pesticides by their very nature are toxic to one or more forms of life. Many pesticides are toxic to man, higher animals, crops, and lower terrestrial or aquatic organisms some of which are vital for biological waste degradation and/or oxygen production mechanism. Build up of residues of pesticides or their toxic degradation products in soil and aquatic ecosystem adds another dimension to the impact potential of pesticides.

Pesticidal chemicals at higher dosages are more toxic to organisms. There is, however, a certain dosage below which the pesticide is not effective.

Toxicity to man and higher animals may result from direct exposure by inhalation, by ingestion, and/or absorption through the skin. Toxicity may also result from ingestion of residues in or on food and feed. Pesticides also irritate eyes and skin. Oral, dermal and inhalation toxicity of pesticides to mammals are indicators of the environmental impact potantial of pesticides. Data

on laboratory toxicity to mammals are not directly applicable to field conditions but provide an indication of the general order of toxicity of the pesticide and possible hazard to man. Table 1 presents a summary of the acute toxicity criteria by which pesticides are assigned to four commonly used categories of toxicity. Most pesticides classified as "highly toxic" to mammals are insecticides, rather than herbicides or fungicides. Because of greater impact potential of dermal toxicity, safer pesticides are being developed with lower dermal toxicity or higher dermal LD_{50} even though oral toxicity is high e.g., the acute dermal and oral LD_{50} of methomyl to laboratory animals are 5,880 and 17 mg/kg respectively.

Table 1 Mammalian Toxicity categories of Pesticides

Toxicity Parameter	Highly Toxic	Moderately Toxic	Slightly Toxic	Relatively non-toxic
Acute oral LD_{50} (mg/kg)	< 50	50-500	500-5,000	> 5,000
Acute dermal LD_{50} (mg/kg)	< 200	200-2,000	2,000-20,000	> 20,000
Acute inhalation LD_{50} (mg/kg)	< 2,000	2,000-20,000		
Dose probably lethal to a 150 lb. man	A few drops to one (1) teaspoonful	1 teaspoonful to 1 oz.	1 oz. to 1 pt. or 1 lb.	>1 pt. or 1 lb.
Signal word required on label	Danger-Poison skull and crossbones	Warning	Caution	

Source: Von Rumker et al (1975).

Data on toxicity of pesticides to wild mammals, fishes, and to lower terrestrial or aquatic organisms are incomplete for many products and almost totally lacking for others especially for older products. By virtue of their biological and chemical properties, herbicides and fungicides are most likely to affect lower terrestrial and aquatic nontarget organisms.

Drift of herbicides or contamination of herbicides with other agricultural chemicals has caused serious crop losses in some agricultural areas. Greatest hazards from use of fungicides appear to be misuse of seed treated with fungicides toxic to mammals. In many countries, misuse of treated seed for direct human consumption or as animal feed has resulted in poisoning epidemics, some resulting in fatalities.

3. CONSIDERATIONS IN STORAGE OF CHEMICALS

Location: Storage facilities for bulk quantities of pesticides should be located as far as possible from other human activities, with proper disposal facilities, and should prevent inadvertent public incursion. The site should be well removed from streams or other bodies of water, and located so that the slope or drainage is away from the water across. It is desirable for such sites to be of sufficient size to accommodate treatment areas for disposal of waste and spillage.

Storage Building: The building should have a concrete floor, above flood level. The floor should have a smooth finish for easy cleaning and to prevent the chemical from soaking into the concentrate. The floor should slope toward a drain so that spills could be washed into the drain. The washings from such drains should pass through carbon filters and treatment equipment before being disposed of.

Other features must include good ventilation, ventilators and windows capable of being opened from the outside, fire control equipment, safety showers, and appropriate security to prevent unwanted access to the storage.

The building should be large enough to allow for isolation of such chemicals as herbicides from other pesticides to avoid cross contamination. Pesticide containers should be stored on pallets. A certain amount of spillage in a storage building is unavoidable. In each storage facility charcoal should be available to adsorb chemicals. In addition lime or calcium carbonate should be available to neutralise materials like phosphates and carbamates. Further absorbent materials like clay can assist charcoal in the adsorption.

The storage facilities should be adequately marked, indicating the nature of materials stored, so that in the case of an emergency, such as fire or an accident, the emergency workers such as firemen are then better able to deal with the problem.

The pesticide containers should be durable, leak proof, and imprevious to moisture. There should be a periodic inspection of barrels, tanks, and bags in storage to check for leaks, damage or deterioration.

4. CONSIDERATIONS IN HANDLING OF PESTICIDES

While handling pesticides in containers, repacking, and/or dispensing into smaller containers, or applying pesticides, a certain amount of spillage of pesticide is inherent, which leads to contamination of the surroundings and persons, especially where operations are manual rather than mechanical. Protective apparel should be used by workers to reduce exposure to chemicals, especially those handling pesticidal concentrates. The duration of exposure of workers to pesticides is important and is directly related to toxicity hazard. If the clothes and skin of a person are contaminated with pesticides, exposure to pesticides continues even when the person has stopped working. Thus the best practice is to bathe with hot water and soap after completion of work and change clothes. The clothes should be washed regularly, and decontaminated if need be before re-use.

Farmers with small holdings do get away with application of pesticides with manually carried equipment without using protective apparel, because the exposure to pesticide is for a short period of time. However, problems arise when the same persons constantly apply pesticides day after day without much protective apparel, e.g. the spray gangs on some of the large estates. Blood samples from 50 workmen who sprayed dieldrin with mist blowers for 4-5 months on to cocoa trees in Grenada, were analysed. The distribution of µg dieldrin/ml blood was as follows:

Class:	above 0.2	0.1-0.2	0.1-0.15	0.01-0.1	0.05
Frequency:	1	1	6	14	28

0.2 µg dieldrin/ml blood was considered to be action level (viz the level is considered critical).

Training in handling pesticides, supervision, and medical checks should be an integral part of an organisation when workers come into continuous contact with pesticides.

Ship holds, trucks, wheel barrows, carts and other equipment used for transporting pesticides, may get contaminated with pesticides. All such equipment needs to be cleaned or decontaminated before being used for handling other items, especially food and feed.

Because of large scale use of pesticides and the persistence of organochlorine pesticides in the environment, use of organophosphate pesticides is on the increase. Organophosphates are more volatile, less persistent, and usually more toxic than organochlorines. In developing tropical countries, (i) because of higher temperatures, vapour action of chemicals is greater and also it is uncomfortable for the workers to wear protective apparel, and (ii) since pesticides are handled more manually than mechanically it is of utmost importance to use pesticides of low mammalian toxicity, to reduce hazards in general and to operators in particular. However, if research work indicates that a pesticide with higher mammalian toxicity needs to be used for a particular pest control, then that chemical should be used specifically for that pest only. Application hazards could be further reduced by using a suitable formulation of the pesticide e.g., use of phorate granules is comparatively safer than the use of phorate emulsifiable concentrate. As an example,

information on various insecticides used in Belize in 1977 and 1978 is given in Table 2, which indicates that some of the insecticides used as emulsifiable concentrates like endrin, demephion, methamidophos, and methyl parathion, have high mammalian toxicity. Unless there is some specific advantage, the use of more toxic materials should be stopped.

Table 2. Insecticides Imported into Belize in 1977 & 1978

Common Name	Formulation	Nature of Use	kg. a.i. imported 1977	kg. a.i. imported 1978	LD_{50} of a.i. mg/kg oral	LD_{50} of a.i. mg/kg dermal	Use
			Chlorinated Hydrocarbons				
Chlordane	WP	I	55	71	457-590		Crops, termite proofing of buildings.
Camphechlor	EC	I		3,907	69	1,075	Crops
Gamma BHC	WP,EC,Aer	I,A	309	346	88-125	1,000	Crops & livestock
Aldrin	EC,WP	I	900	1,157	67	98-200	Crops
Dieldrin	EC	I		186	46	10-102	Termite proofing of buildings
Endrin	EC	I		12	7.5-17.5	15	Crops
			Organophosphates				
Pirimiphosmethyl	EC	I		37	> 2,000	2,000	Crops
Phoxim	EC	I	103	366	1,845	> 1,000	Crops
Fenchlorphos	Aer	A	21	33	1,740	1,000-2,000	Livestock
Malathion	Tech,EC,WP	I	18,000	4,318	1,375	4,100	Crops
Trichlorfon	SP	I	370	226	450-639	> 2,000	Crops & livestock
Dimethoate	EC	I	37	74	215	1,000	Crops
Coumaphos	EC	I,A	108	340	56-230		Livestock
Demephion	EC	I	27	17	64		Crops
Ethoprop	G	I	136	24	61.5		Crops
Methamidophos	EC	I	91	579	21	118	Crops
Methyl parathion	EC	I	52	62	9-25	300-400	Crops
			Carbamates				
Carbaryl	WP	I	45	15,881	850		Crops
Propoxur	EC,D	I	119	465	95-104	> 1,000	Crops, household
Carbofuran	G	I,N	16	145	11	10,200	Crops
Methomyl	LC	I	890	300	17	5,880	Crops

EC, emulsifiable concentrate; WP, Wettable powder; Aer, Aerosol; Tech, Technical; SP, Soluble powder; G, Granule; D, Dust; LC, Liquid concentrate; I, Insecticide; A, Acaricide; N, Nematicide.
a.i., Active ingredient.

5. DISPOSAL OF CHEMICAL PESTICIDES

A pesticide may need to be disposed of because of deterioration below acceptable quality, or the chemical is no longer useful due to some other reason. There are four ways of disposing of chemical pesticides:

1. Use. Using the chemical as a pesticide is perhaps the most effective means of disposal wherever possible. At the low doses normally used, the environment will destroy the material through photochemical and microbiological degradation.

2. Chemical Destruction. Pesticide molecules could be destroyed utilising specific chemical reactions. Chemical destruction, though effective, is expensive, and finally the waste after reaction will still have to be disposed of.

3. Incineration. Incineration is carried out in special furnaces which have a flame temperature of over 800°C, adequate air intake, and a long residence time in the combustion chamber to ensure destruction of the chemical. Further, such incinerators require smoke stacks with treatment devices to avoid air pollution. Pesticides cannot be destroyed by open fires; some of the pesticides are carried away in the smoke.

4. Soil Disposal. Properly managed soil disposal is becoming a popular method. It is much more effective in disposal of organic chemicals, such as many of the pesticides. Soil disposal relies on a combination of chemical and microbiological degradation to innocuous products. There are two quite different methods for disposal of chemicals in soil:

One method utilises pits dug in soil. The individual pits should be limited in size and relatively small quantities of chemical deposited in each pit. The pits should be 10 - 30m apart, have a maximum depth of 2.5m, and have a covering of ½ to 1m of soil. The pit is lined with lime and charcoal. A layer of chemical to be disposed of is then placed in the pit, covered with lime and a layer of soil. Again layers of lime, pesticide, lime, and soil are made. Lime provides an alkaline medium to hydrolyse organophosphates and carbamates to less toxic products. Further, as lime diffuses into the soil it encourages microbial activity that destroys the hydrolysed products. Also, an alkaline medium dechlorinates chlorinated hydrocarbons. In some instances, further breakdown occurs fairly rapidly. For more rapid breakdown of the cholorinated hydrocarbons, addition of animal manure or organic compost with some fertilizer creates aerobic conditions that bring about fairly rapid degradation of the organochlorines. The sites should be selected with extreme care, since the breakdown of the chemical will not be very rapid and leaching could contaminated ground water and nearby streams.

The other method of soil disposal consists of distributing the material over a larger area, 10 - 20 times the normal rate of application, incorporating it into the soil to a depth of 10 - 15 cm. Management of such an area by means of adding fertilizer and maintaining soil moisture accelerates the rate of breakdown. For organophosphates, addition of lime at the rate of 2.5 tons/ha will accelerate the breakdown. The site selected for this biodegradation should be far removed from other human activities and it should not drain into streams. Some provision should be made to drain surface runoff into a sump area before being released.

6. DISPOSAL OF CONTAINERS

Paper and plastic bags used for pesticides should not be thrown into ditches and waterways but should be buried. This may be in a sanitary landfill using additive chemicals to accelerate the breakdown of the chemical.

Very often cans and drums attract other uses. It is impossible to drain many containers completely empty of pesticide. Repeated washings will only reduce the amount of pesticide in the container. To make a container safer, it should be rinsed at least three times. The rinsing may be either with water or with oil, whichever is the most effective solvent for the pesticide formulation. Containers with organophosphate or carbamates should be soaked in a relatively strong alkaline solution followed by a thorough washing with water and detergent, followed by yet another soaking in which charcoal is introduced in water to remove traces of chemical.

The best means of disposal of the larger containers, drums, and barrels is to re-use for the same pesticides. The drums may be reconditioned, involving steam cleaning or removal of an old plastic liner and putting in a new liner.

7. EXTENSION WORK ON PESTICIDES

Hazards due to improper storage, handling and disposal of a pesticide could occur at various levels from a few manufacturers of technical material to innumerable users dispersed over continents. Persons handling pesticides need to be educated. A very large number of users of pesticides are small farmers. Because of the small sized operation and limited financial resource, a small farmer can buy only a small quantity of a pesticide at any one time. This raises the problems of repacking, labelling, storage and handling. Further, a small farmer is limited in his knowledge of hazards of pesticides to himself, his family, his animals, his crops and to consumers of his farm produce. This is a distinct area in which Extension and Plant Protection Services of the Ministries of Agriculture can play an important role.

8. CONCLUSION

Extreme danger can result from improper handling, storing or disposing of chemical pesticides. Even in the relatively small area of the Caribbean many cases of poisoning, several fatal, have been reported within past five years. This paper has presented factual dates on oral and dermal toxicity of many of the pesticides in common use, and lays down stringent guidelines for

their storage, handling and disposal. The need for training of extension officers and farmers to adopt a rigidly disciplined approach is emphasised.

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17. THE ROLE OF EDUCATION AND COMMUNICATION IN PEST AND PESTICIDE CONTROL

MARSHALL McGLAMERY

CONTENTS Page

1. INTRODUCTION – EDUCATION AND COMMUNICATION 237

2. PEST AND PESTICIDE MANAGEMENT 237

3. THE ROLE OF EDUCATION 238

4. THE ROLE OF COMMUNICATION 238

5. CONCLUSION 239

1. INTRODUCTION

The role of education is to provide instruction or technical knowledge. Education also has a role in the discovery and assembling of technical information. Education can be formal (structured) or informal. Universities and colleges are usually involved in education in pests and pesticides. These roles are called research and teaching. Research in pest and pesticide control is the function of the experiment station, while resident instruction has the teaching role. Education is usually more concerned with the "why?" or "how come" than with the "how to". The scouts, consultants, and specialists as well as technicians and scientists all must be trained in pest biology and pesticide chemistry.

The role of communication is to transmit or transfer knowledge in a practical way to the user or public. Communication is usually more concerned with the "how to" rather than the "how come". Thus, communication has a role in interpretation of information. Communication can be verbal, visual or audiovisual. It has long been known that the eyes have better comprehension than the ears. Movies, television, and illustrated lectures are audiovisual. Radio, newspapers, and magazines are examples of visual communication. The agricultural extension service is noted for its communication role in pest control in agriculture. They have long used the "on-the-farm" demonstration to get farmers to recognize and utilize good management practices.

2. PEST MANAGEMENT

The purpose of pest management is to control pests or problem species of insects, diseases, weeds, or parasites. Control means to reduce the pest population to manageable or less than threshold population. Pesticide management is to control the pesticide in such a way as to minimize adverse reactions such as toxicity, resistance, carryover, species displacement, or environmental problems.

Pest management may be likened to a war. First you must know the enemy, his habitat, population, and vulnerabilities. This involves intelligence and reconnaissance. Then, we must prepare the defenses to minimize our losses. Then, we must plan the offensive strategies and tactics to minimize the results of the enemies presence. We must have the attack strategies which will prevent the enemy from getting the advantage. Strategy is the plan to win the war, while tactics are the maneuvers to win the war. After the battle, we must regroup, debrief and then plan new offensive and defensive actions.

Pest management may be divided into several phases: codify, identify, quantify, rectify, and verify. **Codification** is a systems approach which is necessary for the problem to be realized and control programs to be formulated. **Indentification** is necessary to know the significance of the problems and the control measures for the problem. **Quantification** involves determining

the population of pests and comparing to a threshold population. It is also necessary for determining the "real" problems. **Rectification** is the total management program used to control the pest. This involves cultural, mechanical, biological, and chemical (pesticides) methods. **Verification** is the monitoring of the program to determine its success and to determine any adverse effects that the program may be having on the ecosystem.

3. THE ROLE OF EDUCATION

Education's role in codification is to do the research on ecology and biology of the organism to determine the vulnerability of the pest to different types of control. Research on the modification of the environment to best use cultural and biological controls is usually performed at the experiment stations. Chemical controls are also tested at the experiment stations. Then, the control strategy must be formulated.

Education's role in identification is to classify the pest, i.e., the taxonomists' role. Identification is essential for proper control measures to be specificed. You must know the enemy. They must also help prepare proper identification aids for communicators to transmit to the using public.

Education's role in quantification is to determine the threshold populations under different environments so that we can verify the need for control. Scouting techniques must be formulated. We cannot wait until a crisis arises. We must have predictive models to forecast or predict when crisis populations will be present. One of the major problems with threshold levels is that they are usually determined on a single species, while in weed control rarely is there a single species present. One other problem is that diseases and insect populations are mobile, dynamic, and unpredictable, while weed populations are immobile, relatively stable, and relatively predictable.

Education's role in rectification is to formulate and specify the proper programs for controlling the pest. They must help be the conscience of the organization or the unbiased source of information. They must work with industry to determine proper techniques, but they must also help place chemical pest control in proper perspective. Education must help determine the hazards with the use of certain pesticides and methods to reduce these hazards. They must be concerned with the disruption of natural controls, species displacement, the buildup of resistance and the possibility of carryover or residue.

Then, the control tactics must be specified taking into consideration biological, cultural, mechanical and chemical control. Selection criteria for different pesticides must be made. In weed control, we use selectivity tables to help the farmer or applicator choose the herbicide(s) which will best handle the problem. Strategies and techniques must be presented with their advantages and disadvantages.

Education's role in verification is to help monitor the situation after control measures have been applied to determine their effectiveness and make sure we have not intensified the problem or stupified the host. We must be sure that we have nullified the effect of the pest, fortified the host and not just beautified the environs and modified the problem.

4. THE ROLE OF COMMUNICATION

Communication's role in codification is to transmit the systematic programs of control to the users. These are usually written programs in such media as books, magazines, bulletins, and newspapers. They must transmit the information to the "user" in a manner which he can best understand. This often involves the use of demonstrations so that the producers can see the actual results in the field. Most farmers are quite skeptical of small scale research. Communication must also provide the back-feed mechanism to the researchers and teachers so that strategies can be reformulated to better fit the situation.

Communication's role in indentification is to prepare visual aids which will help the user positively identify the pest in the proper stages. This is often the seedling or larval, and not the mature, stages. Rarely is the mature stage the proper stage for control. Morphological identi-

fication is often necessary. The sexual or reproductive stage is rarely the best time for control of weeds or insects.

Communication's role in quantification is to transmit proper scouting procedures to the user, transmit threshold levels to the field, and notify users when threshold populations are expected to be exceeded. The latter information must be information that is transmitted on a short time basis in the way of newsletters, news releases, radio tapes, and live appearances on radio and television. The scouting and threshold information can be transmitted ahead of time, but they must be reinforced in the up-to-date information.

Communication's role in rectification is to transmit the proper control procedures or tactics to the user. This information must include proper timing and rate of application plus the equipment calibration and usage. The precautions and hazards must also be emphasized so that adverse effects can be minimized.

Communication's role in verification is to keep the researchers and teachers informed and honest. We must certify and qualify the usefulness, clarify the issues, and satisfy and edify the public if programs of pest control utilizing pesticides are to survive. The public is often terrified by the press where hazards are amplified and usefulness is falsified. We must justify our actions and unify our approach to signify and testify that what we have done is justified. We must modify and diversify our approaches. We must edify and not just satisfy. We must qualify and not just testify; rectify and not intensify or amplify. We must clarify and not terrify.

5. CONCLUSION

Thus, education and commuication together must help build competence, confidence and conscience into the pest and pesticide control communities. Competence means keeping up-to-date as to modern strategies and methods of pest control and to proper techniques to minimize adverse effects. Confidence is associated with involvement, knowing that what is sought, taught, and bought is actually valid. Conscience is involved when decisions must be based upon ecological and sociological, and not just economic factors.

Thus in summary, education must provide the "how come" and communication must provide the "how to" so that the results will signify to the public, and we personify, the "good steward". The Golden Rule is still valid: We are our "brother's keeper". We must keep the public notified and satisfied if we are to survive.

IV
MANAGEMENT,HEALTH AND LEGISLATION

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18. THE CONCEPT OF AGROMEDICAL APPROACH TO PESTICIDE MANAGEMENT

JOHN E. DAVIES

CONTENTS

		Page
1.	INTRODUCTION	242
2.	REASONS FOR THE AGROMEDICAL APPROACH TO PESTICIDE MANAGEMENT	242
3.	CURRENT AGROMEDICAL PESTICIDE MANAGEMENT PROBLEMS	243
4.	POTENTIAL FOR INTEGRATED PEST CONTROL AGROMEDICAL	243
5.	SUGGESTED INGREDIENTS FOR AN AGROMEDICAL PROGRAM	246
6.	CONCLUSION	247
	REFERENCES	254
	APPENDIX: UNIVERSITY OF CALIFORNIA/USAID WORKSHOP, UNIVERSITY OF ALEXANDRIA, A.R. EGYPT; REPORTS	256

I INTRODUCTION

In this review of the agromedical approach to pesticide management, mention should first be made of what we have come to perceive as agriculture and then to describe how the concept started and evolved.

We have defined agromedicine as "integrated interdisciplinary application of skills and knowledge of agriculture, applied chemistry and medicine to the safe global production of enough food of high nutritional content to meet the health and nutritional needs of man" (Davies *et al* 1978). Such a definition needs clarification in terms of what it is not. Agromedicine is not merely agricultural medicine, nor is it occupational medicine as it is related to pesticides. Rather it is an integrated approach of these disciplines to producing the right amount of the right food for man.

We believe that the integration of the disciplines of agriculture and health is a vitally necessary union for the resolution of problems that have arisen, and are likely to arise in the future in the battle against famine.

At present, more than one person in three in the world, or 1.3 billion people are presently facing malnutrition. These people live in countries which cannot grow enough food or cannot afford to buy enough food from other nations to provide an adequate diet for their citizens. Nearly 70 percent of them live in four Asian countries — India, Pakistan, Bangladesh and Indonesia. The rest live on the African continent and in Latin America. Marasmus and protein-calorie malnutrition are of major concern; if we add to the situation the population predictions, the urgency of the food production issue becomes only too apparent. The world population, which was estimated to be 3,860 million in 1970, is predicted to increase to 4,554 million in 1980, and to 6,726 million at the turn of the century. Most assuredly, therefore, the number of countries facing malnutrition will increase astronomically in the coming years unless food production techniques can rise to meet the challenge.

2. REASONS FOR THE AGROMEDICAL APPROACH TO PESTICIDE MANAGEMENT

Both philosophical and pragmatic considerations have furthered the growth of agromedicine. From a philosophical point of view, the twin problems of safe and enough food, and the reduction of ill-health, have been issues which have been of concern to man from time immemorial. These problems continue to this day and demand a substantial continuing effort to avoid major catastrophy from either issues. Agriculture and health are inseparable partners for the resolution of these concerns. Nutritional deficiencies are not the only major nutritional concerns for the future especially now that research has shown that inadequacies of diet increase susceptibility to infectious disease and that inappropriate diet is casually related to coronary heart disease, cancer and infertility.

It is therefore not surprising that the needs for agriculture to assume a more therapeutic role in addition to its more conventional agricultural role is becoming more and more obvious. If nations are to solve the dual nutritional problems which stem from the deficiencies of food or the inappropriateness of food, future agricultural problems will have to accommodate the qualitiative and quantitative needs of society for a wholsome and adequate diet.

Pests are a major contributant to food shortages and, in many regions of the world, pests, insects, rodents, weeds and a host of other organisms are largely responsible for the transmission of diseases or the loss and destruction of food. Crop losses of 20% to 30% during production and 20% more during storage, are not at all uncommon. This means that nearly 50% of the potentially available food is spoiled during production and storage. Similarly vector-borne diseases extract a heavy toll of human suffering and death and, in 1970 the W.H.O. (1973), estimated that worldwide morbidity was about 100 million cases per annum with a mortality rate of about 1,000,000 per year with the greatest impact on children less than 4 years old. The W.H.O. also stated that schistosomiasis was second only to malaria as the principal cause of morbidity and mortality in the tropics (W.H.O. 1967). The maintenance and spread of this disease was closely linked both to the extremes of lifestyle of the inhabitants and the impact of the manipulation of the environment which resulted from expanded agro-chemical irrigation systems (Beck and Davies 1976).

These general examples illustrate the importance of various pests and their enormous impact on health, food production and welfare and the mutual interests of agriculture and health for effective and economical pest and vector control. They also indicate why such great energy and effort has been and continues to be devoted to pesticide management in public health and agriculture.

Both the short and long range goals of agriculture and health are concerned with the health and welfare needs of society. While medicine seeks to prevent and cure diseases, agriculture seeks to provide food for an adequate and nutritional diet to maintain that health. One without the other is destined to failure. Thus, unwittingly, up until a few years ago, each profession pursued its separate interests, particularly with regard to pest control. No longer is that acceptable since it seems likely that effective future pest control, in both the agriculture and public health arenas, will require the continued and abundant use of chemical pesticides, a technology which can only survive in the future with greater safeguards for the protection of man and his environment.

3. CURRENT AGROMEDICAL PESTICIDE MANAGEMENT PROBLEMS

Pragmatic as well as philosophical considerations have also promoted the agromedical partnership. Problems have arisen and, over the last 10 years, several international pest management surveys have drawn attention to the presence of three serious pesticide management problems. (Nave Revollo 1971 and Davies *et al* 1975). These are:

1. The problems of human and animal pesticide poisoning.

2. The problem of persistence, and

3. The problem of resistance.

These three problems, the first two of which are directly attributable to pesticides, and the third which is indirectly due to the agricultural use of pesticides impinging on and imparing pub-

lic health vector control programs, have been strongly influential on the growth of the integrated pesticide management approach which has been described by Smith in Paper No. 10 in this volume.

Problem No. 1: Pesticide Poisonings

As agriculture and public health have switched from the organochlorine to organophosphate insecticides, human pesticide poisonings have become a problem on a worldwide basis. Furthermore, it is only too apparent from the paucity of poison statistics that this is a problem whose magnitude is still not fully known because, in many areas of the world, acute pesticide related illnesses are often unrecognized and universally under-reported.

In his review of global pesticide safety, Copplestone (1977) discusses this problem and reviewed the WHO estimates of the magnitude of the problem. In 1972, the WHO Expert Committee on the Safe Use of Pesticides (WHO 1973) considered a mathematical model based on the accidental poisoning statistics for 19 countries. The data concluded that there were 500,000 pesticide poisoning cases annually with a mortality rate of 1% in those countries where medical treatment and antidotes were readily available. In other countries, where resuscitative methods were less available, fatialities were presumably higher.

Subsequent to this original estimate of worldwide pesticide statistics and because of the sizeable limits of error of these earlier estimates, the Director General of the WHO requested notification of pesticide poisoning cases and deaths in 1974 from all participating countries. Regrettably and surprisingly, many countries reported back that there were no statistics for their country. In those countries that did reply in one series of reports from six countries, the poisoning rate was 2.9 per 100,000 with a death rate of 1.7 per million (5.9% of cases). In another survey of four countries including Rumania, Syria, Turkey and the United Kingdom, the rate was 5.5 per million of deaths and 4.8 cases per 100,000. Based on the combined death rates of group 1 and 2 the number of deaths annually may be 400 x 5.16 = 20,640.

The magnitude of the problem in the Caribbean and Central America is also unknown but the poisoning cases from El Salvador and Guatemala show, in Table 1 and 2, and death rates in Salvador shown in Table 3, suggest that this is a real problem in these areas. The large number of cases and small number of deaths from El Salvador statistics suggest that the problem there was picker poisoning rather than applicator poisoning, a hypothesis which is supported by the fact that the prevailing climate is hot and dry, somewhat in contrast to the Caribbean (PAHO 1977). An ICAITI survey of Guatemala, Nicaragua and El Salvador estimated that between 4,000 and 5,000 cases of pesticide poisoning occurred annually (Davies 1978).

Insofar as the Caribbean area is concerned, poisoning statistics here also are incomplete but the Pan American Health Organization describes the occurrence of an epidemic of pesticide poisoning which happened in Jamaica in 1976 when 79 cases occurred with 17 deaths and were due to the contamination of flour with parathion brought by sea from the Federal Republic of Germany.

Table 1: Insecticide Poisoning reported by the Health Services of El Salvador, 1969-1974[a/]

Months	1969	1970	1971	1972	1973	1974
January	12	24	2	22	49	41
February	18	7	14	28	13	30
March	6	22	11	32	116	28
April	10	30	20	22	14	32
May	20	9	18	72	18	32
June	45	61	43	68	70	63
July	27	60	39	56	28	78
August	33	16	27	123	72	41
September	53	102	100	385	119	-
October	194	33	53	826	279	-
November	111	38	175	727	376	-
December	55	72	84	500	108	-

Note: 1973, provisional figures. 1974, first eight months only.
Data from hospitals and Social Security Institute included from 1972 onwards.

[a/]Division of Epidemiology, San Salvador, 23 September 1974.

Table 2. Pesticide Poisonings in Guatemala, 1970-1973

Cases	1970	1971	1972	1973
Slight	269	510	583	524
Moderate	361	536	486	508
Serious	28	84	59	68
Deaths	1	4	1	
Total	659	1,134	1,129	1,100

Table 3: Deaths due to Insecticide Poisoning reported by the Health Services, Ministry of Public Health and Social Welfare of El Salvador, 1964-1974[a/]

Year	Deaths
1964	2
1965	1
1966	6
1967	2
1968	7
1969	7
1970	7
1971	10
1972	5
1973	5
1974	3

Note: 1974, first seven months only.

a/ Division of Epidemiology, San Salvador, 9 October 1974.

Problem No. 2: Persistence

Persistence is the second management problem and was highlighted in Central America where serious environmental contamination was recognized in 1974/75. DDT, dieldrin and toxaphene are organochlorine pesticides still widely used in agriculture in Central America, and their indiscriminate and injudicious use had led to widespread environmental contamination and posed a serious economic threat to the meat industry in the area. On most occasions, pesticides have been aerially applied to cotton, leading to widespread contamination of feed and foodstuffs due to the drift to adjoining pasture lands and to cattle grazing there. On several occasions cattle were seen to wander off the pasture to graze in the cotton fields; in addition, from time to time, they were fattened with cottonseed oil contaminated with DDT. Corn, too, was used for fattening purposes, and aldrin had been used both for foliar plant treatment and post emergence treatment of corn. These several practices led to significant contamination of cattle meat from grazing and from feedstuff sources.

Verification of significant contamination of milk, meat, fish and wildlife was demonstrated by an ICAITI survey (Anon 1977). Residues of DDT and its metabolities in milk ranged from 2 to 63 ppm, and residues of this pesticide and its metabolites in meat ranged from 0.81 ppm to 24.5 ppm. Dieldrin residues in meat and milk ranged from 0 to 1.01 ppm.

The area has developed a sizeable meat industry, and 224 million head of cattle, or 25 per cent of the world's total, are raised on these pasture lands (FAO 1972). As a result of environmental contamination, significant economic losses have ensued and a total of $1.5 million was lost to the beef industry (Davies and Beck, 1980). With residues of these orders of magnitude public health concern has also been aroused by the possibility that sizeable human contamination through the ingestion of contaminated meat has occurred. This concern is especially justified in the absence of significant human monitoring of pesticide residues. This is a recurring problem and, even today, the cattle industry in these areas is plagued with unacceptably high and with persistently high residue problems.

Problem No. 3: Resistence

Since this topic has been fully and ably described by Georghiou, (1980), the agromedical concerns in relation to this problem will be dealt with in summary only.

Since 1974, about 1,136 million poeple are still exposed to malaria of whom only 8 million live in areas in the maintenance phase of eradication (Lancet 1975). Although DDT continues to play a dominant role in malaria control, there is no room for complacency. Recent reports have cited political and technical factors which have contributed to the failure of the malaria eradication problem (Davies 1978, Brit, Med. Journ. 1976, Davies 1972). These reports suggest that half-hearted governmental support for malarial eradication, the contributions of political unrest, delays in procurement of supplies, errors in planning, premature cessation of spraying, and inadequate basic health surveys, shortage of trained manpower and limitation of uncertainties of financial resources have been largely responsible for failures in the malaria control programs. However, the agricultural use of pesticides also has impacted on public health vector control programs and anophilene resistance, in many cases, has resulted from the genetic pressures which has stemmed from agricultural pesticide use patterns. Almost certainly it has been these sociological and political problems rather than the decision of the United States to cancel DDT which have contributed to the spread of malaria and other vector-borne diseases in these areas.

4 POTENTIAL FOR INTEGRATED PEST CONTROL AGROMEDICINE

In 1967, an FAO panel on the subject defined pest control as "a pest management system that . . . utilizes all suitable techniques and methods in as compatible a manner as possible and maintains the pest population at levels below those causing economic damage" (Davies 1978). This definition also implies that imposed control measures, notably conventional pesticides, should only be used where economic injury thresholds would otherwise be exceeded. Where pesticides are used as part of the pest control strategy, it is of primary importance that they be specific for the pest and minimally disruptive to the ecosystem.

The FAO panel goes on to state: "Successful development of integrated control depends on adequate understanding of the population dynamics of pests, and of potential pests of the ecology and economics of the cropping systems, and of possible harmful effects to the general environment." This expanded definition emphasizes the central importance of natural pest populations, along with a combination of techniques that contribute to suppression – cultural methods, pest-specific diseases, resistant crop varieties, sterile insects, attractants, parasites or predators, or chemical pesticides, as needed.

Integrated pest managemment (IPM strategies have been shown to reduce significantly the amount and frequency of pesticide applications. In fact, several reports have demonstrated in field studies that parathion application can be significantly reduced, or even abandoned altogether, under certain circumstances. It was shown in Guatemala that reducing the number of pesticides used through the integrated pest control program resulted in a 14% increased crop yield, with an increased profit of 83% on the acreage. Thus, IPM was not only illustrative of successful agriculture, but by reducing the amount of frequency of pesticide application and the preferential use of insecticides with lowered dermal toxicities has significantly contributed to the health protection of the pesticide workers. In essence, therefore, and as seen from a public health point of view, IPM has exemplified ideal occupational health practice. If these newer and innovative IPM techniques facilitate the more efficient use of pesticides of lower mammalian toxicities, then the protection of the pesticide worker will be significantly enhanced.

Traditionally, industrial hygiene practices are greatly facilitated when health personnel are thoroughly familiar with the work environment of the workers. However, in the case of agricultural workers, there are no "factory doctors", and the local, rural, private practitioner is the primary care resource and, only too often, is generally unfamiliar with agricultural practices and strategies. Certainly such physicians are unaware of the varieties of those plant protection techniques which can significantly reduce the pesticide exposure of his agricultural community, and for the future doctors and nurses with responsibility for agricultural workers and their employers could learn much from the farmer about ways to improve the safety of the agricultural laborer.

5 SUGGESTED INGREDIENTS FOR AN AGROMEDICAL PROGRAM

The recognition of the urgent need for an agromedical partnership for pesticide safety was first seen by Dr. Julie Sulianti-Saroso, the Minister of Health in Indonesia in 1969; she was aware of a serious pesticide poisoning problem which was occurring in her country, a problem which had arisen as a result of a sizeable growth in the use of pesticides in this area and, in particular, a switch from organochlorides to the organophosphates. Darmansyah later reviewed problems of pesticide management and safety programs in Southeast Asia (Darmansyah 1977).

Table 4: Summary of Pesticide Poisoning in Indonesia

Period	Cases	O.C.	O.P.	Other	Deaths	Remarks/Sources
January 1967-February 1969	820	478	31	311	125	All types of poisoning (Davies, 1969)
January 1967-December 1970	615	269	11	335[a]	38	Suicides excluded; more than one case per event (Darmansyah, 1973)
April 1971-April 1973	868	138	278	452[b]	134	Suicides excluded; more than one case per event (Ticoalu, 1974)

[a]Arsenicals: 277 cases: [b]Not specified.

B. Reducing the Problem of Persistence

Perhaps proper application and correct formulation are as important as anything that can be done in reducing a problem of persistence or residues. When properly formulated, the material may be applied sufficiently well in advance of harvest to allow decay of the pesticides while still achieving the level of pest control needed. But beyond this, proper application to prevent drift and thereby contamination of other areas is essential. Again, the education and training of those who work with chemicals, as well as the general public, is of utmost importance.

However, in addition to the foregoing there are a number of other practices that would be suggested as guidelines to wit:

1. Research on ecological and environmental factors that relate to the impact of pesticides on humans, both in terms of direct and indirect effects such as nutritional status or the role of parasitic diseases in human susceptibility to chemicals.

2. Monitoring of food, water, and soil for pesticide residues.

3. Medical surveillance of workers including appropriate enzyme tests, e.g. cholinesterase as an assessment of exposure.

4. Human monitoring through the development of tissue banks.

C. Lessening the Problem of Resistence

As indicated, both agricultural pests and disease vectors develop resistance of pesticide after periods of exposure. This comes from continuous use of a single type or class of compound that allows natural selection to build up a resistant population. Frequently the use of a particular chemical in agriculture not only brings about resistance in the agricultural pests but in vectors as well because the areas of infestation are in close proximity. Three practices recommended by agromeedicine to ameliorate the problem of development of resistance are:

1. Vigorous implementation of integrated pest management program where applicable which would include all types of pest control such as cultural, resistant crop varieties, field sanitation, etc.

2. The use of alternative methods of pest control, particularly for vectors such as source reduction, e.g. drainage, etc., for mosquito control.

3. Further research on the development of pest resistance.

II. THE AGROMEDICAL PROGRAM AND FORMATION OF THE AGROMEDICAL TEAM

It is recommended that there be formed agromedical teams at the national, governorate, district, and village levels. The composition of such teams are suggested to be as follows:

A. National Level

A national committee should be formed by and be responsible to the Ministry of Agriculture. It may be desired to form an agromedical division within the Ministry of Agriculture for the purposes of administering not only the affairs of this committee, but to coordinate the committees at the governorate and local levels.

1. It is recommended that the composition of this committee be made up of representatives of the following:

   (a) Ministry of Agriculture
   (b) Ministry of Health
   (c) Ministry of Manpower
   (d) Ministry of Culture and Public Affairs
   (e) A lawyer or member of the legislative body
   (f) Scientific advisors representing the following disciplines:

public health, entomology, toxicology, environmental science, chemistry (analytical and environmental), pharmacology, agricultural economics, and others as need indicates.

2. Responsibilities of National Committee

(a) The planning, direction, and administration of the agromedical program and coordination of the efforts of the governorate and local committees.
(b) Direction and support of technical activities and research.
(c) Collection and evaluation of statistics on agromedical data.
(d) Development of laboratories and laboratory services for monitoring food, feeds, humans, and the environment, and to maintain a national quality assurance program for other laboratories.
(e) Support of research on agromedical problems.
(f) Direction and coordination of the implementation of the agromedical program.
(g) A program of public information to acquaint agriculture, industry, pesticide and agricultural workers and the general public with agromedical practices and problems.

B. Governorate Level

1. A the governorate level, the composition of the committee would resemble that of the national committee, but perhaps on a somewhat reduced scale. It would include representatives of:

(a) The Ministry of Agriculture
(b) The Ministry of Health
(c) The Ministry of Manpower
(d) Appropriate scientific advisors as available.

2. Responsibilities of the Governorate Commitee

(a) As part of the coordinated interdisciplinary national effort, the governorate committee would supervise and follow-up the work of the committee and officials at the local level.
(b) Receive reports from the local level, compile and evaluate the statistics, and based on these develop the appropriate recommendations for practices and procedures and advise the National Committee.
(c) Be responsible for the development and arranging of training programs for individuals responsible for the agromedicine program covering such topics as integrated pest management, nutrition, hygiene, and disposal of chemicals. In its discharge of this responsibility the governorate should work closely with universities.
(d) Provide recommendations and appropriate regulations for pesticide applicators.
(e) Conduct investigation of problems that may arise and validate whether from poisoning or other causes, and assess any environmental impacts.
(f) Maintain medical surveillance of applicators and other exposed workers through health representatives at the local level.
(g) Conduct research and surveys on the various problems.
(h) As appropriate, maintain laboratory services or at least have well coordinated lisison with appropriate laboratories in the Ministry of Agriculture, Ministry of Health, and universities.
(i) Maintain a system of monitoring through biological observation of populations of organisms and any changes that may be occurring.
(j) Conduct a vigorous health education program on agromedicine and the aspects of pesticide management.

C. District Level

1. At the district level, the agromedical team or committee would be comprised of responsible staff from the Ministry of Agriculture and such scientific advisors as may be deemed to be necessary. In addition, assistance of the Ministry of Health and the Ministry of Manpower would be sought as required.

2. Responsibilities of District Committee

The responsibilities of the district level agromedical team would be as follows:

(a) Supervision of the implementation of the agromedical program in the villages giving attention to nutrition, hygiene, and pesticide management.
(b) Train applicators for proper use of pesticides for protection of themselves, the public, and the environment.
(c) Provide re-training for other concerned personnel.
(d) Compilation of infromation and statistics and development of appropriate reports.

D. Local or Village Level

1. At the village level the primary agromedical workers would include an agricultural extension worker having training in agricultural hygiene, preferably at the university level, together with volunteers of the village who may include OMDA, SHEIK, or appropriate available health personnel.

2. The responsibilities of the agromedical personnel at the village level would be to:

(a) Teach and advise the farmers concerning appropriate agromedical practices in agricultural and health with special reference to pesticide management, nutrition, control measures, selection of proper chemicals, use of chemicals, and avoidance of poisoning.
(b) Deliver the first health care (first aid) to poisoned individuals including the use of antidotes and to forward them to the proper places for more advanced treatment.
(c) Investigation of incidents of poisoning.
(d) Provide reports and compilation of statistics.
(e) Re-train and advise applicators for the proper application of pesticides.
(f) Education of field workers, the general public, and employers as needed.
(g) Collection of sample for analyses including food, water, soil, and other environmental samples.

III. SOME SUGGESTED GUIDELINES FOR CONSIDERATION

In the course of its deliberation, Workshop C gave attention to a number of important details, practices, and protocols relating to agromedical aspects of pesticide management. They considered such things as occupational exposure and some of the practices that might be followed to avoid this. In like manner, attention was given to the problems of "environmental" exposure, meaning of course, residues in food, feed, water, and air from which man and other organisms might experience long-term chronic exposure. Whether or not the level would be such as to cause an adverse reaction is, of course, unknown. However, as a matter of prudence it was considered that such exposure should be minimized or avoided wherever possible.

Also, knowing that through the manufacture, formulation, transport, and use of pesticides human error is likely to result in exposure to higher concentration through spills or other accidents, attention was given on the matter of diagnosis and treatment. Requisite to this, of course, is a knowledge on the part of health workers and physicians concerning the symptoms of poisoning and the appropriate treatments to be applied immediately and the longer term therapy. Equally important from the standpoint of good pesticide management is the validation of poisoning by appropriate physical examination and clinical tests, including analyses for the pesticide and its metabolites. All too often, vague illnesses have been ascribed to pesticide poisoning, sometimes resulting in treatment for the wrong cause.

The following then are some of the suggestions offered by the workshop group for consideration in the agromedical program.

A. Prevention of Occupational Exposure

1. Use closed systems in manufacturing and formulation plants, whether in handling liquids or dusts. Liquid or dust transfers should be by closed lines.
2. For specific operations such as filling containers, there should be local ventilation of sufficient velocity to avoid exposure of the operator.

3. In storage of pesticide, consideration should be given to the location of the storage facility, its security, construction, and provision made for dealing with such emergencies as spills and fires.
4. Protective clothing appropriate to each type of operation should be provided the worker as well as safety equipment. Such protective clothing should be decontaminated by laundering or other means as required by the establishment.
5. There should be provision of showers and other hygienic facilities and insistence that the workers utilize these before leaving the plant. Similarly, lunchroom and restroom facilities should be removed from areas of exposure.
6. Where the plant re-uses the containers, adequate facilities should be developed for cleaning of the containers and disposal of the waste, other than in a sewer system. Similarly, where containers are to be disposed of, the correct technical procedures should be followed.
7. There should be a vigorous program of training of workers on the use of safety equipment, protective clothing, and safe use of equipment. Where applicaton equipment is involved, the necessary spare and cleaning parts should be provided.

B. Prevention of Environmental Exposure

1. All manufacturing and formulating plants should be located, whenever possible, away from populated areas and have appropriate pollution control devices in both the air stream and water effluent. Even such simple systems as carbon filters and extractive devises go far in reducing community exposure.
2. Proper procedures of disposal of waste chemicals and containers should be followed. At least four different methods are available for disposal of waste chemicals. Container disposal may, on the other hand, involve a requirement for more elaborate facilities.

3. A frequently encountered hazard in terms of environmental exposure is stockpiling of pesticides that are not used and deteriorate to the point where their effectiveness is questionable. Therefore, it is recommended that careful estimates be made as to the requirements for the supply of chemical to be made and no more than this acquired.
4. Proper application of correctly formulated materials can prevent extensive environmental contamination of non-target areas, water supplies, and organisms. Training should be given to applicators in correct application procedures, a requirement made for the safety type of application equipment, and formulations designed for the specific conditions under which they are to be used.
5. Despite proper application of the correct chemicals, very often residues will remain on food stuffs. These will be very low level residues, but preventive preparation of the food through washing, peeling or cooking can reduce the level to an almost negligible quantity.

C. Diagnosis, Treatment, and Validation of Poisoning

1. Cases of acute poisoning could be verified by the following means:

(a) Taking of exposure history to pesticides.
(b) Physical signs and symptoms characteristic of chemical poisoning.
(c) Clinical demonstration of significant effects, e.g. red blood cell and plasma cholinesterase inhibition in the case of acute organophosphate poisoning.
(d) Identification of the specific compound or its metabolites in the urine or other body tissues. It is highly recommended and urged that an adequate supply of antidote for the various chemicals known to be used should be available at the local level for first aid treatment in cases of pesticide illnesses from other conditions or illnesses with similar symptoms. The following steps *inter alia* may be followed:

(i) Apply simple enzyme tests, e.g. cholinesterase screening tests to any worker who complains of having sustained or having illness that he believes to be due to exposure. This test should also be applied to any worker having regular pesticide exposure.
(ii) Any patient exhibiting three or more of the following symptoms should have the cholinesterase or enzyme screening test: weakness, sweating, headache, nausea, vomiting, diarrhea, abdominal cramps, excessive lacrimation, salivation, bronchial secretion, shortness of breath, pains in the chest, blurring of vision, and convulsion.
(iii) Any patient with either miosis (less than 5mm in size), muscle twitching or fasciculations or clinical evidence of bronchial spasm or bronchial exudation, or having a pulse rate of 50 or less.

If the screening test is positive, the medical authority should be informed at once for further investigation and more sophisticated therapy. Promptness of treatment is of the utmost importance.

2. In all cases a follow-up investigation should be conducted by collecting data concerning the type of pesticide to which the worker has been exposed. This should include the name, active ingredient, method of application, the route of exposure, and the first aid measures taken and any other facts that may be pertinent in analyzing the causes and possible sequelae of poisoning.

Simple, standard laboratory methods are available for determining many of the pesticides and their metabolites. Accordingly, such laboratory services should be readily available as near as possible to the site of manufacture, formulation, and use of the pesticide and must be readily available to the physician to assist in diagnosis. Among some of the methods available for the organophosphates include blood cholinesterase tests, using the tintometric or determination of uninary metabolites by simple and specific laboratory procedures.

3. Investigation and registration – It is important that not only should the exposed victim receive prompt and effective treatment in the case of poisoning, but that all pertinent information also be collected and recorded for future use. Such statistics and information would then provide a basis for the development of recommendations for avoidance of future incidents. Such a follow-up should include:

(a) The development of a system of recording and reporting poisoning incidents from the local level on up to the national level. This would permit evaluation of the intrinsic hazard of pesticides used, the formulation and practice of application.
(b) There should be a surveillance of key non-target organisms or populations of organisms to give an index of environmental pollution. This would require a number of observations over a period of time because of the cyclic and seasonal nature of life cycles of organisms. Again, these reports would begin with observations at the local level, past to the regional, and finally to the national.

It would seem desirable that as the capabilities of the agromedical program escalated, it would be desirable to devise a system for identifying and evaluating the development of resistance of various agricultural pests and vectors. Such information could serve as a basis in developing pest management strategies for dealing with these resistant organisms.

D. Other Factors of Consideration in Human Responses to Pesticides

The rural population faces a number of risks in addition to exposure to pesticides. This includes various parasitic diseases, nutritional disorders, and infectious diseases. Moreover, they are subject to abrasions and trauma, fatigue, heat exhaustion, and exposure to pollens, toxic natural products, and fertilizers. Any and all of these can compound and exacerbate the effect of the pesticide. Indeed, anyone of these may be the primary cause of illness with the pesticide exposure being but a contributing factor. This comes about by the effect of many of these factors on absorption, metabolism, and excretion of the pesticide. It is important, therefore, that these various factors be studied, i.e. investigations carried out, to assess their importance and provide a basis for corrective agromedical practice.

Workshop C

Agromedical Teams Formation and Responsibilities

Recommendations

Cognizant of the enormous wealth which Egypt possesses through its people and its land, the participants in the workshop sought diligently as to how best to preserve and foster these two resources through crop production with simultaneous protection of man and his environment. From agriculture is generated much of the wealth and food for the nation; yet unless the people and workers are adequately nourished and protected from poisoning and vector-borne diseases full production will never be achieved. In such circumstances there will be temptation to invoke new laws and regulations which serve only to complicate the production of food. Therefore, in order to increase food production and provide desired economic growth together with promotion of the health of the people, it is recommended:

1. To establish an Agromedical Program at the national, governorate, regional, and local levels integrating the skills and resources of the disciplines of agriculture and medicine for the economical and bountiful production of food together with the protection of man and his environment.

2. To implement an agromedical program through liaison among Ministries of Agriculture, Health, Manpower, and Education together with other concerned institutions. The agromedical program of the several ministries and Universities should be supported adequately in the areas of education, extension and research.

3. To establish a department of Agromedicine in the structure and infrastructure of the Ministry of Agriculture to carry out this program in cooperation with the concerned ministries.

4. To select a national team of the best technical expertise from agriculture, medicine, toxicology, pharmacy and chemistry, as well as other disciplines, and encourage their application of their knowledge and judgement in the agromedical program. This should be achieved through formation of a scientific advisory body whose judgements and recommendations will be based on the special characteristics of risks and benefits in A.R. Egypt.

5. Establish appropriate courses and training programs for agromedical workers in the colleges and schools of agriculture, public health and medicine and in the relevant ministries.

6. The final report of the agromedical workshop as published in the proceedings should serve as a guidelines in this program.

Protection teams have since been implemented in each of the provinces of Indonesia. The purpose of these teams has been to assist in the diagnoses, treatment, investigation and, ultimately, the prevention of health-related problems from the use of pesticides in Indonesia (Darmansyah, 1977). The concept of interdisciplinary protection teams was an idea which was influential in the development of Recommendation No. 9 in the report of the Secretary's Commission on Pesticides and their relationship to environmental health (USDHEW (1965). The recommendation called for the establishment of a clearing-house in the development of health, education and welfare for pesticide information and the development of pesticide protection teams. The recommendation goes on to stipulate: "Pesticide protection teams should be developed from existing local personnel and coordinated with Federal and State personnel and facilities from agriculture, wildlife, and public health." They are:

1. Augment existing agricultural extension and fish and wildlife efforts relating to pesticides and thereby guide local usage and safeguards.

2. Improve local surveillance of pesticide contamination, facilitate monitoring of human tissue residues of pesticides, and investigate usage patterns and episodes of human toxicity.

3. Provide a rapid flow of local information based on the above activities to and from the clearing-house especially concerning any emergency related to pesticides.

4. Inform the public, users of pesticides, local government and enforcement agencies, and others in the proper and safe use of pesticides, techniques for disposal, and other matters.

5. Stimulate local awareness and constructive concern essential for optimal use of pesticides.

These were the ingredients suggested by an expert group of scientists for pesticide safety in a developed country – the United States. It is interesting to reflect that this recognition of the need for an integrated interdisciplinary framework, and advocated for a developed country, first emanated from a Minister of Health from a developing country where the pesticide poisoning problem had become so acute as to need ministerial intervention. The event was also indicative of the special interest that the third world has for pesticide safety, a trend which seems to have since had wide acceptance. This trend was recognized by the University of California-USAID project which was the forerunner of the Consortium for Integrated Crop Production – one of the sponsors of this pesticide management seminar workshop. Workshops similar to this have been held in El Salvador, Indonesia, Costa Rica, the Philippines and Egypt, at which workshops scientists in the fields of agriculture and chemistry have sought to develop the agromedical team approach to pesticide management. As will be seen from Appendix I, which describes the agromedical recommendations for pesticide management in Egypt, the idea has come a long way and we may want to start with these recommendations in our deliberations on this topic for agromedical approach for pesticide management in the Caribbean.

I feel certain that this Caribbean gathering of experts from the fields of health, chemistry, agriculture and industry will further develop this philosophy, maximizing the unique opportunity to protect the beauty of these tropical islands as well as the health of their inhabitants and those who thrive on their exported agricultural commodities.

6 CONCLUSION

The concept of the agromedical approach to pesticide management as an integrated interdisciplinary operation has been described in some detail; the inevitability of such an approach is made clear in the examination of its component parts, and the manner in which both pesticide management problems and the integrated pest management approach fit into the agromedical concept. It is noteworthy that recognition of the need for an agromedical partnership for pesticide safety was first seen by a developing country – Indonesia, and that subsequently a major programme has been worked out for Egypt. The concept appears to have particular importance and relevance for such territories as those of the Caribbean.

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APPENDIX

University of California/U.S. Aid for International Development Workshop
University of Alexandria, A.R. Egypt
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Workshop C Report — Agromedical Team — Formation and Responsibilities

I. INTRODUCTION

The broad objective of agriculture is the production of a bountiful and nutritious supply of food and fiber for the well being of man. The intent is to achieve this production under optimal and economic conditions. However, in the attempt to produce an assured and ever increasing supply of food, it is necessary to use pesticides to protect plants and animals from the deprivation of these organisms. Not only is adequate food and sound nutrition necessary for man's well being, but protection from vector borne disease as well. Thus, pesticides are used not only in agriculture but also in health and inevitably there is an overlap of interest between the two fields.

Out of this mutual vital concern between medicine and agriculture has developed an interdisciplinary effort—agromedicine. Among the several important objectives of agromedicine is to eliminate or at least minimize the effects of pesticides used in agriculture on man. The interdisciplinary practice of agromedicine involves an approach to community health and well being through food production and protection of the health of both man and his environment. This concept of raising food production by protection is preventive, thereby avoiding the necessity of stringent and detailed recommendations that would otherwise constrain the practice of food production.

The use, or perhaps more properly misuse, of pesticides entail three sources of risk to man, other organisms, and the environment. The first of these is the risk of direct poisoning from over-exposure. It may occur during the occupation of manufacturing, formulating, transporting or applying pesticides. Over-exposure may also occur to those who are inadvertently hit by spray drift or have their water or food supply contaminated. The exposure may come through one of several routes, dermal, respiratory, or direct ingestion.

The second source of risk is more subtle and long term, namely persistence which results in low levels of residue. Finally, there is the third source of problems with pesticides and that is the development of resistance on the part of pests. Not only is this a major problem in agriculture where the crop pests become tolerant to the chemicals used, but also in health where the vectors of many diseases become resistant. Often the resistance in vectors develops through the agricultural use of such chemicals.

Some of the practices recommended by agromedicine to avoid these risks may be enumerated as follows:

A. Prevention of Poisoning

Following of the recommended safe practices in the handling and application of pesticides goes far in preventing human poisoning. This includes selection of the proper chemical, that is the safest chemical that achieves the level of pest control desired, insuring that that chemical is formulated properly in its least toxic form to humans, and provides the greatest and longest degree of pest control. Next in prevention of poisoning is use of the proper application equipment and its operation.

Because pesticides are such sophisticated chemicals, knowledge of their properties and uses is essential. Therefore, education and training of agricultural and health professionals, paramedical and agricultural workers is essential. Beyond this, the use of appropriate protective devices and clothing designed for the specific type of work, e.g. one type for those who are handling the concentrated materials, another for those who work in the field, is needed.

In addition, there is vital need for more information on exposure, through collection of statistics, epidemiological surveys, and research.

19. INTERACTION BETWEEN PESTICIDES AND HUMAN NUTRITION

M. GUERI

CONTENTS

		Page
1.	INTRODUCTION	257
2.	FACTORS AFFECTING PESTICIDE LEVELS	257
3.	DISTRIBUTION OF PESTICIDES IN THE BODY	259
4.	EFFECTS OF NUTRITIONAL STATUS	260
	(a) General	260
	(b) Fats	261
	(c) Vitamin A	261
	(d) Vitamin B	261
5.	CONCLUSION	261

1. INTRODUCTION

In the past four decades increasing attention has been paid to the mechanisms of poisoning and bioaccumulation of pesticides in man. This paper examines some aspects of the relationship between the nutritional status of individuals and their metabolism of pesticides, noting in particular the effects of calorie and protein intake, age, sex and race.

2. FACTORS AFFECTING PESTICIDE LEVELS

As far back as 1946, Ludwig suggested that the cause of death in the case of DDT poisoning in experimental animals was actually starvation due to exhaustion, where all the reserves of glycogen, glucose and lipids were completely depleted. However, in 1949 Buck and Keister showed that the insects died before all the reserves had been depleted to starvation level. Be as it may, the example presented here is only to emphasize the correlation between pesticides and nutrition.

The most striking difference is between males and females. Males, invariably in all studies, accumulate higher levels of DDT residue, although in some cultures there are different patterns of food consumption between men and women. It is unlikely that throughout the countries where surveys have been carried out to assess pesticide residues different food habits are responsible systematically for higher accumulation in men. The different levels of accumulation are more likely due to differences in environmental exposure as well as different psychological processes, as we will see later.

There are also important ethnic differences in pesticide residue in humans. These differences have been shown to be statistically significant in several instances, particularly in several regions of the United States. In post-mortem examinations, the concentration of pesticide residue has been found to be systematically higher in men of African ancestry than in thos of European ancestry, and, within ethnic groups, higher in males than in females. For instance, in a particular study carried out by Jarvis and co-workers in 1968 in Dade County, Florida, out of 159 post-mortem examinations, the concentration of residue of products from DDT was higher in negro females, followed by white men and by white women. The average concentration was 17 ppm in negro men, 12 ppm in negro women, 9.8 ppm in white men and 8.3 ppm in white women. There is no doubt that in many cases the differences must be due to different exposure though in some other cases this explanation does not seem to be sufficient.

If we plot the pesticide residue concentration by sex, ethnic group and age group, the ethnic differences become more apparent in the youngest age groups, but the available evidence suggest

that these differences are probably due to environmental factors (including social factors and food habits) rather than to hormonal factors. We know that the body converts many non nutrient substances (xenobiotics) into less toxic or harmless products. This conversion is called "detoxication". The type of change that takes place depends on the chemical structure of the compound. However, other factors, in addition to the chemical structure, may also be involved. Among these factors we have the species of the animal, the method of administration of the "xenobiotic" and the diet. Most of this detoxication takes place in the liver. However, it has been known for a long time that many pesticides as well as their conversion products can accumulate in man. Most of the pesticides found in man and animal tissues are chlorinated hydrocarbon types, and the concentration of these substances in the tissues of populations in many countries is well known. There have been many surveys in various parts of the world to assess the concentration of pesticides in different foods, vegetables, meats, milk etc., and regular tables indicating the maximum amount of pesticides that should be present in these substances are published: the safe level of pesticides in foods. For instance, WHO in collaboration with FAO, dedicates one of its technical report series almost annually to the 'pesticide residue in food".

From these surveys there is evidence to indicate that the residue levels of pesticides are quite different among different segments of the general population. One would expect that people who are exposed to insecticides because of their occupation would have higher concentrations of pesticide residues in their tissues. This, in fact, is the case. However, there are other stirking differences that should be taken into consideration. Some of these differences may have a relationship with diet and nutrition, some do not, or the relationship is uncertain. The influence of age on pesticide residue concentration is less well defined than sex or ethnic group. It is generally agreed that residue levels rise with increasing age, nevertheless the relationship is not always clear. Hoffman and co-workers in 1976 in the mid-west United States found that the level of DDT or derivatives increased from about 5.5 to 11.5 ppm up to the age of 35-44 years but the concentration became established at 9 ppm in the four subsequent age groups, that is, 45-54, 55-64, 65-74 to the last age group in his sample, 75-84 years. The following year, 1968, Davis and co-workers found in Florida that the increase in pesticide residue with age was apparent both in white and non-white males, but in females the residue level actually declined after reaching maximum in the 6-10 years age group. It has been pointed out that obese persons do seem to accumulate less residue that non-obese, and, as women tend to accumulate fat, the sex differences have been related to this factor.

Obviously, factors such as food habits, physiological state and life style must play important roles in determining the residue levels in man. But at the present time there is very little concrete data indicating the relative significance of any of them. For instance, the data from a residue survey of wild animals and some observations by Hayes and co-workers as far back as 1958, suggestes that carnivores or meat-eaters accumulate more chlorinated hydrocarbon residues than vegetarians. The problem is that food habits of human vegetarians are not strictly comparable with those of herbivorous animals because man's general life habits are much more complicated. For instance, in India vegetarians have in fact more DDT residues in their fat than carnivores, also many vegetarians consume large amounts of oily foods (for instance fried foods) which would contain higher concentrations of pesticide residues than lean meat.

The fact is that the rate of daily intake of pesticides in the general population can be estimated fairly accurately since the pesticide residue in the main food items can be assessed rather precisely. It is also fairly simple to arrive at the average percentage of intake for any particular food item in relation to the total daily food intake. In the U.S. for instance, the foods which contribute the most to the pesticide intake are dairy products, meat, fish, poultry and fruits. Once the pesticides are ingested or otherwise absorbed in the body, they are distributed mainly by the blood. I think we should expend a few minutes on the metabolism of insecticides in the human body as it also has potential nutritional implications. It is interesting that the pesticides are distributed in the blood because most of them are not readily soluble in aqueous solutions. However, it has been shown in rodents (and it can be extrapolated to humans) that some insecticides such as dieldrin are 4,000 times more soluble in blood than in water. But they have affinity for certain of the blood components. Dieldrin, for instance, was found mainly in the erythrocytes, in the red cells of rabbits' blood (and particularly in the cell contents and not in the membrane of the red cells) and in the plasma, but not in the white cells or the platelets. It seems therefore that in rodents (at least) the insecticide binds with the haemoglobin, fixes itself to the haemoglobin as well as probably some other constituent of the cell contents, and it binds also with albumin and globulin in the serum; these two are, as we know, fractions of the serum proteins. We must again keep in mind the fact that serum proteins and haemoglobin are also related to the nutritional status of individuals.

Morgan (1972) and his co-workers observed the distribution of DDT and dieldrin in the blood of workers with a long history of exposure to insecticides, as well as the history of pesticides intake. He found that the percentage of DDT in the erythrocytes was about 12.5%, much less than the percentage of dieldrin which was 39.8%, and is distributed roughly according to the volume of erythrocytes in relation to the plasma. They also found that plasma albumin and globulin are the principal plasma protein constituents associated with blood-borne DDT and its derivatives.

These pesticides occur primarily in certain fractions of the proteins, that is, in the lipoproteins of low density and rich in triglycerides. This again is significant to us (or potentially signicant) because of the relationship between dietary intake of certain fats; the cholestrol and triglycerides concentration in serum and possible cardiovascular disease. In fact, Carlson and Kolmodin (1972) in Sweden found a high prevalence of hyper-liproteinaemia among men exposed occupationally to DDT in spray form. This type of hyper-liproteinaemia is a rare abnormality. It has been described in biliary cirrhosis. However, this was not the case among the Swedish workers studies by Carlson and Kolmodin (1972). It is interesting, however, that hyperlipoproteinaemia has been seen in severe alcoholics. In these individuals it seems as if the lipoprotein abnormality bears close relationship with malnutrition. The authors indicated that there was no evidence of alcoholism among their subjects but they did not indicate whether there was evidence of any specific nutritional deficiency. In fact, in many cases of classic poisoning with different pesticides, there is weight loss; however, it seems that this weight loss is due to anorexia (of lack of appetite) rather than to metabolic disturbances.

We know that in animals (and presumably in man) the insecticide is initially carried by the blood to the different systems, the speed of distribution roughly corresponding to the speed and pattern of blood circulation. By means of radio-active carbon labelled dihydroheptachlor, Kaul (1970) and co-workers found in rats maximum radio-activity 3 hours after injection of the labelled pesticide, except in the intestinal organs where it took 5-7 hours and the liver where it took a maxium of 16 hours. The radio-activity declined thereafter in all organs, suggesting redistribution of the insecticide and its metabolites into the gastrointestinal organs.

Heath and Bandekar (1964), studying the distribution of dieldrin in rats and mice, found that the dieldrin disappears quickly from the blood and it is distributed among all tissues within the first few minutes. The tissues receiving the highest amount of dieldrin per gram were the brain, liver, lungs, kidneys and heart. In approximately 80 minutes, the concentration of the insecticide in most organs, particularly the brain, declined and the dieldrin was redistributed to the gastrointestinal system and fatty tissue. Furthermore, it was shown that dieldrin injected into the bloodstream is excreted into the saliva of the parotid gland (and presumably all salivary glands), the bile and pancreatic juice, thus reentering the gastrointestinal system. These facts are significant to us because the organs mentioned are either involved in the metabolism of nutrients or contain large amounts of an important nutrient: fat. It seems then that after a comparatively long period of time after acute intake of pesticide, the insecticides settle in the fatty tissue. The reason why the build up in the fat is comparatively slow is because the blood supply to the fatty tissue is itself comparatively slow. In chronic administration of insecticides, the final pattern of accumulation in the fat is gradual, reaching a plateau after several months.

3. DISTRIBUTION OF PESTICIDES IN THE BODY

The concentration of pesticide in different organs is interesting. Radomski and co-workers (1968) estimated the concentrations of organochlorine pesticides, postmortem in the fat livers of 271 patients previously exhibiting different disorders of the liver, brain and other tissues of the body. These levels were then compared with pesticide concentrations observed during an earlier study in a random sample of patients' postmortem. Comparisions were also made with a general group with infectious diseases containing (the group) a variety of conditions of proven cause. There was a striking lack of correlation between pesticide concentration in the liver and in the fat of all patients' postmortem, but there was a significant correlation between pesticide levels in the brain and in the fat. No elevation of the pesticide concentration was observed in the presence of brain tumors, but there was found a significant increase in the mean concentration of DDT derivaties in encephalomalacia and in cerebral haemorrhage. There were also significantly elevated fat concentrations of DDT derivatives and dieldrin in cases of portal cirrhosis, but not in the presence of other liver conditions involving fatty metamorphosis. Highly significantly elevated concentrations of pesticides were present in carcinoma of different tissues.

Concentrations of DDT, DDE and DDD, as well as dieldrin in fat were consistently and significantly elevated in hypertension. Here again we see a correlation although still really unexplained satisfactorily between pesticides and nutritionally related conditions. In this group of cases, there was no correlation found between the levels of pesticide in fat and the length of time in hospital or loss of body weight.

Regarding the relationship between fat concentration of pesticide and blood concentration, it can be said that such a relationship is reliable for dieldrin, fair for DDT and poor for endrin. From the fat, the insecticides are released again into the bloodstream during periods of starvation, when the fat deposits are consumed. In these cases, therefore, there is complete redistribution of the insecticide. But the pattern of redistribution seems to be rather constant: for instance, the tissues showing consistent increase of pesticide concentration during starvation at all DDT concentration levels tested were the liver, brain and heart in that order, whereas the ones which showed consistent decline were the kidney and skeletal muscle.

4. EFFECTS OF NUTRITIONAL STATUS

(a) General

Different studies have shown that periodic fasting may facilitate the elimination of DDT accumulated in the tissues of chicken, as well as man and other mammals. In these situations of fasting as well as in those of physiological stress, infectious or traumatic shock as well as weight reduction programmes (all of which involve a significant degree of fat mobilization) there is a movement of pesticides in the body and a decrease of their total concentration in the organism. It is considered therefore that fasting and hypocaloric diets may positively be considered as detoxicating mechanisms of body residues. Nevertheless, we should not overlook that drastic rises of a transient nature may take place in the blood levels, and since the microsomal liver system is not very effective under these fasting conditions, particularly sensitive tissues may be injured. We should point out at this stage that the enzymes associated with the microsomal liver fraction are the main factors responsible for the biological degradation of chlorinated hydrocarbons.

We must also keep in mind the almost extreme use of energy reserves, i.e. fat, by agricultural workers, during certain seasons, for instance, during intensive crop gathering. This is something that perhaps we should look into; what is the level of pesticide among the agricultural population in the Caribbean and what really happened to this pesticide residue during, say, cane cutting season or gathering of the banana crop.

The nutritional status of the individual affects the action of the insecticides. For instance, chlorinated hydrocarbons cause liver damage at high concentrations. The nature of this damage varies from increase in liver weight and fat content to cell necrosis. The susceptibility of the liver to these changes is increased in cases of nutritional deficiencies. On the other hand, Daws and co-investigators in 1973 in workers exposed to DDT at rates equivalent to intakes of 3.6 to 18 mg by mouth daily for an average of 21 years, failed to demonstrate any evidence of liver disease or abnormality of liver function.

As we have mentioned, the enzymes associated with the microsomal liver fraction are the main factors responsible for the biological degradation of chlorinated hydrocarbons, but these enzymes also take part in metabolism of nutrients and physiological constituents, such as steroids, bilirubin, lipids, etc. It can be assumed therefore that the presence of pesticide molecules in foods may change the nutritional utilization of certain nutrients and subsequently change the nutritional status of man and other living organisms.

Moderate undernutrition does not seem to have any effect on the metabolism of pesticides. For instance, Price and co-workers in 1972 studied a group of 16 girls aged 7 to 9 years in Virginia. For two periods each of 4 days, they became accustomed to 9 basal diets considered typical of poor groups in south-eastern U.S. The diet consisted of 2000 calories and 24 grams of protein per day. (In fact, this diet is only 190 kcal and 1 gram of protein less than the recommended dietary allowances). Vitamin A, thiamin (or Vitamin B_1), riboflavin (Vitamin B_2) and niacin were given in marginal amounts. All the girls in the two periods (which, in fact, represents a total of 32 subjects), were given a daily intake of pesticides varying from traces to 1.8 mg lindane and 18 mg DDT. There was no effect of the diet on the pesticide residue content of the diet, urine or faeces. The maximum excretion as a percentage of intake was 3.12% in urine and 6.21% in faeces for Lindane, and for DDT 11.8% and 22.74% respectively.

However, more marked deficiencies may affect the metabolism of pesticides in the body. We know that the quantity and quality of protein given influences the activity of the hepatic microsomal enzymes. In experimental animals, it has been shown that either reduced protein intake or inferior protein quality lead to a decreased activity of hepatic microsomal enzymes and, perhaps for this reason, increased toxicity of pesticides. This has been shown experimently for DDT, dieldrin, endosulfan, endrin, lindane, malathion, parathion, semeton, and toxaphene. In some experiments, however, the evidence related to the influence of reduced protein intake on the action of parathion was inconclusive.

In experiemental animals again, there is some evidence that quality of protein may be even more important than total quantity. Protein quality is, of course, closely related to the amino acid composition of the given protein. It has been shown in laboratory animals that methionine, one of the essential amino acids, (that is, an amino acid that cannot be synthesized by the organism, but has to be ingested in the diet) gave protection to a certain degree against DDT and dieldrin: however, paradoxically, when the protein intake was already rather high methionine had only limited effect or no beneficial effect.

(b) Fats

Fat itself and its composition in the diet influences drug metabolism and the activitv of hepatic microsomal enzymes considerably. It therefore has implications in the metabolism of the pesticides.

It has been shown both in man and in animals that more fat in the diet increases the toxicity of DDT, aldrin and dieldrin: with increased intake of fat, DDT could be deposited in the fatty tissues of the animal. The kind of fat, however, showed no influence on toxicity of chlorinated insecticides. In some other cases however, there was evidence of increased requirements of essential fatty acids (linolie and linolenic acid) after feeding DDT and dieldrin.

(c) Vitamin A

Additional Vitamin A in the diet has been shown to improve the induction of microsomal enzymes caused by DDT, but it had no marked influence on the accumulation of DDT in lipid tissue. On the other hand, DDT causes a significant decline in the liver Vitamin A content. Humans exposed to DDT had elevated serum Vitamin A levels, on the other hand, workers exposed to organophosphate pesticides such as Abate, malathion, parathion, etc. had decreased serum Vitamin A levels. For instance in 1973 Ember and co-workers estimated the serum concentration of Vitamin A in 8 insect control workers during three spraying seasons and from 9 agricultural workers operating organophosphate deriviative sprays for one season, and from 6 industrial workers who had been in contact with this type of pesticide for a long time. Although none of the subjects showed any clinical symptoms of poisoning, they had low levels of Vitamin A in the blood, indicating that they were suffering latent intoxication.

(d) Vitamin B

When there is deficiency of Vitamin B complex, the toxicity of dieldrin is increased. On the other hand, Watson and co-workers in 1973 found no signifcant changes in the organochlorine content of serum from 15 adults whose occupation involved extreme exposure to pesticides for at least 3 years, and 9 healthy unexposed control subjects after 12 weeks of Vitamin B6 treatment, although in the case of Dipterex, an organophosphatic pesticide, Vitamin B6 supplementation seemed to decrease its toxicity, and the same applied to the interaction between this particular pesticide and thiamin.

5. CONCLUSION

In severe nutritional deprivation, the damaging effect of pesticides is enhanced, particularly, perhaps, in the case of severe protein deficiency, and not only the overall amount of protein that is consumed but the quality of protein as well. This is closely related to the overall nutritional intake. For instannce, in the Caribbean we know from numerous nutrition surveys that the intake of protein on the whole is adequate for most of the Caribbean population. Most of this protein however, comes from vegetable sources some of which may be deficient in some of the essential amino-acids. In addition, the surveys have shown that the average energy intake is inadequate, short of the minimum dietary allowances. When the energy intake is inadequate, then the protein is used as a source of energy, as a source of calories, then presumably we are

in fact faced with the same situation as if the protein intake were inadequate because the protein is not used by the organism for what it should be.

On the other hand, if we consider the impact of pests on food production it would seem obvious that we are concerned not only with the problem of the effect of pesticides but with the protective effect of pesticides, when pests destroy as much as 50% of food production, and this seems to fall within the lap of the National Food and Nutrition Councils whose responsibility it is to ensure adequate nutrition for the population.

It appears therefore, that the National Food and Nutrition Councils should become involved in questions dealing with pesticides, pests and pest control. It is time that within a system of National Food and Nutrition surveillance we should start to consider not only the food that is produced and imported, but the food that is destroyed by pests. So far, nutrition workers have been primarily concerned with simple indicators in food and nutrition surveys. In our food balance sheets we have no idea how much of the food which is estimated to be consumed by the population is in fact being utilized by pests.

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20. PESTICIDE MANAGEMENT: CARIBBEAN PERSPECTIVES AND CONCERNS

P. BOYD

CONTENTS

		Page
1.	INTRODUCTION	263
2.	HEALTH POLICY IN THE CARIBBEAN	263
3.	ENVIRONMENTAL HEALTH STRATEGY	264
4.	RISKS FROM PESTICIDES	265
5.	LEGISLATION AND MONITORING	266
6.	CONCLUSION	267

1. INTRODUCTION

The Secretary-General of the Caricom Secretariat was delighted to co-sponsor this Meeting on a subject of such significance and relevance to our Caribbean situation and is very sorry he was unable, because of a prior commitment, to accept the kind invitation to speak at the Opening Ceremony.

You will hardly be expecting from me this morning a technical approach to the subject of toxic pesticides and their use and managment. As I made clear to your organisers, I have no special expertise in the subject.

Taking note of the word 'perspective' in the subject that has been assigned to me and claiming, as I do, deep involvement in health work in the Caribbean, I shall try to place within our system of Caribbean development the issues which are before us at this Meeting.

As you know, I work for the Caribbean Community Secretariat. The Secretariat has a special responsibility to promote human development in the Caribbean Community. Agricultural development and community health work are integral parts of that human development and contribute to the Secretariat's overall goal of helping the people of the Community to enjoy a better life.

Health and agriculture are at once prerequisites and consequences of the overall development effort. Pesticide management is common ground to both sectors.

2. HEALTH POLICY IN THE CARIBBEAN

One of the remarkable features of regional health work in the Caribbean is the clarity and comprehensiveness with which the Health Ministers Conference has defined its policy and objectives. Three years ago, it issued a Declaration on Health Policy in which it mentioned that, within its Environmental Health Programme, it would adopt, as a specific objective, to —

> *"prepare a programme in each country and in the Community as a whole for pesticide control, enacting legislation, harmonising such legislation with that in the rest of the Community, and promote cooperation of the Ministry of Health with the Ministry of Agriculture and other agencies concerned with pesticide control."*

Thus, the Health Ministers see pesticides management as an integral part of their Health Programme.

But there is more than that. Several years earlier the Conferences was concerned about the problem and, as far back as 1972, adopted the first of a series of resolutions requesting the Governments to develop programmes of work.

This year, in July, in Grenada they adopted a resolution, the terms of which are so strikingly in harmony with what you are trying to achieve at this Meeting that, if you will bear with me, I would like to read to you its whole text, which goes as follows:

"Resolution No. 10: Control of Toxic Pesticides; The Conference, recalling Resolution No. 15 of the Fourth Meeting of the Caribbean Health Ministers Conference;

Also recalling the serious outbreak of poisoning in Jamaica in 1976; in which 16 persons died due to accidental contamination of flour with parathion;

Aware of the fact that pesticide control has considerable significance for human health and food production and that it is an integral part of the programme for protection of the environment, preventing pollution of water and food, and the reduction of accidents;

Convinced of the importance of education in improved pesticide management;

Knowing the wide range of chemicals that are now used as pesticides, and aware of the fact that some of them are highly toxic and have already been banned in other countries;

Concerned about the present methods in the Community of storage, handling and disposal of pesticides;

Impressed with the agro-medical team approach to pesticide management;

Appreciating the special significance of laboratory work in pesticide management;

Noting that under the Fifth European Development Fund (EDF) Programme a financial allocation for a pesticide monitoring project is under consideration;

1. COMMENDS the Caribbean Agricultural Research and Development Institute (CARDI) and the United States Agency for International Development (USAID) for their initiatives in this important field;

2. WELCOMES the convening of a meeting on 3-7 November, 1980 in order to examine all these factors;

3. URGES the organisers to take special account of the circumstances, need and resources of the LDCs;

4. REQUESTS Member Countries to —

(a) participate fully in the meeting;

(b) take full advantage of the presence of specialists in the various fields and arrange to consult with them in the week following the seminar.

5. REQUESTS the Secretary-General to continue his efforts to conclude the negotiations with the Caribbean Agricultural Research and Development Institute to develop the capability of the responsible bodies in the Community to monitor the use of pesticides, and their effects on all life forms in the environment, using the Caribbean Environmental Health Institute in Saint Lucia as the base for these activities.

3. ENVIRONMENTAL HEALTH STRATEGY

There is another important consideration that we need to keep in mind when we assess the relevance of this subject to the Caribbean scene.

Two years ago, also in the Grenada, the Secretariat convened a highly significant regional meeting which prepared an Environmental Health Strategy for the Caribbean Community. We

were acting in close collaboration with PAHO and USAID, and participants came not only from the CARICOM Member States, drawn from the professions of engineering, planning, administration and health, but also from some of the leading regional and international agencies, including the two Universities, CARDI and CDB.

The Strategy which emerged did not cover the whole field of environmental health. It dealt with certain basic needs, such as water supply and wastes disposal. It is significant that it gave some attention to pesticide management.

What I am trying to establish is that your activities this week are an entirely logical outcome of the decisions of our policy makers in health and in agriculture in recent years.

The most significant event of all is about to occur. Next month, the Secretariat is bringing together in Jamaica representatives of the Governments from the disciplines of agriculture, education, communications and health to prepare a Food and Nutrition Strategy for the Caribbean Community. We have been doing intensive staff work for over a year in preparation for this Meeting. But I need to emphasise the high relevance of the exercise this week in pesticide management, when we are contemplating a Food and Nutrition Strategy and making plans to ensure that every Caribbean family shall be able, in future, to produce or to buy the food that it needs.

4. RISKS FROM PESTICIDES

I gather that there are some 150 pesticides in use in the CARICOM area at the present time. Our colleague, Mr. Ali of CARDI, has, in his paper on the use of pesticides in agriculture, given us a list of those that are commonly used in the Caribbean Community.

I observe that pesticides are often classified biologically, that is to say, on the basis of the organism which the pesticide controls. Thus, we have insecticides, miticides, herbicides, fungicides, nematicides and others.

The chemical classification is perhaps more appropriate. Most pesticides are organic compounds and so we recognise a group that falls among the chlorinated hydrocarbons, such as aldrin, dieldrin, DDT and chlordane. Then there are the organo-phosphates, which include malathion and parathion. There are the carbamates which include baygon, lannate, etc. There are other chemical classes of pesticides, of course, but the subject is so complex that no system of classification is perfect, and even the one I have in mind would exclude such a complicated, naturally occurring, insecticide as pyrethrin.

In the past ten years, there has been a considerable increase in the use of pesticides for the control of unwanted plants, pests and diseases. We have known for a long time that such chemicals find their way into rivers, ponds and seas, and affect man's vital chemical processes.

We used DDT with great success in the Leeward Islands in the 1930s and succeeded in eradicating malaria. Malaria has not recurred. We were only repeating the historic work carried out by Gigioli in Guyana. It is interesting to contemplate that a large part of this DDT may be still chemically active and that DDT has since been banned in many countries.

This increased use of pesticides has undoubtedly brought with it increased risk of pollution in the environment.

The most dramatic experience we have had in the Caribbean occurred in 1976 in Jamaica, when 16 persons died and several others were admitted to hospital. The cause of the poisoning was later traced to contamination with parathion of a cargo of flour shipped from Germany.

Incidents like this do not detract from the fact that pesticides are of temendous benefit to man and, in the present state of knowledge, are essential to human development. They have eradicated diseases like malaria, reduced insect infestation and controlled diseases of crops and livestock.

In the Caribbean, we have limited information about the toxicity of pesticide to the various forms of life. So far as I know, there has been no documentation of the findings.

The majority of the countries report a disturbingly high number of pesticide deaths from accident and suicide. It is true that the cause of death in most of these cases has not been established scientifically. But some years ago in Trinidad 70 cases were confirmed in the laboratory.

I would like to commend to you the admirable papers of Dr. J.E. Davies on the medical aspects of the problem. He deals with the results of acute, chronic and incidental exposure. He makes very clear the present state of knowledge of pesticides as a cause of cancer. Animal studies certainly suggest that some pesticides produce tumours and some – marginally – produce cancer. There is no real proof with respect to man. But Kingsley considers cancer an occupational hazard of work with pesticides.

Human beings are exposed to pesticides in two main ways. There is a direct pathway and an indirect pathway. The direct pathway involves exposure to pesticides in the course of manufacture and application; dermal contact and ingestion are secondary features of the direct pathway.

The indirect pathway involves human exposure by transmission through air, water or food; theoretically, the whole population of the world is at risk through this pathway.

Man is not the only animal affected. Indeed he is not the most sensitive to pesticides. Basically, birds and fish are more sensitive. In the Caribbean, we have had one or two experiences e.g. three years ago thousands of pounds of fish were found dead or dying in the Gulf of Paria in Trinidad. The cause was never satisfactorily determined, perhaps because the levels of contaminants could not be satisfactorily established.

We are indebted also to Mr. Ali of CARDI for an admirable account of the implications for drinking water supplies. He concludes that pesticide pollution of water in the Eastern Caribbean is below the limits that can be detected by the available equipment, but that careful pesticide management remains an important preventive measure. He points out that the conventional methods of water treatment do not remove all pesticide residues, and special measures are needed.

Obviously, there is immediate need to investigate the risks involved as well as to provide baseline data with respect to pesticide pollution and the existing residue levels in the environment.

5. LEGISLATION AND MONITORING

Very adequate attention has been given in the Caribbean to legislation. All the countries, except three, have adopted pesticide legislation, and, even in these three, alternative mechanisms are available through existing legislation. We need a mechanism for keeping the legislation up to date. All the countries, except two, have established pesticide control committees.

The Governments have certain serious concerns that have reached us from time to time. They need more general information on pesticide problems. So do we in the Secretariat. They feel that there should be wider knowledge of the general precautions, the recognition of symptoms of poisoning and the treatment of such cases. They need a better understaning of the dangers of certain heavy metals and other industrial chemicals (for example, lead, copper and mercury) that may be used as pesticides. They would like to have more literature on the safe use of pesticides for health education and industrial safety. They recognise the urgency of a food safety policy that would include routine monitoring of agricultural products for the presence of pesticide residues. They are all concerned about technical training in pesticide management.

In short, in the Caribbean situation, the essential first step is that we should have a system to monitor pesticide pollution of the environment and maintain a profile of the residue situation. Mr. Davies urges us to include in that system a continuing, equally thorough, human monitoring programme.

The Governments consider that these activities might appropriately be sited at the Regional Environmental Health Institute in Saint Lucia.

6. CONCLUSION

One final word. Do let us remember when we come together in these regional meetings that we have an admirable mechanism for bringing cur conclusions to the notice of the Governments and people of the Caribbean, namely, the CARICOM Ministerial System. Ministers of Agriculture and Health meet every year and you would be wise, I think, to see that your conclusions reach them in the most effective form through the Caribbean Community Secretariat.

21. GOALS AND THE PURPOSE OF PESTICIDE LEGISLATION AND REGULATION

CARROLL COLLIER

CONTENTS

		Page
1.	INTRODUCTION: HISTORY OF PESTICIDE LAWS IN THE USA	268
2.	CURRENT ROLE OF EPA	274
(a)	Classification	274
(b)	Registration	275
(c)	Guidelines	276
3.	PESTICIDES AND USAID PROGRAMS	280
4.	CONCLUSION	282

INTRODUCTION

In this paper the history of pesticide legislation in the USA is briefly reviewed, followed by a discussion of the present role of the Environmental Protection Agency in regulating the use of such substances. Inevitably certain USAID programmes have incurred the use of pesticides and it has become necessary to develop appropriate policies and regulations to govern their use and management.

1. INTRODUCTION: HISTORY OF PESTICIDE LAWS IN THE USA

The Federal regulation of pesticides in the U.S. began as early as 1910 with the issuance of the "Insecticide Act of 1910", which prohibited the interstate sale of any insecticide as a fungicide which was adulterated or misbranded. This Act was concerned with the effectiveness of products and with deceptive labelling and did not require a registration action.

Thirty-seven years later, the first law having a significant effect on toxic pesticides entering into commercial channels of trade was enacted. This Act, the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), like the 1910 Act, was oriented toward protection of the consumer. The law required registration of the pesticide, prohibited adulteration or misbranding, and required for each product a label. All labels were required to contain the name of product, address of manufacturer, a statement of net contents, and a warning or caution statement, when necessary, to prevent injury to man and other vertebrate animals, useful vegetation, and useful invertebrates. Additionally, for chemicals of high acute oral, inhalation, or dermal toxicity, a skull and crossbones insignia was required along with the world "POISON" in red on a contrasting background. It is noteworthy that this law did not allow the U.S.D.A. (the Agency responsible for enforcement of the law) to deny registration regardless of the nature of the chemical as long as its efficacy could be established and labelling requirements were complied with.

This Act was amended in 1959 to include nematicides, plant growth regulators, defoliants, and desiccants. It was not until an amendment in 1964 that the Act allowed the actual denial of a registration. Theretofore, no controls could be imposed on toxic chemicals as long as they complied with all requirements of the law in regard to claims on the label and voluntary registration of their product. The government could officially "protest" the registration of a product, thus giving it adverse publicity, but could do nothing else.

In 1954 the Federal Food Drug and Cosmetic Act was amended to include the requirement for "tolerances" in or on raw agricultural commodities. These tolerances were to be "requested in the form of a petition by any person who has registered, or has applied for registration of an economic poison under the FIFRA." The pesticide petition was required to contain the following:

A. The name, chemical indentity, and composition of the pesticide chemical.

B. The amount, frequency, and time of application of the pesticide chemical.

C. Full reports of investigations made with respect to the safety of the pesticide chemical.

D. The results of tests on the amount of residue remaining.

E. Practical methods for removing the residue which exceeds any proposed tolerance.

F. Proposed tolerances for the pesticide chemical.

Since at the time of this enactment there were many pesticides registered for use on fresh fruits and vegetables, a large number of tolerances were "administratively" established in 1955. The findings of fact and regulation establishing these tolerances were based on "reliable, probative and substantial evidence," received at hearings conducted in 1950. Henceforth, all tolerances have been set upon the basis of formal petitions. Most of these original tolerances established in 1955 are still in force along with many hundreds of newer ones established since that time. The Federal Food Drug and Cosmetic Act was again modified in 1958 to include pesticidal food activities in processed foods. The two relevant sections of the Act, Section 406 and Section 408, are reproduced below:

TOLERANCES FOR POISONOUS INGREDIENTS IN FOOD AND CERTIFICATION OF COAL-TAR COLORS FOR FOOD

Sec. 406. (a) Any poisonous or deleterious substance added to any food, except where such substance is required in the production thereof or cannot be avoided by good manufacturing practice shall be deemed to be unsafe for purposes of the application of clause (2) of section 402 (a): but when such substance is so required or cannot be so avoided, the Secretary shall promulgate regulations limiting the quantity of any such substance in the case of any food, such food shall not, by reason of bearing or containing any added amount of such substance, be considered to be adulterated within the meaning of clause (1) of section 402 (a). While such a regulation is in effect limiting the quantity of any such substance in the case of any food, such food shall not, by reason of bearing or containing any added amount of such substances, be considered to be adulterated within the meaning of clause (1) of section 402 (a). In determining the quantity of such added substance to be tolerated in or on different articles of food the Secretary shall take into account the extent to which the use of such substance is required or cannot be avoided in the production of each such article, and the other ways in which the consumer may be affected by the same or other poisonous or deleterious substances.

TOLERANCES FOR PESTICIDE CHEMICALS IN OR ON RAW AGRICULTURAL COMMODITIES

Sec.408. (a) Any poisonous or deleterious pesticide chemical, or any pesticide chemical which is not generally recognized, among experts qualified by scientific training and experience to evaluate the safety of pesticide chemicals, as safe for use, added to a raw agricultural commodity, shall be deemed unsafe for the purposes of the application of clause (2) of section 402 (a) unless –

(1) a tolerance for such pesticide chemical in or on the raw agricultural commodity has been prescribed by the Secretary of Health, Education, and Welfare under this section and the quantity of such pesticide chemical in or on the raw agricultural commodity is within the limits of the tolerance so prescribed; or

(2) with respect to use in or on such raw agricultural commodity, the pesticide chemical has been exempted from the requirement of a tolerance by the Secretary under this section.

While a tolerance or exemption from tolerance is in effect for a pesticide chemical with respect to any raw agricultural commodity, such raw agricultural commodity shall not, by reason of bearing or containing any added amount of such pesticide chemical, be considered to be adulterated within the meaning of clause (1) of section 402 (a).

In 1964 amendments were made to the FIFRA which:

A. Eliminated "protest" registration and allowed the government to deny certain applications.

B. Expedited procedures for suspending the marketing of previously registered pesticides found to be unsafe.

C. Required a licensing number for each separate registrant.

In 1972, FIFRA was drastically amended by the Federal Environmental Pesticide Act (FEPCA). Approval of a registration was contingent on the following:

"(5) APPROVAL OF REGISTRATION. – The Administrator shall register a pesticide if he determines that, when considered with any restrictions imposed under subsection (d) –

"(A) its composition is such as to warrant the proposed claims for it.

"(B) its labeling and other material required to be submitted comply with the requirements of this Act.

"(C) it will perform its intended function without reasonable adverse effects on the environment .and

"(D) when used in accordance with widespread and commonly recognized practice it will not generally cause unreasonable adverse effects on the environment."

Lack of essentiality could not be used as a criterion for denying registration. Additionally, the 1972 law (and its revised version), had important provisions relating to:

A. Classification of pesticides.

B. Certification of Applicators.

C. Instruction in IPM Methodology.

D. National Monitoring Plans.

E. Experimental Use Permits.

F. Procedures for Suspensions, Cancellations, and Judicial Review.

During this period the Agency also initiated a special pesticide review having the acronym RPAR – that is – Rebuttable Presumption Against Registration. In this process the Agency, utilizing information currently at its disposal "presumes" against the advisability of long term continuance of a registration based on data received after the issuance of the initial registration. By regulation certain "triggers" were defined allowing each a presumption. They are as follows:

(i) Acute toxicity – (A) Hazard to Humans and Domestic Animals.
(1) Has an acute dermal LD_{50} of 40 mg/kg or less as formulated; or
(2) Has an acute dermal LD_{50} of 6 g/kg or less as diluted for use in the form of a mist or spray;
(3) Has an inhalation LC_{50} of 0.04 mg/liter or less as formulated.
(B) Hazard to Wildlife. (1) Occurs as a residue immediately following application in or on the feed of a mammalian species representative of the species likely to be exposed to such feed in amounts equivalent to the average daily intake of such representative species, at levels equal to or greater than the acute oral LD_{50} measured in mammalian test animals as specified in the Registration Guidelines.
(2) Occurs as a residue immediately following application in or on avian feed of an avian species, representative of the species likely to be exposed to such feed in amounts equivalent to the average daily intake of such representative species, at levels equal to or greater than the subacute dietary LC50 measured in avian test animals as specified in the Registration Guidelines.
(3) Results in a maximum calculated concentration following direct application to a 6-inch layer of water more than ½ the acute LC_{50} for aquatic organisms representative of the organisms likely to be exposed as measured on test animals specified in the Registration Guidelines.
(ii) Chronic Toxicity. (A) Induces oncogenic effects in experimental

mamalian species or in man as a result of oral, inhalation or dermal exposure; or induces mutagenic effects, as determined by multitest evidence.

(B) Produces any other chronic or delayed toxic effect in test animals at any dosage up to a level, as determined by the Administrator, which is substantially higher than that to which humans can reasonably be anticipated to be exposed, taking into account ample margins of safety; or

(C) Can reasonably be anticipated to result in significant local, regional, or national population reductions in non-target organisms, or fatality to members of endangered species.

In turn, the registrant (or any other interested party), was given the opportunity to rebut this initial presumption by furnishing new data correcting existing data or furnishing convincing arguments which could shed light or perspective and overturn the original negative presumption. The pesticides are now under the RPAR process (Table 1):

Table 1. Special pesticide review division status report

Rpar's Issued

Chemical (Class of Chemicals) and Contact Person	40 CFR 162.11 Criteria Possibly met or exceeded	Current Status
Benomyl (Branch 3)	o Reduction in non-target species (rebutted) o Mutagenicity o Teratogenicity o Reproductive Effects o Hazard to Wildlife	o PD 1 published, 42 FR 61788 (12/6/77) o PD 2/3 completed and Notice of Determiniation published, 44 FR 51166 (8/30/79); comment period closed 9/28/79 o PD 4 being drafted; will be combined with Thiophanate methyl o Recently received oncogenicity study under review
Cadmium (Branch 3)	o Oncogenicity o Mutagenicity o Teratogenicity o Fetotoxicity	o PD 1 published, 42 FR 56574 (10/26/77); comment period closed 2/10/78 o PD 2/3 being drafted
Captan (Branch 1)	o Oncogenicity o Mutagenicity o Other Chronic Effects	o PD 1 published, 45 FR 54938 (8/18/80); comment period closes 12/1/80
Carbon Tetrachloride (Branch 4)	o Oncogenicity o Toxic effects on liver and kidney	o PD 1 published, 45 FR 68534 (10/15/80); comment period closes 11/24/80
Chloroform Trichloromethane (Branch 4)	o Oncogenicity	o PD 1 published, 41 FR 14588 (4/6/79); comment period closed 7/23/79 o PD 2/3 being drafted
Coal Tar (Branch 4)	o Oncogenicity o Mutagenicity	o PD 1 published, 43 FR 48154 (10/18/78); comment period closed 9/30/78: NTIS# PB80 213879 $9.00 (paper)/$3.50 (microfiche) o PD 2/3 (wood uses only) being drafted
Creosote (Branch 4)	o Oncogenicity o Mutagenicity	o Same as above (Coal Tar/Creosote/ Coal Tar Neutral Oil PD 1 combined)

Diallate (Branch 3)	o Oncogenicity o Mutagenicity	o PD 1 published, 42 FR 27609 (5/31/77); comment period closed 9/9/77: NTIS# PB80 212863 $5.00 (paper)/$3.50 (microfiche) o PD 2/3 completed and Notice of Determination published, 45 FR 38437 (6/9/80); comment period closed 7/9/80); NTIS# PB80 216849 $7.00 (paper)/$3.50 (microfiche) o PD 4 being developed
Dimethoate (Branch 2)	o Oncogenicity o Mutagenicity o Fetotoxicity o Reproductive effects	o PD 1 published, 42 FR 45806 (9/22/77); comment period closed 1/6/78 o PD 2/3 completed and Notice of Determination published, 44 FR 66558 (11/19/79); comment period closed 12/19/79: NTIS# PB80 213846 $11.00 (paper)/$3.50 (microfiche) o PD 4 in Agency review
EBDC's Ethylenebisdithiocarbamates, maneb, mancozeb, metiram, nabam, zineb, amobam (Branch 3)	o Oncogenicity o Teratogenicity o Hazard to Wildlife	o PD 1 published, 42 FR 40618 (8/10/77); comment period closed 12/23/77 o PD 2/3 in Agency review
Ethylene Dibromide EDB (Branch 4)	o Oncogenicity o Mutagenicity o Reproductive Effects	o PD 1 published, 42 FR 63134 (12/14/77); comment period closed 4/3/78 o PD 2/3 in Agency review
EPN Ethyl p-nitrophenyl thionobenzenephosphonate (Branch 2)	o Neurotoxicity	o PD 1 published, 44 FR 54384 (9/19/79); comment period closed 12/29/79; NTIS# PB80 216815 o PD 2/3 being drafted
Ethylene Oxide EtO (Branch 1)	o Mutagenicity o Testicular Effects	o PD 1 published, 43 FR 3801 (1/27/78); comment period closed 5/15/78: NTIS# PB80 213903 $7.00 (paper)/$3.50 (microfiche) o PD 2/3 being drafted
Inorganic Arsenicals Arsenic Acid Arsenic Pentoxide, Arsenic Trioxide, Sodium Arsenate, Ammonium Arsenite, Sodium Pyroarsenate, Lead Arsenate (Basic and Standard), Calcium Arsenate, Sodium Arsenite, Copper Acetoarsenite (Branch 4)	o Oncogenicity o Mutagenicity o Teratogenicity	o PD 1 published, 43 FR 42867 (10/18/78); comment period closed 2/12/79 o PD 2/3 (wood uses only) being developed
Lindane (Branch 3)	o Oncogenicity o Teratogenicity o Reproductive Effects o Acute Toxicity	o PD 1 published, 42 FR 9816 (2/18/77); comment period closed 6/20/77: NTIS# PB80 213911 $7.00 (paper)/$3.50 (microfiche) o PD 2/3 completed and Notice of Determination published, 45 FR 45362 (&/3/80); comment period closed 9/15/80
Maleic Hydrazide MH (Branch 3)	o Oncogenicity o Mutagenicity o Reproductive Effects	o PD 1 published, 42 FR 56920 (10/28/77); comment period closed 12/14/77: NTIS# PB80 216740 $5.00 (paper)/$3.50 (microfiche) o PD 2/3 being developed
PCNB Pentachloronitrobenzene (Branch 4)	o Oncogenicity	o OD 1 published, 42 FR 61894 (10/13/77); comment period closed 2/6/78; NTIS# PB80 216799 $6.00 (paper)/$3.50 (microfiche) o PD 2/3 being developed

Pentachlorophenol and Derivatives (Branch 4)	o Fetotoxicity o Teratogenicity	o PD 1 published, 43 FR 48443 (10/18/78); comment period closed 2/12/79 o PD 2/3 (wood uses only) being drafted
Sodium Fluoroacetate/1080 (Branch 1)	o Reduction in Non-target and Endangered Species o No antidote	o PD 1 published, 41 FR 52792 (12/1/76); comment period closed 3/15/77: NTIS# PB80 216823 $5.00 (paper)/$3.50 (microfiche) o Pd 2/3 being drafted
Strychnine/Strychnine Sulfate (Branch 1)	o Reduction in Non-target and Endangered Species	o PD 1 published, 42 FR 2713 (1/13/77; comment period closed 3/15/77: NTIS# PB80 216807 $6.00 (paper)/$3.50 (microfiche) o PD 2/3 in Agency review
Thiophanate Methyl (Branch 3)	o Mutagenicity o Reduction in Non-target Species (Rebutted)	o PD 1 published, 42 FR 61970 (12/7/77); comment period closed $5.00 (paper)/$3.50 (microfiche) o PD 2/3 completed and Notice of Proposed Determination published, 44 FR. 58798 (10/11/79) comment perid closed 11/12/79. o PD 4 being drafted; will be combined with Benomyl o Recently received oncogenicity study under review
Toxaphene (Branch 2)	o Oncogenicity o Reduction in Non-target Species	o PD 1 published, 42 FR 26860 (5/27/77); comment period closed 9/13/77: NTIS# PB80 216732 $6.00 (paper)/$3.50 (microfiche) o PD 2/3 in Agency review
Trifluralin Treflan (Branch 1)	o Oncogenicity o Mutagenicity	o PD 1/2/3 published, 44 FR 50911 (8/30/79); comment period closed 11/13/79: NTIS# PB80 213937 $8.00 (paper)/$3.50 (microfiche) o PD 4 being drafted
2,4-5-Trichlorophenol Phenol (Branch 2)	o Oncogenicity o Fetotoxicity	o PD 1 published, 42 FR 41268 (9/15/78); comment period closed 11/17/78 o Possibility of TCDD contamination under investigation o 3(c) (2) (B) letters issued requesting additional data from registrants o Some voluntary cancellations and reformations being processed

In 1978 the law was again modified partly because the 1972 law had required a comprehensive re-evaluation of the pesticide chemicals used everyday in the production of food. This re-evaluation, to be accomplished by a re-registration process, had never gotten off the ground. Some of the delay was caused by problems presented by the 1972 Act, as related to trade secret provisions. Thus, 1978 and continuing on until the present, most of the older pesticides registered in the 1950s, 1960s, and even into the 1970s have not been evaluated in the light of modern environmental and/or toxicological concepts and methodology.

Among the provisions designed to speed up re-registration are new provisions for (a) generic registration (b) conditional registration and (c) modification of trade secret provisions.

Another salient aspect of the new law is a requirement that prohibits the Administration from initiating a public review process (RPAR process) unless it is based on validated tests or other significant evidence raising "prudent concerns' 'of unreasonable adverse risk to man or to the environment. Also, the manufacturer is provided a short period of time in which to communicate with EPA, on a private basis, during which time the manufacturer hopefully can satisfy EPA's questions without unnecessary adverse publicity attending the totally public RPAR process.

Another provision of the Act would limit the scope of the prohibition in the Act against the use of a registered pesticide in a manner inconsistent with its labelling by providing the following exceptions:

It was no longer unlawful to:

A. Apply a pesticide at any dosage, concentration, or frequency less than that specified on the labelling.

B. Apply a pesticide against any target not specified on the labelling if the application is to the crop, animal, or site specified on the labelling; unless the Administrator has required that the labelling specifically state that the use of the pesticide against other pests would cause an unreasonable adverse effect on the environment.

C. Employ any method of application not prohibited by the labelling.

The above would obtain unless EPA issues regulations or advisory opinions specifically requiring the use of definite amounts of dilution. In the case of ultra low volume (ULV) uses, the EPA has issued such an advisory opinion.

Also, the new Act specifically allows EPA to waive efficacy data requirements on a pesticide; requires EPA to establish procedures for monitoring man and animals and their environment for incidental pesticide exposure; requires that EPA prior to cancelling a registration for cause, consider restricting the pesticide's use as an alternative to cancellation.

2. CURRENT ROLE OF EPA

With this brief overview of pesticide regulation laws in the U.S., I would like to describe some of the major activities in which EPA's Office of Pesticide Programs is now involved.

(a) Classification

The first of these is the classification process. By this process, pesticides are classified as either restricted or general use materials. If pesticides are classified as restricted, applicators must be certified as having had sufficient training and indoctrination to use the pesticide safely, both in terms of their own personal protection and also with regard to the fellow man and his environment. Authority for such certification in the U.S. has been re-delegated to the respective states when adequate state plans are submitted to EPA. The following extracts provide a sample of currently restricted pesticides and the reasons for their restriction (Table 2).

Table 2. Pesticide use classification

Active Ingredient	Formulation	Use Pattern	Classification[1]	Criteria Influencing Restriction
Aldicarb	Granular formulations 10% and greater	Agricultural Uses	Restricted	Acute oral toxicity Residue effects on avian species
Carbofuran	All concentrate suspensions and wettable powders 40% and greater	All uses	Restricted	Acute inhalation toxicity
Chloropicrin	All formulations greater than 2%	All uses	Restricted	Acute inhalation toxicity
	All formulations	Rodent control	Restricted	Hazzard to non-target organisms
	All formualtions 2% and less	Outdoor uses (other than rodent control)	Unclassified	
Dicrotophos	All liquid formulations 8% and greater	All uses	Restricted	Acute dermal toxicity Residue effects on avian species (except for tree injection)
Phorate	Granular formulations 5% and greater	All uses	Restricted	Acute oral toxicity Acute dermal toxicity Residue effects on avian species
	Fertilizer formulations 1.25% and less	All uses	Under evaluation	
Temephos	All dry and liquid formulations	Aquatic users	Restricted	Effects on aquatic organisms
	All liquid formulations	Orchard	Restricted	Residue effects on avian species
	Dog and cat collars 40.7% or less	Domestic use on pets	Unclassified	
Terbufos	Granular formulations 15% and greater	All non-domestic	Restricted	Acute oral toxicity Acute dermal toxicity Residue effect on avian species
Zinc Phosphide	All formulations 2% and less	All domestic uses and non-domestic uses in and around buildings	Unclassified	
	All dry formulations 60% and greater	All uses	Restricted	Acute inhalation toxicity
	All bait formulations	Non-domestic outdoor uses (other than around buildings)	Restricted	Hazard to non-target organism
	All dry formulations 10% and greater	Domestic use	Restricted	Acute oral toxicity

1 "Under evaluation" means no classification decision has been made and the use/formulation in question is still under active review within EPA

Source: Federal Register/Proposed Rules

(b) Registration

Prior to the 1978 Act the Agency's position was that application for registration of new products and for amendments to registered products would be denied if the applications did not fully satisfy the current data requirements (i.e., if there were "data gaps"). The amended law allowed "conditional" registration, without full submission of data if the EPA determined that a new registration or a new pattern of use for an existing registration would not cause an unreasonable adverse effect on the environment and would be in the public interest.

A major difference between a conditional registration and a full (or unconditional) registration is that of the length of time for which it is permitted. Conditional registrations always are granted on the assumption that at some specific time in the future all required testing procedures for an indefinite full registration will be completed.

One of the general themes underlying any conditional registration is that the Agency must document its reason for such a decision. In particular, the Agency must expressly indicate the deficiencies in the data, the expected duration of the registration, the expected exposure of the environment as a result of the new use, why the data is "satisfactory" for purposes of making the required finding that no significant increase in unreasonable adverse effects will result from the new use during the duration of the registration, and whether arrangements have been made for submission of definitive data.

As stated earlier, the 1978 Act provides for registration of the older group of pesticides (mostly those registered before the formation of EPA) by way of a "generic" standards process based on the dvelopment and promulgation of publically available position documents based on review of all relevant scientific data coupled to "standards" of composition, packaging, toxicity, labelling, and data requirements. The standard is "generic" in that it focuses on active pesticide ingredients and encompasses the conditions which each separate product containing that active ingredient must meet if it is to be registered (or re-registered) in the U.S. Full re-registration can take many years. For example since the first EPA trial standard as developed for the pesticide metolochoior, five such standards have been developed and are available on request from EPA.

(c) Guidelines

The Federal Pesticide Act of 1978 does not impose any specific data requirements but does authorize EPA to require the submission of data when it deems it necessary to assess the risks and benefits of a pesticide in order to determine whether the pesticide may cause unreasonable adverse effects on the environment.

Section 3 (c) (2) specifically requires the Administrator to publish guidelines specifying the kinds of information required in support of registration. While the Agency has proposed such guidelines, these guidelines have not been issued in final form. Development of these guidelines has been a constant process since 1972, and in the numerous iterative processes involved all segments of the world community having an interest in pesticides. A succession of guidelines have been developed, the latest draft of almost finalized versions being as recent as October 1980. Of all the efforts of the EPA Office of Pesticides, these guidelines probably represent the most fruitful of activities. They not only represent the input of EPA regulatory scientists, but also include some of the best scientists from industry, academia, and other Federal agencies. Although these guidelines have not been formalized, pesticide registrants utilizing current versions can with reasonable certainty expect acceptance of their test protocols by EPA if the general patterns of the guidelines are followed.

It is of interest to note that vigorous efforts are now underway to develop test protocols for toxic substances which are acceptable by regulators responsible for different laws within the same agencies, between agencies, and even between continents. Shortly after passage of the Toxic Substances Control Act, a committee was formed to ensure consistency of FIFRA guideline requirements with TSCA regulations and vice versa. On a national level, the International Regulatory Liaison Group (IRLG) has been formed to ensure consistency between such departments as Commerce, Health Education and Welfare, EPA, Interior, Agriculture, etc. Internationally, EPA has actively cooperated with the Organization for European Community Development (OECD). From these efforts, policies are slowly emerging that are acceptable to a wide range of affected groups.

The most recent guideline to be developed is that for the "biorational pesticides". Biorational pesticides are often referred to as biological control agents, and are by definition those chemical or living microscopic pest control agents which are inherently different from ordinary pesticides. Here for the first time a tiered testing system is proposed. Tests are arranged in a hierarchial system and testing schemes commence with short-term studies with the decision to go to a higher tier dependent on the results of a lower tier. Two pages from this scheme are shown below:

Figure 1. Summary of Toxicology and Residue Chemistry Tier Testing Schemes

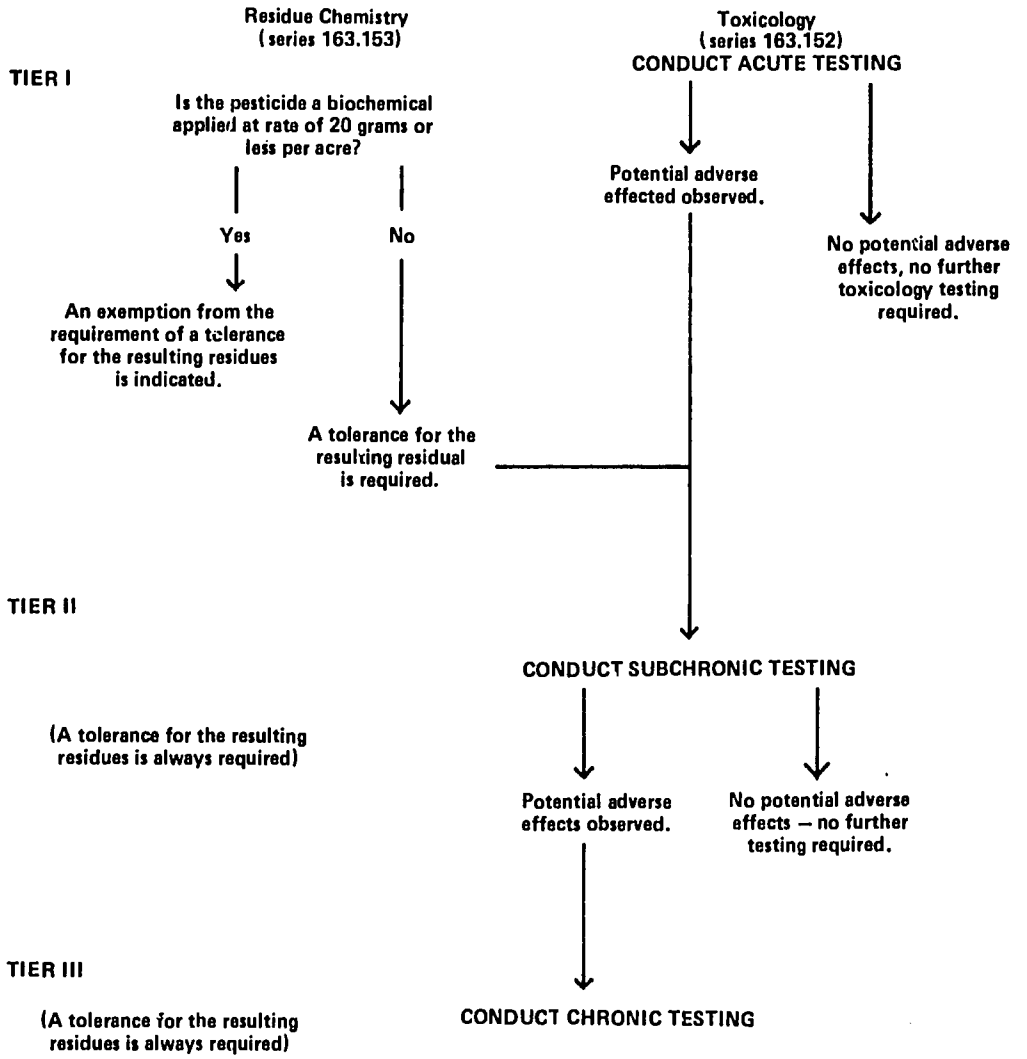
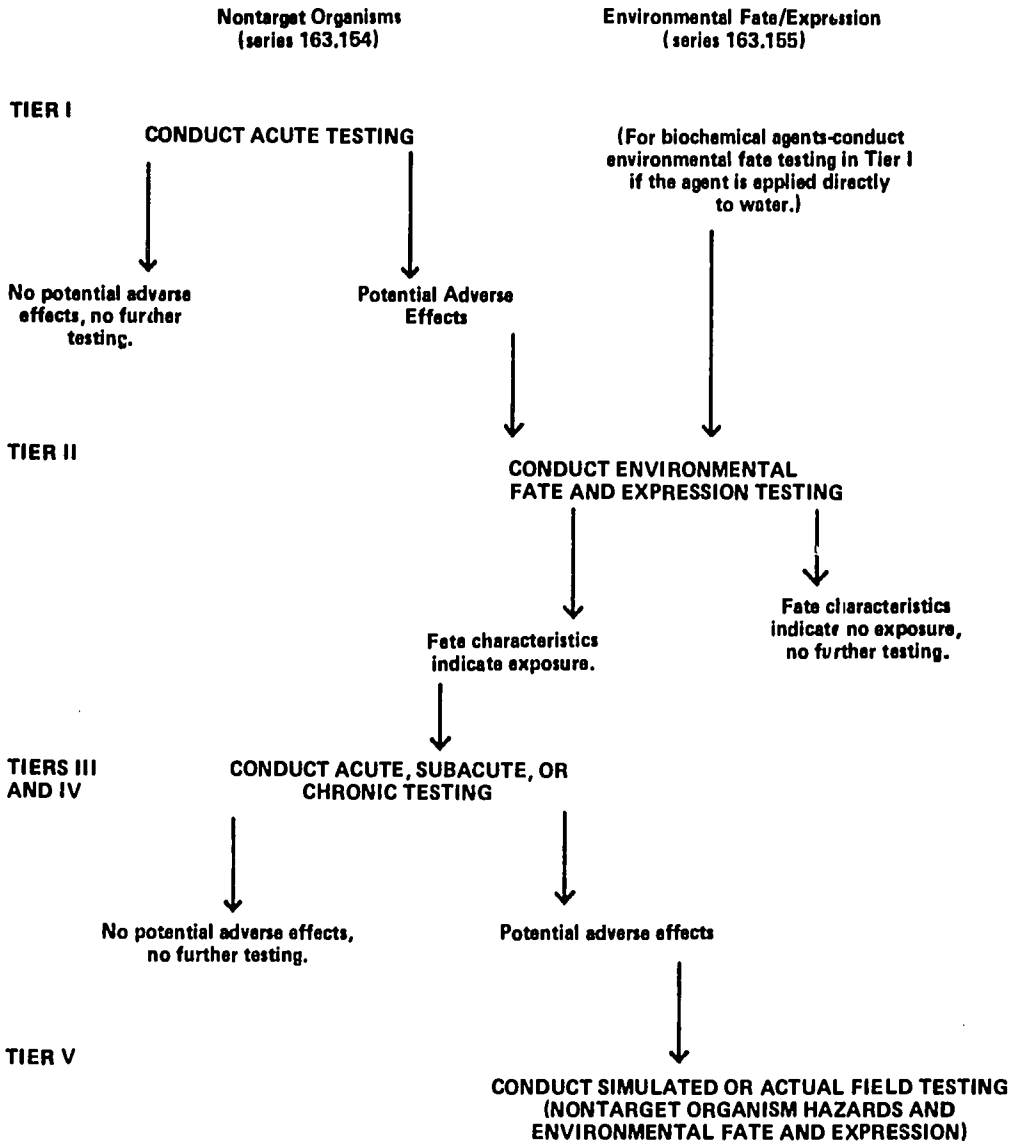


Figure 2. Summary of Nontarget Organism/Environmental Fate and Expression Testing Schemes



This scheme has been favorably received even though the biorational pesticides are an entirely new proposal from EPA.

With the exception of genotoxic testing utilizing microbial systems most of the test methodology associated with the guideline was available even before the inception of the Environmental Protection Agency.

For example, what are now well institutionalized environmental fate requirements by the EPA, were first verbalized by the U.S. Department of Agriculture in 1970 when they still had the regulatory responsibility for the regulations of pesticides. These are shown on the next page.

UNITED STATES DEPARTMENT OF AGRICULTURE
AGRICULTURAL RESEARCH SERVICE
PESTICIDES REGULATION DIVISION
WASHINGTON, D C. 20250

June 23, 1970

NOTICE TO MANUFACTURERS, FORMULATORS, DISTRIBUTORS, AND REGISTRANTS OF ECONOMIC POISONS

Attention : Person Responsible For Federal Registration of Economic Poisons

Guidelines For Studies to Determine the Impact of Pesticides on the Environment

The use of pesticides may result in residues of the parent compound and/or its degradation products in treated areas and possibly in other areas as well. In connection with registration of pesticides for outdoor use, certain studies are necessary to provide information on their impact on the environment.

The basic questions which need to be resolved are listed below: (A brief discussion of the studies needed follows each question. These comments are indicative and not all inclusive.)

1. What is the rate of dissipation of the pesticide in the soil?

   Studies should usually be contained until less than ten percent (10%) of the original amount of parent compound and degradation products remains. Some pesticides may require studies until dissipation is complete. Studies should include analyses for single or repeated applications depending on the use pattern.

2. What is the mechanism of degradation of the pesticide residues?

   These studies may be carried out in the laboratory, but may need to be confirmed with field studies. **Examples of field studies that may be required are:**

   (a) **Photodecomposition** studies in or on soil and water, using sterile and nonsterile samples.

   (b) Degradation and metabolism studies of the **effect of micro-organisms**, and the **effect of the residues on micro-organisms.**

   (c) Degradation studies in water.

   (d) Duration of the biological activity (for example, phytotoxicity).

3. Do the residues leach through the soil?

   Laboratory studies may suffice. If leaching is found to occur, further data will be necessary, for example, the determination of residue levels in ground water.

4. Are the residues moved from the site of application by runoff water?

   Laboratory studies may suffice, but may need to be confirmed with field studies, such as :

   (a) Analysis of soil in untreated areas receiving runoff water.

   (b) Analysis of pond water receiving runoff water.

5. Is the pesticide bound in soils that is, are residues present that are not readily extractable?

   If radiochemical tracer or other studies indicate that the pesticide is bound, additional studies may be needed, for example:

   (a) Identification of the residue.

   (b) Phytotoxicity of the residue.

   (c) Determination as to whether bound residues may be released from the soil by plants such as rotational crops other than those initially grown in treated areas.

6. What levels of the parent compound and principal metabolites will accumulate in fish, rabbit and bird tissue and what dosage related symptoms are exhibited during the laboratory test period?

Such feeding studies should employ a dosage range encompassing both a no-effect level and an effect level. Need for determination of residues in fish, when pesticides are applied to terrestrial sites, will be dependent upon data from leaching and runoff studies.

Harold G. Alford
Assistant Director

3. PESTICIDES AND USAID PROGRAMMES

Now where and how do pesticides fit into A.I.D. programs? Until 1976, little attention was paid to the pesticide component of our foreign assistance programs. Then, responding in part to a stipulation approved by the District Court in the settlement of litigation against A.I.D. by three environmental groups, regulations pertaining to the use of pesticide in A.I.D. funded programs were developed. These were originally promulgated in 1976 and revised in May 1978. (See also the abstract from USAID Requirements for the Supply and Use of Pesticides "Applicability of Pesticide Procedures" Table 3 at end of papers). In summary the regulations provide that pesticide activities shall be subject to an environmental evaluation and shall include economic, social, and environmental risk and benefits. Factors to be considered in such an evaluation are to include but not be limited to the following:

A. The USEPA registration status of the requested pesticide.

B. The basis for selection of the requested pesticide.

C. The extent to which the proposed pesticide use is part of an integrated pest management program.

D. The proposed method or methods of application including availability of appropriate application and safety equipment.

E. Any acute and long-term toxicological hazards, either human or environmental, associated with the proposed use and measures available to minimize the hazards.

F. The effectiveness of the requested pesticide for the proposed use.

G. Compatibility of the proposed pesticide with target and non-target ecosystems.

H. The conditions under which the pesticide is to be used including climate, flora, iguna, geography, hydrology, and soils.

I. The availability and effectiveness of other pesticides or non-chemical control methods.

J. The requesting country's ability to regulate or control the distribution, storage, use, and disposal of the requested pesticide.

K. The provisions made for training of users and applicators.

L. The provisions made for monitoring the use and effectiveness of the pesticide.

APPLICABILITY OF PESTICIDE PROCEDURES

1. Provision of Assistance for the Supply or Use of Pesticides* in Projects.

A. **Pesticides Identified at time of preparation of Project Identification Document (PID) or Project Paper (PP)**

Category	EPA Regulatory Status	Actions Required
1.	Registered for same or similar use without restriction	Risk/benefit analysis of each proposed use and incorporated in Initial Environmental Examination (IEE)
2.	Registered for same or similar use, restricted on basis of user hazard	Risk/benefit analysis of each proposed use in IEE, plus inclusion of training component in project to minimize user hazards of restricted use pesticides
3.	Any pesticide not falling in the first two categories	Risk/benefit analysis which is incorporated into an Environmental Assessment (EA) or an Environmental Impact Statement (EIS)
4.	Any pesticide in categories 1, 2, or 3 but against which EPA has initiated a regulatory action for cause or a rebuttable presumption against registration (RPAR)	Explanation and discussion of regulatory action with requesting government and consideration of these aspects in an EA, or EIS as appropriate
5.	Any pesticide in categories 1, 2, or 3 at time of preparation of IEE, EA, or EIS but against which EPA subsequently initiates a regulatory action.	Explanation and discussion of regulatory action with requesting government and consideration of these aspects in amended IEE, EA, or EIS as appropriate.

B. **Pesticides Identified subsequent to preparation of PID or PP**
Procedures outlines in Section A will be followed, depending upon the EPA regulatory status of each specific pesticide ; actual procurement or use must be approved in writing by the Assistant Administrator or Mission Director who approved the project.

C. **Exceptions to procedures outlined in A or D**

1. Projects under emergency conditions — when the Administrator determines in writing that a pest outbreak has occurred or is imminent and significant human or animal health problems or significant economic problems will occur and there is insufficient time to evaluate the proposed use as outlined in Section A

2. Projects where A.I.D. is a minor donor to a multidonor project (where A.I.D.'s total contribution will not exceed $1,000,000 or 25% of the estimated project cost or where A.I.D.'s total contribution will not exceed 25% of estimated project cost of projects costing more than $1,000,000 and A.I.D. does not control the planning or design of the multidonor project)

3. Projects where pesticides are to be used only for research or limited field evaluation under the supervision of project personnel.**

II. **Provision of Assistance for the supply or use of pesticide other than in projects e.g. Commodity Import Programs (CIP)**
Assistance shall be provided only if A.I.D.'s Administrator determines in writing that an emergency exists as defined under C-1 or there are compelling circumstances such that failure to provide would seriously impeded the attainment of U.S. foreign policy objectives or the objectives of the Foreign Assistance Program.

* Where a number of pesticides are involved and they fall into different categories, they will all be considered together in a single document, i.e., IEE, EA, or EIS, e.g., one may require only an IEE and a second an EA. Both would be considered in EA.

** See Rule 16, Environmental Procedures for other requirements.

Table 3. Abstract from USAID Requirements for the Supply and Use of Pesticides

This policy has been re-affirmed and strengthened by the Presidential Environmental Message of August 2, 1979, wherein federal agencies were instructed to:

> "Modify as soon as possible existing pest management, research, control, education, and assistance programs to support and adopt IPM strategies wherever practicable within the limits of existing resources."

4. CONCLUSION

Inevitably the laws relating to pesticides have evolved slowly, and registration procedures have become increasingly complex as the dangerous ecological effects of these toxic substances have become more clearly recognised. It is of course, essential that the environment be adequately protested and this the EPA attempts to accomplish. USAID, for its part, is obliged to recognise the environmental and toxic hazards of pesticides, and has to ensure that in its programmes no unnecessary risks are permitted.

22. BENEFIT-COST ANALYSIS OF INTEGRATED PEST MANAGEMENT PROGRAMS

RONALD D. LACEWELL and C. ROBERT TAYLOR

CONTENTS

	Page
1. INTRODUCTION	284
Pest Losses	285
Benefit-Cost Analysis	285
2. DYNAMICS OF PRODUCTION	285
3. MICRO-ECONOMIC ANALYSIS	287
Methods of Analysis	287
Budgeting Analysis	287
Linear Programming	287
Statistical Analysis	287
Implications of Selected Systems	288
Texas High Plains Cotton Program	288
Short-Season IPM Cotton Programs	289
South Texas	289
Lower Rio Grande Valley	291
West Texas	292
Texas Extension Service Statewide Cotton Program	292
Other Cotton IPM Programs	293
Other Crops	294
4. MACRO-ECONOMIC ANALYSIS	294
The Farm Income Paradox	290
Models for Evaluating Aggregate Impacts	298
Partial Budgeting	298
Mathematical Programming	298
Econometric Simulation	299
5. CONCLUSION	300
REFERENCES	300

TABLES

1. Typical Per Acre Costs and Returns for Cotton by Selected Years and Regions 286

2. Estimated Impact of the Texas High Plains' Reproductive Dispause Boll Weevil Control Program 288

3. Implications of a Short-Season IPM Cotton Production System for South Texas 290

4. Lint Yields, Insecticide Applications and Use, and Net Returns of Short-Season and Conventional Production Techniques With and Without Irrigation, Lower Rio Grande Valley of Texas, 1973-75 291

5. Implications of a Short-Season IPM Cotton Production System for West Texas 292

6. Implications of the Texas Agricultural Extension Service IPM Programs for Cotton 293

7. Implications of Selected Cotton IPM Programs in Southern States 294

8. Social Benefits and Costs of Full Adoption of IPM on Cotton 295

FIGURES

1. Texas High Plains Diapause Boll Weevil Control Program 289

2. Economic Impact of Short Season System – 1979 289

3. A Graphical Illustration of Welfare Measures 295

4. A Graphical Illustration of the Aggregate Impact of Adoption of New Technology 296

5. Situation Where Aggregate Profits Increase 297

6. Situation Where Aggregate Profits Decrease 297

1. INTRODUCTION

Economics is the key to adoption of new crop production systems. It must increase the farmer's profit or he has no incentive to adjust from traditional crop production practices. The increase in profit for a producer due to use of integrated pest management (IPM) can be increased yield, reduced costs, or reduced yield and reduced cost of production where the cost reduction is greater than the value of the yield reduction. If rapid adoption of viable IPM programs is to be encouraged, it is critical that the economic implications be demonstrated to the producers. To further emphasize the importance of economic incentives, consider the statement of Steven D. Jellinek, Assistant Administrator for Toxic Substances, EPA, to hearings before the subcommittee on agricultural research and general legislation, October 31 and November 1, 1977,

> *". . . I think IPM is really not going to be widely accepted by farmers until they can have some assurance of its economic benefits... Most farmers in this country are used to buying a product and not a service. What we are talking about with IPM, in its most basic form, is a service. My definition of IPM is an environmentally protective, systematic approach to pest management that relies upon expert advice on when and how to plan for dealing with pest problems.*
>
> *The economic proof of IPM's benefit, though it has been shown in many demonstration projects, is going to have to be brought directly to the individual farmer. He is going to have to learn that buying advice can be more profitable than buying chemicals."*

Thus, the economic implications to the agricultural producer of any new production system require identification and demonstation if producer adoption is to be expected. The economic impacts of different crop production systems or IPM programs are realized at the farm level, regional level and in some cases at the national level and also have important temporal implica-

tions. The farm and regional or micro implications and national or macro implications are discussed in detail later in this paper.

Pest Losses

Disease, nematodes, insects and weeds are estimated to have caused annual damages to crops and livestock of $11.8 billion from 1951-60 in the United States (U.S. Department of Agriculture 1965). Similarly, annual pest related losses to agriculture in Canada were reported at $1.6 billion for 1964 (Fischer 1965). These losses are approximately 44 percent of total farm income. As farm level prices increase then pest damages increase.

Since pests reduce production they directly affect gross receipts. These losses often occur after all other inputs have been applied. This then has serious implications for producer net income. For example, if net income is 20 percent of gross receipts, a loss of 10 percent reduces net income by 50 percent (to 10 percent of gross receipts). Thus, a 20 percent pest loss would reduce net income to zero (Fischer 1965). This is an element of pest damage not often discussed and largely explains a farmer's actions late in the production season to preserve his production from pests.

Benefit-Cost Analysis

Benefit-cost analysis traditionally relates to government sponsored programs in water or other resource development projects. The analysis requires identification of all benefits (change in income less change in costs or increase in producer profit) as well as all project investment, operation and maintenance costs. The costs and benefits are estimated for each year and discounted back to a present value. The percent value of benefits are then divided by the present value of all costs to obtain the B/C ratio. If the ratio exceeds 1.0 then the project is justified on an economic basis.

For this paper, there will be discussion of some programs with the so-called B/C ratio. However, for the most part, the focus of this paper is on implications for the farm operator and no consideration of research costs or government cost incurred to develop and implement the IPM program included.

In a complete benefit-cost analysis there are several components that are required. Generally these components are (1) taxonomy of pesticide use effects, (2) economic production, (3) human health, (4) environmental impacts, (5) aesthetic impacts and (6) distribution or equity effects such as social, income and international trade effects (Epp, et al. 1977). This paper will emphasize economic production with some limited discussion of distribution effects.

2. DYNAMICS OF PRODUCTION

An optimal or profit maximizing production system can be affected by changes in the economic situation or biological setting. For example, inflation and/or insect pest resistance to insecticides can threaten economic viability of traditional production practices. This implies the need to continually be developing new production systems and the importance for a farmer to adopt viable new technology.

With the advent of DDT and very inexpensive input prices, high levels of inputs and calendar scheduling of insecticide treatments were economically advantageous to the producer. The goal of maximizing yields was not far removed from maximum profit and served as a good proxy. Furthermore, insecticide scheduling reduced risk faced by the producer.

However, conditions changed and seriously affected the economic viability of the traditional production systems. For illustrative purposes consider the Texas Trans Pecos region. In the early 1970's the price of natural gas increased from $0.40 per one thousand cubic feet (mcf) to $1.85/mcf. This increased the price of producing cotton in 1975 to approximately $0.77 per pound of lint (Patton and Lacewell 1977). Market price for cotton lint was near $0.55 per pound. The change in the price of one input (natural gas) resulted in cost of production for all crops exceeding market price. Thus, producers either adjust production practices to lower costs per unit of output or abandon cultivation. Many thousands of acres were idled in the Texas Trans Pecos in the 1970's.

The Lower Rio Grande Valley of Texas emphasizes the effects of both price changes and insect resistance to chemicals. Farmers have been unable to control mid and late season tobacco budworm, *Heliothis virescens*, infestations of which are aggravated when beneficial insects and spiders are destroyed by early season control measures directed at boll weevil, *Anthonomous grandis* Boheman, and fleahopper, *Pseudatomoscelis seriatus* Reuter, (Namkin and Heilman 1973). The average number of insecticide applications was above 10 in the late 1960's and early 1970's, with as many as 25 applications by some producers, often with only limited effectiveness (Frisbie, et al. 1972).

Comparing per acre costs and returns for cotton produced in the 1960.s with that of 1979 provides an indication of the changing economic situation faced by cotton farmers (see Table 1). In the three regions there is an increase in expected gross revenue from cotton ranging from 89 percent increase on the Texas High Plains to a 99 percent increase in the Lower Rio Grande Valley. Costs of production increased over these years proportionately more than revenue for the High Plains and Valley; i.e., 148 and 140 percent increase, respectively.

Table 1 Typical Per Acre costs and returns ($) for Cotton by Selected Years and Regions

Item	Year	
Texas High Plains	1967[a]	1979[b]
Total returns	151.70	287.00
Variable costs	59.81	186.65
Fixed costs	49.96	85.91
Total costs	109.77	272.55
Net returns	41.93	14.45
Lower Rio Grande Valley	1964[c]	1979[b]
Total returns	129.25	257.10
Variable costs	71.27	170.43
Fixed costs	38.90	94.40
Total costs	110.17	264.82
Net returns	19.08	-7.72
Texas Coastal Bend	1965[d]	1979[b]
Total returns	153.25	302.40
Variable costs	79.78	162.25
Fixed costs	127.55	234.34
Net returns	25.70	68.06

[a]Grubb, Moore and Lacewell (1967).

[b]Texas Agricultural Extension Service (1979).

[c]Hatch and Moore (1964).

[d]Moore and Rogers (1965).

Thus, for these regions expected per acre net revenue has declined. This is especially significant when the effect of inflation is considered; i.e., the net returns in 1979 dollars would be much less in 1965 dollars. This suggests that many producers are operating under conditions of higher costs and with lower expected net returns. This represents an increase in risk and economic vulnerability. Costs of production in the Coastal Bend increased less, proportionately and absolutely, than revenue from cotton. Thus, for this region expected net returns are higher, which helps hedge against the higher costs of production and effect of inflation over the past few years. It is important to emphasize that the Coastal Bend represents a region where dramatic adjustments in production systems including variety, cultural practices and harvesting methods

have occurred. The implications of the new cotton production system now adopted throughout the Coastal Bend region are discussed in detail later.

These examples illustrate the changing economic conditions facing farmers. The objective of maximizing yield is now invalid if the producer is to be economically viable. This means adjustments in quantities and timing of inputs as well as higher levels of management. This is a never ending process involving new varieties, cultural practices, irrigation techniques and pest interactions. This paper describes some techniques used for economic analysis of new crop production systems and discusses economic implications of some selected systems.

3. MICRO-ECONOMIC ANALYSIS

Micro-economic analysis in this section refers to an evaluation at the farm or regional level. An underlying assumption is that a new or alternative production system, if adopted, would not affect a sufficient number of acres to cause enough supply response such that there would be a product price effect .i.e., increase or decrease in cotton production sufficiently large enough to impact on the price of lint. This section emphasizes cotton and particularly Texas IPM programs due to familiarity with the economic studies conducted.

Methods of Analysis

Although it is generally recognized that an economic analysis of a new crop production system is important, it is not widely understood that there are alternative analytical methods that can be employed. The following discussion provides an overview of some of the economic evaluation techniques that can be employed for microeconomic analysis.

Budgeting Analysis

The most widely used technique for economic analysis of new crop production systems is budgeting analysis. Basically, the analysis involves developing a per acre crop enterprise budget including all inputs, quantities applied, costs, yield and returns for the traditional production practice and the new or alternative production system.

In generating the data for enterprise budgets that compare two or more systems of production, it is important that variations in varieties grown, management levels, climatic conditions, entomological, agronomic, and regional habitat be accounted for (Adkisson, Frisbie and Lacewell, 1978). Variation due to plant variety differences, irrigation practices and management capabilities may obscure differences between a sample of producers selected at random within a new crop production system when compared to non-program participants or the control group.

Crop enterprise budgets comparing a traditional production system with a new production system reveal very little about management requirements associated with a system. The budgets simply identify what inputs are used, quantity and cost along with expected yield and value.

Linear Programming

Linear programming (LP) is a means of extending beyond a per acre evaluation and considering an entire farm region or even the nation. Linear programming maximizes an objective function, usually profit for a farm or region, subject to resource constraints. An advantage of LP is the opportunity to include soil groupings, labor availability, land constraints, irrigation limitations, financial (cash flow) considerations and many other factors that affect an overall farm organization.

Again, the basis of the LP lies in crop enterprise budgets. Resource requirements and expected per acre profit for applicable enterprises produced with the traditional and the new production system are incorporated into the model. An appropriately designed LP model permits adjusting crop prices, input prices and resource availability quickly and efficiently to establish sensitivity of the profit maximizing farm organization. This is a more complete analysis of new crop production systems and indicates the implications on producer profit as well as the farm organization, thus a more detailed and complete analysis than possible with budgeting or break-even techniques.

Statistical Analysis

Statistical analysis of new crop production systems is usually done to compare producers using a new system with those following the traditional production system. The evaluation can

be as simple as estimating average yield between the two groups or as sophisticated as developing a yield response function. Much of the work has emphasized standard statistical techniques to determine if there is a statistically significant difference in yield, costs and profit between producers using a new system and those not using the system. These results are useful in scientific evaluation of new programs, and measures such as standard deviation and coefficient of variation provide insight into the producers' experience and what may be expected.

The range of applications and value in economic and biological evaluations are broad and encompassing. In economic analysis of new crop production systems there is a need for greater emphasis on statistical techniques with well designed samples of participating and nonparticipating producers to establish scientifically credible results for policy makers.

Implications of Selected Systems

New production systems specific to a certain area are being developed throughout the U.S. for all crops. Any one of these programs has little or no effect on total production or crop price. Thus, site specific analysis is appropriate. This section considers several of these production systems with emphasis on cotton.

Texas High Plains Cotton Program

In 1964, a program was initiated to prevent the westward spread of the boll weevil to the more than 2 million acres of cotton on the Texas High Plains. The regional program focused on reproductive-diapause boll weevil control. An analysis was done to investigate the impact, had this area-wide program not been instigated (Lacewell et al 1974). The results are presented in Table 2 and Figure 1.

The High Plains Program results in a 77 thousand bale increase in cotton production, over an 8 million pound reduction in pesticides applied which leads to an energy savings of 6.5 million gallons of fossil fuel and cost reduction of $12 million. Profit was increased an estimated $27 million due to the program.

Table 2 Estimated Impact of the Texas High Plains' Reproductive Diapause Boll Weevil Control Program[a]

Item	Unit	With Program	Without Program	Program Effect (Percent Change)	
Production	1000 bales	1,740	1,663	+77	(4.6)
Pesticide Use	1000 pounds A.I.	1,803	10,048	8,245	(82.0)
Energy Savings	1000 gallons fossil fuel	NA	NA	6,500	
Cost Reduction	$1000	NA	NA	12,000	
Profit Increase	$1000	NA	NA	27,000	

[a]Lacewell et al (1974).

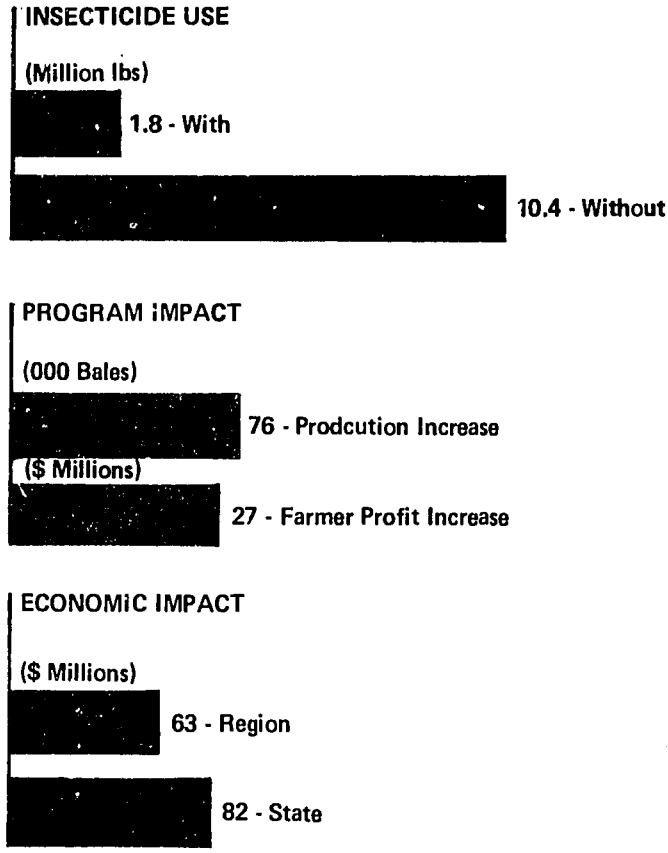


Figure 1. Texas High Plains Diapause
Boll Weevil Control Program

Short-Season IPM Cotton Programs

Due to rapidly increasing national gas prices (high costs of production) and accelerating insect resistance to pesticides, new IPM cotton production systems were developed for Southern Texas and West Texas. The production strategies are based on short-season (deterministic) cotton varieties and carefully controlled inputs such as fertilizer, irrigation water and insect control treatment.

South Texas. Short-season cotton production systems have been developed for several regions in Texas. The discussion will begin with South Texas (Sprott, et al 1976). The short-season cotton production system for South Texas is associated with a 30 percent yield increase while inputs are reduced 33 percent (Table 3). Production costs are 13.8 cents per pound lint less with the IPM program and total energy use is reduced from 102 gallons of fossil fuel equivalent per acre to 69 gallons. Producer profit was increased from $12.40 per acre to $104.97 per acre.

The success of this system is demonstrated by the very rapid complete adoption throughout the Coastal Bend Region of Texas (over 250,000 acres of cotton). Within a three-year period all cotton gins had to be modified for the stripper cotton where pickers had been used previously.

In 1979 the short-season cotton production system resulted in an $11 million increase in producer profits and increase in regional economic activity of $94 million as shown in Figure 2. The research costs of this program over a seven year period was $2.3 million, less than the increase in farmer profit for 1979 alone.

Table 3 Implications of a Short-Season IPM Cotton Production System for South Texas[a]

Item	Unit	Production Techniques Tradtional	IMP	Change	(Percent)
Yield	pounds/acre	500	649	+149	(30)
Pesticide Use	pounds/acre	9	6.6	-2.4	(27)
Production Costs	dollars/acre	278	282	+4	(1)
Production Costs	cents/lb lint	47.6	33.8	-13.8	(29)
Energy Use[b]	gallons/acre	102	69	33	
Energy Use	Kcal/acre	3,624,453	2,445,378	-1,179,075	(33)
Energy Use	Kcal/lb lint	7,249	3,768	-3,481	(48)
Profit	dollars/acre	12.40	104.97	+92.57	(646)

[a]Sprott et al (1976).

[b]Includes all inputs on a fossil fuel energy equivalent.

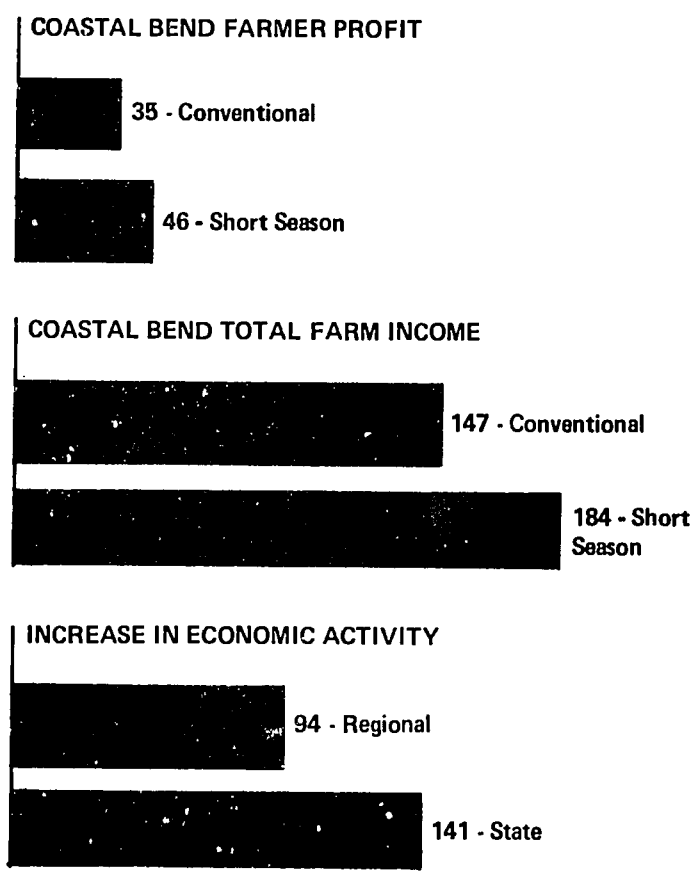


Figure 2. Economic Impact of Short Season System - 1979 ($ Millions)

Lower Rio Grande Valley. The economic implications of a short-season cotton production system applicable to the Lower Rio Grande Valley were evaluated in 1975 (Larson et al). The study indicated that if such a system were adopted, insecticide use could be reduced by as much as 1,091,500 pounds (from 2,788,500 to 1,697,000 pounds) and farmers' net returns increased by $4,330,200 (from $11,017,900 to $15,348,100). Energy savings would amount to about 300 thousand gallons of fossil fuel equivalent for the region.

Many cotton producers in the Lower Rio Grande Valley have adopted the short-season cotton production system. In 1978 an analysis comparing production with the short-season system and traditional system was conducted using 1973-75 producer records (Collins et al, 1979).

Analysis of data for production of short-season versus conventional techniques on light soils in the Lower Rio Grande Valley (LRGV) is summarized in Table 4. Analysis of lint yield between conventional production and a short-season production system with irrigation and for dryland shows that only irrigated cotton grown by conventional techniques was statistically different from all other yields. Insecticide use and number of applications were substantially higher for conventional techniques for both dryland and irrigated production. The coefficient of variation for yield shows that relative variation of short-season production regardless of the water practice, was lower than conventional cotton production. However, even with reduced input levels for short-season irrigated cotton production, the net returns favored conventional management by $21.97 per acre.

Dryland short-season production without irrigation best typifies the short-season technique. By using only negligible levels of insecticide, dryland short-season production had the highest average net returns of all dryland and irrigated options ($126.31 per acre). The coefficient of variation on lint yield for dryland short-season cotton was slightly higher than for irrigated short-season cotton but the net returns were $116.79 per acre more for dryland. There are dramatic cost, energy and pesticide implications associated with dryland unirrigated short-season cotton produced in the Lower Rio Grande Valley (LRGV).

An analysis currently underway indicates that for 1976-78, the yields for shot-season and conventional cotton production practices are not significantly different. Further, the yields are comparable to the 1973-75 short-season cotton yields. This suggests the short-season system has been adopted by all producers and in fact no conventional producers now exist. This is an excellent example of technology transfer.

Table 4 Lint Yields, Insecticide Applications and Use, and Net Returns of Short-Season and Conventional Production Techniques with and without Irrigation, Lower Rio Grande Valley of Texas, 1973-75[a]

Item	Lint[b] Yield (pounds per acre)	Coefficient of Variation of Yield (percent)	Insecticide Applications (number)	Insecticide Use (pounds)	Net Returns[c] (dollars/ acre)
Irrigated					
Conventional	580.6(A)	33.8	13.2	22.1	31.49
Short-Season	457.0(B)	25.1	11.0	14.0	9.52
Difference	123.6	8.7	2.2	8.0	21.97
Dryland					
Conventional	512.7(B)	33.0	5.79	12.32	94.98
Short-Season	474.9(B)	30.1	.44	.15	126.31
Difference	37.8	2.9	5.35	12.17	-31.33

[a]Collins, Lacewell and Norman (1979).

[b]Means with the same letter are not statistically different among all groups at the .05 percent level.

[c]Net returns above variable costs a cotton lint price of $0.50 per pound and cottonseed price of $100.00 per ton were used.

West Texas. Natural gas prices increased 450 percent in the Trans Pecos Region of Texas in a few months around 1975. The impact was to increase production costs between $30 and $100 per acre in the area, which relies heavily on irrigation for crop production. Average annual rainfall is 9 inches. Thus, without a non-irrigated crop production alternative and with the high priced gas, profits from crop production became negative and many thousands of acres of irrigated cropland were idled.

The region is characterized by very high costs of production which means they apply large levels of fertilizer, irrigation water and pesticides. A short-season IPM cotton production program was developed that shifted to the deterministic varieties, reduced fertilizer and in turn irrigation dramatically (Condra, Lindsey and Neeb 1975). By reducing the foliage, insect pest problems were very nearly deleted. Table 5 presents a summary of the program.

In this IPM program, yield is reduced. However, the dramatic reduction in costs of production more than offsets the revenue loss associated with the yield reduction. Per acre costs of production are reduced 46 percent. With the reduced level of inputs, energy use per acre is reduced 57 gallons in fossil fuel equivalents. Profit is increased from a negative $105 to a positive $81.50 per acre.

Cotton grown in West Texas used the IPM program and additional acres are coming into production. Farmer interest is very high and the system is being adopted from the Fort Stockton area to El Paso, some 200 miles.

Table 5 Implications of a Short-Season IPM Cotton Production System for West Texas[a]

Item	Unit	Production Technique Traditional	IPM	Change	Percentage
Yield	pounds/acre	700	630	-70	(11)
Pesticide Use	applications	7	2	-5	(71)
Nitrogen	pounds/acre	250	60	-190	(76)
Irrigation	inches/acre	40	30	-10	(25)
Production Costs	dollars/acre	490	265	-225	(46)
Production Costs	cents/pound	70	42	-28	(40)
Energy Savings[b]	gallons/acre	NA	NA	+57	
Profit	dollars/acre	-105	81.50	+186.50	(N.A.)

[a]Condra, Lindsey and Neeb (1975).

[b]Includes all inputs on a fossil fuel energy equivalent.

Texas Extension Service Statewide Cotton Program

In 1972 the extension service in several states began implementing IPM programs. Texas selected four regions and emphasized cotton. The programs were designed to provide data for economic evaluation. In each region a group of participants and a like group of non-participants were selected. A comparison of the two groups provides an indication of program performance. Table 6 summarizes the effect of the IPM program.

For 1973 and 1974, the extension service IPM program increased yield and farmer profit while reducing pesticide use per bale of cotton. However, in 1973 total pesticide use by program participants was higher than for non-participants by about 1 pound per acre. The increased yield,

however, makes the overall efficiency of pesticide use greater for participants than for non-participants; i.e., yield per pound of pesticide applied was greater for program participants.

Energy savings with the IPM program were .5 gallons in 1973 and 2 gallons in 1974 of fossil fuel equivalent. The social benefits of the program as measured by the benefit cost ratio was $7.33 return in 1973 and $4.60 return in 1974 for each dollar of program cost, including program cost allocated to the farmer.

Table 6 Implications of the Texas Agricultural Extension Service IPM Programs for Cotton[a]

Item	Unit	IPM Program Effect[b] 1973[c]	1974[b]
Yield Increase	pounds/acre	+60	+36
Pesticide Savings	pounds total	-33,696e	+83,343
Pesticide Total	pounds/bale	12.62	10.47
Pesticide Savings	pounds/bale	.92	3.12
Energy Savings	gallons total	-28,651e	90,118
Energy Savings	gallons/bale	.5e	2.0
Programs B/C	benefit/dollar cost	7.33	4.60
Profit Increases	dollars/acre	+36.16	+24.14

[a]Lacewell, Casey and Frisbie (1974).

[b]Based on a comparison of program participants and non-participants.

[c]Participant acres were 35,913.

[d]Participant acres were 36,969.

[e]An increase in total pesticide use and, hence, increased energy was associated with the IPM program on a total basis but a reduction on a per unit of output basis.

Other Cotton IPM Programs

There are IPM programs for many crops in many regions. Extension service IPM programs were implemented throughout the South. Table 7 briefly outlines some of the implications of these other extension IPM cotton programs.

Three of the four programs showed no yield change but a substantial reduction in number of pesticide applications. This resulted in reduced costs and less energy use. The North Carolina Program suggested a yield increase of 204 pounds of lint per acre but details of production were not available. Although the cost reduction per acre was small in Mississippi and Alabama, over several million acres the impact can be substantial, though the incentives in many cases are not sufficient to attract individual producers.

Table 7 Implications of Selected Cotton IPM Programs in Southern States[a]

State	Program Acres	Per Acre Effect of IPM Program Yield (pounds)	Pesticide Applications (number)	Cost (dollar)	Energy (gallon)
Mississippi	28,233	0	-2.8	-3.50	-2.3
Alabama	38,759	0	-2.0	-3.00	-1.7
Arkansas	N.A.	N.A.	-6.0	N.A.	-5.1
North Carolina	76,000	+204	N.A.	N.A.	N.A.

[a]Lacewell and Taylor (1978).

Other Crops

There are numerous IPM programs for crops and livestock. For example, an IPM program for grain sorghum in Oklahoma indicates an increase in producer profit of about $3.00 per acre (Salken et al 1976). An IPM program for alfalfa if implemented is estimated to save farmers in the eastern United States about $44 million annually (Zavaleta and Ruesink 1980). Biological control of parlatoria scale on olives in California is saving the industry $1 million annually in control costs. IPM applied to apples is making it possible to reduce treatments by 30 percent and more (Huffaker and Lacewell 1978).

Thus, there are many examples. Unfortunately, several have not been evaluated as to economic implications and often due to lack of appropriate data; i.e., no records or no control group. Nevertheless, the evidence demonstrated above suggests strong incentives for IPM from a chemical use, production output and farmer profit viewpoint.

4. MACRO-ECONOMIC ANALYSIS

When a new crop production system is demonstrated to be more profitable for an individual producer, there is a tendency to infer that income to producers as a group will also increase. However, with adoption of the system this is not necessarily the case. Increased production with a new system may lower farm prices and the price effect may more than offset the reduced costs and/or higher yields associated with the new system. Consequently, early adopters of the new system will have higher profits, but as more and more producers adopt, price will be affected. Then producers must adopt just to remain economically viable. After most or all have adopted the system, profits to the group may be lower than with the old system. Of course, there may be a differential impact on individual producers, i.e., producers who had serious pest problems with the old but not new system will gain, while others will lose.

This section first presents a theoretical explanation of the aggregate farm income paradox. Then, alternative economic models which can be used to evaluate the aggregate impacts of new crop production systems are discussed.

The Farm Income Paradox

A recent study by Taylor and Lacewell (1977) of the aggregate economic impacts of adoption of currently available integrated pest management on cotton illustrates the farm income paradox. Adoption of cotton IPM in all areas where an individual producer would have a profit incentive to adopt would, after complete adoption, lower aggregate farm income by 43.9 million dollars annually. Aggregate farm income decreases because increased production with full adoption of IPM decreases lint price by 7.3 percent. Farm income increases in areas with serious pest problems (such as parts of Mississippi and California), but income decreases in areas without serious pest problems (such as the Texas High Plains), with the aggregate losses exceeding aggregate gains. But because of the lower cotton price, consumers gain, resulting in a net social benefit.

Table 8 presents a social accounting of the benefits and costs (excluding environmental considerations) of IPM on cotton. In present value terms, consumer welfare increases by $2,024 million, producers' income decreases by $593 million, and non-producer program costs are an estimated $176 million. Net benefits to society increase by $1,255 million with full adoption of IPM on cotton. Thus, consumers and society in general gain, but producers as a group lose. This suggests that new crop production systems should be justified on the basis of consumer and social benefits and not necessarily benefits to producers.

Table 8 Social Benefits and Costs of Full Adoption of IPM on Cotton

	Present Value (Million Dollars) Of :		
Consumer Welfare Changes	Producers' Profit	Non-Producer Program Costs	Net Social Benefits
$2,024	-$593	-$176	$1,255

The farm income paradox can be theoretically illustrated with the aid of the demand-supply diagram shown in Figure 3. A demand curve is a reflection of consumers' marginal willingness to pay for a commodity. Because consumers pay one price for all units they purchase, they are said to enjoy a "surplus" on intra-marginal units since their willingness to pay exceeds the price. This surplus — the area below the demand curve and above the price line in Figure 3 — is a measure of the net benefits consumers derive from the commodity.

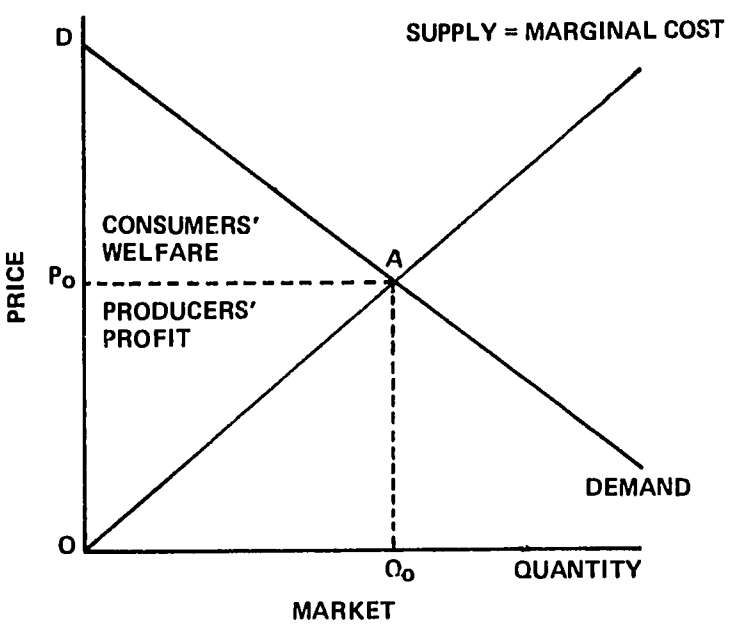


Figure 3. A graphical illustration of welfare measures.

Assuming profit maximization, a supply curve reflects marginal production costs, and the area under the curve measures total variable production costs. Thus, the area below market price and above the supply curve measures producers' profit, which is a return to fixed factors of production. And, in the absence of pollution costs, the net social benefit drived from production and consumption of a commodity is the sum of consumers' welfare and producer income. This is represented by the area OAD in Figure 3.

Adoption of a new crop protection system generally shifts the supply curve downward and to the right as a result of higher yields and/or lower production costs. Figure 4 shows the impact of such a shift on social welfare, which increases by the area OAB. This graph also illustrates the gain to consumers, which is the area P_OABP_N

Figure 5 illustrates the effects of a supply shift on producers' income. Comparing profits under the old and new systems, it can be seen that profits equal to the area P_OACP_N are lost, while profits equal to the area OBCD are gained. For the case illustrated in Figure 5, it can be seen that the area gained exceeds the area lost. Consequently, producers' profit increases with the new system. Figure 6 illustrates the case where profit losses exceed gains. In this instance, the supply curve shifted more at high prices than at low prices. This non-parallel supply shift will typically be the case because producers with low marginal costs (at the lower end of the supply curve in Figure 6) will tend to be those without serious pest problems, while producers with high costs will tend to be those with pest problems and thus those that would be most benefited by new crop protection systems.

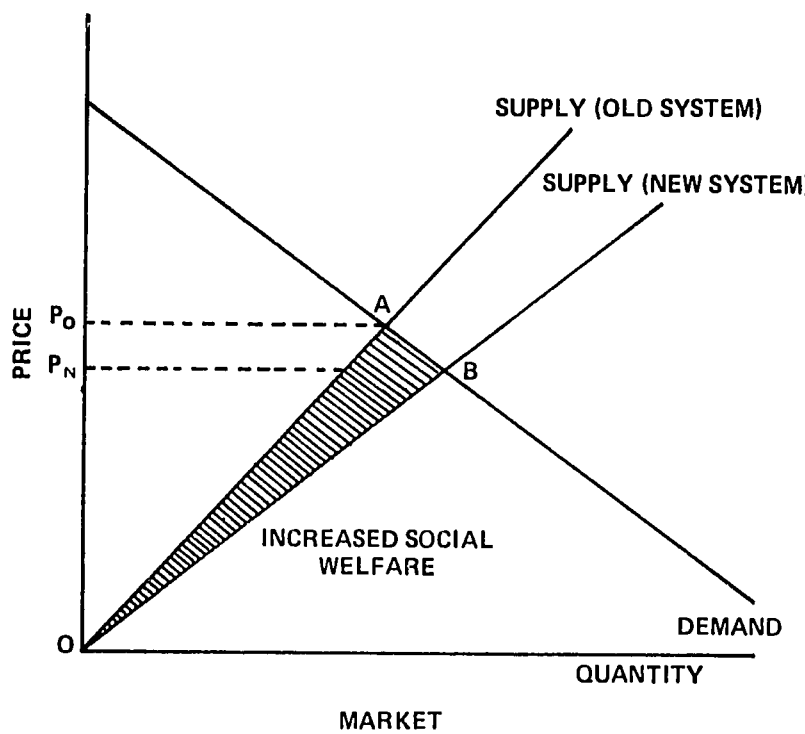


Figure 4. A graphical illustration of the aggregate impact of adoption of new technology.

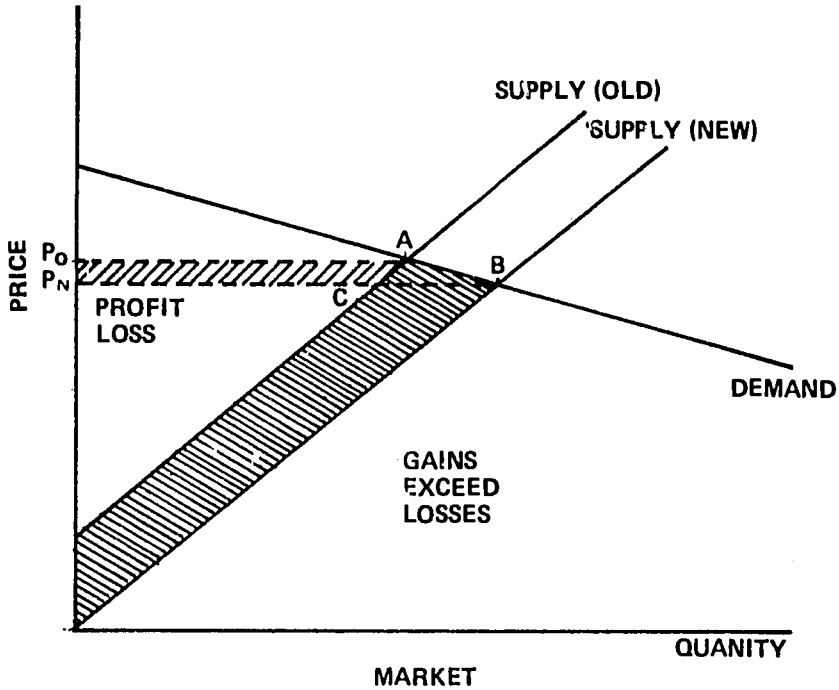


Figure 5. Situation where aggregate profits increase.

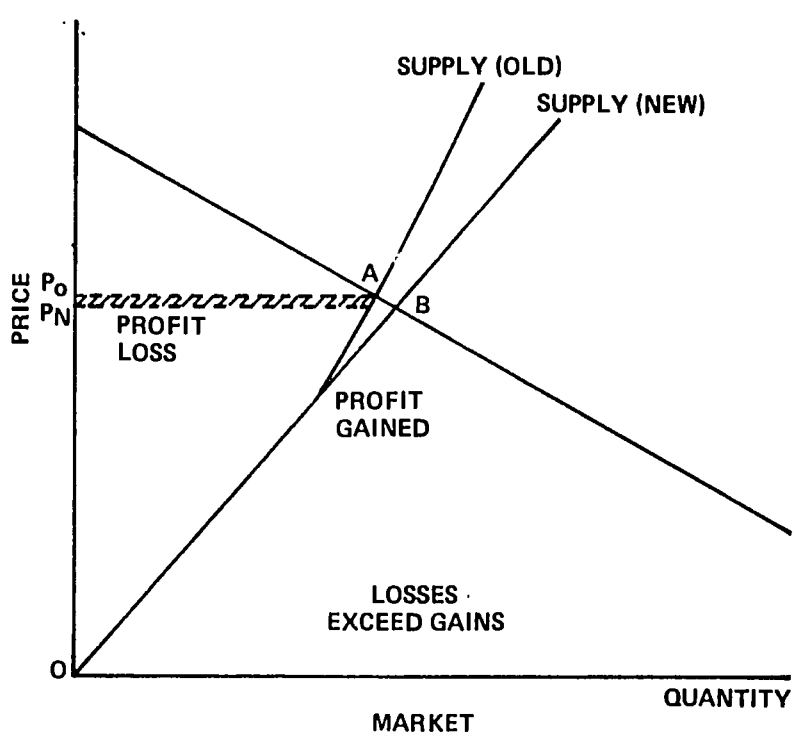


Figure 6. Situation where aggregate profits decrease.

Models for Evaluating Aggregate Impacts

Because the economic implications of individual farm or representative farm analyses differ from the aggregate effects of a large number of producers adopting, it is imperative that economic analyses recognize the impact of crop protection systems on commodity prices. Approaches for analyzing aggregate impacts generally fall into one of three categories: (a) partial budgeting; (b) regional and/or national mathematical programming models and (c) econometric-simulation techniques. The nature of each of these approaches, and advantages and disadvantages of each is discussed in the following sections.

Partial Budgeting

This approach, which provides a first approximation to the major economic effect of a new crop production system, is often used when the per-acre production cost and/or yield effects are very small or when the analysis must be completed in only a few days.

In this approach, only the benefit and cost items that are expected to change significantly with the new production system are considered. If no changes in crop acreage are expected, this approach reduces to computing the change in per-acre profitability of the affected crops. If, however, the acreages of one or more crops are expected to change, one must make allowance for these changes. One must also consider price changes if aggregate production is changed.

As long as the consumer-producer surplus framework is used, this is a theoretically reasonable approach. It permits one to obtain "ball-park" estimates in a short time, usually a day or two. The basic pitfall of the approach is that one must subjectively specify how much acreages will change, how much production will change, how much price will change, and how other relevant factors will change. This is a pitfall because the assumptions underlying the estimates are not apparent. Also, the economic system is so complicated that the human mind cannot always comprehend the interactions and changes that will result when the system is altered such as may occur when a pesticide is withdrawn.

If the per-acre cost and yield impacts of a new crop production system are expected to be large, say more than a few percent, and if time is available, the mathematical programming and/or econometric approaches offer greater potential than partial budgeting in assessing the economic impacts of the policy action.

Mathematical Programming

Mathematical-programming models show what a producer "ought to do" to maximize a well-defined objective function (e.g., maximize profits or minimize costs), given a set of available physical and economic resources. The effects of a new production system can be estimated with such a model by comparing what the producer ought to do if the new system is not available with what he ought to do if it is available. This type of comparison indicates what happens to the value of the producer's objective function as well as to resource use when the new production system is adopted.

It is often claimed that production risk is a very important factor in influencing farmers' decisions about pesticide applications and adopting new production systems. Conceptually, risk aversion behavior can be incorporated into mathematical-programming models. Unfortunately, these models require so much information that they are not practically operational on a large scale. Consequently, they generally must focus on practical operational objective functions, specifically, expected profit maximization or a function consistent with profit maximization. Estimates obtained from these models are accurate only to the degree that farmers are in fact expected profit maximizers.

A programming model can pertain to an individual farm, a group of farms comprising a region or a nation. A farm or small-area model is appropriate for analyzing the effect of a new crop production system on a national basis only if the resulting adjustments do not affect the market price of the crops on which the new system is used or the price of related crops. National models are most appropriate for widespread technologies and we concentrate on these models because many new crop production systems would affect crop prices and also because a farm or regional model can be conceptually viewed as a sub-model of a national model.

The traditional national and interregional linear programming (LP) models have been structured to minimize the variable costs of producing and transporting a specified (fixed) bundle of products, given resource availability. Typically, the fixed bundle of products or quantities demanded has not been changed when making runs of the model for policy changes such as

energy shortages, withdrawal of a pesticide or technology. Since quantity adjustments will usually occur with such a change, this use of a national LP model will give distorted estimates of the effects of the change.

To overcome this distortion, the model can be structured to maximize consumers' plus producers' surplus less transportation costs, given resource availability. This surplus version of a national model will give a competitive market and spatial equilibrium solution both with and without the new crop production system of IPM program in question.

Econometric Simulation

To date, econometric models of agricultural sectors have seldom been used to evaluate crop production systems. However, their use for this type of analysis looks very promising, and they may indeed provide more accurate estimates than either partial budgeting or mathematical programming.

The critical step in using an econometric-simulation model to evaluate crop production systems is specifying exactly how the system will shift the supply curve. In the following theoretical derivation it is assumed that farmers' decision processes and the variables to which farmers respond do not change, but that some technical parameters and levels of variables do change. Under these assumptions, the supply shift can be analytically derived. To illustrate the derivation, consider the following simple four equation model which has the elements common to most econometric models of agricultural sectors:

Acreage response:

(1) $A_t = f(A_{t-1}, NR^*_t, G_t)$

Yield time trend:

(2) $Y_t = g(t)$

Demand (domestic + export):

(3) $Q^{(d)}_t = h(P_t, I_t)$

Market equilibrium conditions: Find P_t such that

(4) $A_t Y_t = Q^{(d)}_t$

where A_t = planted acreage in year t; P_t = price in year t; NR^*_t = expected per-acre net returns in year t, which depend on expected price, expected yield, and production costs; Y_t = yield per planted acre in year t; $Q^{(d)}$ = quantity demanded in year t; G_t = vector of policy variables and I_t = vector of exogenous variables influencing demand in year t. With this model specification, the supply function is given by the product of equations (1) and (2); that is, $Q^{(s)}_t = A_t Y_t$. A new crop production system will cause a change in supply, ΔQ_t; and the new supply curve $(Q_t + \Delta Q_t)$ will be:

(5) $(Q_t + \Delta Q_t) = (A_t + \Delta A_t)(Y_t + \Delta Y_t)$.

By obtaining information on ΔY_t and ΔC_t for the new crop production system, the new supply curve can be derived (for a complete derivation, see Taylor, Lacewell and Talpaz, 1979). Thus, the model can be simulated for both the old and the new crop production system and the results compared to determine the aggregate impacts of the new system.

Econometric models of this type can be set up as either deterministic (i.e., without variability in acreages, yields and quantity demanded over time) or stochastic (i.e., with variations in these values over time) simulations. The stochastic simulation formulation is the more useful of the two because it shows how the values of the various variables can fluctuate over time. A stochastic model is even more useful for a situation in which a new crop production system would change the variability of yield. For this situation, one can introduce extraneous information about relative yield variability and then change the variance of error for the case of the new crop production system. Thus, the effects of the new crop production system on the variability of the various interrelated variables in the model as well as their expected value can be evaluated.

A relative advantage of the econometric approach is that an "outsider" who is familiar with this general type of model can readily see the critical assumptions that were made. Consequently, an outsider can quickly get a subjective notion of the validity of the particular econometric model that was used. With a mathematical programming model, however, an outsider would have to spend literally months studying the model structure and data to assess subjectively the validity of the model. Obviously, few, if any, outsiders are willing to make this type of investment. Hence, few, if any, checks on the validity of a large mathematical-programming model will be made.

The appeal of the mathematical models such as econometric and programming models is that individual pieces of the system can be brought together in a logically consistent way. And, if the assumptions behind the various pieces are valid, one can be confident that the whole is valid.

The econometric and programming approaches provide more accurate and more detailed estimates of economic effects than the partial budgeting approach. Consequently, they should be used if the per acre yield and production cost are sizeable enough to affect crop prices and/or the location of production.

5. CONCLUSION

Viable integrated pest management programs (IPM) are dependent upon increasing a farmers' net returns. The economic implication of several IPM programs indicate energy savings, reduced pesticide use and increased farmer profit. A short-season cotton production system for South Texas is associated with a 30% yield increase, reduced costs of 33% and farmer profit increase from $12 per acre to $103 per acre. This particular program has resulted in an $11 million increase in producer profit in the region and a total economic impact of $94 in the region. Other IPM programs with emphasis on cotton production show a benefit-cost ratio of 7.3 and 4.6, i.e., benefits exceed costs significantly.

Relatively small IPM programs have little or no effect on crop price hence a farm or regional level analysis is adequate. However, large IPM programs can have an effect on total production of a crop or crops and impact price. For example, an IPM program for cotton throughout the U.S. is estimated to cause a price decline sufficient to reduce farmer profit by $593 million through the country. On the other hand, the lower cotton price is a benefit to consumers amounting to $2,024 million. With a program cost of $176 million, the overall benefits to society of the IPM program would be $1,255.

This indicates the level of benefits available from IPM programs and some of the ramifications and complexities of an economic analysis. It is essential that care be taken to assure credibility in an economic analysis of IPM programmes.

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23. ALTERNATIVES TO CHEMICAL PESTICIDES IN PEST MANAGEMENT

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CONTENTS

		Page
1.	INTRODUCTION	303
2.	AN HISTORICAL PERSPECTIVE	304
3.	THE SHIFT TOWARD CHEMICAL CONTROL	305
4.	ALTERNATIVES FOR IPM PROGRAMS	305
(a)	**Biological Control**	306
	(1) Classical Biological Control	306
	(2) Conservation and Augmentation	307
	(3) Inundative and Inoculative Releases	307
	(4) Use of Pathogens	308
(b)	**Host Resistance**	308
	(1) Plant Resistance	308
	(2) Pest Resistance in Domestic Animals	309
(c)	**Cultural Control**	309
	(1) Sanitation	309
	(2) Destruction of Alternate Hosts and Volunteer Plants	310
	(3) Crop Rotation	310
	(4) Soil Tillage	310
	(5) Trap Crops and Trap Logs	310
	(6) Habitat Diversification	310
	(7) Water Management	310
(d)	**Physical Control**	311
(e)	**Autocidal Insect Control**	311
	(1) Sterile-Male Method	312
	(2) Genetic Control	312
(f)	**Pheromones**	312
(g)	**Miscellaneous Techniques**	313
5.	ECONOMIC CONSIDERATIONS	313
6.	CONCLUSION: PROMISES AND LIMITATIONS	313
	REFERENCES	313

1. INTRODUCTION

The techniques for controlling pests draw from a wide range and history of applied science and technology. Some of the most effective techniques, such as pest-resistant crop varieties, crop rotation, and biological control, were known and used many years before modern chemical pesticides were introduced. However, control of pests shifted toward chemical means as effective pesticides became available. Recent problems such as pest resistance to pesticides became available. Recent problems such as pest resistance to pesticides and the increasing costs of chemical

control have renewed interest in the "old" control techniques. Promising new alternatives to chemical pesticides, including insect pheromones and weed and insect disease agents, are being developed. The alternatives, used singly, in combination with others, or in combination with pesticides, promise cost-effective solutions for a wide variety of pests. This paper discusses the primary kinds of alternatives that have been used in integrated pest management programs or have shown promise in preliminary evaluations.

2. AN HISTORICAL PERSPECTIVE

The techniques for controlling pests draw from a wide range and history of applied science and technology. Ancient civilizations developed many biological, cultural, and physical methods for the protection of crops, animals, and selves. Many of these practices subsequently proved scientifically valid, though originally derived from crude empirical methods.

Several centuries before Christ, for example, the Chinese learned to control insect pest densities by exploiting "natural enemies" and by adjusting crop planting times. By A.D. 300 the Chinese were establishing colonies of predatory (insect-feeding) ants in citrus orchards to control caterpillars and large boring beetles (Flint and van den Bosch, 1977).

The first methods of weed control involved human, livestock, and mechanical energy. From 6000 to 5000 B.C. weeds were controlled by human hands. Crude wooden implements, including hoes, used from 3000 to 2000 B.C. were supplemented by hand sickles and the first wooden plow about 1000 B.C. A wooden spiked-tooth harrow had been invented by 500 B.C., and improved wooden plows became available during A.D. 1600-1800. The first all-steel plows, drawn by horses or mules, were introduced in 1837 (Timmons, 1970).

Plant pathologists developed important disease management concepts and techniques during the late 1800's and early 1900's. Plants resistant to diseases were recognized in the 19th century and breeding disease-resistant crop varieties was accelerated after the discovery of Mendel's laws of heredity in 1900. Following these breakthroughs, the approach was quickly exploited for the control of important plant diseases of many cereal and some horticultural crops (Walker, 1950).

The late 1800's and early 1900's also witnessed major developments in public health pest control. A mosquito management strategy that integrated manipulation of the aquatic breeding habitats (draining, filling, impounding, and flushing), and occasional use of kerosene to kill immature mosquitoes in the water had been developed by the early 1900's. Construction of the Panama Canal (completed in 1914) was therefore possible because the United States was able to manage the malaria and yellow fever mosquitoes which had prevented the French from succeeding earlier.

The latter half of the 19th century and the first part of the 20th marked a significant era in pest control. Partially by intuition and partially because there were no effective alternatives, leading pest control specialists advocated an ecological approach that integrated an array of pest suppressive techniques, such as resistant crop varieties, cultural practices, and biological control. From these efforts some of the most ingenious management systems ever developed for agricultural insect pests evolved (Smith et al., 1976), and the modern approach to pest control known as "integrated pest management" was born.

For example, management of the boll weevil *(Anthonomus grandis)* was based on ecological principles well before suitable chemical control technology emerged (Smith et al., 1976). This major cotton insect pest, considered by most pest control specialists to be native to Mexico or Central America, spread into the southern U.S. cotton region in the late 1800's. Within a decade a management system was developed that integrated cotton varieties that matured early, before the weevil populations increased significantly; an array of cultural control practices (such farming practices as planting and harvesting schedules and destruction of postharvest crop residues); and natural biological and environmental controls. In 1919, the insecticide calcium arsenate was discovered to control the pest. However, pest control specialists recommended that it be applied only if the nonchemical control measures failed to prevent the boll weevil from causing economic damage (Table 1).

Table 1 Guidelines for controlling the Boll Weevil developed by USDA Entomologists in 1923

1. Cultural practices, such as selection of proper cotton variety and phytosanitation practices to destroy cotton residues after harvest, are essential.

2. Use of poison (calcium arsenate) should be supplementary to cultural measures and its success depends on the cultural measures.

3. Poison application should be withheld until the weevils have punctured 10-15 percent of the cotton squares (flower buds).

4. Poisoning should merely be a device to protect the crop which has been made by other expedients.

5. Do not expect to eradicate the boll weevil.

(after Hunter and Coad, 1923).

3. THE SHIFT TOWARD CHEMICAL CONTROL

Despite the ingenuity and apparent effectiveness of some of the early management schemes developed for agricultural and public health pests, they frequently did not provide satisfactory pest control gauged by present standards. The ecologically oriented approach thus shifted to control by chemical pesticides as effective materials became available. Pesticides were often more effective, were much simpler to use than the more complex and labor-intensive nonchemical approaches, were cheaper, gave greater yields, and provided readily available and inexpensive insurance to the user. Their use displaced many of the earlier control techniques, such as cultural and biological control, pest-resistant crop varieties, and habitat management.

Chemical pesticides will continue to be significant in food and fiber production, forestry, and public health. But the inherent drawbacks of heavy dependence on them have become increasingly apparent. Apart from rising concern about the environmental and health hazards, their continued use is being challenged by the evolution of significant groups of pests that resist the chemical materials and the escalating costs of chemical control. These problems have given impetus to the search for such alternatives as insect hormones and pheromones, weed disease agents, and a variety of other "innovative" techniques. In addition, some of the old proven biological, cultural, and physical methods are being given renewed emphasis.

4. ALTERNATIVES FOR IPM PROGRAMS

The alternative methods have shown greatest promise when used to suppress pests in integrated pest management (IPM) schemes (Adkisson, 1977; Huffaker, 1980). The main principle involves manipulating the environment so to make it less favorable for the pest species or more favorable for the pests' natural enemies. First consideration is given to use of naturally occurring mortality elements of the pest environment, including weather, diseases, predators, and parasites. Artificial control measures are employed only as required to reduce and maintain the pests at tolerable levels, based on criteria developed to identify when and where control is justified. The ultimate objective is to control pests in an economically efficient and environmentally sound manner.

Table 2 lists examples of alternatives to chemical pesticides. Some of these alternatives are now being used in IPM programs; all have potential value in integrated pest management. Yet for many of the most serious pests, there are no suitable alternatives, and for the foreseeable future, chemical pesticides will remain basic tools in integrated pest management.

The list of alternative methods is almost endless. Space will not permit a comprehensive review of even the primary methods. Only the primary kinds that have been used in operational IPM programs or have shown promise in preliminary evaluations will be discussed.

Table 2 Examples of alternatives to chemical pesticides

Insects, mites and other invertebrates	Plant diseases	Weeds	Birds, mammals, and other vertebrate pests
Biological control Parasites Predators Pathogens	Disease resistance	Insects and other herbivores	Noise and physical repellents
Plant and animal resistance	Reduction and losses by manipulations of plants and pathogens	Diseases	Chemosterilants
Environmental manipulations Plant spacing Species diversity Timing Crop rotation Plant hormones Water management Fertilizers Soil preparation Sanitation	Control of plant pathogens by natural enemies	Environmental manipulation Choice of variety Seedbed preparation Method of seeding or planting Seeding rates and row spacing Fertilization Cultivation Irrigation and water management Erosion control Design of irrigation and drainage canals and ponds Managed grazing Sanitation	Chemical repellents
Induced sexual sterility	Disease- and nematode-free seed and propogating material	Natural stimulants and inhibitors	Trapping and shooting
Physical and mechanical control Window screens Light traps Fly swatters Protective packaging Sifting devices Barriers Flaming and burning	Crop rotation and soil management	Plant competition	Behavior
Attraction and repellency Attractants Repellents	Destruction of inoculum sources	Revegetation of weed- and brush-infested grazing lands	Environmental manipulation
Genetic manipulation of pest populations Lethal genes Male-producing genes	Vector control	Breeding highly competitive forage species	Exclusion
	Nematode attractants and repellents		

(Anon., 1965)

(a) Biological Control

Biological control is the science of natural enemies in regulating the numbers of their hosts (Wilson and Huffaker, 1976). In practice, biological control is the use or encouragement of "beneficial" living organisms for the reduction of pest organism populations.

Although still grossly underused, biological control is gaining world recognition as a primary and often essential component of successful integrated pest management. There is substantial evidence that long-term suppression of a complex of pests is highly unlikely without the help of natural enemies. Yet biological control cannot be expected to work against all pests. It may completely solve problems with one or a few pest species, substantially but insufficiently affect others, and be of little or no use for others (Wilson and Huffaker, 1976).

(1) Classical Biological Control

"Classical biological control," which involves deliberate introduction and establishment of natural enemies in areas where they did not previously occur, has been clearly highly effective. In January 1975, there were 213 cases reported worldwide of partial to complete success involving the introduction of natural enemies of important pest insects and arthropod relatives, snails, and weeds where they had not previously occurred (Huffaker, 1975).

Classical biological control is well known in the Caribbean where it has yielded excellent results against some pests. The introduction of the parasites *Prospaltella opulenta* and *Eretmocerus serius* into Barbados in 1964 to control the citrus blackfly *(Aleurocanthus woglumi)* was highly successful and has been accredited for saving the island's citrus industry from depredation by the blackfly (Pschorn-Walcher and Bennett, 1967). The introduction of the parasites *Apanteles flavipes* and *Lixophaga diatraeae* into Barbados has effectively controlled the sugarcane borers *(Diatraea* spp.*)* (Alam et al., 1971). The value of this control has been estimated at 4 to 8 thousand tons of sugar per year (Simmonds and Bennett, 1977). There are other successful examples involving classical biological control here in Barbados and other Caribbean countries (Tucker, 1936, 1954; Simmonds and Bennett, 1977; Huffaker and Messenger, 1976).

Economic returns from classical biological control programs that have been evaluated have been estimated at $30 for every dollar invested (Messenger et al., 1976). This is a rather remarkable accomplishment in view of the fact that 13 to 14 years ago (no recent information is available) the worldwide annual investment for biological control, including research, development, and implementation, was $10 million (based on 1967 estimates) compared to the $84 million spent yearly (1966 estimates) on the research and development of chemical pesticides (Huffaker et al., 1976).

The most spectacular and the greatest efforts in classical biological control have involved perennial crops (e.g., grape vineyards and orchard crops) and rangeland. Success with pests of row crops has been limited. There have been no successes with classical biological control of row crop weeds. Of the approximately 110 agricultural insect and mite pest species under partial to complete control by introduced natural enemies reported by DeBach (1964), only 13 involved pests of row crops (including sugarcane). This low figure is partially explained by the lack of vigorous pursuit of classical biological control in row crop agriculture. Further, the constantly evolving nature of the row crop environment may not permit establishment of an effective host-natural enemy relationship such as that which often characterizes the more stable environments of orchards, vineyards, and rangelands (van den Bosch et al., 1976).

(2) Conservation and Augmentation

Conservation and augmentation of natural enemies are deliberate actions to protect and maintain natural enemy populations or to increase their beneficial effects, such as

* Applications of supplementary foods to retain, arrest, attract, and sustain natural enemies when natural prey populations are small or when non-prey food, such as plant pollen, is inadequate for the enemies
* Provision or management of shelter utilized by natural enemies in such places as the edges of crop fields or in trees for use by insect-feeding birds
* Selective use of chemical food to increase the effectiveness of natural enemies.

Supplementing food to increase the effectiveness of natural enemies is a relatively new approach and has been attempted for only a few predatory insects and mites in agricultural crops (Hagen, 1976). Experimental applications of artificial honeydew (aphid insect excrement) and bee pollen in the form of food sprays have induced early egg deposition of two predatory insects, aphid lions (chrysopids) and lady beetles (coccinellids), in treated alfalfa and cotton fields, resulting in significantly smaller aphid (*Aphis* sp.) and bollworm (*Heliothis* sp.) populations (Hagen et al., 1970).

Augmentation of natural enemies by providing or managing shelter has received limited attention, but it is promising for some pests. A substantial reduction of the tobacco hornworm *Manduca sexta*, a serious tobacco pest, was achieved by the predatory wasp *Polistes* following erection of nesting shelters for them at field margins (Lawson et al., 1961).

Conservation of natural enemies through the selective use of insecticides has received the most emphasis in the conservation and augmentation category. This technique involves use of the lowest possible dosage of an insecticide for control of the target insect pest, restricting application to part of the crop fields or trees, and timing the treatments to minimize damage to the natural enemy populations (Rabb et al., 1976). Knowledge of the biology, ecology, and behavior of the insect pests often makes possible application of insecticides to very restricted areas that the insect pests utilize for feeding, breeding, or hiding. The technique was demonstrated by Isley (1926) against the boll weevil more than 50 years ago. Isley advocated "spot-dusting," which consisted of applying calcium arsenate only to areas of the cotton fields where the post-hibernating boll weevils colonized in the spring, as determined by field scouts who checked the fields routinely. These restricted treatments, made to a very small part of the total field area, effectively controlled the boll weevil while sparing natural enemies in the rest of the field, minimizing both costs for application and adverse effects on nontarget organisms.

This basic technique is currently used quite effectively against the boll weevil in parts of Mexico, Central America and the United States, and is also being used against other insect pests, and has great potential against numerous insect pests (Newsom et al., 1976).

(3) Inundative and Inoculative Releases

Inundative and inoculative releases are the colonization of large numbers of a natural enemy

to destroy the pest population immediately (inundative releases) or repeated colonization of relatively small numbers of a natural enemy to build up the beneficial organisms over several generations (inoculative releases). Releases of native parasites and predators to control insect pests biologically have been effected for many years on a small scale (Ridgway and Vinson, 1977). Some commercial firms sell parasites and predators for use by home gardeners, farmers, and livestock owners. This approach is quite successful against some agricultural insect pests in the People's Republic of China, (NAS, 1977).

(4) Use of Pathogens

Relatively few pathogens (microscopic disease-causing agents) have been exploited as pest control agents, and the number of potentially useful pathogens is incompletely known. Some of these agents have shown much potential and offer an excellent alternative to chemical pesticides for IPM programs.

There are four general kinds of pathogens considered as biological control agents: fungi, bacteria and rickettsia, protozoa, and viruses. The status, potential, and limitations of these groups in pest control programs were discussed recently in a publication by USDA (1978).

Bacillus thuringiensis, a bacterial pathogen infecting a wide range of insect pests, is the most common microbial insecticide in use today. This spore-forming pathogen produces endospores which enable it to live in a dormant state in an unfavorable environment. When an insect eats vegetation containing the spores, it remains alive for several days, but its gut becomes paralyzed and it cannot eat. The disease agent is marketed by several companies for use against the insect caterpillar pests that attack a wide variety of vegetables, flowers (chrysanthemums), and ornamental and shade trees. It can be used on edible products up to the time of harvest. It is readily available by mail from suppliers and in many garden shops, nurseries, and department stores. The bacterium is quite effective, especially when combined with resistant crop varieties and resident natural enemies.

Several species of fungi show potential as control agents against insects and mites. The fungus *Beauveria bassiana* is used widely in the Soviet Union and the People's Republic of China where it is reportedly highly effective against forest and orchard pests (USDA, 1978).

Viruses, one for controlling bollworms (*Heliothis* spp.) of cotton, one for controlling the gypsy moth *(Lymantria dispar)* on trees, and one for controlling the Douglas-fir tussock moth *(Orgyia pseudotsugata)* on trees, are examples of other disease agents commercially available in the United States.

(b) Host Resistance

Plants and animals have evolved diverse means to avoid, tolerate, or recover from attacks of other organisms. Plant and animal breeders have used this natural process to their advantage by hybridizing and by deliberate selection of plant varieties and animal breeds resistant to pest attack in a technique known as "host resistance." This is a proven, effective, economical, and safe method of pest control ideally suited for management of plant diseases (Nelson, 1973) and insects (Beck and Maxwell, 1976), and it is compatible with such desirable pest suppression methods as biological control. In weed control, the phenomenon of allelopathy (Rice, 1974), the inhibition of growth of the weedy plants by chemicals released by the crop plants, has not been extensively explored but may have great potential also. The development of breeds of animals that show resistance to arthropod attack is not as advanced as the work with crop plants, but some resistant breeds of cattle and sheep have been developed (NAS, 1969).

(1) Plant Resistance

The use of crop varieties resistant to attack or damage by plant diseases and insects has been practiced for many decades. Early examples of the development of plant resistance by selective breeding include potato varieties resistant to potato late blight *(Phytophthora infestans)*, the disease responsible for the Irish famine of the mid-19th century. Since then, there has been slow but steady progress in the development and use of resistant varieties, and some of the principal devasting insect, disease, and nematode pests have been overcome by this method.

Mechanisms of pest resistance in plants are generally complex and not easily defined (Browning et al., 1977; Beck and Maxwell, 1976). The basis for resistance is generally physiological (e.g., the plant produces toxins which inhibit the pest) or mechanical (e.g., the plant leaves have

dense mats of hair which deter feeding by insects). Another useful type of resistance is tolerance, in which the plant has the ability to sustain high levels of a pest without severe economic damage. Pest resistance may be due to a single dominant gene or it may involve many genes.

The successful development of resistant crop varieties has been a major factor in increasing and maintaining high levels of crop productivity. From the standpoint of the farmer, pest-resistant varieties are usually the most effective, easiest, and most economical means of controlling insect and plant disease pests.

Development of disease-resistant crop varieties requires a continuing and reasonably expensive research program. The costs, however, are an excellent investment. The availability of pest-resistant varieties is particularly important for crops with relatively low values per hectare. On such crops, costly chemicals cannot be used because the profit margin is too narrow.

Ideally, multiple resistance to diseases, nematodes, and insects would be incorporated into every crop, but developing plants that resist some pests while maintaining acceptable yield is a slow process. Occasionally, varieties developed to resist one pest may be more susceptible to another that had not previously caused much economic damage. Insects and diseases are continuously evolving strains that may adapt to formerly resistant plant varieties. Development of multiple-pest-resistant plants is clearly a long-term interdisciplinary effort entailing the cooperation of a range of experts.

Despite the time and the costs of developing resistant crops, potential economic rewards are great. The return on investment for research on plant resistance is exceeded only rarely by other methods of control.

(2) Pest Resistance in Domestic Animals

Compared with plants, the development of resistant animals is not nearly so advanced because manipulation of pest-resistant characteristics is much more difficult. A longer time is required to complete a generation, the animals have relatively few offspring per generation, and only a small number of breeds or lines may be available to the breeder. Nevertheless, development of resistant livestock breeds has promise. For example, some of the best known lines of purebred Hereford cattle have been selected on the basis of light-colored hair coat, because they are less susceptible to the horn fly *(Haematobia irritans)*. Australian sheep ranchers have found that English breeds of sheep are less susceptible to attack by wool maggots (immature forms of calliphorid flies) than are the Spanish-developed Merino breed. Crosses between the breeds show intermediate resistance (NAS, 1969).

(c) Cultural Control

Cultural control is the deliberate manipulation of the environment to make it less favorable for pests by disrupting their reproductive cycles, eliminating their food, or making it more favorable for their natural enemies. Many procedures, such as strategic scheduling or plantings, tillage, irrigation, harvesting, and fertilizer applications, crop rotation, destruction of wild plants harboring pests that migrate to crops, and use of pest-free seed and planting stock, can be employed to achieve cultural control. One of the oldest and most effective methods of pest suppression, cultural control, is widely applicable in IPM schemes.

Many cultural practices are simple, inexpensive, and easily adopted by individual farmers, foresters, ranchers, livestock managers, recreational managers, or homeowners, with only slight modification of routine operations. Yet successful implementation of some cultural practices requires participation over a large geograohical area (Stern et al., 1976). The following are just a few examples of the diverse ways in which the cultural control method can be used.

(1) Sanitation

Sanitation involves the removal or destruction of breeding refuges or overwintering sites of pests. Prompt disposal of garbage, enclosure of food in tight containers, and regular sweeping are basic in preventing infestations of cockroaches and other household pests. Removal of pieces of wood from under houses and other buildings reduces the chance of infestation by subterranean termites (*Reticulitermes* spp.). Frequent removal of waste from livestock quarters is a proven method for reducing house flies *(Musca domestica)*, stable flies *(Stomoxys calitrans)*, and other insects that breed in this material. Storage of garbage in tight enclosures, covering of sewer holes, and frequent removal of garbage and other organic wastes are proven management techniques for the Norway rat *(Rattus norvegicus)* and house fly when applied on a communitywide basis in urban areas. Removal of fallen fruit from orchards and destruction of tree prunings are

useful in reducing the insect and disease pests which overwinter in these materials.

Removing diseases plants (roguing), pruning infested parts, and removing or effectively treating plant material containing disease organisms (e.g., treating potato tuber piles with chemicals, burning stubble) have been successful in plant disease management (Zentmyer and Bald, 1977).

(2) Destruction of Alternate Hosts and Volunteer Plants

Pest populations may often be effectively suppressed by destruction of their alternate plant hosts (i.e., their secondary hosts, weeds or the volunteer crop plants along the edges of crop fields). This technique, in effect a weed control, has been more effective against plant diseases than other pests.

(3) Crop Rotation

Much has been learned about preventing pests from becoming seriously destructive in cultivated fields by following the principles of good crop rotation; a crop of one plant family is followed by one from another family that is not a host crop of the pest to be controlled. Agronomic research and practice, however, have shown that some rotations are advantageous to pest control but may be harmful for other reasons; for example, rotation from sod crops on hilly land may lead to soil erosion. Crop rotation is most effective against pests with a restricted plant host range and, for insects, those with limited capability to migrate.

(4) Soil Tillage

Until recently, tillage was the only known method for controlling many weed species. The practice is rapidly being replaced on much crop land with herbicides because they are easier, less energy intensive, and more profitable over the short run. Herbicides also eliminate soil erosion, soil compaction, water loss from the soil, and pruning damage to the crop plants' roots, problems usually associated with tillage (Day, 1978). As a result, some cropping operations are switching to reduced-tillage or no-tillage systems whose success depends on effective herbicides. Serious side effects of tillage are loss of organic matter, especially in warm soils, and accelerated loss of soil to wind and water erosion if the soil is left bare for an extended period (Glass, 1975).

The no-tillage technique also has been effective in the control of a variety of insect pests, plant pathogens, and nematodes.

(5) Trap Crops and Trap Logs

The practice of attracting pests to small plantings of crops which are then destroyed or sprayed with a toxicant has been quite successful against some plant nematodes, parasite weeds, and insect pests (Flint and van den Bosch, 1977).

(6) Habitat Diversification

Increasing crop diversity (i.e., intermixed plantings of several crops, as opposed to monoculture) can sometimes be used to increase predator and parasite populations in a given crop or to attract insect pests away from susceptible crops to nonsusceptible crops.

Because wrong intermixes can increase pest problems on one or more of the intermixed crops, the advantages of the practice must be carefully weighed against potential harmful side effects (Smith and van den Bosch, 1967).

(7) Water Management

Water management procedures (e.g., timing of irrigation, flooding, drainage) based on a sound understanding of pest biology may provide economical and effective control of some pests. Drainage of irrigated pastures, regulation of water levels in rice paddies, and avoidance of stagnant water buildup in old tires, tree crotches, and other breeding habitats are particularly important mosquito mangement practices.

Careful control of irrigation water is one of the most effective ways for controlling soil pathogens. Flooding of fields has been used to control some root-infecting fungi. In some cases, reduced irrigation or rainfall prevents root knot nematode eggs from hatching, thereby reducing larval invasion of the crop roots (Van Gundy, 1972). Management of irrigation water can also reduce certain weed problems (Glass, 1975).

(d) Physical Control

Physical controls are direct or indirect (nonchemical) measures to destroy pests outright or to make the environment unsuitable for their entry, dispersal, survival, or reproduction. Like cultural controls, they exploit weak links in the pest's life cycle or specific behavioral patterns. Many physical controls require costly equipment and considerable labor and therefore may not be economically justifiable.

Physical controls include temperature manipulations, such as heat and steam sterilization of soil in greenhouses to destroy disease organisms (Raychaudhuri and Verma, 1977). Steam heat is often used to kill insect pests and mildew in furniture and clothing (NAS, 1969). Heat treatment is very important in the production of virus-free plant stock and is routinely applied to seeds, cuttings, sets, tubers, bulbs, and rhizomes (Raychaudhuri and Verma, 1977).

Examples of other physical controls are

- Cold storage used to control many stored-product pests
- Burning vegetation infested with pests
- Insect light traps
- Shooting and trapping nuisance birds and mammal pests and predators
- Screens on windows and doors, serving as barriers to flies and mosquitoes
- Adhesives (sticky bands) around tree trunks to control insect pests such as ants and cicadas
- Fly swatter
- Mechanical sifting and separating equipment used in flour mills and food processing plants to remove insects
- Use of "insect-resistant" containers for storing food, animal feeds, seeds, fabrics, and other stored products
- Laser beams to treat seeds for control of insects and disease organisms.

Many physical techniques have only limited application and probably will never play a major role in integrated pest management.

(e) Autocidal Insect Control

Autocidal control involves rearing and release of insects that are sterile or are altered genetically in order to suppress members of their own species that are causing pest problems.

(1) Sterile-Male Method

The sterile-male method involves artificially sterilizing large numbers of insects by irradiation or chemical sterilants so that after being released into an area inhabited by a wild population, the sterile males mate with wild females. If the wild population is flooded with large numbers of sterile males and they out compete the wild fertile males, the wild females produce substantially fewer offspring than they normally would. Repeating this procedure for several consecutive generations may eventually annihilate the wild population. This is one of the most ingenious pest control methods yet developed; it has been widely publicized, primarily because of its successful application against the screwworm fly *(Cochliomyia hominivorax)*.

The adult female screwworm lays her eggs in the open wounds of cattle, deer, other large mammals, and occasionally human beings, where the maggot stage feeds and develops. She mates only once prior to laying her eggs, and after mating with a sterile male, lays a normal number of eggs, but they are infertile. Dr. E.F. Knipling of the U.S. Department of Agriculture concluded in the late 1930's that these behavioral characteristics and the pest's naturally low population density (about two adult females per square mile) were ideal for application of the sterile male principle. By the early 1950's eradication of the pest was achieved on the Caribbean island, Curacao, and subsequently in Florida in the United States (Knipling, 1967).

Massive releases of sterile-male screwworms have been made continuously in the southwest United States since the early 1960's in a control program financed by livestock owners and the USDA. This program was extremely effective for about a decade, and it even appeared at one time that eradication of the screwworm was feasible throughout the region. During the period of greatest success, the program cost about $5 million per year compared to an estimated savings of $100 million per year (1962 dollars) (Knipling, 1967).

But, beginning in 1972 and continuing through 1976, the program was much less effective,

for reasons not entirely known. Perhaps a genetic weakness developed in the screwworm culture being reared under artificial conditions, resulting in diminished competitiveness of the sterile males (Bush et al., 1976).

Unusually large migrations of screwworm flies from Mexico may also have contributed to the increased screwworm problem, leading screwworm experts to believe that effective suppression may be achieved again by extending the release program far into Mexico in an effort to curb migration into the United States. A new screwworm rearing facility was constructed in Tuxtla Gutierrez, Chiapas, Mexico, under a U.S.-Mexican cooperative agreement to provide sterile males for release in Mexico as an adjunct to the U.S. release program administered in Mission, Texas.

Releases of sterile male screwworms have been made throughout a large region of Mexico since 1977, and screwworms in the United States have been brought under control again.

The sterile-male technique has also been successful against other insects. On the small island of Rota, near Guam, two fruit pests, the melon fly *(Dacus cucurbitae)* and Oriental fruit fly *(Dacus dorsalis)*, were eradicated. Procedures for sterilization and rearing have also been developed for several other important insect pests, the stable fly, horn fly, and mosquitoes. Field tests have shown considerable promise, but additional large-scale field tests are required to refine the technique and make it economical (USDA, 1976).

The possibility that the sterile male method can literally eradicate an entire pest population from an area, thus providing a permanent solution to the particular pest population under consideration, has attracted a great deal of interest. Consequently, use of this technique in combination with other in IPM schemes aimed only at keeping pests below damaging levels has received little attention. The sterile-male technique may well be practical when used in a way that is somewhat similar to the way inundative releases of insect parasites and predators have been used, i.e., sustained releases directed at selected pest generations. However, difficulties with and the high costs of rearing, sterilizing, and liberating the sterile insects are currently prohibitive except possibly against a few insect pests (Waterhouse et al., 1976).

(2) Genetic Control

Like the sterile-male method, genetic control involves release of reared insects for mating with wild populations. However, whereas sterile males produce inactive or inviable sperm, genetic control involves genetically altered insects whose sperm is active, carrying genes that make the wild populations less vigorous, less prolific, or genetically sterile as a consequence of hybridization.

Many characteristics of insects lend themselves to genetic manipulations. Populations of insects are easily altered by selection, natural or artifical; this genetic plasticity is evidenced by their adaptations to various ecological situations. In addition, their short generation times and relatively high reproductive potential make them excellent subjects for selective breeding and genetic experimentation.

Genetic research on insect pests has centered on hybrid sterility, cytoplasmic incompatibility, conditional lethals, and growth alterations. None has yet reached the stage of practical implementation, and most are in a very early stage of research; however, genetic control may have considerable potential in future management of some insect pests.

(f) Pheromones

Insects emit and respond to chemicals called pheromones. Pheromones identify members of a colony, trigger fight or flight reactions, or are used to mark a path toward food sources. In many species, the pheromone emitted by one sex attracts the opposite sex of the same species. Pheromones have been identified for many serious insect pests, and there has been much research on utilizing synthetic pheromones in pest control programs.

Two approaches have been taken with synthetic pheromones: permeating the environment with the pheromone of the target insect to the extent required for disruption of mating and dispersing the pheromone in traps or restricted sites in a field or forest where the insects are lured and destroyed.

The use of insect pheromone traps has received extensive publicity in recent years and many types of insect pheromone traps and pheromone compounds are commercially available. Traps often produce spectacular catches, leading some to believe that the traps are having a

major impact on a pest population. But because the traps may be attracting insects from great distances, the catches in themselves are not proof of the trap's effectiveness unless they can be related to a decreased pest population in the area. Problems in designing large-scale trapping experiments have precluded accurate assessment, except perhaps in a few isolated cases. Theoretical evaluation and a limited number of field experiments have indicated that both pheromone disruption and pheromone trapping have the greatest potential when directed against very low-density insect populations. These techniques, then, will probably have their greatest value when combined with other techniques that assist in achieving the low-density requirement (Knipling, 1979).

(g) Miscellaneous Techniques

Miscellaneous techniques showing promise against a limited number of pests include insect chemical growth regulators, various chemical insect attractants other than pheromones, repellents, feeding deterrents, seed germination inhibitors, and numerous others.

5 ECONOMIC CONSIDERATIONS

Only rarely have pest control techniques been evaluated in terms of the relative costs of the level of control achieved and the costs of the control practice itself. Information derived from acceptable cost-benefit analysis is very limited. Because most available estimates have relied almost exclusively on opinions of the "experts," their accuracy is questionable. Further, few estimates of control benefits have weighed the "hidden" costs required to develop the techniques or the "external" costs of their use – environmental effects, for example. Therefore, there are limited data on costs/benefits of the various alternatives or comparisons of the cost effectiveness of alternatives and pesticides when used against a given pest or pest complex.

However, evaluation of past efforts of some of the alternatives indicates a favorable benefit/cost ratio for them. For classical biological control, as noted above, the benefit/cost ratio has been about 30 to 1. Similarly, a favorable benefit/cost ratio has been shown for the use of pest-resistant crop varieties.

6. CONCLUSION: PROMISES AND LIMITATIONS

The alternatives, used singly, in combination with others, or in combination with pesticides, promise cost-effective solutions for a wide variety of pests. Integrated into IPM systems, they can lead to a reduction in pesticides without loss of yield or quality. As a side benefit, they can contribute in delaying the development of pesticide-resistant pest strains and minimize the adverse impact of pesticides on nontarget organisms and the environment.

But no alternative is a panacea any more than DDT was to all insect problems. The use of any control measure – even the introduction of a pest-resistant variety – can have unexpected and undesirable consequences. For example, genetic strains of insect pests may evolve that resist plant varieties, insect growth regulators, or other control techniques that were once effective. A basic assumption in using alternatives therefore should be that no single control will be permanently successful because of the remarkable adaptive powers of pest organisms. Experience in many parts of the world has shown that the most lasting form of pest protection is achieved when the burden of pest control is systematically spread over a combination of biological, chemical, cultural, and physical methods in cohesive integrated pest management systems.

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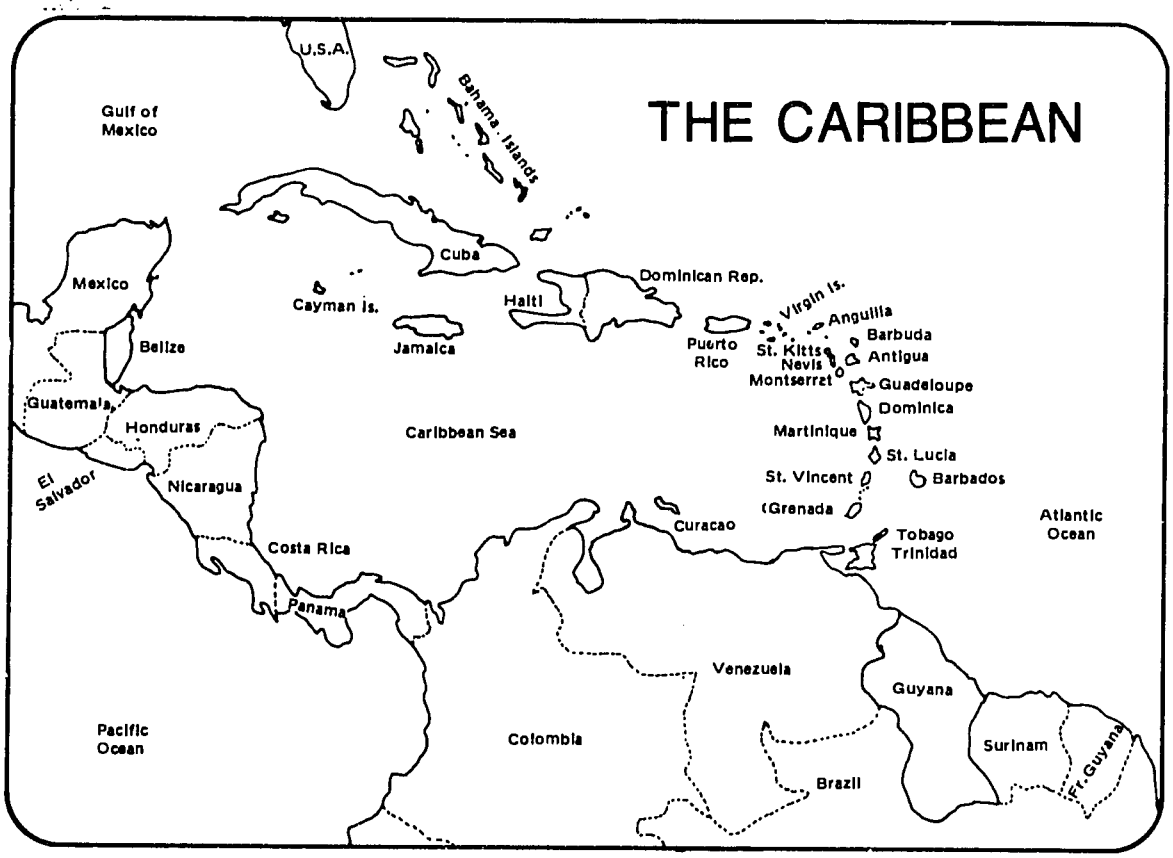

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PEST AND PESTICIDE MANAGEMENT

IN THE CARIBBEAN

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CONTENTS

All papers bear the title PEST AND PESTICIDE MANAGEMENT, and most cover both agricultural and public health aspects. In the following list, therefore, no title is given for the paper, but indication is given in those cases where it is solely concerned with agriculture or public health respectively.

EDITOR'S INTRODUCTION 7

1. ANTIGUA
   KENTISH, FLORITA E. Plant Protection Officer, Department of Agriculture, Dunbars, Antigua and
   McKAY, DALTON B. Pest Control Officer, Ministry of Health, St. John's, Antigua 12

2. BAHAMAS
   CAREY-OUTTEN, V.A., DAVIES, H. and LYN, J. Ministry of Agriculture, Nassau, Bahamas 21

3. BARBADOS (Health)
   FOYE, PETER. Senior Public Health Engineer
   BURNETT, WENDELL. Public Health Engineering Assistant
   BROWNE, CHARLEY. Chief Pest Control Officer, and
   SHEPPARD, ALONZO. Chief Public Health Inspector, Aedes aegypti Control Unit, Ministry of Health, Jemmott's Lane, Bridgetown, Barbados 26

4. BARBADOS (Agriculture)
   ALLEYNE, ESLIE H. Entomologist, Ministry of Agriculture, P.O. Box 505, Bridgetown, Barbados 38

5. BELIZE
   CAWICH, AGROPINO. Research Officer, Belize Sugar Industries Ltd., P.O. Box 52, Belize City, Belize, and
   ROCHES, ALBERT. Public Health Inspector, San Ignacio Hospital, Cayo District, Belize 50

6. DOMINICA
   CLARENDON, HANNAH. Plant Protection Officer, Ministry of Agriculture, Botanic Garden, Roseau, Dominica, and
   HILL, JAMES. Senior Environmental Health Officer, Ministry of Education and Health, Roseau, Dominica 58

7. DOMINICAN REPUBLIC
   VARGAS, JORGE. Chief Inspector, Pesticide Division, Calle No. 110 Santo Domingo, Dominican Republic 66

8. GRENADA
   BUCKMIRE, J.U. Caribbean Agricultural and Development Research Institute, St. George's, Grenada, and
   OGILVIE, GEORGE L. Agricultural Officer (Crop Protection), Ministry of Agriculture, St. George's, Grenada 71

9. GUYANA
   McDONALD, FRANK. Production Manager (Plant Protection), Central Agricultural Station, Mon Repos, East Coast, Demerara, Guyana, and
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15. ST. KITTS-NEVIS (Agriculture)

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GRIFFITH, FLORES. Plant Protection Officer, Ministry of Agriculture, Castries, St. Lucia 157

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APPENDIX: ALLEYNE, E.H. Toxicity of Pesticides in use in the Caribbean 199

ABBREVIATIONS

The following abbreviations have been used, sometimes without any explanation, in various parts of the text, and are listed here in alphabetical order for the convenience of readers.

CARDI	Caribbean Agricultural Research and Development Institute
CDB	Caribbean Development Bank
UWI	University of the West Indies
CPCU	Caribbean Pesticide Control Unit
CIBC	Caribbean Institute of Biological Control
CICP	Consortium for International Crop Protection
IPM	Integrated Pest Management
SNEM	Service National des Endemies Majeures

EDITOR'S INTRODUCTION

This volume contains the several papers outlining the status of pest and pesticide management in sixteen Caribbean countries, geographically extending from Belize, through the Greater and Lesser Antilles to Guyana — a distance of some 3,000 miles: the map and table at the end of the introduction give some idea of the size of the region and of the range of sizes of the several countries which range from 215,000 km^2 for Guyana to 101 km^2 for Montserrat.

The following guidelines were sent to the Government of each participating territory:

Guidelines for Preparation of Country Position Papers on the Status of Pest and Pesticide Management

As background contributions to the Seminar/Workshop on Pest and Pesticide Management in the Caribbean, each country is asked to prepare a position paper describing the status of pest and pesticide management. Ideally a single paper should be presented for each country, however, if that is not feasible, separate reports can be submitted from the agricultural and health sectors. The papers will be distributed as background material during the seminar/workshop and published in the proceedings of the seminar/workshop; the contributing authors will be fully credited. Insofar as available information permits, the following areas should be covered.

The Pests

The major pests impacting the urban, health and agricultural (including livestock) sectors should be listed with some indication of the current management of control programmes. For the food crops, the pests should be discussed according to the crops affected; for livestock, according to kings of animal affected.

The Pesticides

Statistics should be provided on the kinds and amounts of pesticide used. Insofar as feasible, these should be categorised as to kinds of pesticides and areas of use. Are there any trends indicated either as to amounts of pesticides or kinds?

Pesticide Hazards

Provide any statistics available as to human intoxication or deaths from pesticides. Are there any trends indicated? Are there any special problems of pesticide use, e.g. spills, disposal, application, environmental impact? Are there any indications of the development or resistance in pest populations to pests? Give examples for all of these areas if possible and cite literature, if any.

Pesticide Alternatives

Do any pest control programmes involve alternative control measures? Give examples. What levels of expertise are available for research and extension with alternative control measures, e.g. biological control, host plant resistance, cultural controls?

Extension and Educational Programmes

Is the extension service involved in pest control programmes? What is the nature of this involvement? Are there any educational programmes involving pesticide use and safety? What is the target audience?

Agromedical Team Approach

What collaborative afforts have been established in this area for pest and pesticide related problems? Are any contemplated for the future? If in existence, what is the nature of the collaboration?

In general the papers followed the suggested format, though with some individual differences, e.g. some authors have added introductions, others have not; some have combined agricultural and public health aspects, others have separated them, and in three cases, Barbados, Jamaica and St. Kitts-Nevis, separate papers have been submitted. No attempt has been made in the editing to make major alterations so long as the information provided has been clearly set out, and there is necessarily considerable variation in style and expression from author to author. Inevitably the amount and detail of the information given has varied considerably from country to country. Further, the papers were written with discussion at a Workshop as the primary objective, and while a number of colloquialisms have been replaced in the editing by more formal phrasing, it was not deemed necessary to rephrase throughout nor, in some instances, to replace the first

person singular or plural by circumlocutions. Wherever possible editorial queries about the papers have been discussed with the authors, who were invited to submit corrections; unfortunately, owing to the breakdowns in communication that from time to time occur in the Caribbean, not all the corrections requested were obtained. In some instances the editor has been able to rectify obvious errors, but there is little doubt that some will not have been detected; for these the editor apoligises to both reader and author.

In spite of the variation in detail between the nineteen papers, together they provide a comprehensive and valuable survey of the status of pest and pesticide management in the whole Caribbean area. The similarities of the problems, both in agriculture and in public health, are evident, but the degree of sophistication with which they are handled in the different countries varies from minimal to advanced. In every case many problems are recognised, and misuse of chemicals by farmers is the norm rather than the exception: the reader is left wondering why more fatal accidents have not occurred. So, it appears, have the relevant Government agencies in many of the countries reviewed, for most have enacted pesticide control legislation or are seriously considering doing so. Unfortunately, however, in several cases where legislation has been undertaken, it is, for one reason or another, inoperative. The seminar/workshop under review has, as indicated in the workshop reports in Volume I, highlighted this, and a number of participants have returned from the workshop to their home countries determined to ensure that legislation is enacted and/or enforced.

In one or two of the Invited Papers (Volume II) it was noted that some pesticides which were banned in the U.S.A. and other developed countries, were exported to countries whch had no effective legal controls. The danger of this was briefly recognised by the U.S.A. and, according to a recent newspaper report* an executive order to control pesticide exports from that country was signed by President Carter five days before he left office. However, this was rescinded by President Reagan on 17th February, 1981, restoring the status quo. The urgency for Caribbean countries to control their importation and use of pesticides continues to be acute: these countries are easy targets for those manufacturers who wish to exploit ignorance or absence of legal safeguards.

Everyone closely connected with Caribbean agriculture well knows the general inadequacy of well-trained extension services; this has been stressed in most papers, and the need for improved training and communication methods is clearly seen in virtually all countries. The need for an integrated agromedical approach is also well recognised, as has been shown in the composition or proposed composition of the bodies that do or will develop regulations governing the use and management of pesticides.

Many Caribbean countries use large quantities of pesticide. Pollard (Paper No. 4 in Volume II of this Report) suggested that the quantities used in Trinidad and Tobago both on the per km^2 and per capita basis were alarmingly high. but when the Trinidad figures are compared with others calculated from data given in the papers in this volume (see Table at end of Introduction), they are among the lowest of those countries that have provided records. Barbados has outstandingly high figures; this is related to the high proportion of cultivated land (about 70% of the total area of the island) and to high degree of sophistication in both sugar and vegetable production. Even so, these figures do at least signal caution.

That unnecessarily large quantities of pesticides are frequently used (not only in the Caribbean) was brought out in several of the contributions in Volume II, and was implicit in some of the control regimens described in the present volume. Several of the contributors also noted the dangers to health and to the environment resulting from ignorance, mis-use and over-use of these chemicals. The region as a whole suffers from a lack of facilities for thorough investigation and quantification of such environmental effects as may or may not be resulting from the use of pesticides; a certain amount of uninformed speculation inevitably arises.

Along with the possible ecological hazards arising from the widespread use of pesticides, there are real dangers to individuals as a result of ignorance or carelessness. For example instances have been quoted of operators using their bare hands to mix pesticides, and the writer's attention has been drawn to the case of a farmer, afflicted with some lesions of the right hand and arm, and the loss of his finger nails, who was regularly stirring paraquat concentrate into water by immersing his arm up to the elbow in the solution. The connection between this action and his skin condition had not been recognised. This was in a Caricom territory with a relatively good

Barbados Advocate News, 14th March, 1981

Government Extension Service, yet an individual could exhibit such ignorance. Similarly the use of pesticides (again paraquat has been specifically identified) to poison fish in rivers is an act of mis-use of almost unbelievable callousness or ignorance.

In most Caribbean countries interest has been shown in "management practices" using non-chemical methods, mainly biological control by predators*, or some form of Integrated Pest Management. A double as to whether IPM techniques could be applied to farmers growing a heterogeneous mixture of crops in small or relatively small areas has been expressed. Certainly large scale management areas would be virtually impossible in most of the island territories, but it should be quite practicable to devise techniques embodying IPM principles: this is the challenge to the pest control officials in the several participating countries. An encouraginging item from Thailand, a country of peasant farmers, has recently been published (Mabbett, 1980), describing sampling methods and spraying regimes against four major pests of cotton, (bollworm, aphid, whitefly and jassid), in which the farmers follow a simple sampling routine and spary according to the findings. The normal two-weekly spraying has been reduced by 40%. There is plenty of room for techniques of this kind in the Caribbean where in some countries cabbage, for example, is sprayed twice a week, often with a "cocktail" of two or three pesticides – a technology, as shown by Tikasingh (1980), that can be self-defeating. Indeed, one is tempted to wonder whether in the progression of Caribbean agriculture (food crop production at any rate) from a subsistence level to a relatively large scale commercial system, we have not too readily adopted some of the worse aspects of "developed" technology. That the "primitive" methods of many Haitian farmers, for example, have much to teach conventionally trained agricultural scientists, has recently been emphasised by Mechin (1981). Perhaps Haiti, recognising this, may be able to develop its agriculture without copying the mistakes of others.

We, in this region, have much to learn and are fortunate to have the opportunity presented by the Seminar/Workshop to be brought up to date on current thought and to have been forced to examine our own practices (and malpractices) in some depth.

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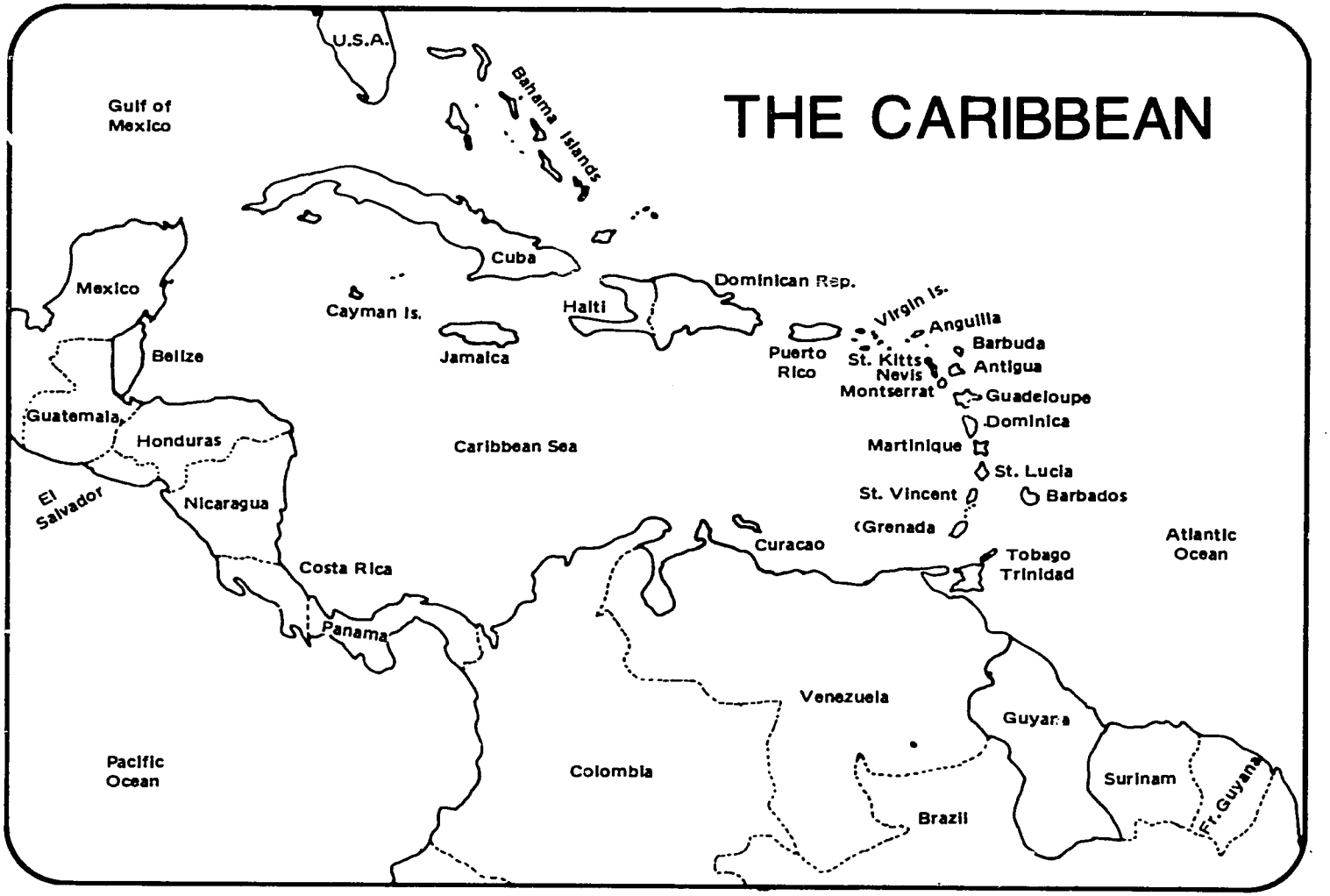
* *The concept of biological control by predator is not new in the Caribbean. Ligon (1973), writing of conditions in Barbados ca 1650, says "Caterpillars we have sometimes in abundance, and they do very great harm; for they light upon the leaves of our Potatoes, which we call Slips, and eat them all away, and come so low, as to eat of the Root too: and the only remedy we have is to drive a flock of Turkies into the place where they are, and they will devour them"*

Caribbean Countries — Areas, Populations and Pesticide Loads

Country	Area (Sq Km)	Population	Pesticide Use/Kg/Year		
			Whole Country	Per Km^2	Per Capita
Antigua	440	70,000	NA	-	-
Bahamas	13,934	185,000	NA	-	-
Barbados	430	240,000	1,035,788	2,409	4.05
Belize	23,050	152,000	65,680	283	0.43
Dominica	751	83,000	20,010	27	0.24
Dominican Republic	49,986	4,012,000	NA	-	-
Grenada	344	110,000	396,992	1,154	3.61
Guyana	214,969	714,000	334,502	1.6	0.47
Haiti	27,700	5,500,000	NA	-	-
Jamaica	11,396	2,109,000	7,991,383	701	3.79
Montserrat	101	12,900	NA	-	-
St. Kitts/Nevis	262	48,000	NA	-	-
St. Lucia	616	112,000	53,000	- 86	0.47
St. Vincent	344	113,000	344,500	1,001	3.05
Trinidad & Tobago	5,128	1,061,000	983,801	192	0.93
U.S. Virgin Islands	344	90,000	NA	-	-

Sources: Areas and populations adapted from Whittaker's Almanack 1980. Pesticide use is taken from the "Country papers" in this volume, and except for Guyana these refer to formulations as purchased, ranging from 5% to 80% a.i. The figures for Guyana are kg. a.i. For the UK the pesticide load is approximately 3.9 kg a.i. per ha treated and 0.4 kg. a.i. per head of population (calculated from data of Sly 1977).


THE CARIBBEAN
U.S.A.
Gulf of Mexico
Bahama Islands
Cuba
Mexico
Cayman Is.
Haiti
Dominican Rep.
Jamaica
Puerto Rico
Virgin Is.
Anguilla
Barbuda
St. Kitts
Nevis
Antigua
Montserrat
Guadeloupe
Dominica
Belize
Guatemala
Honduras
Caribbean Sea
Martinique
St. Lucia
St. Vincent
Barbados
El Salvador
Nicaragua
Grenada
Curacao
Atlantic Ocean
Tobago
Trinidad
Costa Rica
Panama
Venezuela
Guyana
Pacific Ocean
Colombia
Surinam
Fr. Guyana
Brazil

1. ANTIGUA

PEST AND PESTICIDE MANAGEMENT

FLORITA E. KENTISH
and
D.B. McKAY

INTRODUCTION

There are virtually no recorded statistics in Antigua on pest outbreaks and the measures used to control them, and on their successes or failures, nor are there records of the effects of pests on yields of crops. The following information, therefore, has been gathered chiefly from recent surveys of government agricultural stations and small farmers' holdings, from discussions with extension officers, and from day to day observations of pest and pest damage symptoms seen in the field.

A wide range of pesticides, especially insecticides (listed in Table 1, at end of paper) is currently used for crop protection in Antigua. The large number of pesticides indicates a deficiency in selection and allows more opportunity for misuse of chemicals. Although recommendations to farmers usually involve the use of the "safer" chemicals, there is at present no other distinction made in Antigua between 'safe' and 'restricted' presticides.

I. AGRICULTURAL SECTOR

THE CROPS

The more important food crops, their major pests and current control measures, are indicated below, with food crops listed first (in alphabetical order) followed by cotton and sugar cane and finally fruit.

Food Crops

Cabbage

Cabbage looper *(Plusia* sp.) diamond back moth *(Plutella xylostella),* and cabbage butterfly *(Pieris* sp.*)* are the main insect pests. Chemical control is by Lannate, Ambush, Diazinon and Surecide. There is some indication that diamond back moth larvae are developing resistance to Lannate; Ambush and Surecide have proved highly effective against this pest.

Black rot of cabbage, *Xanthomonas campestris,* has recently shown a significant increase; the most popular variety of cabbage, K-K Cross, is known to be susceptible to this seed-borne disease. A contributory factor is that Brassicas are frequently grown from season to season in the same field; rotation is seldom practised. Efforts are being made to have farmers destroy old crop debris by deep ploughing or burning, and to have cabbage seeds hot water treated before planting.

Corn

The major pests are corn earworm *(Heliothis zea)* and army worm *(Spodopteris* sp.*),* against which Lannate, Surecide, Gardona and Dipterex are used.

The only disease so far to appear (and this on one small farmer's plot) is smut. The treatment is removal and destruction of affected plants.

Cucurbits – Squash, cucumber, melon, pumpkin

Insect pests are aphids and the melon worm *(Diaphania* sp.*);* Malathion and Dipterex are the usual insecticides for control.

The important diseases are powdery mildew (widespread and serious) downy mildew and blossom end rot; fungicides employed are Benlate, Copper-Count N. Dithane, Kocide, Cupravit blue.

Cucumber mosaic virus is spread by aphids; control is by attacking the vector and destroying a host plant "wild cucumber".

Egg Plant

There are three major insect pests; flea beetle *(Epitrix* sp.*)*, Egg Plant lace bug, which can do appreciable damage in dry weather, and leaf miners. Sevin and Malathion are used against the two former, Perfekthion against the last.

Okra

Okra is commonly attacked by aphids, usually controllable by a single application of Malathion; *Heliothis* sp. and *Pectinophora* sp. occasionally attack the fruit: these, and stink bugs *(Nezara viridula)* are combatted by a single application of Malathion, Lannate, Phosvel or Dipterex.

Peas and Beans — String beans, cowpea, black-eye, pigeon pea, bodie beans, etc.

Insect pests include red spider mite, for which Kelthane is used in severe cases; leaf miners, tunnel and patch, treated by Dimethoate, Malathion or Dipterex, and green and brown stink bugs.

The main diseases are leaf spots and root rot, for which Benlate or Dithane M-45 are used. Bean mosaic virus also occurs; control is applied to the aphid vectors.

Peppers — Sweet and hot

Several insect pests can be serious: aphids, leafhoppers, pod borers *(Curculio)*, armyworm, corn earworm and stink bug; Dipterex, Rogor, Lannate and Malathion are used to combat these. For cutworms and slugs chlordane is employed.

Potatoes (Sweet)

Sweet potato weevil is the major pest. Several treatments are used:

(i) Spray with Surecide or Lannate alternated every two weeks in the wet season, more frequently in the dry season.

(ii) Digging up and burning infested plants.

(iii) Removing culls from the field.

(iv) Harvesting mature potatoes early.

(v) Using resistant varieties.

Leaf eating caterpillars and spider mites also attack this crop; spraying with Lannate or Rogor is the control measure.

Tomatoes

Insect pests are: leaf miners, tomato fruit worm *(Heliothis* sp.*)*, tomato hornworm, stink bug; for control Lannate, Carbaryl, Phosvel, Dipterex and Rogor are used. Tomato russet mite is controlled by Kelthane.

Diseases are early blight and fruit rot, for which Manzate D and Benlate are used.

Yam

Yam scale is treated by spraying the vine and tubers with Malathion; leaf feeding caterpillars with Dipterex.

There are several unidentified fungal diseases; cuttings are treated with Benlate and Manzate alternately; *Anthracnose* has been identified and is treated by spraying the foliage with Dithane M 45 using a mist blower.

Cotton

A number of insects attack cotton, in particular armyworms, pink bollworm *(Pectinophora gossypiella)*, cotton leafworm *(Alabama argillacea)*, aphids, green stink bug and cotton stainer *(Dysdercus andreae)*. Chemical control is by Malathion, Carbaryl and Endosulfan, based on the results of a regular scouting programme (on Government estates), and a threshold has been established for *Spodoptera* (armyworm), *Heliothis* and *Alabama*. Experiments are under way on biological control by an egg parasite, *Telenomus remus*. There is a closed season from May 1st to July 31st.

Sugar Cane

The one serious insect pest of sugar cane is the stem borer, *Diatraea saccharalis*. No insecticide is used. Nematodes are believed to limit yields but no work has been done on this.

Fruit

Banana

Banana borer and banana weevil are treated by soil application of chlordane. A number of unidentified nematodes can cause serious losses of crop and these are treated by Furadan or Mocap, pre-or post-emergent to the plant.

The two major diseases are Panama disease (requiring destruction of affected plants), and bunchy top virus; if present, sterilisation of pruning equipment is necessary. Only resistant varieties should be used. (Measures against these diseases are used only on Government stations).

Citrus

Eleven species of scale insects on citrus have been recorded in Antigua (Walker et al, 1974), the major ones being West Indian red scale *(Selenas pidus articulatus)*, star scale *(Vinsonia stellifera)*, and cottony cushion scale *(Icerya purchasi)*. Malathion controls most. Citrus rust mite has recently been identified on Ortanique.

The main disease is sooty mold, which usually requires no treatment other than that of the scale with which it is associated.

Pineapple

The only insect pests of economic importance are scale and mealy bugs. Scale, if present in large numbers, is controlled by Malathion or Diazinon; mealy bugs by planting only clean material, dipped in Diazinon emulsion.

Pineapples are not routinely tested for nematodes, but these are recognised to be a serious limiting factor to production of this crop, and the soil is routinely treated with nematicide.

LIVESTOCK

Cattle

a) Ticks

Three types have been identified; cattle tick *(Boophilus microplus)*, dog tick, *(Rhipicephalus sanguineus)*, and *Amblyomma carnegatum*. *Boophilus* is the most serious pest of cattle and sheep in Antigua.

b) Mange

Farmers tend to refer to all skin conditions as mange. However, both mange caused by mites, and dermatitis, caused by a bacterium, *Dermatophilus congolensis*, do exist in Antigua. The latter may result from scratches from thorny bushes, eg. Acacia sp., or from bites from ticks or other biting insects. This type of dermatitis is more prevalent in the rainy season.

c) Worms

Tapeworm and gastrointestinal nematodes are a problem among small farmers' herds; Government herds are regularly treated.

Goats

May suffer from mange around the mouth.

Sheep

Suffer from ticks and worms. Sheep and goats are primarily owned by small farmers and left to roam with little attention.

Government Management Practices

The Government Livestock Division practices and stresses rotational grazing especially as this can eliminate many ticks, though roaming sheep and goats can easily disrupt the cycle.

Government provides:

a) A dip service to the general public fortnightly. Department's herds are also routinely

dipped fortnightly. 'Dipping' is practised by small farmers haphazardly, usually only when there is a severe outbreak of ticks, mange etc.

b) A Spray race at Olivers, a government Livestock Station.

There is a regular practice of changing the dipping chemical every 3-4 months to avoid resistance in the pest to any one chemical).

Pesticides in common use in animal husbandry

a) By Livestock Stations:

For Mange: Gamatox

For *Dermatophilus:* Treatment on an experimental basis:

(i) Mixture of sulfur, vaseline, iodine and formaldehyde painted on:

(ii) Injectible antibiotic – Liquamycin

For Flies: Burgator or Coopertox

For Sinking-in Ticks: Supona is found very effective; but is only used occasionally as it is very expensive).

b) By Small Farmers:

For ticks: Sevin, Toxaphene, used separately or sometimes mixed.

Small farmers do not usually use chemicals which government stations use, due to the greater cost and the fact that these chemicals are not usually available in small quantities.

Failings of the System:

The Livestock Division needs to keep more abreast of pest problems (to monitor and follow up) and small farmers need to use chemicals properly and to know when to treat.

PESTICIDES

The actual pesticides (insecticides, fungicides, nematicides and herbicides) used in Antigua are listed in Table 1.

Crop use:

Insecticides are the major chemicals used and are heavily relied upon in vegetable production (especially on large acreages). Attempts are now being made to use insecticides for specific pests, instead of solely on a crop basis.

Fungicides used by farmers are usually applied to the leaves. Little if any seed treatment (e.g. with Thiram or Captan) or side dressing is done.

Herbicides are used chiefly in sugar cane and cotton, and to a lesser extent in vegetables, to clean up hard-to-control weeds such as nut sedge, *Cyperus rotundus*, and devil's grass (Bermuda grass), *Cynodon dactylon*. Trials on herbicides usage are being undertaken at the Agricultural Research Station at Dunbars.

PESTICIDE HAZARDS

As only low pesticide dosages are used in the control of pests in public health situations, pesticide hazards are insignificant in these operations. There are, however, many hazards with the increasing agricultural use of chemicals.

Livestock:

No human illness or deaths are known or have been recorded. Some pesticide-related deaths were suspected in livestock as far back as 1972, but these were never documented or proven; they were associated with extensive outbreaks of ticks, and the death of cattle was thought to be due to a combination of over doses of toxaphene and tick fever.

Crops:
Hazards arise from the causes listed below:

i) very poor application techniques, in particular:
- poor nozzle selection
- poor maintenance of spray equipment
- non-use of protective clothing
- improper or lack of calibration of sprayers
- incorrect calculation of rates of application of chemicals

ii) Retailing of chemicals frequently done without proper labelling (restrictions of use, rate of application, caution etc. not included).

iii) There is no restricted list of chemicals (all pesticides are equally available to public).

iv) No routine check-ups of persons regularly handling pesticides are undertaken.

Occasional reports of human illnesses believed to be pesticide-related are known (these are usually as a result of not observing re-entry periods). One death due to pesticide poisoning is recorded. This however, was due to accidental oral poisoning; Gramoxone (paraquat) was mistaken for "Codol" as it was in a Codol container.

PESTICIDE REGULATIONS

A set of regulations has been drafted by the Pesticide Control Unit. These include Importation, storage and sales regulations; worker protection and produce (prevention of contamination by pesticides) regulations, but there is no functioning pesticide legislation because those Pesticide Regulations have not yet been acted upon.

PESTICIDE ALTERNATIVES

Currently in crop production and livestock management, chemical control is our major, and sometimes, only means of control of pests. However, other means used in particular situations are:

i) Resistant Varieties: commercial seeds are ordered with resistance to certain pests in mind, and in addition, varietal trials are run to determine the suitability of varieties to local environmental conditions.

ii) The need for disease-free planting material and seeds is recognized. Attempts are being made to this end, (e.g. use of tissue culture yam cuttings developed by CARDI (Mantell and Haque, 1979), and hot water treatment of brassica seeds).

iii) Rotation of Crops: Practised to some extent, but not sufficiently. Farmers need to be given a deeper appreciation of different classification of crops for operating successful rotation systems.

iv) Destruction of old plant debris: This, like crop rotation, is practised to a small extent, but not routinely, e.g. culled potatoes and vines, cabbage stalks etc., are usually piled between rows and left to rot.

v) Clean up of lands with wild cotton, since these provide suitable diapausing sites for pink bollworm, *Pectinophora gossypiella*. This clean-up has been lax as the plant protection unit was non-functioning for some time. A campaign is now being launched to locate these areas, and root up and burn wild cotton plants throughout the island.

vi) **Pheromone traps (Gossymone)** have been employed to assess outbreaks and monitor population density of Pink bollworm, and will be repeated this Season.

vii) **Biological control**, in the case of Fall armyworm, *Spodoptera frugiperda*, has been experimented with. Mass-rearing of a tiny wasp, *Telenomus remus*, an egg-parasite, was undertaken. Field releases and recovery of the parasites have been made. A larval parasite (*Apantales* sp.) of the Diamond back moth, *Plutella xylostella*, has been found on cabbage; attempts are being made to mass-rear this parasite.

EXTENSION AND EDUCATION PROGRAMMES

Government activities in this field include:

Agricultural Science teachers' workshop (covered economic pests of Antigua, their identification and damage symptoms).

Instruction on pesticide handling and safe use.

A recent Pest Control Workshop and Field trip for small farmers primarily, as well as extension officers and general public. This was widely advertised and covered pests, pest damage, pesticides and their uses and safe handling, calculations and calibration, and pesticide equipment.

Preparation of hand-outs on rates of application of commonly used pesticides which are distributed to farmers.

Preparation of revised Farmers' Crop Guide. Pest control recommendations are included.

Radio and T.V. agricultural programmes (temporarily discontinued).

AGROMEDICAL TEAM APPROACH

This is not at present a strong aspect of our pest management system; but it is hoped that in time it will be.

There is a Pesticide Control Board consisting of Agricultural Officers and a Chief Medical Officer, though at present it is non-functioning. This board has proposed a set of Pesticide regulations on worker safety, pesticide sales and storage etc., which are yet to be adopted. Future plans of the Agromedical team are:

- Adoption of working pesticide regulations
- Stocking of antidotes for Pesticides
- Analysis of Pesticide residues in plant and animal products
- Greater emphasis on protective clothing, periodic examination of pesticide operators etc.

II. PUBLIC HEALTH SECTOR

The major pests known and dealt with are flies, mosquitoes, cockroaches, bedbugs, ticks, termites and rats.

a) **Flies:**

Houseflies, stable flies and latrine flies are quite common. There are management practices to guard against them as they may transmit disease such as typhoid and paratyphoid, cholera and dysentry.

Current control:

Preventative measures are often used as these are less expensive and more effective than sporadic attempts at control. These comprise:

i) Proper disposal of house refuse and stable manure.

ii) Proper use of dust bins (regular emptying).

iii) Fly-proof latrines.

iv) Concrete floors in stables and hen houses and regular cleaning of these.

v) Aerosol spraying using knock-down preparations with residual action (e.g. Baygon).

vi) Trapping: commercial sticky fly traps.

b) Fleas:

Four species are known to be present:

Pulex irritans mainly on man and pigs
Ctenocephati des canes mainly on dogs
Ctenocephati des felis mainly on cats
Ceratophyllus fascilus mainly on rats

Fleas, in particular dog fleas, are presently on the increase in Antigua, therefore special measures are taken to control them.

Current control:

Chemical spray treatment of sleeping places of pets or entire house (if pets have free-run of house) especially dark areas.

c) Bed Bugs:

Cimex hemipterus: The common bed-bug of the tropics. Bed bugs are declining in importance, but are still prevalent at certain public institutions, such as the Mental hospital, or the Home for the Aged (Fiennes Institute).

Control:

For heavy infestations, residual spraying is done (Diazinion concentrate or mixed).

d) Lice

A declining problem in Antigua (found as isolated cases) but wherever found must be quickly dealt with as human lice are vectors of many dreaded diseases (typhus, trench, relapsing fevers).

e) Cockroaches

Several species are known to be present, but the most prevalent and difficult to control is the German roach, *Blatella germanica.*

Control:

Residual spray; Baygon concentrate is the most successful. Many other insecticides are used; but not very successfully as cockroaches rapidly build up resistance.

Good housekeeping measures are stressed to housewives, restaurant owners etc.

f) Ticks

Ticks are commonly found among animals in Antigua; they are known to be carriers of tick borne relapsing fever, rickettsia and other diseases.

Control:

Dipping animals (2-3 weeks intervals), or dusting with Sevin – a very safe and common treatment, used in dog kennels, poultry houses etc.

g) **Mosquitoes**

Aedes aegypti, the vector of yellow fever and dengue fever is still present in Antigua. The status of this pest is doubtful, but vigorous efforts are being made to eradicate it.

Control:

(i) Addition of insecticide to all water-holding containers: Baytex to non-drinking water and Abate to drinking water.

(ii) Keeping yards free of old tins, bottles and other containers.

(iii) School campaign – the Health Department has visited many schools educating children about *A. aegypti*, and appealing to them to help eradicate it.

(iv) Fogging – mechanical fogging machines mounted on vehicles (with Malathion mixed with diesel) are used island-wide on a regular schedule.

(v) Repellents – several brands of mosquito 'coils' (with Pyrethrum as active ingredient), are commonly used by householders.

h) **Termites**

Termites are at present a serious problem in certain areas, particularly villages. Tunnelling termits seem to be most prevalent. There have been recent discoveries of termites in books at the Government Printery, Magistrates Court and the Public Library.

Control:

Raw diesel spray application.

i) **Rats and Mice**

The species *Rattus rattus* is identified as the number one problem. There is presently an anti-rat campaign being conducted after a lapse in such work for the past 10 years.

Control:

Rat Bait – the active ingredient being zinc phosphide – is mixed with attractive substances such as condemned tinned food stuffs, cornmeal, flour etc., and is distributed without cost to the public with instructions for use.

Currently, there is only one commercial pest control agent functioning in Antigua. The unit carries out duties similar to the Public health inspectors; setting baits (in this case, commercially prepared baits) for rats and mice, and spraying for roaches, ants and termites.

Table 1 Pesticides available in Antigua

Insecticides and Acaricides:

Ambush (permethrin)	Malathion
Chlordane	Metasystox
Decis	Orthene
Diazinon	Phosdrin (mevinphos)
Dimethoate (Perfekthion)	Phosvel (leptophos)
Dipterex	Rogor (dimethoate)
Disyston	Sevin (carbaryl)
Folithion (fenitothrion)	Surecide
Kelthane	Toxaphene
Lannate (methomyl)	Volaton

Fungicides:

Benlate	Maneb
Copper Count N	Manzate-D
Cupravit Blue	Morestan
Daconil (Bravo)	Peltar
Dithane (maneb)	Vapam
Kocide	

Herbicides:

Dacthal	Milquat
Dalapon	Prometryne
Diuron (Karmex)	Reglone
Eptam (EPTC)	Round up
Gramoxone (paraquat)	TOK-E 25
Hyvar-X	

Nematicides:

Furadan (carbofuran)	Nemacur (fenamiphos)
Mocap	Vydate-L (oxamyl)

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2. BAHAMAS

PESTS AND PESTICIDE MANAGEMENT

V.A. CAREY-OUTTEN, H. DAVIES
and J. LYN

1. INTRODUCTION

Bahamians have always been actively engaged in farming, the majority being done on the Family Islands, with some done in New Providence. The farming was typically 'pot-hole' or subsistence. The farmer planted his seeds in pockets of soil in the limestone rock, and harvested when the crop was produced.

Agrichemicals (fertilizers and pesticides) were hardly ever used, though occasional attempts at insect control were made using DDT or Chlordane. Farmers were unable to distinguish pest problems.

In the last 10-15 years, as the Ministry of Agriculture and Fisheries expanded, modern agricultural practices were demonstrated to farmers. As a result, the farmers' knowledge of insect, disease and weed problems, and livestock pests broadened. This led to a rapid increase in the use of pesticides for both crops and livestock.

LIVESTOCK PESTS

There are no ectoparasites of any economic importance in The Bahamas. Apart from a few ticks found some years ago on a confined dairy herd in New Providence, no evidence of ticks on any other of the Family Islands has ever been discovered. Surveys have been conducted on Eleuthera Island for ticks by the Department of Agriculture and United States Department of Agriculture, and the Canadian Department of Agriculture.

The major endoparasites of economic importance in The Bahamas are the gastro-intestinal nematodes in sheep and goats. The Bahamas are free of flukes and lungworms. The major livestock pests are shown in Table 1 (at end of paper).

CROP PESTS

The major pests affecting the agricultural sector are shown in Table 2.

THE PESTICIDES

The pesticides employed are also indicated in Table 2, but are summarised by category and chemical classification in Table 3. There are no statistics for the quantities used, though the majority are from the Carbamate and Organic Phosphate groups:

PESTICIDE HAZARDS

We do not have any statistics available as to human intoxication from pesticides. There have been no recorded deaths due to pesticides. Occasionally, Family Island farmers have complained of experiencing nausea or dizziness after spraying. However, they have never sought medical aid.

In general farmers tend not to use safety precautions when mixing and applying chemicals and may become over-exposed. They do not use masks or gloves either. They do not understand that the chemicals can cause serious illness or death. This problem is seen mainly with the smaller, less educated farmers.

Disposal of containers and left over pesticide mixtures presents a serious problem. The ground water supply in some of the major farming islands is only three to five feet from the surface. As a result, any chemical that is put into the ground, or buried containers, have an excellent chance of contaminating the water system.

We also have the problem of making farmers follow the recommended time intervals between the last pesticide application and the harvest of a crop. We have had instances in which produce (in particular tomatoes) were offered for sale to the Government's Produce Exchange covered in a pesticide dust. The farmers obviously dusted just before harvesting.

These are serious problems faced by the Department of Agriculture. The use of pesticides in agriculture is increasing steadily as the farmers are becoming more modernized and business-like.

There is also the increasing problem of pests becoming resistant to pesticides and the farmers having to use even stronger chemicals to obtain control. For example, the cowpea *Curculio* has become totally resistant to Toxaphene. It destroys all plantings of black eye peas in certain areas, and can no longer be controlled by pesticides.

The spider mites of cassava are becoming increasingly resistant to Kelthane. At the beginning of the outbreak, we gain some control, but after a few sprayings the mites become uncontrollable.

The continuous use of Thiobenzole as a wormer resulted in the emergence of a resistant strain of *Haemonchus contortus*. Now, the different categories of worm medicines are used in rotation to prevent a re-occurrance of this problem.

PESTICIDE REGULATIONS

There are no Pesticide Acts or related legislation in force affecting pest control or pesticides. It is anticipated that some regulations will be issued by the Department of Agriculture. A committee has been formed to spearhead the establishment of regulations.

PESTICIDE ALTERNATIVES

Very little is being done with alternative control measures. Those practised are usually well known farm practices such as crop rotation to prevent build up of insects and diseases, crop sanitation, discing and ploughing fields that have been harvested, again to prevent build up of insects and diseases; and planting resistant varieties.

There have been attempts by the Ministry for biological control of insect pests. The first attempt – the control of citrus black fly by a parasite, *Prospaltella opulenta*, was very successful. Very little citrus black fly is seen in The Bahamas now, and when found it is usually highly parasitised.

Attempts were made to control the fall army worm by the egg parasite *Telenomus remus*. Several releases of the parasite were made, but the parasite was never able to establish itself. The farmers were still using pesticides on their corn crops, killing both the parasites and the army worms.

The use of *Bacillus thuringiensis* for the control of the cabbage lopper has been widely accepted by Bahamian farmers. It is also used for the control of the cassava horn worm.

EXTENSION AND EDUCATIONAL PROGRAMS

The Extension service is actively involved in Pest Control programs as part of the farming services provided by the Ministry.

The Extension service tries to anticipate the pest problems for each crop/livestock. The various control measures for each of the pest problems are considered. The best possible treatments (spraying or alternative measures) are recommended to farmers. The recommendations are made only after the Extension Officer has visited the area first hand to determine the sepcific problem(s), and its prevalence throughout the area.

When the pest problem was not anticipated, and is not well known, consultants from other countries (Florida, Caribbean) are brought in to diagnose the problem. Control measures are

then discussed for dissemination and implementation by the Extension Service.

Field days, demonstrations, radio programmes, the monthly farming newsletter are all used by the Extension service to educate the farmer on the methods of control for the crop and livestock pests. These means are also used to educate the farmer on pesticide safety.

THE AGROMEDICAL TEAM APPROACH

This will be organized at the same time as the pesticide regulations are developed.

Table 1 The major pests of livestock in the Bahamas

Pest	Livestock	Management Programme
Lice	Goats, Pigs & Sheep	Benzene hexachloride, Mange control by Purina
Tick (ear)	Goats & Sheep	Mange control by Purina Asuntol 50
Mange	Pigs	Mange control by Purina Benzoyl Benzoate
Nematodes	Pigs, Goats, Sheep and Cows	(Levamisole hydrochloride) Tramisol; Piperazine, Thiobenzole, Loxan
Warbles (found only in imported animals)	Cows	Ruelene
Scabies		Purina Mange Control Ascabiol + Benzoyl benzoate

Table 2 The major pests affecting agricultural crops in the Bahamas

Crop	Major Pests	Management Programmes	Trends
Corn	Spider Mites Armyworms Ear Worms Corn Blight	Kelthane Sevin and/or Lannate Dithane M-45 (every 3 days)	Lannate is mainly used. Very little fungicide.
Crucifers	Aphids Loopers Diamond back Black Rot	Malathion Dipel/Thuricide (every 5 days) Rotation	Dipel/Thuricide are mainly used.
Cucurbits	Cucumber Beetles Melon Worm Pickle Worm Downy Mildew Powdery Mildew	Sevin and/or Lannate Benlate Karathane, Dithane M-45 (every 3-5 days)	Insecticides and fungicides used regularly.

(Table 2 Continued)

Crop	Major Pests	Management Programmes	Trends
Okra	Powdery Mildew Aphids	No control practised Malathion only on young plants.	Almost no pesticide application.
Onions	Thrips Pink Root Blast	Malathion Bravo (every 5-7 days)	Insecticide and fungicide used in combination
Pigeon Peas	Pod Borers	No control practiced	
Peppers	Flea Beetles Cucumber Beetles Bacterial Spot Frog Eye Spot Early Blight	Sevin Dithane M-45 or Kocide 101 (every 5-7 days)	Mainly insecticides. Fungicides used only as needed.
Potatoes	Caterpillars Flea Beetles Cucumber Beetles Early Blight	Sevin Dithane M-45 (every 5 days)	Insecticides & fungicides used together.
Sweet Potatoes	Sweet Potato Weevil	Use of good planting material, rotation.	
Tomatoes	Caterpillars Flea Beetles Cucumber Beetles Early Blight	Sevin or Methoxychlor Dithane M-45 (every 5 days)	Insecticides and fungicides used together.
Cassava	Cassava Horn Worm Spider Mites	Dipel/Thuricide Kelthane (every 5 days)	
Bananas	Banana Borer Moko Disease Sigatoka Leaf Spot	Nemacur is the only Pesticide applied here. Resistant varieties are being planted for disease problems.	
Citrus	Root Weevil Aphids Mites Scales Greasy Spot Melanose	Chlordane Malathion Kelthane Benlate or Kocide 101	Usually Malathion is used by the farmers with no other additive.

Table 3 List of Pesticides used in the Bahamas

Insecticides (1)	Fungicides
Bacillus thuringensis (B)	Benlate (C)
Chlordane (CH)	Bravo (MO)
Cygon (OP)	Captan (MO)
Diazinon (OP)	Dithane 278 (C)
Furadan (C)	Dithane M22 (C)
Karathane (MO)	Dithane M45 (C)
Kelthane (D)	
Lannate (C)	
Malathion (OP)	
Methoxychlor (D)	
Nemacur (OP)	
Sevin (C)	
Thimet (OP)	

(1) Includes Nematicides and Acaricides

Symbols for chemical classification:

C = Carbamates
OP = Organophosphate
CH = Chlorinated hydrocarbons
MO = Miscellaneous organic
D = Diphenyl compounds
I = Inorganic
B = Biological

3. BARBADOS

PEST AND PESTICIDE MANAGEMENT (HEALTH)

P. FOYE, W. BURNETT, C. BROWNE and A. SHEPPARD

RODENT CONTROL

The Pest Control Unit of the Ministry of Health and National Insurance is part of an overall Animal and Human Project. The aim of the programme is to control the diseases which can be transmitted from animal to man. This Unit deals with the control of rodents, i.e. rats and mice, the only rodents to be found in Barbados. The staff consists of one Chief Pest Control Officer, one Supervisor, one Driver and twelve Rodent Control Assistants.

The priority of this unit is to control rodents at all government places e.g. schools, school meals centres, police stations, agricultural stations, markets, slaughter houses etc; much attention is paid to the air and seaports. From time to time surveys are taken as well as block baiting at various places throughout the island that are known to be rodent infested. Bait is given to householders free of cost, approximately one kilogram per person.

THE PESTICIDES

The Pest Control Unit uses a variety of anticoagulant poisons and only one acute poison.

The anticoagulants and their active ingredients are:-

Racumin concentrate solid	(coumatetralyl)
Racumin concentrate liquid	(coumatetralyl)
Warfarin concentrate solid	(Warfarin)
Diphacin 120	(Sodium salts of diphacin)
The acute poison –	
Zinc phosphide	(Zinc phosphide)

During the period September 1979 to August 1980, the following poisons and the amounts were prepared, distributed and/or placed by members of this Unit at various homes and government buildings throughout Barbados.

Table 1. Rodenticides distributed in Barbados by Pest Control Unit, 1979-80

Racumin (Solid)	19 drums	of	25kg. each	475 kg
Racumin (Liquid)	9 drums	of	25 litres each	225 litres
Warfarin (Solid)	3 drums	of	50 lbs each	69 kg
Diphacin 120 (Solid)	3 drums	of	100 lbs each	135 kg
Zinc phosphide	500 grams			0.5 kg

Liquid bait is being used more and more at warehouses and food businesses. Good results are achieved, especially in places where drains, gutters etc. are free of water.

EDUCATIONAL PROGRAMMES

Attached to this unit is an Health Educator who is responsible for all health educational activities. The unit recognizes that in any educational programme, public awareness must be achieved and maintained. To this end, much work and effort is concentrated in this area, in order to motivate individuals and groups into the desired action necessary for controlling rodents in Barbados.

Following are some of the activities presently underway:-

1. Preparation and distribution of leaflets and posters.

ii. Preparation of radio spots.

iii. Providing information and technical know how in the preparation of slides for cinema and T.V.

iv. Talks to schools, groups etc.

v. Organising lectures at hotel schools.

vi. Organising community participation.

vii. Projection – finalising plans for the inclusion of rodent education at all primary schools.

MOSQUITO CONTROL

The Ministry of Health also operates a Mosquito *(Aedes aegypti)* Eradication Service. The major pests encountered by the Aedes staff are *Aedes* and *Culex* mosquitoes, and no mosquito finding is left unattended.

At present two insecticides are used by the Aedes Inspectors. These are: Baytex and Abate (tradenames) which are used extensively throughout the island. There is no evidence to prove that the *Aedes* Mosquito has built up any immunity against the Baytex insecticide.

The operations of this *Aedes* Unit include the spraying of approximately 2330 kg per year. Also disused tires are burned when no danger of fire is present. Well covers are hermetically sealed and traps to wells are checked.

In an effort to eliminate the breeding or potential breeding grounds for these mosquitoes, efforts are made to get householders to dispose of disused containers. Attention is paid to boats on beaches and disused or derelict vehicles. Educational programmes have apparently resulted in very limited success. The continued efforts of the *Aedes* Inspectors and the Public Health Inspectors (in terms of general sanitation) are required to keep the situation under control.

PESTICIDE REGULATIONS

The Pesticides Control Board is the primary regulatory body with respect to pesticides, and the health side of this Board is attended to by the Chief Medical Officer of Health who retains a permanent seat on the Board. The Chief Medical Officer has access to technical and medical information on pesticides that are supplied by concerned agencies like W.H.O. and the U.N. Programme's International Register of Potentially Toxic Chemicals (IRPIC). The Chief Medical Officer is the Barbados National Correspondent for IRPIC. No person may manufacture, import, store, use, distribute, sell or expose or offer for sale any pesticide other than a pesticide approved by the Board.

The Board requires that applications bearing particular information be submitted for necessary approval. Aspects relating to the chemical ingredients, their form, etc. must be accurately spelt out.

The toxic effects on the handlers of the pesticides, as well as the toxic effects on wild life, must be expressed. Methods of analysis must be identified and the effectiveness of the pesticide with regard to the climatic conditions in Barbados stated. The Board also considers labelling of the pesticides and authorises research relating to pesticides. The Board's approval extends for a three year period or less, as determined by certain factors, and the Board may withdraw its approval at any time if it becomes necessary in the interest of public health, the safety of domestic animals or the preservation of wild life. A licence issued by the Board is granted for the approved period after which renewal will be determined by the Board. The Board therefore has powerful authority to regulate the import, use, manufacture, etc. of pesticides. Table 2 lists pesticides that have been approved in Barbados, restricted for special use or conditions or banned.

The Ministry of Health does not have pesticides regulations per se, but deals with the manufacturing and waste disposal aspects, as well as Occupational Safety and Health functions under the umbrella of the Health Services Regulations and the Factories Bill. Special attention is given to applications for the establishment of pesticide-related businesses in Barbados. This includes manufacturing and formulation enterprises, and commercial pest control operations.

Required provisions include:

i. Cautionary placards that can be easily and conveniently read.

ii. Pre-employment physicals and periodic clinical test(s) as deemed necessary.

iii. Adequate working space — special consideration for rooms in which the pesticide is manufactured or manipulated.

iv. Adequate ventilation of any gases, vapours, dusts etc.

v. Proper flooring and working bench covering, such that they are smooth, impervious, easily maintained and cleaned.

vi. Suitable protective clothing and equipment.

vii. Strategic location of eye-wash faucets and industrial shower in case of any accidents.

viii. General welfare facilities, i.e. changing rooms, lockers, lunch rooms.

ix. Arrangements for the safe disposal of liquid and solid waste — industrial incinerators in certain cases.

GENERAL CONSIDERATIONS

The Environmental Engineering Division of the Ministry of Health is also active in the area of Occupational Safety and Health. The occupational hazards of work relating to pesticides are well documented. Care and special attention are required if such hazards are to be minimized or eliminated. Despite the provisions required during the construction or initial establishment stage, it is deemed necessary that continued monitoring of the operations be undertaken.

The correct use of pesticides, the wearing of protective equipment, the early identification of ill side-effects, all require continual attention. Laxity or disconcern on the part of pest control company managers/supervisors may well jeopardize the health of his workers and the public in general. It must be noted that these operations usually utilize pesticides that are only approved with restrictions. If highly hazardous pesticides such as **aldrin, dieldrin, pentachlorophenol, zinc phosphide** and **DDVP** are going to be used, then strict precautionary measures must be followed. The risk associated with the long term exposure to such substances cannot be neglected. The workers must be educated in the proper handling and use of these pesticides, and protective policy rules established and enforced. Precautionary policies for such operations vary and there is need for more vigilance on the parts of government and the employers. Table 3 gives a breakdown of the large scale pest control operations in Barbados with respect to pesticides used, protective occupational health measures etc.

Another major concern of the Ministry of Health in connection with pesticide management, is the potential for the contamination of the ground-water resources so essential for health. Recommended standards have been developed by various national and international agencies, but even these are only quasi-protective with regards to long term consumption. The need for continued research in these matters is required. In the meantime, proper management of pest control and pesticide use operations must be carefully examined. The strict adherence by manufacturing firms to waste control practices authorized by the government's regulatory bodies is required. Sampling of the drinking water for the presence of pesticides must be undertaken and the situation assessed. Application dosages must be determined such that the precious drinking water remains safe and that periodic monitoring of the situation be undertaken to ensure that contamination of the ground water never occurs.

Pest and Pesticide Management must attend to certain health considerations. As more knowledge is gained and more awareness achieved, guideline policies must be reformulated. The existence of mankind and life in general depends on the careful management of our ecosystems. Pesticide use and pest control can be highly beneficial or highly disastrous. The Ministry of Health is attempting to ensure that it is highly beneficial.

Table 2 List of Pesticides approved by the Pesticides Control Board*

FULL APPROVAL

INSECTICIDES

A & P Ant and Roach Killer
A & P Bug Killer
A & P Flying Insect Killer
Actellic 50 EC
Adios
Airborne
Aircraft Insecticide Spray
Albolineum
Allethrin (Pymanin)
Ambush 50 EC
Ars Brand Mat
Ars Brand Mosquito Coil
Ars Non Gas Spray
Asuntol 50 WP
Attack (Jeyes)

Basudin 60 EC and 40 WP
Banish
Banish II
Baygon (Technical Propoxur 96%)
Baygon Cockroach Bait
Baygon Dust
Baygon EC 20
Baygon Fly Bait
Baygon Spray
Baytex 50 EC
Baytex 1000 EC
Baytex 40 WP
Belmark
Bercotox
Bio-Spray Day
Bird Protector
Birlane
Black Flag Ant and Roach Killer
Black Flag Flying Insect Killer
Black Flag Multi-Action Killer
Blitz
Blitzem
Bob-Martin Insect Powder
Bob-Martin Pestroy Aerosol
Bolt Roach Bait
Bomber
British Airways Flying Insect Killer
British Airways Single Shot Aerosol
Bromophos
Black Flag Triple-Action Bug Killer

C. 10.20 Oil Concentrate
Chlordane 5% Dust
Chlordane 10% Dust
Chlordane 4 EC
Chlordane 8 EC
Chlordane Technical (Liquid)
Chlordane Worm Killer (Murphy)
Chlordane Gel
Cidial 50 L
Ciodrin
Cooper Flykiller
Cooper Roach Killer
Cooper Strike Aerosol
Cooper WP
Crawl-Tox Pressurised
Crop Saver
Cygon

Danex
Danex 50 EC
Decis
Derris Dust (Murphy)
DFO-Concentrate 10/20
Diazol (Diazinon) Diazinon 60 E
Dibrom 14 Concentrate
Dibrom 8 Emulsive
Dipel
Dipterex SP 95
Dowfume MC2

Fenitrothion Wettable Powder 40%
Fentro
Ficam W
Finis
Fish Mosquito Coil
Flea and Tick Dip
Flea and Tick Powder
Flick Ants and Roach Killer
Flick Bugs and Dog Spray
Flick Chlordane
Flick DFO Concentrate 25%
Flick Fly Bait
Flick Mosquito Coils
Flick Nutrax and Mosquito Spray
Flick P.B. Powder
Flick Raider Aerosol

*Quoted from Alleyne EM (1970), Safety Guide for Pesticide Users: Bull No. 2, Ministry of Agriculture, Barbados.

Flick Rid Comps
Flick Roach Fumes
Flick Smoke Generator
Flick Termite Powder
Flick Tick and Flea Powder
Flick Timbex
Flick Trax 50 EC
Flick Trax 100 EC
Flit
Floret Fly Killer
Flyol
Flypel Gel
Flytox
Folithion EC 50
Folithion 1000 EC
Fumasol A
Fundal 500 EC

Galecron 50 EC
Gammatox
Gamma BHC Dust (Murphy)
Gammalin 20
Gammexane Smoke Generator 25
Gardona
Geisler Lice Powder
Green Cross Fruit Tree and Garden Spray
Green Cross Golden Decot Fly Bait
Green Cross House and Garden Insect Blaster
Green Cross Slug Destroyer

Heptachlor 2 EC and 3 EC
Heptachlor 5% G
Hexyl Plus
Hosathion
Hot Shot Fly and Mosquito Killer
Hot Shot Roach and Ant Killer
Hot Shot Roach and Bug Killer
Hot Shot Roach Hives

ICI Aerosol Insect Spray
Insect Repellent (612 Plus) (Aerosol)
Insect Repellent (612 Plus) (Liquid)
Insect Repellent (612 Plus) (Waxy Stick)
Insecticidal Spray Polish
Insecticidal Wax Polish
Iodofenphos 50% WP

Katori Mat (Super Mat)
Kelthane EC
Killmaster
Kilval
Kik Repellent
Kincho Mat Electric Destroyer
King Brand Mosquito Repellent Mat

Leopard Mosquito Coil
Lexect
Liminate – R – Brand Residual Insecticide
Lindane Smoke Generators
Long Life (Jeyes) (Disinfectant/Detergent/Insecticide)
Lion Brand Mat
Lion Mat
Liquid Ant Killer

Mafu Spray
Maladrex 57
Malathion
Malathion Dust Puffer Packs
Malathion Dust Greenfly Killer
Malathion ULV & 57
Mal-Kill
Marine Insectrol
Marlate
Mesurol Snail Pellets
Metaldehyde
Metaldehyde Slug Killer
Metasystox 25 EC
Metasystox R
Metasystox RLC 50
Methoxychlor 3 EC
Mighty Killer Insecticide
Mitigan 42 EC
Mocap 10G
Moon Tiger Mosquito Coils
Moth Balls
Moth Preofer Aerosol
Murfume Lindane Smoke Pellets
Murphy Chlordane Worm Killer
Murphy Combined Pest and Disease Spray
Murphy Derris Dust
Murphy Gemma Puffers
Murphy Malathion 4% Dust
Murphy Sevin Dust
Murphy Systemic Insecticide

Nemacur 5% and 10% G
Nemagon
Nogos 50 EC
No-Roach Aerosol
Nutrax

Off Insect Repellent
Orthene 75 SP
Orthene Insect Spray
Ortho Bug Geta Snail & Slug Pellets
Ortho Diazinon Granules
Ortho Diazinon Insect Spray
Ortho Diazinon Soil and Foliage Dust
Ortho Home and Garden Insect Killer
Ortho Household Insect Control
Ortho House Plant Insect Spray
Ortho Indoor Plant Insect Spray
Ortho Klor 44 Chlordane Spray
Ortho Liquid Sevin
Ortho Malathion 50 Spray
Ortho Orthene Insect Spray
Ortho Pest-B-Gon Insect Bait
Ortho Systemic Rose and Flower Care Spray
Ortho Tomato and Vegetable Insect Spray

Padan 50 SP
"Peacock" Brand Anti-Mosquito Coils
Perfekthion
Pestmaster 98% and 100%
Phosdrin
6.12 Plus Insect Repellent Liquid
6.12 Plus Insect Repellent Spray

6.12 Plus Insect Repellent Stick
Pulvex Anti-Flea Dog Collar
Pulvex Beauty Shampoo
Pulvex Dog Wash
Pulvex Flea and Tick Spray
Pulvex Flea Soap
Pulvex 6-Use Dog Soap
Pulvex Zema Dip
Purina Dairy Spray
Purina Dog Powder
Purina Dog Spray
Purina Dusting Powder (Poultry)
Purina Face and Horsefly Bomb
Purina Fly Bait
Purina Home Insect Spray
Purina House Spray
Purina Insecticide Mist
Purina Mange Control
Purina Rub-on Insecticide
Purina Wound Protector
Pybuthrin 33
Pybuthrin 44
Pyrenone Malathion Safeticide Residual Spray
Pyrethrin

Quick Kill

Raid Ant and Roach Killer
Raid Flying Insect Killer
Ravyon 40 EC and ULV
Rawleigh Ant and Roach Killer
Real-Kill Ant & Roach Killer
Real-Kill Flying Insect Killer
Refined Naphthalene Balls
Regiment Insecticide
Rentokil Insectrol Spray
Rentokil Preservative for Wood – Brown
Rentokil Preservative for Wood – Clear
Rentokil Preservative for Wood – Green
Rentokil Termite Fluid
Rentokil Tick & Flea Powder
Rentokil Timber Fluid Concentrate
Rentokil Woodworm Fluid
Rogor

Safeticide Brand Aerosol Insecticide
Safeticide Brand Insecticide
Safeticide Conc. Brand Insecticide
Safeticide Residual
Safeticide Residual Spray (Pyrenone Malathion)
Sevin Dust (Murphy)
Sevin 5% and 8%
Shellgard Dog Bands
Shelltox Aerosol
Shelltox And & Roach Killer
Shelltox Flykiller Strip
Shelltox Liquid (with vapona)
Skram Insect Repellent
Skram Pressurised Insect Repellent
Slugex Pellets
Slug Gard
Slug Mini Pellets
Slugit Liquid (Murphy)
Slugit Pellets (Murphy)

Solignum Architectural
Solignum Builders Green
Solignum Coloured
Solignum Colourless
Solignum Exterior Brown
Solignum Fensol
Solignum Green Horticultural
Solignum Oak Interior
Solignum Red Cedar
Solignum Woodbeetle Killer
Solignum Wood Preservative
Spray It Fly Killer
Spic 5G (Slug Bait)
Sprigone Aerosol Spray
Springtime Insecticide
Star Tiger
Stanley Moth Cake
Sumithion 50 EC
Supa Bug
Supakil
Supa Swat
Supona
Surecide 25 EC
Sure Shot Insect Killer
System
Systoate 40

Tantoo Repellent (Liquid)
Teak Oil
Texaco Spray Insecticide
Thiodan
Thionex.
Tick Killer
Tiovel
Trichlorphon
Triona (White Oil Spray)
Topgard Systemic Liquid
Toprose Systemic Spray
Turbair Flydown
Turbair Kilsect
Turbair Lindane
Turbair Systemic

Vape Mat
Vapo Bombs
Vapona EC
Vapona Fogging Cone
Volaton
6-VSC Dog Soap

Whitmir P-T-140
Wolman Salts CCA-C
Woodtreat 55
Yates Carbaryl
Yates Maldison
Yates Pest Master
Yates Tomato Dust

HERBICIDES

Actril
Afalon
Alg – X (Algaecide)
Ametrex
Amex – 820
Amiben
Amine 2, 4-D
Amine Solution 2, 4-D
Amizine
Ansar 529 HC
Asulox
Atlavar
Atranex
Atrazine 80 W

Banvel D
Banvel – DE
Basafon
Basagran
Broadside
Butoxone

Candex
Candex 70
Cotoran

Daconate
Dacthal W-75
Dalapon
DEF 6
Diphen
Diurex Di-on
Diuron WP
Dowpon M
Dymid 80% WP

Enide 50 W

Fernasan 75 W

Gesagard 50 WP
Gesapax 500 FW
Gesapax 80 WP
Gesapax Combi 500 FW
Gesapax Combi 80 WP
Gesaprim 500 FW
Gesaprim 80 WP
Gramevin
Gramoxone
Green Cross Estemine 2, 4-D

Hyvar X

Igran 500 FW
Isospontox

Karmex

Lasso
Lawn Weedkiller

Nata TCA

Ortho Brush Killer Spray
Ortho Contax Weed and Grass Killer
Ortho Garden Weed Preventer
Ortho Spot Weed & Grass Killer
Ortho Troix Liquid Vegetation Killer

Parachem 25
Patoran WP
Perflan 80 WP
Pesco 18-15
Phytar 560
Planavin
Preforan 30 EC
Pyramin

Reglone
Ronstar
Roundup

Surflan 75 WP

Tordon 472
Treflan EC

U 46 D Fluid

Varitox
Vegatrol A – 4T
Velpar

Weedar Amine
Weedar 2, 4, 5-T
Weedar 64
Weedar 96
Weedazol
Weed-Ex
Weed-Hoe
Weedol
Weedkiller W
Weed Preventer (Green Cross)

FUNGICIDES

Afugan
Antracol WP 70
Aretan 6

Benlate
Botrilex

Brassicol
Bravo 6F
Bravo 500
Bronocot

Calixin
Captan

Captan 50 WP
Cupravit Blue

Daconil
Difolaton 4F (Ortho)
Dithane M-45
Dyrene

Kocide 101

Manzate D
Manzate 200 (Maneb)

Orthocide
Orthocide 50

Pelt 44 (Liquid)
Pelt 44 WP

Peltar (Liquid)
Perenox

Rose Mildew Specific (Murphy)

Super Moss and Lawn Killer

That Flowable Sulfur
Tinestan 60 WP
Top Cop
Turbair Copper
Turbair Maneb

Wood Preservative (Shell)

Yates Fruit Tree Spray
Yates Maneb
Yates Zineb

RODENTICIDES

Alphakil Rodent Bait
Bolt Rodenticidal
Dee-Rat Concentrate
Diphacin 120 Concentrate
Drat (Liquid)
Drat (Oily Solution)
Flick Rat Blox
Flick Rat Cakes
Flick Rat and Mouse Bait
Flick W.B. 840
Hot Shot Rat and Mouse Pellets
Mouse Dust Lindane 50%
Prolin Rat and Mouse Killer
Purina Rat Control Pellets
Purina Rat Kill (Pellets)
Purina Rat Kill (Powder)
Racumin Liquid
Racumin Ready Made Bait
Racumin Tracking Powder
Ramik and Ramik Green

Ramik Throw Packs
Rat and Mouse Cakes
Ratak
Rat Killer Ars (formerly Dethmor)
Rodine 'C'
Rodine Biotrol Concentrate
Rodine Biotrol Rat Bait
Rodine Warfarin
Rodine Warfarin (Liquid)
Rozol
Shurkill
SMCP Zinc Phosphide
Sorexa – C – R
Vacor Rat Killer
Warfarin
Warfarin 1%
Warfarin Rat & Mouse Bait
Zinc Phosphide
Zinc Phosphide 25%

APPROVED – WITH RESTRICTION

INSECTICIDES

Aldrin
(Soil-use only)
Arkotine D18
(For onions only)
DDT 25% EC
(For onions only)
DDVP Technical
Dieldrin
(Restricted to Pest Control Operators only)

Furadan 50 and 10G
(No re-packaging)
Lannate
Lannate L
Nogos
Phostoxin
(Restricted to Commercial Pest Control Operators only)
Phosvel 3 EC

FUNGICIDES

Polyoxin
(For experimental trials — six months)

HERBICIDES

Gramoxone
(Not to be repackaged)
Mill-Quat
(To be sold in Manufacturer's original container)

Reglone
(Not to be rebottled)

BANNED CHEMICALS

INSECTICIDES

Azodrin
Bromadiolone (Maki)
Endrin
E:P:N:
Furadan 4F
Tamaron
Vydate L
Weedone
Weedone 64 Brushkiller
Weedone 2,4, 5-T

HERBICIDES

Ramrod

Table 3 Pesticide Operators — Occupational Safety and Health Consideration

Early Bird Co.

Type of Operations (% distribution)	Chemicals Used	No. of Staff	Protective Equipment
Termite Control (50%) Building pre-treatment (30%) Other Pest Control (20%)	Malathion Baygon Chlordane Aldrin Kerosene	6 Males	Overalls Masks Respirators Helmets Gloves provided for all staff
Medical Examination	**Occupational Illnesses**	**Training Programme**	**General Comments**
Periodic medicals done for cholinesterase	No known cases of Occupational illnesses	Inservice Training	Need for worker awareness about use of chemicals and protective equipment Results of medical exams should be checked by M.O.H.

Flick Pest Control

Type of Operations (% distribution)	Chemicals Used	No. of Staff	Protective Equipment
Termite control (33%) Building pre-treatment (17%) Rodent control (50%)	Chlordane Baygon Diazinon, D.D.V.P. Zinc Phosphide Arsenic Dieldrin Methyl bromide Warfarin Chloro-phacinone	27 Males	Overalls Boots Gloves Respirators Safety guards provided for all staff
Medical Examination	**Occupational Illnesses**	**Training Programme**	**General Comments**
No medicals done routinely but on request	No known cases of Occupational illnesses	Inservice Training	Medical examinations should be done; workers should use protective equipment provided. Training programme should expand to bring about worker safety awareness.

Rentokil Ltd.

Type of Operation % Distribution	Chemicals Used	No. of Staff	Protective Equipment
Termite Control (25%) Building pre-treatment (15%) Rodent control (60%)	Aldrin, Baytex Dieldrin Penta chlora-phenol, Ficam Propoxur Diazinon, Zinc Phosphide Warfarin Malathion	30 Males	Gloves, Boots Respirators Goggles Overalls Safety Guards provided for all staff
Medical Examination	**Occupational Ilnesses**	**Training Programme**	**General Comments**
No medicals done	No known cases of occupational illnesses	Inservice Training films, etc.	Similar to Flick Pest Control

Parsons Ltd.

Type of Operations (% distribution)	Chemicals Used	No. of Staff	Protective Equipment
Termite control (50%) Building pre-treatment (33%) Rodent control (17%)	Chlordane Methylbromide Warfarin Hydroxy cum Diazinon D.D.V.P.	21 Males	Overalls Respirators Gloves Boots provided for all staff
Medical Examination	**Occupational Illnesses**	**Training Programme**	**General Comments**
No medicals done	No known cases of occupational illnesses	Inservice Training	Similar to Flick Pest Control

Ministry of Health, Aedes Aegypti Control Unit

Type of Operations (% distribution)	Chemicals Used	No. of Staff	Protective Equipment
Mosquito control (100%)	Baytex Powder Abate Malathion Baytex emulsion	93 Males	Overalls, Boots, gloves, respirators Provided for one dispenser (only)
Medical Examination	**Occupational Illnesses**	**Training Programme**	**General Comments**
Pre-employment and periodic medicals done for cholinesterase	One (1) case suspected dermatitis	Advice on safety by Senior staff members	Much training in safety should be given to workers of this organisation. Workers should be directed to use protective clothing provided.

Ministry of Health, Rodent Control Unit

Type of Operations (% distribution)	Chemicals Used	No. of Staff	Protective Equipment
Rodent control (100%)	Racumin (0.5%)	16 Males	Gloves, Respirators, Helmets, Overalls, Plastic aprons Provided for all staff
Medical Examinations	**Occupational Illnesses**	**Training Programme**	**General Comments**
No medicals done	No known cases of occupational illnesses	Expert training in rodent control, films etc.	This small operation could benefit from further training sessions on safety.

4. BARBADOS

PEST AND PESTICIDE MANAGEMENT (AGRICULTURE)

Dr. E. ALLEYNE

INTRODUCTION

For centuries, agriculture has been the major contribution to the Barbadian economy, with sugar cane being the only crop of economic importance. Few pests and diseases affect sugar cane locally and this feature and the fact that once planted, harvesting and ratooning of sugar cane occurs for 4 to 5 years before the plants are uprooted, has perhaps misled farmers into the belief that sugar cane cultivation typifies other crops. Few crops other than sugar cane were grown on a large scale prior to the 1960's in Barbados, although trials were conducted on many of them. The other major crops prior to this period were the root crops, yams, sweet potatoes and cassava. These were grown mainly on land which had been thrown out of sugar cane after completion of a 5 or 6-year cycle, and after one year, the field was again put into sugar cane. These crops filled the gap in the cycle and were therefore of limited economic importance. Although they were affected by many pests and diseases these did not cause undue alarm.

However, with the arrival of the second world war there was an acute shortage of food and Government attempted to alleviate this problem by passing the Food Production (Defence) Control Order in 1942. Under this law all owners of land were required to plant a minimum of 35% of their arable land in food crops, mainly yams, sweet potatoes and cassava. This resulted in a decline in sugar cultivation for 2 to 3 years, but once the war was over the situation returned to the pre-war state (Table 1).

Table 1: Estimated area (hectares) of Sugar cane reaped in years 1940 - 1955

Year	Area	Year	Area
1940	1638.3	1948	1609.2
1941	1636.1	1949	1607.5
1942	1627.9	1950	1669.7
1943	1518.6	1951	1741.7
*1944	1488.3	1952	1811.3
*1945	1495.4	1953	1861.9
1946	1622.9	1954	1872.1
1947	1636.8	1955	1865.7

*Decreases due to Food Production (Defence) Control Order 1942, No. 2

Vegetable production gathered momentum in the early 1960's. There is little doubt that the high cost of vegetable food imports, which seriously taxed foreign reserves, may have had some influence, but also contributing were the ever increasing scarcity of agricultural labour, high wages, and the presence of the local market of a wide range of new pesticides and pesticide application equipment.

As would be expected, this increase in vegetable production resulted in a corresponding decrease in both sugar cane and root crops production (Table 2). It will be noted that only half as many root crops were grown in 1979 as in 1970, while during the same period vegetable production tripled. There was also a sizeable decrease in the area under sugar cane.

Table 2: Estimated Area (in hectares) harvested by major Commodity Groups*

Commodity Groups	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
Root Crops											
Sweet potato	490.4	565	670.6	758.3	414.3	202.4	440.9	285	494.8	494.8	304
Yam	877	1229.1	1143.7	959.9	619	406.7	526.8	460.9	469.9	679.6	586
Total	1367.4	1794.1	1814.3	1718.2	1033.3	609.1	967.7	745.9	964.7	1174.4	890
Sugar	20437.0	20152.6	19730.8	17775.7	18751.4	16776.9	1611.3	15896.8	15861.5	15772.2	15887.7
Vegetables											
Beans (string)	77.6	58.3	89.1	83.4	85.8	97.2	75.3	93.1	97.2	106.2	89
Beets	14.2	14.2	16.2	24.3	20.4	25.1	24	22	23.7	25.4	33
Cabbage	24.3	36.0	48.6	72.5	68.5	93.1	85.4	73.4	116.6	97.2	144
Carrots	106.3	96.2	126.5	110.1	121.5	106.3	132.8	125.5	131.6	202.4	382
Cucumber	11.1	22.1	25.8	41.9	52.8	79.9	73.6	60.4	132.5	142.4	188
Onion	18.0	53.9	90.0	112.5	81.0	81.6	81.0	67.4	68.7	73.7	41
Tomato	71.0	69.6	81.4	87.2	109.9	97.6	99.1	100.2	86.0	161.9	157
Total	322.5	350.3	477.6	531.9	539.9	580.8	571.2	542.0	656.3	809.2	1094

*Source: Economic Planning Unit, Ministry of Agriculture, Food and Consumer Affairs

The diversity of agricultural crops presently cultivated brings with it concomitant pest and pesticide problems. This paper highlights the major pests and pesticides associated with agricultural crops in Barbados.

PESTS AND DISEASES

Sugar Cane

Sugar cane has been cultivated in Barbados for many years and much work has been done on the pests and diseases associated with it. The major insect pests are the sugar cane moth-borer, *Diatraea saccharalis;* the sugar cane root-borer, *Diaprepes abbreviatus;* and the brown hard back, *Clemora smithi.*

D. saccharalis has been the subject of extensive on-going biological control programmes for a period of close to 50 years. A wide range of insect parasites has been used in attempts to control this pest (Alam et al 1971, Alam 1980). In 1939 over 352 million adults of *Trichogramma fasciatum*, were reared and released in sugar cane fields throughout the island. Records indicate that insecticides have not been used to control *Diatraea.*

Although biological control was attempted with *D. abbreviatus* and *C. smithi*, many insecticides have been tested in an attempt to control these root-feeding pests. As early as 1910 badly infested sugar cane stools were fumigated with carbon disulphide and paradichlorobenzene but results were unsatisfactory. Another more extensive experiment was also conducted using carbon disulphide and slaked lime, solutions of potassium cyanide, carbon disulphide, Jeyes fluid, formalin and fusel oil in various strengths and quantities. Potassium cyanide, carbon disulphide and fusel oil gave very encouraging results in the limited areas tried (Anon 1910. Handpicking of *D. abbreviatus* adults was strongly recommended.

An entomologist joined the local Ministry of Agriculture in 1928 and more frequent and systematic insecticidal trials were conducted. D.D.T., Gammexane (BHC) and other chlorinated hydrocarbons were tested. Natural enemies were also bred and released.

In 1952 aldrin at 4.48 kg/ha and BHC dust were tried. In 1954 malathion and diazinon were tested (Anon 1955) but like all previous attempts at insecticidal control, results were generally disappointing. Since then *D. abbreviatus* has continued to inflict severe losses on the sugar cane industry, and new insecticides have been tested as soon as they are available locally in an effort to find at least one effective chemical, but so far soil treatments by all insecticides used have proved inadequate. Recently there has been a shift in the approach to the control of *D. abbreviatus.* Behavioural studies have indicated that adults congregate in large numbers on maize *(Zea mays)* primarily for mating, although sugar cane leaves seem to be the preferred oviposition sites. Experiments are being presently conducted in which small areas of maize are being planted within larger areas of sugar cane, in an attempt to attract adults of *D. abbreviatus* away from sugar cane to the more preferred maize, where contact insecticides can be used against them. Soil insecticides still continue to be the preferred method of control against these insects with carbofuran, chlordane and heptachlor being the most commonly used.

Few serious diseases affect sugar canes in Barbados. Mosaic disease was first recognised in Barbados in November 1920, but because of a very vigorous breeding programme, varieties have been selected which are resistant to this disease. In the mid 1960's leaf scald was discovered in sugar cane, but again resistant varieties have nullified the pest problem. As recently as 1979, sugar cane smut *(Ustilago scitaminea)* was discovered in Barbados, but fortunately almost all the varieties grown locally have proved resistant. Additionally, the West Indies Central Sugar Cane Breeding Station has employed a plant pathologist who has been working on fungicidal control. So far no encouraging results have been obtained (Whittle A.M. (1980). Sugar cane rust *(Puccinia melanocephala* (syn: *P. erianthi)* has also being identified but, like smut, is not expected to be a serious problem.

Rodents, particularly rats, *(Rattus* sp*)* have been pests of sugar cane for many decades and various types of baits have been used to control them. Rodent control was usually handled by the local Agricultural Society, based on the recommendations of the government entomologist. In the 1930's barium carbonate, red squill and thallium sulphate were used. At present 15 rodenticides are registered for local use, most of them containing anticoagulants.

Because of the shortage of agricultural labourers, control of weeds in sugar cane is mainly by herbicides. In 1938, the first large scale herbicide trial was conducted. It was set up to determine the effect of a thiocyanate compound and sodium chlorate against nutgrass, *Cyperus rotundus;* devil's grass, *Cynodon dactylon*, pond grass *Commelina elegans*, and "Red weed", *Portulaca halimoides*. The thiocyanate compound, called Aero Brand Weedkiller and manufactured by American Cyanamid and Chemical Corporation was applied at 358.4 kg and 716.8 kg/ha, while sodium chlorate was applied at 22.4 and 11.2 kg/ha. Although the thiocyanate compound gave superior control, it was not recommended because it was estimated to cost BDS$ 158.39/ha which was far more expensive than hand weeding (Anon 1938).

2, 4-D compounds have been used for many years and are still the most popular herbicides used in sugar cane weed control.

Root Crops

Yams

Next to sugar cane, yams have been the crop most widely cultivated (Table 2); although the area is steadily decreasing. It has been grown on plantations mainly in fields which have been thrown out of sugar canes. Few insect pests have been associated with this crop in Barbados.

The major problem has been the internal brown spotting desease, the causal agent of which is believed to be a virus. In 1965 it was estimated that 50% of yam shipments from Barbados were lost as a result of this disease, (Mantell & Haque, 1979). Recent research, (Mantell, et al 1979), has produced a rapid propagation system using tissue culture technique; and this has enabled disease-free progagative material to be produced.

Sweet potatoes

Like yams, sweet potatoes have been one of the favourite crops grown both on plantation land and on small holdings. Many leaf feeding caterpillars attack and often defoliate sweet potatoes. The major ones are *Alabama argillacea*, *Protoparce cingulata* and *Spodoptera sp.* A mixture of Paris green (0.45 kg) and lime (2.7 kg) was for many years the standard treatment against these insects (Anon 1931).

A far more serious pest is the West Indian sweet potato weevil, "Scarabee", *Euscepes postfasciatus*. This insect has no local recorded natural enemies and even two or three larvae in a tuber can affect the flavour to the extent that it becomes unfit for human consumption. Propagative cuttings (slips) are usually dipped in insecticides before planting.

Before the advent of chlordane, now the most commonly used insecticide on sweet potatoes locally, various oils and lead arsenate sprays were used as foliage sprays. DDT, chlordane and other chlorinated hydrocarbon insecticides have been used extensively both in foliage and soil treatments. Recent laboratory studies conducted by the Entomological Division of the local Ministry of Agriculture, indicate the *E. postfasciatus* has become very resistant to most of these pesticides. Because of this, emphasis is being placed on the testing of varieties in an effort to find those which possess resistant properties.

Cassava

Like yams and sweet potatoes, cassava has been grown in Barbados for a very long time. In 1942 a cassava factory was completed and cassava was processed both for human consumption and as animal feed. Cassava yields were low and the factory was forced to work far below its capacity and eventually to cease operation.

A few insect pests and mites are associated with cassava in Barbados, but the damage is never serious enough to merit insecticidal treatment.

Cotton

Cotton has been grown in Barbados since the middle of the sixteenth century. This crop flourished until the early 1920's when the pink bollworm, *Pectinophora gossypiella*, was acciden-

tally introduced (Ingram, 1980). Since then there has been considerable fluctuation, mainly attributed to the incidence of the pink bollworm. After not being grown for many years there was a revival in the early 1970's, but with a little more than 80.9 hectares cultivated in 1979-1980 as compared with 436.7 hectares in 1974-1975, the future of this crop is uncertain.

Besides the pink bollworm Ingram (1979) listed eleven other insect pests on cotton in the island. The leaf feeding caterpillars of the leaf worm *Alabama argillacea* and *Spodoptera* spp. were the most devastating.

P. gossypiella has resisted some of the best insecticides and present recommendations for control depend as heavily on a "close season" as on the use of insecticides. The "close season" was introduced in an attempt to eliminate pink bollworm during the period when cotton is not cultivated. This season runs from May 15th to August 15th every year and during this period all cotton, wild cotton and dried okras must be destroyed as these are alternate hosts of the pink bollworm. The rationale behind the close season is that during this period host plants will not be present and thus the insects would be starved to death. However, close seasons are not strictly observed and as a result high populations of pink bollworm adults are present and attack bolls very early.

Recently, attempts have been made to control this pest by using insect pheromones as attractants, as well as testing ULV and EC formulations of new insecticides. The synthetic pyrethroids have given very encouraging results. No major diseases affect cotton in Barbados.

Vegetables

Carrots

There are few insects which attack carrots and seldom does the damage done necessitate treatment. When such attacks occur one of the wide range of contact insecticides is used. There are, however, many serious disease problems; these include *Alternaria* and *Cercospora* leaf spots and southern blight *(Sclerotium rolfsii)*. For the two leaf spots chlorothalonil (Bravo, Daconil) and benomyl (Benlate) have been used extensively, while for soughern blight cultural control (deep plpughing) has been quite effective.

Tomatoes

Tomatoes have not been grown successfully during the wet season; July to November. During the remainder of the year farmers must be alert to the many insect pests and desease problems, and during fruiting to bird damage, which is perhaps the most serious of all the maladies. Recent studies conducted by the Entomological Division indicated as much as 80% bird damage in an irrigated tomato trial. The tomato hornworm, *Manduca quinquemaculata*, and leaf miners, *Liriomyza* spp., are perhaps the most common insect problems. In the 1930's these insects were controlled quite effectively by spraying with lead arsenate (1.2 kg lead arsenate per 100 litres of water). Four applications at about 10-day intervals were often necessary for control. Insecticides were changed as newer, more effective ones became available and for many years D.D.T. was the only insecticides used.

At present many of the new organophosphates, carbamates and synthetic pyrethroids are being used.

A number of diseases also affect locally grown tomatoes. Bacterial spot, tobacco and cucumber mosiac virus, green leaf spot *(Stemphylium)* and blossom end rot are the most common ones. The fungul and bacterial diseases are still adequately controlled by copper fungicides like cupric hydroxide (Kocide 101, Cupravit) at 2.80 kg/ha. These are now being alternated with mancozeb (Dithane M45) or propineb (Anthracol) at 1.68 kg/ha.

Onions

Experiments with onions began in the late nineteenth century. It was felt that, from trials conducted within the Ministry of Agriculture, onions could be grown as well in Barbados as anywhere else. However, little interest was being shown by farmers (Anon 1910).

In 1966, Jeffers and Gooding obtained yields of 15 tons per acre from a trial. Other trials were conducted in late 1966 and onion acreage has increased steadily ever since with commercial production starting in 1967 (Eavis and Jeffers 1970).

Initially, few pest problems were experienced but as the areas under onions increased so did the frequency and number of pest and disease problems. Onion thrips *(Thrips tabaci)*, which can cause severe losses, affect the plant when it is nearing maturity. The effect is often extremely dramatic with plants changing from green to brown in a day or two and dying two or three days later. D.D.T. has been used in the early stages (first 6 weeks) of the crop and this is the only crop for which this insecticide is registered locally. Methyl parathion and parathion, which were used in the late sixties and early seventies, have been banned by the local Pesticide Control Board. Recently the pyrethroids, permethrin (Ambush), decamethrin (Decis) and fenvalerate (Belmark) have been used in preference to D.D.T. These compounds have also given good control against the leaf miners. Occasional leaf feeders damage onions but these are easily controlled by contact insecticides.

Onion blast has long been recognised as perhaps the most serious problem in onions. Despite the more recent studies (Small, 1973, Lorbeer et al, 1974): the causal agent of this disease is still uncertain, although it is strongly believed that a combination of physiological as well as environmental factors could be significant contributors (Small, 1980, personal communication).

Besides blast, other diseases affect onions. The major ones are Fusarium basal rot, *(Fusarium solani)*, black mould *(Aspergillus niger)*, southern blight *(Sclerotium rolfsii)*, *Erwinia carotovora* and purple blotch, *Alternaria porri*. PCNB (Botrilex) is presently recommended as a soil treatment against *S. rolfsii*, while benomyl (Benlate), anilazine (Dyrene), chlorothalonil (Bravo, Daconil), triphenyltin acetate or mancozeb (Dithane M45) have been used in spray programmes with good results.

Weed control forms an important part of onion cultivation and it is the only crop besides sugar cane in which herbicides are used regularly. Pre-emergence herbicides DCPA (Dacthal W 75) and the post-emergence herbicide nitrofen (TOK 50W) are the two chemicals presently recommended.

Crucifers

Cabbage is the only member of this family that is grown on a large scale. It is a very popular crop and unlike onions, which is grown predominantly on plantations, is also grown by farmers with small holdings, as well as home gardeners. Despite the use of a large number of high yielding imported varieties, cabbage is subjected to pest and disease problems almost continuously. The predominant insect pest is the diamond-back moth, *Plutella xylostella*. More difficulty has been experienced in controlling this insect than any other pests attacking cabbage. Because of its feeding behaviour, many of the conventional sprays as presently applied do not reach the insects and this is mainly responsible for the long held belief that the insect is resistant to most of the available insecticides.

In 1976, seventeen insecticides, each at two different concentrations, were tested in field trials against *P. xylostella* and permethrin and fenvalerate gave excellent control (Alleyne 1976). Another very troublesome insect pest is the cabbage white butterfly, *Ascia monuste*, but this is controlled by most of the contact insecticides available locally, including those used against the diamond-back moth. Within recent years another insect which was never regarded as a serious pest has gained prominence. It is the cabbage budworm, *Hellula phidelialis*. Biological studies are now being conducted and control trials will be implemented shortly.

The most serious disease of crucifers is black rot. However, it is quite adequately controlled by a combination of cultural practices and hot water treatment of seeds. Leaf spots occur infrequently and control is obtained by using carbendazim (Benlate, Dersol, Mildothane) or chlorothalonil (Daconil), depending on the type of spots.

Cucurbits

Cucumbers are the most commonly grown of the cucurbits. A wide range of leaf feeding caterpillars attack this crop but these are controlled by malathion and many of the other common contact insecticides. Aphids are very fond of young leaves of cucurbits and although ladybird beetles are often present as well, control is seldom achieved. The insecticides used against the leaf feeding caterpillars also control these aphids.

Powdery mildew *(Erysiphe cichoracearum)* and downy mildew *(Pseudoperonospora cubensis)* are the major disease problems. Benomyl (Benlate), carbendazin (Derosal), Mildothane, or

pyrazophos (Afugan) control powdery mildew while anulazine (Dyrene) or mancozeb (Dithane M45, Manzate 200) are very effective against downy mildew.

Peanuts

Until recently, peanuts were grown almost exclusively by the small landowners. However, they are now grown by a few large farmers as well, and efforts are being made to further increase interest at the plantation level. The plant is attacked by loopers and other leaf-feeding lepidoptera, but carbaryl (Sevin), and fenitrothion (Folithion) have given very effective control. The red-necked peanut worm; *Stegasta bosqueella*, a major pest of peanuts in USA, was recorded for the first time on peanuts in Barbados in the early 1970's. Since then yearly surveys have been conducted to assess its level of infestation and results have indicated that the populations are relatively low. However, the situation is being closely monitored.

A more serious problem is the red-spider mite *Tetranychus* sp. This mite bronzes the leaf and either seriously reduces yields or kills the plant. Some of the systemic insecticides have been used to control it. Oxydemeton-methyl (Metasystox-R) is the one mainly used. Dicofol (Kelthane, Mitigan) an acaricide, is used as well.

Numerous diseases are associated with peanuts locally. These are:

(1) Damping off (various fungi)
(2) Crown rot *(Aspergillus niger)*
(3) Southern blight, *(Sclerotium rolfsii)*
(4) *Rhizoctonia* root rot
(5) *Pythium* root rot
(6) *Mycosphaerella* leaf spot, *(Mycosphaerella arachidis)*
(7) *Alternaria* leaf spot, *(Alternaria alternata)*
(8) *Cercospora* leaf spot, *(Cercosporidium personnatum)*
(9) *Diplodia* blight
(10) Rust, *(Puccinia arachidis)*

The chemicals used for the control of this complex of disease problems are captan, thiram, PCNB (Botrilex), fenaminosulf (Dexon), benomyl (Benlate), mancozeb (Dithane) and chlorothalonil (Daconil, Bravo).

Minor Crops

As would be expected in a predominantly agricultural society, many crops are grown. However, not many of these are of economic importance. These include beans, peppers, lettuce, eggplants, maize, okras, bananas, plantains, citrus, mangoes and several others. Because of the relatively small scale on which these are grown, and their limited economic importance, they are not considered for discussion on this occasion.

Livestock

Pests associated with livestock in Barbados have received very little detailed examination and most reported problems pertain to ticks and fleas. Cadogan and Atherley-Roberts (1980) conducted a survey of cattle, sheep, goats and a few other animals, and found that the Southern cattle tick, *Boophilus microplus*, was most common. Farmers know very little about the organisms, however, they will treat their animals once they see or suspect that the animals are being attacked. The most popular chemical used is carbaryl (Sevin) usually as a 5% dust. However, an 80% W.P. formulation of the same chemical is readily available and widely used in crop pest control, and farmers often use this formulation for both crop and animal pest control. Reports have been made of resistance by some ticks to this compound.

PESTICIDES

There has been a dramatic increase in the use of pesticides in Barbados during the last few decades. This can be largely attributed to increased vegetable production with its many pest and disease problems, and the scarcity of agricultural labour. Table 3 shows the total quantities of all pesticides (including aerosols and other household pesticides) imported between 1960-1967. The volume of pesticides imported increased by 54% during this period.

Table 3 Pesticides (including aerosols and other household sprays) imported into Barbados between 1960-1967*.

Year	Quantity (kg)	% increase over 1960 level
1960	198,266	-
1961	228,486	15.2
1962	256,405	29.3
1963	275,400	38.9
1964	287,002	44.8
1965	286,040	44.3
1966	302,331	52.5
1967	305,300	54.0

*Source: Economic Planning Unit, Ministry of Agriculture, Food and Consumer Affairs.

Between 1968 and 1979 figures were available for individual pesticide groups i.e. insecticides. rodenticides and molluscides etc, fungicides and herbicides. The total volume of these three categories (Table 4) show that the 1979 figure was just over 200% higher than the 1968 one. When the pesticide groups are examined individually it is observed that insecticides are by far the most widely used of all the pesticides and in 1979 the volume of insecticides was more than the combined volume of fungicides and herbicides.

Herbicides and fungicides usage increased dramatically in 1972 but the increase since then had been marginal until an upsurge in 1978.

There has been a decided shift in emphasis from the organochlorine compounds to the organophosphate, carbamates and synthetic pyrethroids. Many of the former compounds have been banned or their use severely restricted by the local Pesticide Control Board. For a full test of pesticides approved, approved with restrictions, or banned see Paper No. 3 in this volume (Foye et al.).

PESTICIDE HAZARDS

It is unfortunate that in a country where large volumes of pesticides are used, there is no pesticide monitoring system, neither are there residue tolerance limits placed on commodities for consumption. These are by no means the only problems associated with pesticide usage. Because of the predominance of sugar cane, in which few pesticides are used, Barbadian farmers have had very limited exposure to pesticides until a decade or so ago. The sudden interest in, and availability of pesticides, has been well ahead of educational programmes on spraying technique, toxicity and other pesticide areas. However, steps are being taken, although somewhat slowly, to acquaint pesticide users with such problems.

Associated with the sudden increase in pesticide usage, is the reported incidence of resistance by some pests. The most frequently reported are *P. xylostella*, the cabbage diamond back moth, and the West Indian sweet potato weevil, *E. postfasciatus*, but tests so far conducted have corroborated evidence of resistance in the latter insect only.

PESTICIDE REGULATION

A Pesticide Control Board was set up in 1973 to determine the suitability of all pesticides imported and sold in the island. Approval for importation or manufacture of a pesticide must be obtained from the Board. There are three subcommittees which are responsible for:-

(i) insecticides, rodenticides, molluscicides, acaricides, attractants etc.

(ii) weedicides

(iii) fungicides

Table 4: Imports of insecticides, Fungicides and Herbicides between 1968-1979*

	Insecticides		Fungicides		Herbicides		Total	
Year	Quantity (kg)	%increase over 1968 level	Quantity (kg)	% increase over 1968 level	Quantity (kg)	% increase over 1968 level	Quantity (kg)	% increase over 1968 level
1968	207,397	-	9,452	-	126,860	-	343,691	-
1969	303,345	46.3	11,599	22.7	233,893	84.4	548,837	59.7
1970	240,064	15.8	2,098	-	220,416	73.7	462,578	34.6
1971	242,642	17	6,695	-	203,879	60.7	453,216	31.9
1972	270,066	30.2	22,981	143.1	324,090	155.5	617,137	79.6
1973	277,872	34	11,941	26.3	282,833	122.9	572,646	66.6
1974	232,779	12.2	21,701	129.6	300,238	136.7	554,718	61.4
1975	311,302	50.1	20,826	120.3	245,852	93.8	577,980	58.5
1976	347,378	67.5	42,454	349.2	245,787	93.7	635,619	68.2
1977	387,241	86.7	9,252	-	286,815	126.1	683,308	84.9
1978	290,440	40.1	43,640	361.7	339,210	167.4	673,290	96.9
1979	605,642	192.0	30,549	223.2	399,587	215.0	1,035,778	201.4

*Source: Economic Planning Unit, Ministry of Agriculture, Food and Consumer Affairs.

The subcommittees consist of specialists in the particular pesticide discipline. Members are drawn from the Ministries of Agriculture and Health as well as from the University of the West Indies, Cave Hill Campus, Barbados. The Board functions under the following legislation:-

(i) The Pesticide Control ACt 1973-36 published as a supplement to the Official Gazette dated 16th August, 1973.

(ii) The pesticides control (Approval of Pesticides) Regulations 1974. Published as a supplement to the Official Gazette No. 2 dated 6th January, 1975.

(iii) The Pesticide Control (Labelling of Pesticides) Regulations 1976. Published as a supplement to the Official Gazette No. 45 dated 3rd June, 1976.

PESTICIDE ALTERNATIVES

Non-chemical control of pests and diseases has always been practised in Barbados. In fact it is only within the last 20 years or so that chemicals have been widely used here. The major crop on which nonchemical methods were pursued was, of course, sugar cane. *Diatraea saccharalis*, the sugar cane moth borer, has been the subject of a vigorous and continuous biological control programme lasting more than 50 years. Alam (1980) lists a number of parasites which has been tested over the years in trials. Of those insects examined *Trichogramma fasciatum*, *Apantales flavipes* and *Lixophaga diatraeae* have been well established and are performing quite satisfactorily. Alam et al. (1971) observed that because of the high parisitism by these insects, crop damage was reduced from 15% in 1966 to 6% in 1970. This is an ongoing programme and new parasites are continuously being evaluated.

Early attempts at controlling the sugar cane root borer, *Diaprepes abbreviatus*, by insecticides failed and cultural and other nonchemical methods were used. Hand-picking was one of the most popular ones used. Young boys were paid US$0.01 per pint for adult beetles. Between August 1911 and April 1912, 26,316,954 adults were caught with 17,492,893 of these caught in December alone (Anon 1913). In addition, the giant toad, *Bufo marinus*, which was introduced into Barbados in 1880 feeds on these beetles, was reared in a pond located at the local Ministry of Agriculture, and two other plantations. The toads were released in the field, but unfortunately this method was not very successful as the toads did not reproduce in sufficient numbers, nor did farmers cooperate.

A firefly, *Pyrophorus tumulosus*, which is quite well established locally is believed to be a predator of the larval stages of *D. abbreviatus* and *C. smithi*, but despite their numbers they seem to have very little effect on populations of pests.

More recently biological control programmes were widened in scope and studies were conducted to find parasites and/or predators capable of controlling the diamond back moth on cabbage (Munir 1973). So far an indigenous parasite *Apanteless sp*; and an exotic Braconid, *A. plutella* introduced into the island from India seem capable of controlling this insect pest. However, since cabbages are normally sprayed weekly with insecticides, the population levels of these parasites in the field have been subjected to severe insecticidal pressure.

Alam (1976, 1977) also attempted biological control programmes on nut grass, *C. rotundus*, but results obtained so far are inconclusive. A list of the endemic and exotic natural enemies of pests of sweet potatoes has been compiled but no assessment of their effects has been undertaken. Cadogan (1980) has investigated the biological control of the sooty mold complex on Barbados cherries *(Malphigia glabra)*.

The mongoose, *Herpestes sp.* was introduced into Barbados in the early 1900's to control snakes which were a problem at that time. Apparently the snakes have disappeared, the mongooses have increased in numbers and have themselves become a pest of poultry. In 1930 the local entomologist called for the intensification of the programme to eradicate the mongoose because it was destroying beneficial birds, lizards and frogs which are predators of many insect pests. He suggested that the bounty for the capture of a mongoose be increased.

EXTENSION AND EDUCATION PROGRAMMES

The Plant Protection Division of the local Ministry of Agriculture has always been in very close contact with extension services, providing information on pests and pesticides as they become available. This is accomplished in a number of ways ranging from field days to publications of literature. The plant protection specialists organise workshop sessions for extension officers, but few such workshops have been arranged for farmers although the officers of the Plant Protection Division are always available for advice. Radio and Television programmes assist in the dissemination of information. Radio programmes (2 or 3 times per week) offer the most up-to-date information, though television programmes are less frequent.

A number of publications have been released; Alleyne 1975, 1976, 1980 a, b, 1979 a, b; Cadogan 1980 a, b; Chandler et al. 1979 and Cadogan 1980, a, b in which pest problems and pesticides are discussed.

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5. BELIZE

PEST AND PESTICIDE MANAGEMENT

A. CAWICH and G. ROCHES

THE PESTS

The major insect, arachnid and rodent pests of crops, livestock, health and urban areas are listed in Table 1. The most economically important crops grown in Belize in 1976 were: **sugar-cane, maize, rice, citrus** and **beans.** These crops made up 96% of the approximately 110,000 acreas cultivated in that year. (Anon. 1976).

The froghopper *(Aneolamia postica jugata)* causes serious losses in **sugar cane.** These losses were estimated at 100,000-150,000 tons of cane during 1978 and 1979, despite substantial pesticide usage for its control (Cawich, 1979). Other pests include yellow aphids *(Sipha flava)* lacebugs *(Leptidictya tabida)* loopers *(Mocis latipes)* and rats *(Sigmodon hispidus).*

Substantial losses are also sustained in **maize** particularly due to the armyworm *(Spodoptera frugiperda),* the earworm *(Heliothis zea)* and the weevil *(Sitophilus zeamais).* Control of these pests are not entirely effective.

Considerable pesticide usage is required in **rice** to control the armyworm *(Spodoptera frugiperda),* which could cause total loss if left uncontrolled, and the chinch bug *(Mormidea pictiventris)* which could cause up to 15% loss if left uncontrolled (Scott, personal communication). Very good control of rice pests is practised except on small growers' land which accounted for some 18% of the 1976 rice crop (Anon., 1976).

Citrus is the second most valuable crop grown in Belize and, like sugar cane, most of the crop is exported to Europe. The most important pest of this crop is the Mexican fruit-fly, *Anastrepha ludens.* Mandatory control of this pest has been imposed by the Citrus Growers Association. The control programme consists of systematic treatment of the entire perimeter of orchards and spot treatment of trees within the orchard with ground sprayers. Good control is achieved with this programme (Sharp, personal communication). Another important problem is the parasitic vine *Struthanthus orbicularis* (Denham, 1979).

The most important pests of **beans** are: the bean beetle *Epilachna borealis* and the grain weevil, *Acanthoscelides obtectus.* The level of control achieved with these pests is not satisfactory.

Most pests found on other crops only occur occasionally, presumably due to the relatively small acreages cultivated. Some of these crops, particularly vegetables, could not be grown commercially without adequate chemical control of these pests.

In 1976, the cattle and pig population was reported at 48,900 and 18,000 head, respectively. These populations are considered low, (Anon. 1976). The most important pests affecting livestock production are ticks and the screworm fly *Callitroga americana* (Cooper, personal communication). The most common tick types found in Belize are *Amblyoma* spp. The beefworm, *Dematobia hominis,* is of importance in producing wounds which may subsequently become infected and/or affected by screworm larvae. The born fly *Lyperosia irritans* is of very little clinical significance. Routine control measures employed in Belize are generally inadequate and the use of tropically adapted, resistant breeds of cattle is therefore important. A screworm eradication programme is planned for the near future.

The vampire bat, *Desmodus rotundus,* is an important pest of localities which have suitable vampire bat habitats. A vampire bat control programme employing injections of diphenadione is available to farmers.

The most important public **health** and urban pests are: the malaria mosquitos *(Anopheles albimanus),* the yellow fever mosquitos *(Aedes aegypti),* the housefly *(Musca domestica)* and the cockroaches *Periplaneta americana* and *Blatella germanica.* Control of the malaria and yellow

fever mosquitos is undertaken by the Ministry of Health and is considered effective. Cockroaches are controlled by individual householders but the degree of control is not satisfactory.

Other pests such as the bed bug *(Cimex lectularius)* and lice *(Pediculus humanus* and *Pthirus pubis)* are also occasional pests which are generally properly controlled by individual householders.

Rats *(Rattus rattus)* and mice *(Mus musculus)* are serious house pests which cause substantial damage to food and household property. Subterramean termites *(Reticulitermes* sp.*)* and dry wood termites *(Kalotermes* sp.*)* cause substantial damage to buildings. Rodent and termite control are not generally satisfactory.

THE PESTICIDES

The list of insecticides used in 1979 is given in Table 2. Herbicides and fungicides have also been included for comparison. Similar amounts of insecticides and herbicides were used – 37 and 35 tonnes, respectively. Fungicide usage (28 tonnes) was lower than insecticide and herbicide usage.

Most of the insecticide was used to control froghoppers in sugarcane, and armyworms and chinch bugs in rice. Control of black sigatoka, *Mycosphaerella musicola* in bananas, accounted for most of the fungicide used. Considerable amounts (more than 1 tonne) of insecticides were also used for mosquito control *(Aedes aegypti* and *Anopheles albimanus)*, and on citrus, for control of Mexican Fruit-fly *(Anastrepha ludens)*. A large amount of insecticides of low formulation percentages (Aerosols and liquids) were also used against household pests.

Pesticides usage has been increasing and is expected to continue to increase as higher production is required. Acreages under cultivation and the use of fertiliser have been increasing, and is expected that pesticide usage will increase correspondingly. Already during 1980, on account of yield losses sustained in sugarcane due to froghopper and smut disease, *Ustilago scitaminea*, farmers have increased fertilizer and herbicide usage substantially to attempt to maintain production in the unaffected fields. The banana industry is also expanding and is expected to use more fungicides.

PESTICIDE HAZARDS AND REGULATIONS

No deaths have occurred in the areas where most of the spraying is done to control froghopper. However, one death has been reported from misuse of the household formulation of propoxur.

At least six deaths have occurred due to ingestion of paraquat over the last two years – voluntary ingestion in three cases and accidental ingestion in the three others.

Honey bees are seriously affected during August and September in the Northern Districts when spraying for froghopper control is conducted.

Only one case of development of resistance has been recorded. This was *Aedes aegypti* becoming resistant to DDT. Pirimiphos methyl is now used to control this pest.

There are no existing pesticides or plant protection acts affecting pest control and pesticide usage, thus, there is very little control on the purchase and usage of pesticides. Consequently, pesticides such as the highly toxic and long residual chlorinated hydrocarbons – Aldrin and Dieldrin – which are used for ant control in non-crop areas and for termite control, but are not recommended for use in vegetables or sugar cane, are, in fact, being used in these crops.

The availability of adequate application equipment and protective clothing as well as guidelines for their use, is limited. The hazard of intoxication, contamination of food stuffs, drift damage to livestock and crops, development of resistance and increase in importance of minor pests may, therefore, be expected to increase unless measures are taken to regulate the usage of pesticides, application equipment and protective clothing.

PESTICIDE ALTERNATIVES

Productivity per unit area is expected to increase as a consequence of the increase in produc-

tion costs, the decrease in the availability of new land and the impact of extension and education programmes. This increase is expected to be obtained through better cultural practices, thus cultural control is expected to play an important part in future pest control programmes.

Release of parasites for biological control in Belize has been reported by Bennett and Yaseen (1972) for two pests – the diamond-back moth *(Plutella xylostella)* and the mahogany shoot borer *(Hypsipyla grandella)*. A search was also conducted in the early seventies by the West African Station of the Commonwealth Institute of Biological Control for parasites of froghoppers for possible importation into Belize. The result was not encouraging.

The facilities and level of expertise available for research and extension with biological control, host plant resistance, and use of selective pesticides are limited. This will have to be improved in order to make a significant contribution to pest control programmes.

EXTENSION AND EDUCATION PROGRAMMES

The extension service is involved in pest control programmes, in an advisory capacity, and is directed to farmers, or in the case of health pests, to the public. However, cases of direct operational involvement occur in the control of vampire bats, *Desmodus rotundus*, and in the control of *Anopheles albimanus* and *Aedes aegypti*. Control programmes for these pests are planned, implemented and supervised by independent bodies and not the affected individuals.

Further involvement along the same lines with other pests would probably yield better control than is at present achieved in most crops and livestock, especially those which involved numerous small producers. This approach would also facilitate the study and implementation of alternative control measures, particularly the development of resistant varieties and biological control.

AGROMEDICAL TEAM APPROACH

A Pesticide Control Committee was formed in early March 1975, under the chairmanship of the Chief Medical Officer. This committee consisted of two representatives of the Ministry of Health, two representatives from the Ministry of Agriculture and two representatives from the private sector.

The objective was to consider and make recommendations on the regulations necessary for the proper handling and usage of pesticides in Belize. The committee met and made recommendations at the end of March 1975. It has not held another meeting since that time.

With the increase in pesticide usage which has occurred since 1975, it is now essential that this committee be revived and become functional in determining the pesticides that may be used on the various crops, who may use specific pesticides – especially the more toxic and or long residual chemicals, and what equipment and protective clothing must be used. This committee could also set guidelines for research to be conducted to ensure that the most selective chemicals are used to control a particular pest, and to monitor the development of insect resistance to pesticides.

Table 1. Major insect, arachind and rodent pests of crops, livestock, health and urban areas of Belize.

CROPS	PESTS	MAIN CONTROL MEASURE
Export Crops		
Sugarcane	*Aeneolamia postica jugata*	Chemical
	Sipha flava	Biological
	Leptodictya tabida	Biological
	Diatrea spp.	Biological
	Mocis latipes	Biological
	Sigmodon hispidus	Biological
Citrus	*Anastrepha ludens*	Chemical
	Expothalmus vitticolis	Biological
	Loxa spp.	Biological
	Atta spp.	Biological
Bananas	*Cosmopolites sordidus*	Biological
Honey	*Galleria mellonella*	Cultural
Papaya	*Toxotrypana curvicaudata*	Chemical
Mangoes	*Anastrepha spp.*	Chemical
Food Crops		
Rice	*Spodoptera frugiperda*	Chemical
	Rupella albinella	Chemical
	Sogata spp.	Chemical
	Mormidea pictiventris	Chemical
Maize	*Spodoptera frugiperda*	Chemical
	Diatrea lineolata	Cultural
	Diabrotica balteata	Chemical
	Heliothis zea	Chemical
	Sitophilus zeamais	Chemical
Beans	*Epilachna borealis*	Chemical
	Empoasca spp.	Chemical
	Acanthoscelides obtectus	Chemical
Ground Nuts	*Diabrotica* spp.	Chemical
Coconuts	*Rhyncophorus palmarum*	Chemical
Vegetables	*Heliothis zea*	Chemical
	Liriomyza spp.	"
	Myzus persicae	"
	Plutella xylostella	"
	Diabrotica spp.	"
	Pieris rapae	"
	Phyllotreta spp.	"
	Empossca spp.	"
Root Crops	*Cylas formicarius*	
ANIMALS	**PESTS**	
Cattle, Sheep & Horses	Ticks -	
	Amblyomma spp.	
	Anocentor nitens	

(Table 1 Continued)

ANIMALS	PESTS	MAIN CONTROL MEASURE
	Boophilus microplus *Ixodes affinis* *Haemophysalis juxtarochi* *Rhipicephalus sanguineus*	
	Mites - *Psoroptes* spp.	
	Insects - *Musca* spp. *Stomoxys calcitrans* *Haematobia stimulans* *Lyperosia irritans* *Callitroga americana* *Dermatobia hominis* *Tabanus* spp. *Haematopota pluvialis* *Anopheles albimanus* *Culex fatigans* *Aedes aegypti* *Phlebotomus* sp. *Solenopotes* sp. *Linognatus* spp. *Haemotopinus* spp. *Damalinia* spp.	
Swine	*Haematopinus suis* *Sarcoptes* sp.	
Poultry	*Cnemidocoptes mutans*	
Pet Animals	*Haemophsalis juxtarochi* *Rhipicephalus sanguineus* *Ctenocephalides canis* *Linognathus* sp. *Cerratophylus* sp.	
HEALTH AND URBAN PESTS	*Anopheles albimanus* *Aedes aegypti* *Culex fatigans* *Periplaneta americana* *Blatella germanica* *Musca domestica* *Rattus rattus* *Mus musculus* *Cimex lectularius* *Pediculus humanus* *Pthirus pubis* *Reticulitermes* sp. *Kalotermes* sp. *Lyctus* sp.	

Table 2. List of Pesticides and approximate amounts used in Belize during 1979. (Sources: Hofius Limited – Automotive and Agricultural Division, Prosser Fertilizer and Agrotec Co. Ltd., James Brodie and Co. Ltd. – Agricultural Division, Shell Ltd., Banana Control Board.)

CHEMICAL	AMOUNTS USED active ingredient: metric tons	USE
HERBICIDES		
Broadleaf & Shrub Herbicides		
Bentazone	0.05	No information
Dicamba	0.01	Pastures
Ioxynil	0.20	Sugar cane
Picloram	0.20	Pastures
2-4-D amine	7.00	Sugar cane, corn, rice
2-4-D ester	2.00	Corn, sugar cane
2,4,5 - T	0.60	Pastures
	Total 10.06	
Selective Grass & Broadleaf Herbicides		
Alachlor	0.05	No information
Ametryne	4.10	Sugar cane
Asulam	0.12	Sugar cane
Atrazine	1.10	Maize, sugar cane
Dalapon	5.10	Sugar cane
Diuron	4.00	Fruitcrop, sugar cane
Hexazinone	0.50	Sugar cane
Linuron	0.01	No information
Propanil	4.80	Rice
	Total 19.83	
Non-Selective Herbicides		
Glyphosate	0.02	Roadways, drains
Paraquat	5.50	General
	Total 5.52	
INSECTICIDES		
Clorinated Hydrocarbon Insecticides		
Aldrin	1.16	Ants, termites
Chlordane	.04	Termites
DDT	2.00	Health
Dieldrin	.29	Termites,
Endrin	.08	Ants, termites,
Gamma-BHC	1.20	Lumber
Toxaphene	4.00	Rice insects
	Total 8.77	

(Table 2 Continued)

CHEMICAL	AMOUNTS USED active ingredient: metric tons	USE
Organo-Phosphorus Insecticides		
Coumaphos	0.15	Cattle
Diazinon	0.60	Health
Dichlorvos	0.60	Urban
Malathion	3.20	Sugar cane, citrus
Methamidophos	0.24	Sugar cane
Monocrotophos	0.36	Rice insects
Parathion	0.02	Vegetables
Phoxim	0.28	Maize
Pirimiphos methy	1.20	Aedes aegyti
Trichlorphon	0.90	Corn, urban
	Total 7.53	
Carbamate Insecticides		
Bendiocarb	0.60	Mosquitos
Carbaryl	17.50	Sugar cane, vegetables
Methomyl	0.25	Mangoes, vegetables
Permethrin	0.05	Vegetables
Pirimicarb	0.13	Vegetables
Propoxur	2.30	Urban, sugar cane
	Total 20.83	
Synthetic Pyrethroids	0.05	Urban
Microbial Insecticides		
Bacillus thuringensis	0.07	Vegetables
Nematicides		
Carbofuran	0.03	
Ethoprophos	0.05	
	Total 0.08	
FUNGICIDES		
Benomyl	1.25	Bananas
Chlorothalonil	8.37	Bananas
Copper Sulphate	0.50	
Maneb	17.60	Bananas
Propineb	0.15	
Thiram	0.20	
	Total 28.07	
Anti-Coagulants		
Coumatetralyl	.10	Grains
Difenacoum	.30	Vegetables
	Total 0.40	

Total all pesticides 65.68 metric tons

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6. DOMINICA

PEST AND PESTICIDE MANAGEMENT

H. CLARENDON and J. HILL

I. AGRICULTURAL PEST CONTROL

1. THE PESTS AND PESTICIDES

In the past, that is up to 20 years ago, the pesticides which were used were fairly limited; citrus and bananas were sprayed, the chemicals used were Copper, Malathion and banana spraying oil, though a considerable number of pests have long been present (Table 1).

Vegetable farmers used little or no pesticides up to 7 years ago and even now there is still little use of chemicals for vegetables. During the past 5 years, only citrus and bananas have been regularly treated, the chemicals being Malathion, Copper, Albolineum, spray oil, Benlate, Nemagon, Furadan, Mocap. For the past two years, the awareness of chemicals has increased, but not always in the way we would like. Previously all chemicals were sold by the Division of Agriculture for use in accordance with its recommendations, though Sevin, Aldrex and rat poison were sold "over the counter". More are now being sold such as Murphy systemic, Dimethoate, Diazinon, Malthion, in addition to Sevin and rat poison. Tables 1 and 2 show the more important agricultural pests and the range of chemicals used in Dominica.

Most farmers are looking for insecticides to kill bugs, aphids and caterpillars. The range of chemicals has increased (Table 2) but most still goes through the Division of Agriculture (apart from chemicals used in the banana industry). Up till the end of 1979 the Division of Agriculture had full control over the retail of most chemicals, with one firm retailing Sevin and rat poison by the pound, while another retailed slug pellets, Slugit liquid, Malathion, Rogor and Aldrin. In 1980 another firm has started selling Diazinon and Tri-miltox forte.

Since Hurricane David there has been a tremendous upsurge in pests, including the Cabbage White butterfly, aphids, bugs, armyworms, corn ear worms, fruit worms, cabbage bud worm as well as fruit flies. There has been a large increase in the amount of many of the chemicals used during the year 1979-80 compared with the previous year, as shown in Table 3.

There was no restriction on the use of chemicals, no alternative measures were recommended at the time because of the great need to increase production and chemical control had to be relied on heavily. However, the dangers of the situation were realised and action to remedy it has been taken – see below. The pesticides currently actually offered for sale in Dominica are listed in Table 4, where they are listed under their chemical classification.

2.PESTICIDE HAZARDS

Few deaths have occured due to the improper handling of pesticides. There have been cases of over exposure among agricultural workers – but no direct medical evidence.

Over the past year (post hurricane David) there have been six recorded deaths due to Gramoxone, but deliberate in that it was taken intentionally. There were two cases of mishap due to incorrect labelling and poor storage.

There have been reports of water intakes being contaminated by pesticides, but no direct evidence. There was one case of fish poisoning in the north where the river was suspected to be contaminated with Mocap but again no direct evidence, and one case of a water supply being contaminated with Malathion.

There have been reports of borers developing resistance to Heptachlor, and of cutworms to organochlorines.

The Banana Growers Association is the biggest storer and supplier of chemicals. After the hurricane, this store room was broken down and chemicals washed out into the sea, but no

effect on sea life reported. Problems with banana spray oil contaminating the water supply and burning vegetables have been reported. There have been application problems with farmers using their hands to apply chemicals and spraying with the wind against them.

3. PESTICIDE REGULATIONS

There is a Pesticide Control Law, with a number of regulations covering registration, labelling, recommendations, storage, application, residues, worker exposure and environmental impact. There were few firms buying chemicals and storing them; the little that was brought in was circulated quickly so there was little storage problem. In fact, the Banana Growers Association and the Division of Agriculture were the biggest storers and handlers and thus there was no incentive to enforce the law.

The Pesticide Control Board should now be revived, and a Pesticide Inspector appointed, whose duty it will be to ensure that regulations are followed. An education programme is required to bring agents up to date with regulations and implementing them. The regulations do not cover retailing, but we think that no chemicals should be retailed without the authorised recommendation of the Division of Agriculture or a qualified agriculturalist.

At regular intervals fruits, and water from catchment areas, should be sent to CPCU for analysis; we need to use this facility much more than we have done in the past. In addition, both spraymen and workers handling chemicals should have regular annual (or more frequent) ups for signs of toxicity due to accumulation of residues in their bodies.

4. PESTICIDE ALTERNATIVES

Mr. Munir Alam, CARDI Entomologist visited Dominica at our request to help identify pest problems regarding injury level and the best control measures both in terms of biological control and selective pesticides.

A team from CDB involving Dr. Winston Small, Dr. Eslie Alleyne and Mr. Carol Reckord came to carry out seminar workshops on the island on disease and pest control. It seems evident that the Division requires more support from CARDI, UWI, CPCU and CIBC in setting up integrated control programmes on small farms, where mixed farming is normally practised. A coordinated effort is needed to bring about a balanced approach – wise and selective use of pesticides, effective biological control programmes measuring pesticide residue both in crop and environment as well, careful screening of chemicals which are tested under local conditions, and development of resistant varieties established in our environment.

5. EXTENSION AND EDUCATIONAL PROGRAMMES

It was noted above that until recently the use of pesticides, except by the Banana Growers' Association and Government, was small, but, since Hurricane David in 1979 the situation changed rapidly.

Since January 1980 the Division of Agriculture has had to take stock of the position, with the intention of reducing the sudden heavy reliance on chemicals. Seminars and radio programmes were organised to explain to farmers the dangers involved both to themselves and to the environment by excessive use of chemical control. The Division will continue to educate farmers to identify problems and about the alternatives to pesticide control – field sanitation, crop rotation, quarantine, using resistant varieties, proper land preparation, proper land use practices and other cultural techniques which promote good crop health and high yields.

6. AGROMEDICAL TEAM APPROACH

Doctors should be brought up to date on all chemicals on sale and in use on the island, especially their toxicity and treatments. With regular inspection and residue analysis in water and food, we will be obtaining a fair idea of the extent of accumulation of pesticide we are receiving both in our bodies and our environment. With the Pesticide Control Law really being put to use, both the agricultural, medical and public health sectors will be able to work together for the benefit of all.

II. PUBLIC HEALTH PEST CONTROL

Pest or vector control activities in Dominica started in 1932 when larvicidal work was introduced as a control measure using malariol. In 1947 residual spraying of houses was undertaken, using D.D.T. technical and wettable. These activities were instituted in an effort to control the density of mosquitoes, and in particular the *Anopheles asquasalis* mosquito, the vector of malaria in Dominica, and also the *Aedes aegypti*, the vector of yellow fever and dengue fever.

In the past two decades, there have been two anti-*Aedes aegypti* and one malaria eradication programmes. Both of the former failed to achieve their objectives as they were frequently interrupted and finally suspended due to inadequate funding. The malaria eradication programme was more successful and was terminated in 1966, since no more cases of the disease could be found at the time. During the duration of the two programmes mentioned earlier, the following insecticides were used: Baytex (fenthion), for perifocal and residual spraying of houses and refuse dumps; Abate (temephos) in water tanks, drums, artificial containers in and around dwellings. Larvicidal oils continued to be used in water bodies for mosquito control.

From 1970 to the present time vector control activities have been reduced to minimum routine measures operating along the following lines:-

(i) The use of larvicidal oils and insecticides on water bodies to control mosquito breeding.

(ii) Residual spraying of houses to destroy mosquitoes, flies and household pests.

(iii) Smokes and ULV space spraying for the control and destruction of flies, mosquitoes and other household pests.

(iv) The spraying of dumping grounds with insecticides against flies.

(v) Baiting of rats, and distribution of rat bait to individuals, with instructions for use.

(vi) Perifocal treatment around dwellings.

(vii) Treatment of water tanks, barrels, artificial containers.

(viii) Control of insects e.g. termites, roaches, bed-bugs, fleas, ants and ticks in the various public institutions and on private and public premises.

A full scale vector control programme has recently been proposed to replace the current routine measures, because of the threat of epidemics of malaria, yellow fever, dengue, typhoid, leptospirosis etc. Emphasis will be placed on the control of house flies and mosquitoes. The implementation of this programme in the next financial year will depend on the availability of funds.

The insecticides, and quantities used in the public health programme, are shown in Table 5 at the end of this paper.

TABLES

Table 1. Major Agricultural Pests in Dominica

Plants	
Trees	
Citrus –	Fiddler beetle, nematodes, slugs and snails, fruit flies, fruit moth, mites, scale, aphids.
Mangoes –	Moth, fruit flies.
Soursop –	Snow scale.
Guavas –	Fruit flies.
Bananas & Plantains –	Borers, slugs & snails, spider mites, nematodes, thrips.
Coconuts –	Scales, mites, borers, rats.
Cocoa –	Rats.
Coffee –	Leaf miners, pod borers, snow scale.
Vegetables	
Cabbage –	White butterfly caterpillar. Moth caterpillar. Looper, leaf miners, bud worm, cutworms, nematodes.
Tomatoes –	Aphids, bugs, mites, nematodes, borers, cutworms, leaf miners.
Corn –	Corn ear worm, leaf miners, looper, cutworm.
Carrots –	Nematodes, cutworms.
Lettuce –	Cutworms.
Spinach –	Caterpillars, leaf sticker, cutworms.
Cucurbits –	Melon worm, leaf miners, aphids, bugs, fruit worm, cutworm, army worm.
Green Peas –	Pod borers.
Passionfruit –	Army worms.
Watercress –	White butterfly caterpillar.
Eggplant –	Lace bug.
Beets –	Cutworms, leaf stickers.
Okra –	Bugs, aphids.
Christophene –	Bugs.
Sweet Pepper –	Mealy bugs, scale, aphids, bugs.
Celery, Parsley –	Cutworms, nematodes.

Livestock

Pests and the animals they infest

Pest	Animals affected
Ticks	Cows, sheep, goats, dogs.
Mites	Sheep, dogs.
Fleas	Dogs.
Lice	Poultry.

Table 2 Range of Pesticides used in Dominica

1960-1970	1970-1975	1975-1980
Albolineum	Albolineum	Ambush
Aldrex	Agroxone	Antracol
Banana Spray Oil	Aldrex	Benlate
Copper (Cobox, Perenox)	Antracol	Captan
Dithane	Banana spray oil	Chlordane
Dowpon	Chlordane	Copper (Nordox)
Gesapax	Copper (Nordox)	Cupravit
Gramoxone	Cupravit	Decis
Karmex	Diazinon	Diazinon
Malathion	Dieldrin	Difolatan
Metadex	Dimethoate	Dipel
Metasystox	Dipterex	Dimethoate
Rat Poison	Folithion	Dipterex
Reglone	Gesapax	Dithane
Rogor	Gramoxone	Furadan
Sevin	Heptachlor	Gramoxone
Simazine	Karmex	Heptachlor
2,4-D	Maneb	Hyvar
Zineb	Metasystox	Karathane
	Nemagon	Karmex
	Reglone	Kelthane
	Simazin	Malathion
	Slugit	Metasystox
	Terrachlor	Mocap
	Triona	Nemagon
	2,4-D	Peltis
	2,4,5-T	Primicid
		Racumin
		Sevin
		Sigma
		Slugit Pellets
		Slugit Liquid
		Supona
		Terrachlor
		Thiram
		Trimiltox forte
		Voltan
		Warfarin
		Weed Killer T

Table 3 Pesticides in Dominica

Amounts Used

Chemicals	1974-1975	1978-1979	1979-1980
Albolineum	10 gals.	-	-
Aldrex	100 lbs.	-	2 gals.
Ambush	-	-	3 gals.
Antracol	-	-	200 lbs.
Benlate	-	4,015 lbs.	6,074 lbs.
Captan	-	-	250 lbs.
Chlordane	-	35 gals.	35 gals.
Copper (based)	110 lbs.	660 lbs.	1,500 lbs.
Decis	-	½ gal.	2 gals.
Diazinon	-	10 gals.	10 gals.
Difolatan	1 gal.	5 gals.	115 gals.
Dipel	-	30 lbs.	20 lbs.
Dipterex	-	-	110 lbs.
Dithane	36 lbs.	48 lbs.	-
Furadan	-	110 lbs.	500 lbs.
Gramoxone	-	6,842 gals.	7,242 lbs.
Heptachlor	10 gals.	35 gals.	35 gals.
Hyvarx-X	-	200 lbs.	300 lbs.
Karathane	-	5 gals.	-
Karmex	-	318 lbs.	450 lbs.
Kelthane	-	5 gals.	-
Malathion	15 gals.	43 gals.	150 gals.
Metadex	15 lbs.	-	-
Mocap	-	7,033 lbs.	7,400 lbs.
Nemagon	5 gals.	-	-
Peltis	-	-	2,470 lbs.
Primicid	-	-	792 gals.
Rat Poison	140 lbs.	210 lbs.	3,000 lbs.
Sevin	220 lbs.	220 lbs.	220 lbs.
Slug Pellets	-	100 lbs.	2,200 lbs.
Supona	-	10 gals.	10 gals.
Terrachlor	-	80 lbs.	20 lbs.
Thiram	-	50 lbs.	50 lbs.
Triona	5 gals.	27 gals.	-

Total weight imported in 1979-80 = 20,010 kg

Table 4 Pesticides sold in Dominica

Organochlorlines	Carbamates	Organophosphates	Copper Compounds	Herbicides (Miscellaneous) Organic compounds	Metaldehyde
Aldrin	Antracol	Diazinon	Copper Nordox	Atrazine	Mesurol
Chlordane	Benlate	Dimethoate	Cupravit	Dowpon	Metadex
Dieldrin	Captan	Folithion	Neutral copper	Gesapax	Metaldehyde powder
Heptachlor	Dithane m 45	Malathion	Perenox	Gramoxone	Slugit liquid
	Furadan	Metasystox		Hyvar-X	Slug Pellet
	Peltis	Mocap		Karmex	
	Thiram			Linuron	
	Tri-miltox-forte			Reglone	
	Zineb			Simazine	
				2-4-D	
				2-4-5-T	

Table 5 List of Insecticides used during 1979 and for the nine months of 1980 in the Dominica Public Health Programme

Type of Insecticides	Quantity used
Abate (temephos)	118 lbs.
Baygon E.C. 20	5 quarts
Baytex (fenthion)	320 litres
Malathion 5%	60 quarts
Malathion 95%	220 quarts
Larvicidal oil	120 quarts
Rat bait	1 ton warfarin

7. DOMINICAN REPUBLIC

PEST AND PESTICIDE MANAGEMENT

JORGE VARGAS

INTRODUCTION

The Dominican Republic is located in the West Indies sharing its territory (the Island of Hispaniola) with the Republic of Haiti, and lies in a subtropical zone, being bordered on the north by the Atlantic Ocean and on the south by the Caribbean Sea. It has a land area of 48,000 km^2 and a population of about 5.5 million.

The economy is based primarily on agriculture, though industry and mining are also important. Although the country has some mountainous areas, (which are forested or in pasture and livestock), there are large flatland areas and valleys with both intensive and extensive agriculture, some being rainfed but substantial portions having irrigation. Part of the agricultural production is devoted to export crops, principally fresh vegetables and sugar cane products, such as sugar and molasses: these products are well accepted on the world markets, including the United States of America, Puerto Rico, Venezuela, and Europe.

PESTICIDES AND CROPS

The areas in which pesticides are used can be divided into four important crop-types:

A. – Rice producing zones

B. – Sugar cane producing zones

C. – Cotton producing zones

D. – Vegetable producing zones

Other minor categories would be leguminous crops, plantains, bananas, corn, and sorghum. Other crops not mentioned use little pesticides. In Table 2 (at end of paper) is a list of the pesticides most commonly used on the above mentioned crops. The value of imported pesticides is shown in Table 1 (below).

Table 1 Net value per year of Pesticide Imports from 1974 to 1979

Year	Value RD$(pesos)
1974	5,709,333
1975	7,060,835
1976	6,607,409
1977	7,766,439
1978	7,708,432
1979	9,756,602

The figures above include imports of the chlorinated hydrocarbons, Heptachlor and Endrin, which have reached as much as 100,000 kg with a value of RD$ 50,000 per year. In 1979 however, the importation of these pesticides was reduced considerably because of the restrictions imposed by the Plant Protection Division of the Secretary of State for Agriculture, and at the present time these products are sold only through the official stores of the Secretary of State for Agriculture, so that their distribution is strictly controlled.

PESTICIDE REGULATIONS

The Pesticide Registration Division is the official entity charged with enforcing regulations dealing with the importation, sale, and use of agricultural chemicals in the Dominican Republic. This division was formed by Public Law No. 311 on May 24, 1968, but it was not until Regulation No. 1390 was established for the application of Public law No. 311 on August 30, 1971 that the importation, sale, and use of pesticides was effectively regulated and organized. Because of the lack of a basic well organized structure the country suffered in the past from many problems in connection with the regulation and use of pesticides. The official organization for pesticide registration did not have laboratories, economic resources, and the technical personnel that was required, nor did the rural areas have adequate technical assistance. As a result of recent development in organisation the Pesticides Registration Division now has 5 technicians and 3 sections: Registration section, Testing section, and the Inspection section. These sections have the support of 20 technicians who are biologists, specialists in plant pathology and vertebrate pest control, and 60 field personnel. They also have the support of the Pesticide Rsearch Laboratory.

In addition to Public Law 311 and Regulation 1390, there is a resolution made by the Secretary of Agriculture on June 22, 1972, that prohibits the use of chlorinated hydrocarbons on certain crops (tobacco, potatoes, casava, sweet potato, yam, squash, dasheen, beets, carrots, celery, radish, garlic, onion, pepper, lettuce, strawberries, tomato, cucumber, eggplant, melons, watermelon, and grapes) and regulates the import, sale, and use of chlorinated hydrocarbons in the country.

PESTICIDE RESIDUE LABORATORY

The laboratory was inaugurated on December 15, 1978 and was created as a support unit for the Prevention and Management of Pesticides Program. At the present time, pesticide residues are analyzed for chlorinated hydrocarbons in vegetable products for export, edible oils, milk and its derivatives, eggs, human fat tissue; cholinesterese activity in human serum is also analyzed. By the end of 1981 it is expected that quality control analysis of pesticide formulations will be undertaken.

AERIAL PESTICIDE APPLICATION PROGRAM

This program has a total of 5 small aircraft and has been operated by the Plant Protection Division since 1978. A model installation is available for training the pilots and agricultural technicians in calibration and aerial application of pesticides, as well as an inspection unit for regulating these services, especially for private firms that operate some 45 planes in the country.

EXTENSION AND EDUCATIONAL PROGRAMMES

Training in pesticide management is given by qualified and experienced personnel of the Plant Protection division.

The subjects taught are:

1. **Agricultural pesticide toxicology**

   The chemical properties and toxicology of the pesticides used to control diseases and pests are described, and training is given on the dangers of these products to humans and animals as well as to the environment.

2. **Pesticide Formulations and their Interpretation**

   The way different pesticides are formulated for field use and pertinent label information are explained in this course.

3. **Prevention and Control of Pesticide Poisoning**

   This course gives instruction in how to prevent pesticide poisonings, and also how to manage and handle pesticides to avoid spills, leaks, and environmental contamination.

4. **Pesticide Management Security**

   How to manage pesticide use and storage at the field, store, and warehouse level.

5. **Use and calibration of pesticide application equipment**

   The proper use and care of pesticide application equipment is demonstrated.

6. **Public law 311 and its regulations and resolutions**

   The laws that govern the use and sale of pesticides are explained.

Through these courses agricultural technicians, farmers and store personnel have benefitted. The number of people who have taken the courses are as follows:

Secretariat of Agriculture technicians	80
Technicians from related institutions	75
Sales personnel	5
Agrarian Reform farmers	60
Total	220

It is estimated that for each person trained another 10 people will benefit; thus when a total of 220 have been trained, a total of 2,200 will have benefitted.

Also, discussions and talks on different aspects of the application of public law 311 have been given to technicians. Between 1978 and 1979 ten conferences on this subject have been given. Posters, bulletins, and pamphlets have been printed. With these materials technicians, businessmen, and farmers have been informed about the correct use of pesticides and the public has been informed about the amounts of pesticides imported.

FINAL CONSIDERATIONS

Finally, it should be pointed out that although much effort has been given to promote proper pesticide use, many problems still exist. Until recently it was common to see aerial application of Endrin, Aldrin, and other chlorinated hydrocarbons, especially in rice and cotton areas. This has changed, principally due to:

1. Restrictions established by Public Law 311 with regards to pesticide registration and sale.

2. The resolution by the Secretary of Agriculture restricting the sale of chlorinated hydrocarbons to government operated farm supply stores and then only by permission of government technicians.

3. The fact that registration status for these chemicals was not renewed in most cases; only when specific cases warranted it.

It is still very common for farmers to apply pesticides without proper protection in the form of gloves, head gear, face protection, gas masks, etc. nor do they observe the simple precautions of not smoking, eating or drinking while applying pesticides. Also, farmers do not observe proper time intervals for reentry into sprayed fields. However, as a result of radio programs, posters, conferences, training courses and education by other means, all of these improper practices have decreased.

Table 2. Most used pesticides and the crops on which they are used in the Dominican Republic

INSECTICIDES

Common Name	Commercial Name	Crops
aldicarb	Temik	Plantain, cotton
Bacillus thuringiensis	Thuricide HP Bactospeine, Dipel	Pasture, sugar cane fruit crops, tobacco
carbaryl, sevin	Carbaryl, Sevin	Rice, corn, pasture, casava
carbofuran	Furadan	Rice and plantains
DDVP	Nogos	House pests, stable pests
diazinon	Diazinon	House pests, pastures
dicrotophos	Carbicron, Bidrin	Gardening, fruit crops, vegetables (garlic, onions)
dimethoate	Sistemin, Cygon, Rogor, Perfektion	Coffee, cacao, potatoes, citrus, ornamentals
ethoprop	Mocap	Plantains, tobacco, pineapple, vegetables
malathion	Malathion	Vegetables, rice, pasture, fruit crops, ornamentals
methamidophos	Monitor	Vegetables, tobacco, fruit crops
methomyl	Lannate	Vegetables, tobacco, fruit crops
methyl parathion	Metil Paration, Partin	Rice
carbofuran	Furadan	Rice and plantains
pyrethrins (decametrina)	Decis	Cotton, vegetables rice

HERBICIDES

atrazine	Gesaprin 50	Corn
benomyl	Benlate 50 WP	Coffee, cacao, plantain, peanut
butachlor	Machete	Rice
copper oxychloride	Cuprvit 50 WP	Garlic, onion, beans, potatoes
diuron	Karmex 80 P.M. Diuron 80 Weburon	Coffee, cacao, sugar cane, potatoes, plantain, casava
kasugamycin	Kasumin 2% EC	Rice

(Table 2 Continued)

HERBICIDES

Common Name	Commercial Name	Crops
linuron	Afalon 50 WP	Garlic, onion, beans, peanuts, potatoes, tobacco
mancozeb	Dithane M-45	Garlic, onion, beans, potatoes, peppers, tomatoes
paraquat	Gramoxone 20 EC Pillarquat 24 EC Millquat 20 EC	Plantain, fruit crops
polycupric organic fungicide	Trimiltox	Potatoes, garlic, onion, tomato, peppers
propanil	Propanil 35 EC Stam F-34	Rice
simazine	Gesatop 80	Garlic, onions
tricyclazol	Bim 75 WP	Rice
tridemorph	Calixin 75 EC	Plantain
2,4-D amine	U-46 D Fluid, 2,4-D Sandoz,	Rice, coffee, cacao, pasture, sugar cane, tobacco

8. GRENADA

PEST AND PESTICIDE MANAGEMENT

K. BUCKMIRE and G. OGILVIE

INTRODUCTION

Grenada in common with most Caribbean islands is endowed with two seasons, dry from January to May and rainy from June to December. The island is also blessed with fertile soil, a climate with a year round temperature of 25-30°C, an annual average rainfall of 1000-3000 mm (depending on locality) and lush vegetation on hilly terrain. This tropical island climate and topography provide permanent areas for a number of pests of economic food and tree crops.

With the recent expansion of food and vegetable production to supply both the local and export markets farmers are becoming very conscious of the incidence of pests. It is thought that the demand for better quality produce and the higher price paid for top grade crops have further contributed to this awareness of pest problems. These pressures have resulted in a rapid growth of imported pesticides.

The combined effects of extensive pesticide usage, the import regulations of the overseas customers, and the stimultaneous concern that pesticide contamination can have on an island ecology have prompted the implementation of a Pesticide Control Board. Pest management and safe pesticide management in Grenada is considered of great importance both for increased agricultural productivity and for protection of the environment and human resources.

MAJOR PESTS IN GRENADA

The climatic features, topography and origin of Grenada, indicate that the economy of the State will have to be centred on agriculture. In spite of the recent attempts at industrialisation and crop diversification tree crops are still the most important foreign exchange earners. Recognizing this, Government's industrial plan and export expansion are based on agro-industry and the fresh fruit trade.

Table 2 (at the end of paper) identifies the major crop pests in Grenada and Carriacou.

The main pests that warrant chemical control are thrips, scale, cocoa beetle and froghopper. However, mites, coreid bugs and fungal diseases are important. It is to be noted that in this paper the term pest has been defined to include only members of the animal kingdom: fungi and weeds have not been included, though fungicides and herbicides have been listed along with pesticides in Table 3.

THE PESTICIDES AND PATTERNS OF PESTICIDE USE

Table 1 is a summary of the pesticides used by the agricultural sector in Grenada during 1979. Insecticides account for only 3.7% of the total. Fungicides, though high, are almost exclusively used by the banana industry. Indeed, if the banana spray oil is excluded from the total of chemicals in Table 1, then the proportion of insecticides as a total of the pesticidal chemicals rises to 26%. Herbicides are used mainly by banana growers, yet with the increased awareness and committment of the government of vegetable production it is expected that this group of chemicals will increase dramatically in the years ahead.

Table 1 Pesticide Usage figures for the four major export crops Grenada, 1979

Crops	Pesticide (kg and litres)				Total Chemicals (1) (kg)
	Insecticide	Fungicide	Nematicide	Herbicide	
Banana	125 l	2,447 kg 340,950 l	10,250 kg	15,467 l	
Cocoa	10,000 l	13,333 kg			
Nutmeg & Mace	3,796 l				
Sugar cane	624 kg				
Totals	14,545	356,730	10,250	15,467	396,992

(1) Assuming 1 litre approximately = 1 kg

Source: Grenada Banana Co-operative Society
Grenada Co-operative Nutmeg Association
Grenada Cocoa Industries Board
Cane Farmers Association

According to Ifill (1979) more than 90% of the farms in Grenada have two or more crop combinations. Of a total land area of 83,600 acres for Grenada and the Grenadines some 46,577 are under agricultural production. It is estimated that farms 5 acres and under occupy 12,500 holdings extending over 18,500 parcels. Most of the fungicides are supplied to the 1600 acres of cocoa and 3500 acres of banana. However, since most of the cultivations exhibit polycultural cropping, this, together with the use of aeroplanes for application of the fungicides to the banana plants, leads to the estimate that over 80% of the agricultural growth in Grenada is treated by one or more applications of fungicides annually. Though approximately 10,000 litres of Folithion (fenitrothion) was used in the cocoa spraying programme (from the ground, not aerial) for the entire period 1979 up to October, 1980, 10,683 litres of Dieldrin and 5000 litres of Folithion have been sprayed in the past 12 months. Recent personal observations indicate that the incidence of cocoa thrips *(Selenothrips rubrocinctus)* is extensive while cocoa beetle *(Steirastomia breve)* damage appears severe. The 1000 acres of sugar cane planted in Grenada has during the period April to September 1980 been sprayed with over 6,000 kg of endosulfan for control of the froghopper *(Aeneolamia varia)*. Table 3 (at end of paper) lists the pesticides used in Grenada.

PESTICIDE REGULATIONS

The administration and enforcing of pesticide regulations has had some problems. However a Pesticide Control Board, which has its origins in the Pesticides Control Act No. 28 of 1973, is the implementing organ of the Act, came into effect on April 1, 1980, and regulations are likely to be more firmly controlled. The functions of the Board are to enforce the following legislation:

1. Act No. 28 of 1973 – Pesticides Control Act, 1973.

2. People's Law No. 88 of 1979 – Pesticides Control (Amendment) Law, 1979.

3. Statutory Rules and Orders No. 9 of 1979 – Pesticides Control (Labelling of Pesticides) Regulations.

4. Statutory Rules and Orders No. 10 of 1979 – Pesticide Control (Approval of Pesticides) 1979 Regulations, 1979.

Pesticides are to be imported only through the following procedures:

A. Before placing an order for importing a pesticide a completed Application Form I must be submitted to the Board by the Importer along with the ancillary information required as indicated by the Secretary of the Board.

B. The Board, through a Pesticide Approval Sub-Committee, considers each application, and the granting of approval is indicated by receipt of a completed stamped copy of Form 2.

C. To obtain a licence for importation of a pesticide the applicant completes Form 3, and this along with the completed stamped copy of Form 2 is presented to the Controller of Supplies, Ministry of Trade.

D. The applicant then receives three copies of the completed licence form and pays a fee of $(EC)25 to the Inland Revenue Department. The receipt for this fee will bear both the approval and licence numbers.

E. The completed licence forms and receipts are presented to the Pesticides Control Board where the forms are stamped, validating the licence. One copy is kept by the Board and one each by the Customs Department and the Importer. The importer must present his or her copy of the licence to the Customs Department when clearing the goods.

F. Under a single licence several consignments of the approved chemical can be imported. However, for each lot the Customs clearance forms have to be validated by the Board before delivery will be approved.

INTEGRATED PEST MANAGEMENT

Public concern with the adverse environmental effects of pesticides conflicting with the farmers' desire for increased production of high grade commodities have prompted the Ministry of Agriculture and the Pesticide Control Board to suggest a package of practices for pest control, especially in cocoa. The systems being suggested are:

1. The use of traps, for the cocoa beetle, made from either cut cocoa branches or from bits of stem and branches of the wild chesnut, *Pachira insignis*. These are either baited with a pesticide or unbaited.

2. Improved cultural practices such as replanting of shade trees, clearing of drains, and the use of lime to increase the pH of the soil.

3. A planned insecticide spray programme so that application cycles will correspond with the activities of the insects and the physiological development (flushing) of the trees.

The planners in Grenada are being strongly urged to undertake total review of the pest control systems in the country. In this connection the reorganised science and Technology Council will be mandated to co-ordinate, monitor and make recommendations on all aspects of pest and disease management. It is recognised that there are many areas of weakness. Mention can be made of lack of facilities and trained personnel for:

A. Quarantine regulations.

B. Monitoring of pest regimes, especially fruit flies and the bachae ants.

C. Preliminary analysis of suspected areas of concern and or emergencies.

For the present CARDI contributes to the defining of the pest management problems and advice on pesticides and alternatives. The Institute also assists in the training of middle and lower management personnel in crop protection systems. These include hazards and relationship between the natural regulating agents and pesticides. It is felt that a greater role can be assigned to the CARDI Pesticide Laboratory, which, it is hoped, could include analytical monitoring of soil, plant portions, fresh and sea water. It is further hoped that in the near future the laboratory will also help in the training of staff for the National Quality Control Laboratory.

AGROMEDICAL TEAM APPROACH

In Grenada few people would recognise that an agromedical approach to pesticide usage is functional. Yet the composition of the Pesticide Control Board can be considered the beginnings of an agro-medical approach to pesticide management. With the Board consisting of the Chief Technical Officer Health, the Chief Medical Officer, an Entomological Toxicologist, a professional agriculturist, the produce chemist, and an applied chemist as the Secretary it is reasonably structured for the agromedical approach. The feeling has been expressed at Board meetings that policy decisions now need to be transformed into actual performance in the field. This entails training and education. There is an urgent need for training for management, labour and the business community in animal (including human) and plant pesticide safety.

DISCUSSION AND RECOMMENDATIONS

Diversification of agriculture, improved production and increased acreage under crops will intensify the pest regimes and ultimately the use of pesticides. However, Grenada with an island ecosystem and limited foreign exchange can ill afford the luxury of injudicious use of pesticides.

In this paper an attempt has been made to highlight the major crop pests and to relate their control to the pattern of pesticide usage. The concept of integrated pest management, as well as an ombryonic agromedical team under the Pesticide Control Board, show that Grenada has begun to develop the organisational structures for better pest and pesticide management. At the same time these experiences have identified many weaknesses in the system of plant and animal protection. It is being suggested that Grenada can benefit from the following:

1. Training of personnel in pest and pesticide management.

2. Training in application and maintenance of pesticide equipment.

3. Analysis of components of the environment to determine the status of pesticides in the ecosystem.

4. Plant and Animal Quarantine facilities and monitoring equipment for specific insect pests.

5. Information for management, labour and the farmers on all aspects of pest and pesticide managment.

6. Agromedical approach to solid waste disposal, especially in the rural areas.

Table 2 Major Plant Pests of some Crops in Grenada and Carriacou

Pest	Crop
Aeneolamia varia	Sugar cane
Amauromyza maculosa	Bean, Lettuce
Ancylostomia stercorea	Pigeon pea
Aonidomytilus albus	Cassava
Araecerus fasciculatus	Nutmeg
Aspidiella sacchari	Sugar cane
Aspidiotus destructor	Citrus, coconut
Cadra cautella	Cocoa, nutmeg, pigeon pea
Callosobruchus maculatus	Cowpea, pigeon pea
Ceroplastes cirripediformis	Cassava
Cerotoma arcuata	Cowpea, beans
Cerotoma salvini	Cowpea, beans
Chalacolepidius wren	Mango
Cholus spinipes	Pineapple

(Table 2 Continued)

PEST	CROP
Corycyra cephalonica	Animal feed, cocoa, nutmeg
Corynothrips stenopterus	Cassava, pawpaw
Corythaica cyathicollis	Egg-plant
Cosmopolites sordidus	Musa spp.
Diaphania hyalinata	Cucurbits
Diaprepes famelicus	Citrus
Diatrea centrella	Sugar cane
Diatrea saccharalis	Maize, sugar cane
Dymicoccus brevipes	Pineapple
Elasmopalpus lignosellus s	Maize
Empoasca spp.	Beans, carrot, pawpaw
Epitrix fasciata	Eggplant, tomato
Epitrix hirtipennis	Egg plant
Eriophyes querreronis	Coconut
Erinnyis ello	Cassava
Euscepes postfasciatus	Sweet potato
Heliothis virescens	Pigeon pea
Heliothis zea	Maize, tomato
Hypothenemus moschatae	Nutmeg
Icerya montserratensis	Citrus, pigeon pea
Liriomyza munda	Beans
Lonchaea chalybea	Cassava
Malalgus caribbeanus	Limes (Carriacou)
Manduca sexta	Tomato
Meloidogyne sp. (nematode)	Carrot, tomato, okra
Metamasius sp.	Sugar cane
Mononychellus caribbeanae	
Neotermes wagneri	Cocoa
Nezara viridula	Eggplant, bean, cowpea, tomato
Oryzaephilus mereator	Mace, maize, animal feed
Oryzaephilus surinamensis	Mace, maize, animal feed
Phthia picta	Tomato, cowpea
Pseudococcus aonidium	Musa spp
Rhyncophorus palmarum	Coconut
Saissetia oleae	Citrus
Scaptericus vicinus	Maize, sweet pepper, tomato
Selenothrips rubrocinctus	Cocoa, guava, mango, avocado
Spodoptera frugiperda	Maize, sugar cane
Steirastoma breve	Cocoa
Sitophilus zeamais	Maize
Taeniotes amazonum	Citrus
Tenebrio sp.	Animal feed, nutmeg
Tetranychus urticae	Beans, sweet pepper
Tribolium castaneum	Animal feed, cocoa, flour, maize, nutmeg
Trichoplusia ni	Cabbage, tomato
Xylotes sp.	Limes (Carriacou)

Table 3 Pesticides available in Grenada

(F) Fungicide	(H) Herbicide	(I) Insecticide	(M) Miscellaneous
Antracol	ACP (Alanap)	Abate	Asam
Atranex	Agroxone	Actellic	Black Rat
Bansarmid	Ametrex	Akton	D.D. Soil Fumigant*
Benlate	Ansar	Aldrin	Fine Phosphate
Cupravit	Combi	Aldrex	Kelthane EC (Miticide)
Dithane	Dacthal I	Ambush	Methyl Bromide
Peronox	Dalapon	Arkotine	Nemacur
Phostoxin	Esteron	Asuntol	Nemagon
Reglone	Glyphosate	Azodrin	Racumin
Sigma	Gramevin	Baygon	Racumin Ready Made Bait
	Hyvar	Baygon Cockroach Bait	Racumin Tracking Powder
Supona	Paraquat	Baygon Fly Bait	Raid Ant & Roach Killer
Wolf Fungicide	Tok	Baygon Spray	Ranick Rat Bait
	Unipon	Baytex	Ratak
	Weedkiller	Baytex Hog Fog Concentrated	Rodine
		Bidrin	Rodine Mice & Rat Sachet
		Birlane	
		Bolt Residual (Roach killer)	
		Bolt Residual Spray	
		Chlordane	
		Chlordecone Concentrated & Gel	
		Ciodrin	
		Cooper Fly Killer	
		Cooper Roach Killer	
		Cygon	
		Decis	
		Diazinon	
		Dieldrin	
		Dipterex	
		Dursban	
		Endrin	
		Folithion	
		Furadan	
		Gardona	
		Gamatox	
		Heptachlor	
		Hot Shot Flying Insect Killer	
		Hot Shot Roach, Ant Bug Killer	
		Insectoral Cockroach & Ant Powder	
		Insectoral Tick & Flea Powder	
		Lindane Smoke Generator	
		Maladrex	
		Malariol	
		Malathion	
		Malathion Spray (Purina)	
		Metasystox	
		Primicid	
		Purina Fly Patrol	
		Purina Poultry (Insecticide)	
		Purina Rat Control	
		Rogor 40	
		Sector Ant Killer	
		Sector Fly Killer	
		Sevin	
		Total-col	
		Triona	
		Vapona	
		Volaton Granules	

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9. GUYANA

PEST AND PESTICIDE MANAGEMENT

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INTRODUCTION

Pest Management is an all embracing term and is now generally accepted in scientific and technical circles for the more commonly used term 'pest control'. Pest management is any of the forms used by man to suppress pest populations by all appropriate methods to keep the populations below the 'economic-injury levels' i.e. below the population densities at which they cause economic losses or pose as nuisances to man's health and welfare.

The strategies of pest management include exclusion through quarantine and other regulatory methods, cultural practices including rotation; protection by chemical means, immunisation through breeding for resistance and biological control achieved by pest parasites or predators. All of these methods can be attempted singly in pest management, or all or some integrated in a more sophisticated and complex control system referred to as intergrated pest management.

Pesticide management is the technology concerned with the safe, efficient and economic use and handling of pesticides from the time of manufacture until the final utilisation and disposal. The processes of formulation, packaging, transport, storage, official registration for use and sale, selection for use, application and the disposal of containers and unwanted material are included. In addition, pesticide management is concerned with the problems of residues in food and the environment and their impact on the Welfare of man. It seems then logical to infer that any sound pest management programme is intricately connected with pesticide management.

Pest and pesticide management in Guyana is gradually gaining greater importance than ever before as agriculture, including crops and livestock, is rapidly expanding with new acreage being put into beneficial use and new crop types either introduced or brought into economic production in the food production drive to stave off the world food crisis that now looms large, particularly in the developing countries most of which are in the tropical zone. These developing countries with tropical, humid climates such as Guyana often lack data or sufficient data on pest and pesticide management, which is directly related to the dearth of skilled manpower and lack of other resources and facilities. The situation is even further complicated by a more complex ecosystem than that found in the temperate zones.

This presentation attempts to highlight the status of the important pests of the economic crops and livestock, those affecting human health and welfare and the level of pesticide management as it now exists in Guyana.

CROPS AND CROP PESTS

Sugar Cane:

The moth borers, *Diatraea centrella* and *D. saccharalis* cause 3 - 5 percent joint infestation and losses run into thousands of dollars annually. The field rat, *Holochilus brasiliensis*, is a major pest in lands recently taken into cane from bush and savannah (Bates, 1969, Bhim, personal communication). Smut of sugar-cane, *Ustilago scitaminea*, and sugar-cane rust, *Puccinia melanocephala*, are recent diseases of sugar-cane and perhaps cause more damage indirectly by the restitution factor, viz highly productive canes being replaced by lesser yielding varieties, along with concomitant losses due to the cost of the eradication processes and methods.

Perennial grass weeds continue to be a problem and the escalating costs in chemical control method plague the industry.

Some of the major weed species in Guyana (Sukdeo and Bhim, 1979) according to soil grouping are:

i) Frontland and Heavy Clays:
Leptochloa filiformis, *Leptochloa* spp.

Digitaria sanguinalis, Digitaria spp.
Cynodon dactylon, Echinochloa colonum
Physalis angulata, Momodica charantia
Cyperus rotundus, Paspalum conjugatum

ii) Reef areas: High areas of predominantly sandy soils or thin clay layer overlaying a deep sandy substratum.
Leptochloa filiformis, Brachiaria mutica
Cyperus luzalae, Cyperus ferox
Cyperus rotundus, Paspalum virginatum

iii) Pegasse (Organic Soils):
Luziola spruceana, Blechnum serrulatum
Andropogon bicornis, Imperata brasiliensis.

iv) Aquatic Weeds:
a) Sub emergent - *Cabomba aquatica Utricularia* sp.

b) Emergent - *Nymphaea* spp., *Nelumbo* sp., *Montrichardia arborescens*
Caladium sp.

c) Floating:
Eichornia crassipes, Paspalum repens,
Leersia hexandra, Neptuna prostrata.

d) Semi-aquatic - found on edges of waterways:
Echinochloa polystachya

Rice:

Paddy bug, *Oebalus poecilus,* causes both qualitative and quantitative losses (Kennard, 1966). In 1970, the quantitative loss alone was estimated to be four million dollars (Rai, 1974). The angoumois grain moth, *Sitotroga cerealella,* and the lesser grain borer *Rhizopertha dominica,* cause 6 - 8 percent (Rai and Croal, 1974; C.P. Kennard, Guyana Rice Board, Personnal Communication).

The exotic weed, muraina grass, *Ischaemum rugosum,* since its introduction into Guyana around 1904 from Suriname has proved to be a major pest of rice in Guyana. Thousands of dollars are now being spent annually to control this weed pest along with other important weed species in particular Birdseed grass, *Echinochloa colonum,* and monkey-tail (tigertail), *Echinochloa crusgalli* var. *pavonis.* Rice blast, *Pyricularia oryzae,* and Brown leaf spot of rice, *Cochliobolus oryzae,* can in some years cause serious losses. Losses ranging from 10-25 percent can be due to the two diseases during epiphytotic occurrences (L. Small, Personal communication).

Coconut:

Moth borer, *Lapaeumides dedalus,* infests up to 40 percent of palms and the infested palms bear 32-46 percent fewer nuts than uninfested palms (Rai, 1973). A pest complex – ant *(Azteca* sp.) + mealybug *(Nipaecoccus nipae)* + scale *(Aspidiotus destructor)* – infests about 1000 ha. on the East Coast of Demerara and reduces yield by 57 percent (Rai, 1977a). These pests along with leaf defoliating caterpillar, *Brassolis sophorae* are estimated to reduce coconut yield by 20 percent on a national scale.

Plantain and Banana

The banana root weevil, *Cosmopolites sordidus,* is a serious pest along the riverain areas. 'Moko' disease or bacterial wilt, *Pseudomonas solanacearum,* causes an estimated loss of 10-40 percent in yields and deaths of plants (McDonald, 1979, unpublished data).

Coffee:

Termites, *Nasutitermes costalis* and *N. ephrate,* make nests on coffee plants, one nest per plant. Two to four percent of plants die annually in 6-9 year old plantations due to termite infestation. Further, infested plants bear about 37 percent fewer berries by weight than the uninfested ones (Rai, et al. 1977).

White spine disease, *Sceleretinia coffeicola,* and frog-eye disease, *Cercospora coffeicola,* together reduce yields by 10-15% (McDonald, unpublished data).

Tomato:

Fusarium Wilt, *Fusarium oxysporum* var. *lycopersici*, is indigenous in Guyana and causes 10-40 percent loss annually (Muller and Neemsarran, 1973). The nematode *Meloidogyne incognita*, reduces yields by 10-25 percent (McDonald, 1974).

Solanaceous Vegetables:

Tomato and egg-plant have recently been attacked by Pinworm, *Keiferia lycopersicella*, causing serious economic damage.

Cruciferous Leafy Vegetables

Cabbage, pak-choy and related crucifers are seriously damaged by bud worm, *Hellula phidilealis*, and if not sprayed with insecticides every 4-7 days 37 to 100 percent plants are destroyed (Rai and Badrie, 1977).

Bacterial wilt or 'black rot' of cabbage has virtually eliminated all varieties other than 'KK'-cross hybrid which is tolerant to the bacterium *Xanthomonas campestris* in Guyana. In some years bacterial wilt disease causes complete loss of susceptible cabbage varieties (McDonald, 1979).

Sweet Potato:

Sweet potato weevil, *Cylas formicarius*, destroys 20-25 percent of the tubers and is a serious constraint in sweet potato production. There is no effective control measure at the present time.

LIVESTOCK AND LIVESTOCK PESTS

Cattle:

The most serious pests are the ectoparasites, ticks, *Boophilus microplus*, which transmits piproplasmosis, mange, *Sarcoptes scabei*, var, bovis, and screwworm, *Cochliomyia hominivorax*. There is no data quantifying losses due to these above pests but most occur throughout in tropical Guyana.

Sheep and Goats:

The ectoparasites screwworm, *Cochliomyia hominivorax*, mange, *Sarcoptes scabei* var. *ovis*, and intestinal nematodes, namely round worms, *Haemonchus* spp., are the most serious pests. Here again there is no actual data on their effects in the sheep and goat population.

Pigs:

The ectoparasites mange, *Sarcoptes scabei* var. *suis*, and intestinal nematodes, roundworms, *Ascaris suum*, in piglets, are the main pests, while lungworm, *Metastrongylus* spp., also occurs.

Poultry:

Ectoparasites affecting poultry are lice (wing louse) *Liperus carporis*, body louse, *Menacanthus stramineus*, mites, *Cnemidocoptes*. spp. Intestinal parasites (nematodes) are *Ascaridia galli* and *Hatarakis gallinarum*.

PEST MANAGEMENT (CONTROL PROGRAMMES)

Research on pest management of crops, and to a lesser extent livestock, has been intensively undertaken during the last 15 years in Guyana. Entomologists, plant pathologists, nematologists and parasitologists have always been scarce but even with this limitation, much has been achieved in terms of reducing losses and holding the pest populations below the economic injury level, thus keeping damage at tolerable levels. Table 1 shows the results of research work done in pest management in Guyana on the various crops and livestock.

Little research is done on storage pests and losses due to poor storage and handling. This is an area which demands some urgent attention in the very near future.

Pest management in livestock depends solely on the administering of drugs, usually at the manufacturer's recommendation. There has been some research in the control of ticks, *B. microplus*, in Guyana (Rawlins and Rai, 1973).

PESTS AFFECTING HUMAN HEALTH AND WELFARE

Mosquitoes: i) Anopheles

PESTS AFFECTING HUMAN HEALTH AND WELFARE

Mosquitoes: i) *Anopheles malariae* which is a vector of Malaria
ii) *Aedes aegypti* - vector of yellow fever and dengue fever
iii) *Culex fatigans* - vector of filaria

Rodents: Rats,

Household Insects: Cockroaches, House Flies.

Control of pests affecting community and urban health, welfare, and development hinges on health education programmes and chemical control campaigns. There are also a few eradication programmes organised from time to time by the Ministry of Health Education Unit. Table 2 indicates what measures are being taken to control the various pests and vectors affecting health.

Table 1 Examples of current management of the major pests on important crops and livestock in Guyana

Crop	Pest	Control	Gallons a.i./ha
Rice	Paddy bug, *Oebalus poecilus*	Spray monocrotophos	285
		Spray carbaryl	1,402
	Rice caterpillar *Spodoptera frugiperda*	Spray fenitrothion	170-225
	Paddy bug *Sitotroga cerealella*	Spray surface of sacks of bagged paddy with phoxim	100 g/7 tons paddy
Coconut	Coconut caterpillar *Brassolis sophorae*	Inject monocrotophos into palms	72-100
Sugar-cane	Moth borers *Diatraea centrella* *D. saccharalis*	Biological control by Amazon Fly *Metagmistylum mimense*	
	Sugar cane smut *Ustilago scitaminea*	Tolerant varieties B41227	
	Sugar cane rust *Puccinia melanocephala*	Tolerant varieties B41227	
	Weeds	Pre-emergent sprays: Various weedicides Gesapax Combi WP + 2,4-D	
		Post emergent Spot spraying: Asulox + Actril	

(Table 1 Continued)

Crop	Pest	Control	Gallons a.i./ha
Sugar-cane	Aquatic weeds	Gesapax 80WP at 0.5 ppm, Karmex 80WP at 0.5 ppm	
Plantains and Banana	Weevil *Cosmopolites sordidus*	Spray 0.5% monocrotophos on traps	
	Moko Disease *Pseudomonas solanacearum*	Cultural practices including sanitation, clean planting material, resistant variety Pelipita	
Tomato	Fusarium Wilt *Fusarium oxysporum* var. *lycopersici*	Tolerant varieties	
Coffee	Termites *Nasutitermes costalis*	0.5% Aldrin poured in nests	
Livestock Cattle	Tick *Boophilus microplus*	0.1% Supona	

Table 2 Examples of Pests and Vector control Programmes affecting human health

Pest/Vector	Pesticide used
Anopheles malariae (malaria vector)	Batex 40% (Wettable Powder) DDT 100% (Technical) DDT 75% (Wettable Powder) Malathion 95% (ULV)
Aedes aegypti (yellow fever and dengue fever vector)	Abate 1% (Sand granules) Malathion 95% (ULV)
Culex fatigans	(The above are used for all three mosquitoes).

PESTICIDES

The quantities and types of pesticides used in Guyana from 1971-1979 are given in Tables 3-6. Over 80 percent of all herbicides, insecticides, and fungicides are used in the two main crops, rice and sugar-cane. The remaining 20 percent of the three main pesticides in Guyana are used on the various other crops, e.g. coconut, plantain and bananas, green vegetables, and also on livestock and pests of human health.

Herbicides as a group account for an average of 80 percent of all pesticides used in Guyana over the last 9 years, (Table 6). Insecticides average only 15.9 percent of the pesticides used over the same period. Molluscicides, fungicides, and rodenticides are still used in only relatively small quantities, amounting to 1.9, 1.3 and less than 1 percent respectively of all pesticides (Table 6).

Over the past 9 years there has been fairly consistent usage of the various types of pesticides, in spite of the economic problems resulting from shortage of foreign exchange coupled with the steady increases in prices since 1974.

Weedicides, insecticides, and fungicides usage in other cultivations other than rice and sugar-cane would be expected to increase with time, but would not reach the levels of usage in rice and sugar-cane, given the acreage which these two crops over, unless unforseeable and unlikely drastic changes in cropping patterns occur.

The use of chlorinated hydrocarbon insecticides in real terms (kg a.i.) and as a percentage of total insecticides used has been on the decrease (Table 4). The same trend exists in the usage of mercurial fungicides (Table 5).

There exists in Guyana an overall awareness of the highly toxic pesticides which are not widely used in that country. Screening of a large number of commercially available insecticides, weedicides, and fungicides against specific crop pests, developing specific formulations and methods of application, and determining minimum effective dosage in the field, are being continuously carried out in Guyana with the objective of finding out the formulations and techniques of application which, at a low dosage, give the best control of the target pests.

PESTICIDE HAZARDS

Data available on pesticide hazards in Guyana directly relating to human deaths or intoxication are based on drastic cases reported to the Ministry of Health, samples of which were analysed by the Ministry's Analyst Department, the only unit in the country at this time which is involved in pesticide residue analysis.

There is no system of impact monitoring, inclduing measurement of pesticides residues, nor any kind of measurements, physical, chemical, or biological, in relation to the known uses of pesticides: viz there is no systematic and organised surveillance of pesticides after use.

The data obtained from the Analyst attempt to differentiate cases classified as deliberate ingestion of pesticides by persons to commit suicide, from those classified as accidents involving pesticide usage or the eating of agricultural produce with high content of pesticide, resulting in deaths or intoxications.

Table 7 gives the statistics for the years 1975-1979 of deaths/intoxications incurred by the ingestion of several kinds of pesticides by persons either accidentally or by design. What is important in this context are those deaths, human or animal, supposedly due to pesticide residues, usage, handling, exposure, etc. It is obvious that the chlorinated hydrocarbon and the organophosphate groups are the common pesticides likely to be involved in deaths or intoxications due to high levels of the pesticide in food. In 1975, two deaths were reported to be due to parathion ingestion through meals prepared from green vegetables.

In 1977, three deaths were proved to have been caused by the ingestion of Gramoxone (paraquat) found in bora and calaloo. The spraying of the weedicide on the crop had been deliberately done by a neighbour to destroy the crop.

Table 3 Quantities of Herbicides purchased for Sugar (S) and Rice (R) Cultivations

Herbicides	Crop	kg a.i.								
		1971	1972	1973	1974	1975	1976	1977	1978	1979
Propanil (E.C.)	R	556	545	1,226	512	7,473	9,534	1,022	2,958	2,952
2,4-D Amine	R	2,289	2,073	4,565	7,164	15,785	16,344	1,907		0
2,4-D Amine	S	83,853	98,699	75,476	125,202	94,042	96,015	103,525	175,744	88,999
Asulam (E.C.)	S	908	13,802	29,056	30,872	40,565	24,075	0	25,139	18,216
Dalapon salts (W.P.)	S	56,926	62,645	29,425	25,963	0	0	0	13,323	14,406
Triazines (W.P.)	S	1,893	6,127	17,718	92,678	51,050	80,750	62,900	58,274	54,046
Ioxynil (E.C.)	S	396	5,760	13,500	3,960	4,518	1,440	1,215	4,165	2,027
PCP (E.C.)	R,S	562	335	255	153	0	0	0	0	1,160
Sodium chlorate	S	23,831	28,930	18,579	19,764	19,347	5,616	6,931	4,336	2,317
TOTAL	R&S	171,214	219,915	189,800	306,348	233,560	233,774	177,500	283,939 5	184,123

Table 4 Quantities of Insecticides used on Sugar (S) and Rice (R) Cultivations and Used for Human Disease Vector (V) Control during period 1971 - 1979

Insecticide	Used For	kg a.i.								
		1971	1972	1973	1974	1975	1976	1977	1978	1979
Chlorinated Hydrocarbons (C.H.I.)										
DDT (WP & EC)	V	1,304	1,304	1,304	1,103	1,172	1,379	3,448	0	0
BHC (dust)	S	16,332	17,617	8,443	24,547	4,740	18,636	4,728	8,867	16,699
Lindane (WP, EC)	F	215	1,005	1,688	1,181	0	936	1,022	6,404	99
Aldrin (WP., EC)	S,R	1,407	1,306	3,323	5,561	3,085	1,107	118	4,330	1,043
Endrin (granuleś)	S	96	46	52	27	9	0	36	39	6
TOTAL (C.H.I.)	V,S,R	19,354	21,278	14,810	32,419	9,006	22,058	9,352	19,240	17,848.0
Organophosphates and Carbamates (O.P. & C.I.)										
Trichlorphon (SP)	R,S	2,365	1,723	3,380	4,915	4,000	2,182	11,000	7,347	1,274
Phosphamidon (EC)	R	0	0	0	2,192	0	0	0	0	0
Pirimiphos methyl (EC)	R	0	34	46	284	1,135	2,270	0	1,533	1,254
Fenitrothion (EC)	R	1,439	2,270	4,540	5,460	18,773	11,350	0	15,351	16,686
Monocrotophos (WSC)	S,R	2,180	2,313	3,019	6,344	8,172	5,448	9,207	14,140	10,450
Dimethoate (EC)	S	0	0	145	170	0	0	0	0	0
Malathion (EC)	S,V	1,984	5,150	4,893	5,899	1,678	4,534	1,736	2,321	3,236
Temephos (granules)	V	42	42	42	42	11	43	46	450	225
Fenthion (WP)	V	1,114	1,078	1,140	926	520	846	580	700	13,875
Carbaryl (WP)	R	3,638	0	11,591	15,454	15,454	0	3,863	10,537	8,033
TOTAL (O.P. & C.I.)	V,S,R	12,762	12,610	28,796	41,686	49,743	26,673	26,432	52,389	55,033
TOTAL (C.H. & O.P. & C.I.)	V,S,R	32,116	33,888	43,606	74,105	58,749	48,731	35,784	71,629	72,880
C.H.I. as present of all insecticides used		60	63	34	44	15	45	26	27	25

Table 5 Quantities of Molluscicides, Rodenticides and Fungicides purchased for Sugar (S) and Rice (R) Cultivations

Pesticides	Crop	kg a.i.								
		1971	1972	1973	1974	1975	1976	1977	1978	1979
Molluscicides										
Niclosamide (WP)	R	328	0	1,273	1,433	1,273	0	0	798	896
Brestan (WP)	R								3,051	453
PCP (Powder)	R	0	0	0	0	4,545	0	0	0	0
Copper sulphate	R					4,545	9,090	19,318	38,474	11,798
TOTAL (Molluscicides)		328	0	1,273	1,433	10,363	9,090	19,318	41,605	13,147
Rodenticides										
Thallium sulphate (bait)	S	4	5	4	6	150	165	0	118	206
Zinc phosphide	S	4	18	65	24	39	0	0	0	0
Endrin (bait)	S	269	736	530	414	261	131	274	0	0
TOTAL (Rodenticides)		277	759	599	444	450	296	274	118	206
Fungicides										
Mercurials (powders)	R	17	0	36	0	30	60	0	379	191
IBP (EC)	R	0	0	218	2,781	13,075	10,896	974	3,477	4,021
Thiram (WP)	R	0	0	0	0	1,705	1,704	0	765	4,678
Benomyl (WP)	R	0	137	0	1,137	1,135	1,137	0	915	655
TOTAL (Fungicides)		17	137	254	3,918	15,945	13,797	974	5,536	5,545

Table 6 Estimated Quantities of Pesticides used in Guyana*

Pesticides	k.g. a.i.								
	1971	1972	1973	1974	1975	1976	1977	1978	1979
Herbicides	196,896 (83.9)**	252,903 (86.3)	218,270 (80.6)	352,300 (79.3)	268,617 (73.2)	268,240 (76.5)	204,125 (75.9)	340,727 (72.3)**	220,948 (67.3)
Insecticides	36,933 (15.7)	38,971 (13.3)	50,147 (18.5)	85,221 (19.2)	67,561 (18.4)	56,041 (15.9)	41,152 (15.3)	82.377 (17.4)	87,458 (26.6)
Molluscicides	377 (0.2)	0	1,464 (0.5)	1,648 (0.4)	11,917 (3.2)	10,454 (3.0)	22,216 (8.3)	41,605 (8.8)	13,147 ((4.0)
Rodenticides	319 (0.1)	873 (0.3)	689 (0.3)	511 (0.1)	518 (0.2)	.340 (0.1)	315 (0.1)	0	0
Fungicides	20	157	292 (0.1)	4,506 (0.1)	18,337 (5.0)	15,867 (4.5)	1,120 (0.4)	6,643 (1.4)	6,654 ((2.0)
TOTAL	234,545	292,904	270,862	444,186	366,950	351,542	268,928	471,352	328,207

* The quantities of pesticides used in Guyana each year with respect to herbicides, insecticides, and fungicides have been estimated by adding 15% to that purchased for sugar cane and rice cultivations and used for human disease vector control (insecticides only) to allow for pesticides used on other crops and in households. Existence of stocks and statistical differences between the year of purchase and use could affect quantities; however, these are unlikely to affect long term trends which are being projected.

** Figure in bracket is percent of total for that year.

During 1978 in one case a group of five labourers was intoxicated due to water contamnated by chlordane. No deaths occurred.

There were four reported deaths of sheep after eating grass sprayed with paraquat.

The fact seems to suggest deaths or intoxications due to pesticides are more often deliberate actions to commit suicide rather than hazards posed by the use of pesticides. Even if these cases are taken as presented, though probably a too simplistic approach, the situation demands a system for impact monitoring.

There is no data suggesting spills, disposal, etc. affecting the environment. This again might be due to lack of monitoring and tracing the fate of pesticides in the general environment, subsequent to known applications in the field. In the two large agricultural industries, rice and sugar, there have been no reports of any serious spills and application problems affecting human health and the environment over the past 10 years.

Documentation on resistance of any pest to any commonly used pesticide both in the agricultural and health sectors is unavailable. It was, however, observed that the pin worm pest, *K. lycopersicella*, has shown immunity to several commonly used insecticides on the solanaceous crops tomato and egg-plant. Trichlorphon, malathion, monocrotophos, fenitrothion all proved ineffective in pin worm control trials (A.K. Sinha, C.A.S. Mon Repos, personal communication). It is significant to note that the relatively recent introductions of pyrethroids in the country have given the only chemicals (permethrin and decamethrin) to prove effective in the chemical control of pin worm.

Table 7 Number of human/animal deaths or intoxications after intake of various pesticides during 1975-1979

Kind of Pesticides	1975	1976	1977	1978	1979
Aldrin	-	-	12	2	-
Chlordane	-	-	-	2	-
DDVP	-	-	-	1	-
Dithane M 45	1	-	-	-	-
Dieldrin	1	2	7	1	-
Endrin	-	-	-	1	-
Fernimine	6	-	-	1	-
Folithion	4	-	3	1	1
Formalin	8	7	5	4	2
Heptachlor	-	-	-	1	-
Gramoxone	5	-	3	2	16
Lindane	-	1	7	1	-
Malathion	58	48	40	18	17
Monocrotophos	6	1	-	12	39
Parathion	11	-	-	-	-
Warfarin	2	-	-	2	-

Data supplied by the Analyst Department, Ministry of Health, Guyana.

PESTICIDE REGUALTIONS

There is draft Legislation entitled the Guyana Pesticide Control Ordinance dealing specifically with:

i) prohibiting the importation, formulation, sale and use of pesticides;

ii) the manufacture, packing, formulation, advertisement and sale of pesticides;

iii) controlling the use of pesticides, and

iv) protecting workers against the hazard of poisoning by pesticides.

Under the Ordinance there are regulations which include (i) prevention of fraud and ensuring that pesticides actually perform as claimed and, (ii) ensuring the safety to users, non target organisms and the environment.

The areas the regulations cover are registration for use, sale, safe use, distribution, labelling, and handling.

In view of practical considerations the acute toxicity levels of active ingredients (a.i.) of pesticides to be freely available in Guyana have been fixed at oral LD50 to rats 200 mg/kg and dermal LD50 to rats 300 mg/kg (Rai, 1976). Pesticides with higher acute toxicity can be used in the country for specific pest control, but an evaluation of the biological efficacy against the pest and the toxicity hazard posed by the technique of application have to warrant the decision. These considerations, including regulations in import and sale of pesticides in Guyana, have been suggested in the Ordinance and a sample list of pesticides is provided as shown in Table 8.

The Food and Drug Act of Guyana is complementary and it is expected that enforcement of permissible levels of pesticides in food and feed will be carried out under the Food and Drug Act. (Rai, 1977).

The prerequisite for any pesticide legislation to be effective and regulations enforced is related to the scientific data at hand, which is derived from analyses, surveys on pesticides, surveys and the assessments of hazards associated with usage, pesticide residues on food crops, feed and fibre. All these requirements for any effective ordinance demand, however, trained personnel and facilities.

PESTICIDE ALTERNATIVES

The most outstanding example of biological control in Guyana is the control of the serious pest of the sugar cane moth-borers *D. centrella* and *D. saccharalis* by the Amazon fly *Metagonistylum minense* since its introduction during the 1930's. Apart from this one highly successful example of biological control, it is yet to become an important component of pest management in the country.

Two regional organisations, the Commonwealth Institute of Biological Control (CIBC) and the Biological Control Unit of the Caribbean Agricultural Research and Development Institute (CARDI), have on-going research in biological control. Guyanese agriculture is still to benefit in any significant way by the research undertaken by the two organisations. CARDI has undertaken initial work to introduce predators on armyworm, *S. frugiperda*, on corn and black-eye pea, and parasites on the diamond-back moth, *Plutella xylostella*, on cabbage.

Screening crop varieties for host resistance to the more important fungal and bacterial diseases has been going on continually with the outstanding examples in the identification of a cabbage variety 'K-K' cross hybrid tolerant to *Xanthomonas campestris* the causative agent of the destructive disease, bacterial wilt (Muller and Neensarran, 1973 unpublished data), and selection of five tolerant tomato varieties to Fusarium wilt caused by *Fusarium lycopersici* race 1 (Muller and Neensarran, 1973).

Research work on 'Moko' disease or bacterial wilt of plantain and banana is continuing to develop cultural practices using buffer zones with resistant but non commercial varieties to the bacterium *Pseudomonas solanacearum* race 2.

Table 8 Restrictions on Import and Sale of Pesticides — Sample List
(After Rai, 1977)

GPCC approved common name	Other Names	Nature (i) of use	Acute LD 50mg/kg Oral	Acute LD 50mg/kg Dermal	Remarks (ii)
tetrachlorvinphos	Gardona, CVMP, Rabon	I	4,000-5,000	2,500	A
malathion	mercaptothion, carobfos	I	1,375	4,100	A
formothion	Anthio, Aflix	S,I,A	365	1,680	A
dibromochloropropane	DBCP, Nemagon, Fumazone	N	170- 410	1,420	A A
clonitralid	Bayluscide	M	5,000		A
metaldehyde	Antimilace, Namekil	M	250-1,000		A
dichlorvos	DDVP, UDVF, Vapona, Nogos	I,A	56 - 80	107	A
mirex	Dechloran	I	306	800	Technical mirex for preparation of ant control baits (B)
aldrin	aldrine, HHDN	I	67	98-200	Aldrin dust or WP for soil pests (A) Technical aldrin for ant bait preparation (B). EC for termite profing (B).
monocrotophos	Azodrin, Nuvacron Monocron	S,I,A	8-23	354	WSC for the control of pests of rice coconut, and corn (B)
dicrotophos	Bidrin, Carbicron	S,I	22	225	C
fensulfothion	Dasanit, Terracur p	I,N	2-10	3.5-30	C
Namacur	fenamiphos, Bay 68138	S,N	8-10	73-84	C

(i) Insecticide; S, Systemic; A, Acaricide; N, Nematicide; M, Molluscide; F, Fungicide.
(ii) Any formation of these pesticides (A) or only specific formulations ('A' indicates that the formulation/s may be imported ted into Guyana and sold freely: B, specified formulation to be imported and for the specified use. To be sold on prescription from official of the Ministry of Agriculture only; C, not to be imported into Guyana.
N.B. All import licences are to be prepared by SPCC approved common names.

The Guyana Sugar Experimental Station and the Guyana Rice Research Unit have been continuously involved in screening of varieties tolerant and/or resistant to the important diseases of sugar-cane and rice respectively. Both areas of research have achieved successes during the years, particularly rice varieties resistant to blast, *Pyricularia oryzae*, and the sugar-cane varieties tolerant to smut, *U. scitaminea*, and rust, *P. melanocephala*.

Cultural controls are always stressed in plant protection control programmes to farmers.

No alternative control measures have yet been determined in the livestock sector, but pasture spelling is being considered for the control of the most serious pest of cattle, *B. microplus*, as it was shown that in Guyana the survival period of the non parasitic stages of the tick pest ranges from 7-25 days (Rawlins, 1973).

In the health sector the alternative to pesticide usually lies largely in Health Education through the Community Environmental Health Programme. Active participation of the community in Hygiene and sanitation, proper sewerage, refuse, and garbage disposal, is sought and encouraged.

EXTENSION AND EDUCATION PROGRAMMES

Extension and education staff of the Ministry of Agriculture are involved in pest and pesticide management programmes in the districts. They are required as extension agents to educate farmers in up-dated pest control measures obtained from the Plant Production Unit of the Crop Research Division. These agents also benefit from a formal annual training course in Crop Protection Unit. The extension staff also assist in carrying out pest control research on farmers' fields.

Seminars and field-days on plant protection and safe use of pesticides are annual features of the Extension and Education Division in all parts of the agricultural community.

The Guyana Rice Board and the Guyana Sugar Corporation have well established extension units involved in pest management. Training courses both for supervisors and users of pesticides are on-going throughout the year in both industries.

There is no special unit in the livestock division dealing with education in pest and pesticide management, but this is considered as routine and is done by the veterinarians and livestock assistants who form the extension arm of the Livestock Division.

In the Health Sector there is a Health Education Unit of the Ministry of Health. The Enviromental Health Officers as part of their routine duties mount programmes on proper disposal of refuse and garbage, control of rodents, etc.

AGROMEDICAL TEAM APPROACH

An organised agromedical approach to pesticide usage and management is generally lacking, though in the larger agricultural industries, rice and sugar, there is some coordination of the medical personnel and the Research Units in relation to the safe use of pesticides, and there is exchange of information on antidotes for specific pesticides. The Sugar Industry has in its employ a Safety Officer and a specially trained nurse in occupational health, who cover all aspects of occupational hazards, including those from pesticides. They form a link between the medical personnel and the agricultural personnel.

The Analyst Department is contacted from time to time for analysis of pesticide residues on an ad hoc basis, but not as part of a coordinated team. This area of an agro-medical team approach in pesticide management is almost non existent in Guyana at its present stage of agricultural development.

CONCLUSION

Pest Management will continually be brought to the fore as Guyana continues research in reducing pest losses in crops, livestock, and in minimising the nuisances and diseases of man

caused by human pests. Pesticide Management is a component of any efficient management system and requires a cadre of trained personnel, facilities, and other resources.

To increase food production with minimum risks, while at the same time reducing damage in the environment, including users of pesticides, calls for juidicious use of these chemicals. Though there is a distinct need for Pesticide Legislation in Guyana, there also has to be nation wide consciousness of its importance by a deliberate effort to educate the society on the hazards and toxicity of pesticides. The instrument of the law is not only needed, but the means to implement these laws are also equally necessary. It then follows that without facilities, trained manpower, etc. to do impact monitoring, no pesticide law or regulations can be expected to fulfill the purpose for which it is intended.

This paper seeks to highlight the areas that need improvement in Guyana:

1) Continuing research to minimise losses in crops and livestock;

2) To improve Health programmes by controlling the various well-known pests and vectors of human diseases.

3) To improve systems of pest management including integrated pest management (IPM).

4) To have a system of surveillance, and monitoring of pesticides after use.

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10. HAITI

PEST AND PESTICIDE MANAGEMENT

MARC SOLIS and Jn. PAUL SAMEDY

INTRODUCTION

Haiti occupies the Western third of the West Indian Island of Hispaniola, the remaining portion being the Dominican Republic. It has an area of 27,750 km² and a population of about 6 million. About 4/5 of the island is mountainous, with three mountain ranges running roughly east to west; some 40% of the total land surface lies at an altitude of 500 metres or over, 30% between 300 and 500 metres, and only 30% below 300 metres. Coastal plains and valleys occupy about 1/5 of the total land mass and these are the main agricultural areas. Population pressures have led to severe deforestation of much of the mountainous areas.

The climate is warm and equable, with annual mean temperature at sea level ranging from 25° - 29°C; relative humidity averages about 70% with monthly averages ranging from 63% to 75%. The rainy season varies somewhat in different areas of the country; there are normally two peaks, April/May and September/October.

PART I – PUBLIC HEALTH

Malaria is the most serious public health problem; dengue fever, though affecting much smaller numbers, is also a matter for concern. Table 1 shows recent statistics for these two diseases on a country wide basis.

Table 1 Cases of Malaria and Dengue Fever reported in recent years

Year Disease	1975	1976	1977	1978	1979	1980
Malaria	24,733	15,070	27,679	60,472	41,251	60,627
Dengue	351	99	270	36	110	NA

Filariasis, another mosquito-borne disease, also occurs in Haiti, but no statistics as to its incidence are available.

The area affected by malaria is about 19,100 km², viz. 69% of the whole country. In this area four species of *Anopheles* mosquito occur: *A. albimanus*, *A grabhamii*, *A vestitipennis* and *A. crucians*. *A. albimanus* is the major, probably the only, vector of malaria in Haiti. It is essentially a mosquito of hot, humid conditions and in the dry season its numbers diminish greatly.

Between 85% and 97% of the malaria infections in Haiti are caused by *Plasmodium falciparum*.

HISTORY OF ANTIMALARIAL MEASURES IN HAITI

Antimalarial campaigns are directed at the vectors, i.e. the mosquitoes, both at larvae in breeding areas, and at adults. For many years reliance was placed on a mixture of diesel oil and gasoline in the proportion of 10:1 by volume, used as a larvicide. In 1978 Abate 500E was introduced and the diesel oil/gasoline mixture was replaced by a mixture of diesel oil and Triton X-100 at the rate of 0.5 litres to 50 gallons of diesel oil. Malathion is used as an alduticide both by fogging, using a 5% solution of Malathion 95% concentrate in diesel oil, (viz. 1 gallon Malathion plus 19 gallons of diesel oil), and by ULV spraying of Technical Malathion 95-96%. Table 2 shows quantities of chemicals used annually in this programme from 1973 to 1980.

Table 2 Use of Malathion and Abate in vector control programme, 1973 to 1980

Year	1973	1974	1975	1976	1977	1978	1979	1980
Abate (gallons)	0.2	0.2	1.3	3.9	2.6	102.2	252.1	12.3
Malathion (gallons)	0.0	46.5	118.5	322.8	270.00	556.5	1366.0	269.6

Chemical Use

The use of Malathion and Abate in the vector control programme has been noted above. In addition, programmes of house spraying have been continuing for almost 30 years. In October 1954 spraying with DDT technical grade at 2 gm/m² was initiated by Insect Control Program (CCI). In August 1957 CCI became the Malaria Control Program, and was promulgated by Presidential decree on August 20th, 1958. Its essential objective was to eradicate malaria from the whole country. To this end in 1962 house spraying was started on a total coverage basis, using technical grade DDT at 2 gm/m² twice a year. For administrative purposes the malaria affected area of 19,100 km² was divided into three zones, 1 - north, 2 - west and 3 south, and each zone into sectors: there are 22 sectors in all (as shown in Map No. 1 at end of paper). In the toal area of 19,100 km² there were some 900,000 houses, and a population of 4.3 million. The program has been interrupted several times by hurricanes (Flora, Cleo, Inez, Allen) and in some places by abnormally heavy rainfall and flooding.

Initially 6-monthly spraying with DDT was the sole method of attack in localities situated at levels below 500 metres, but in 1965, after three years of spraying, the strategy was changed and a mass drug distribution programme was instituted.

From 1968 attempts to combat malaria in Haiti, as in many other countries, faced increasing difficulties. Resistance to DDT was developing in *A. albimanus* and by 1970 had been observed in many localities throughout the country (Map No. 2); although DDT spraying was continued for some years, during 1977 and 1978 it was done only in some limited rural areas and from 1979 it has been stopped altogether. Attempts have been made to replace DDT spraying with other chemicals.

Fenitrothion 40% WP was first applied in house spraying in July 1978, in the eastern and western parts of the city of Cayes, on the southern coastal plain. The spraying programme has been planned to include 30,459 houses situated in 453 different localities, with some 106,000 inhabitants, and using some 138,000 kg of Fenitrothion.

Malathion was first applied as aeral ULV spraying in late 1972 in the Miragone Valley. Between October 27th and December 17th, six spraying cycles were completed, using a total quantity of 12,100 litres of the 95% concentrate at a rate of 330 ml/ha (4.5 oz/acre).

Evaluation of the Chemical Spraying Programme

In May 1979 the malaria eradication programme was reviewed by a multidisciplinary team of the Government of Haiti, WHO and USAID. Among other recommendations the team stressed the need to set up a properly designed field trial to compare the effectiveness of the three residual insecticides, DDT, Fenitrothion and Malathion, and to determine whether DDT still retains any satisfactory degree of effectiveness, despite the resistance of the vector, especially in areas of low material endemicity. The work plan for the trial is indicated in Table 3: spraying was to be on a total coverage basis at 2 gm technical grade product/m², with cycles of 6 months for DDT and 3 months for Fenitrothion and Malathion. The trial is currently under way and no results are yet available.

Table 3 Work Plan for Insecticide Trial

Insecticide	No. of Localities	No. of Houses	No. of Inhabitants	Quantity of Insecticide (kg)
DDT	185	15,647	43,200	17,515
Fenitrothion	215	11,893	34,579	53,588
Malathion	203	14,401	42,087	39,391

SAFETY MEASURES AND TOXICOLOGY

All the safety measures recommended must be strictly observed by all personnel involved in spraying. Checks should be kept on blood cholinesterase by tintometric determination – any person showing a cholinesterase level of 50% of normal should be removed from activities with the pesticide until the cholinesterase level returns to 62.5% or higher.

PART II – AGRICULTURE

INTRODUCTION

It is well recognised by Government that pesticides play an important role in the control of various biological agents detrimental to agricultural productivity. Losses due to these agents can have serious adverse effects in the country's economy, and the implementation of national or regional pest control programs is regarded as of urgent importance. Special attention is being given to the avoidance of crop losses, both in the field and in the warehouses, and the destruction of rodents, which are also disease carriers, is given high priority.

THE PESTICIDES

Pesticides are being increasingly used by farmers for crops such as cotton, rice, maize and beans. In the Government sector the IDAI (Institut de Developpement Agricole et Industrial) is mainly interested in cotton and uses the following insecticides.

Malathion – against the caterpillar, *Alabama argillacea*
Dieldrin – against Picude, *Anthonemus grandis*
Kelthane – against red spider mite, *Tetranychus bimaculatus*
DDT – against the green stink bug, *Nezara viridula*

These chemicals are applied with knapsack sprayers of 5 gallons or 20 litres capacity.

In maize production sevin has been found effective for killing caterpillars and borers, when applied at a concentration of 5 teaspoons/gallon, though the use of this (and other chemicals) very much depends upon the economic means of the farmer.

For beans only a few applications of Sevin are necessary to control *Empoasca* sp. and *Bemisia tabaci*. Viricuivre and Peltar are used against *Xanthomonas phaseoli*. Peltar appears to be the more effective, but this is based only on the result of a single trial.

Mesurol is used to treat seeds to prevent attack by slugs. Lannate is sometimes used in the maize fields to prevent losses at the milk stage from birds and other pests.

Zinc phosphide, Hydrogen phosphide (Phostoxin), warfarin and chlorophacinone are used to kill rodents.

A list of pesticides available in Haiti is given in Table 4 (at end of paper).

RODENT CONTROL

The high priority given to rodent control has already been noted. A rat control program was undertaken in 1977 in Petit Goave by the ACDI (Agence Canadienne pour le Developpement International), through the Canadian-Haitian Development project, to determine how successful a concerted and well-co-ordinated campaign could be. The rats were to be killed just before the spring rains, in March, and evaluation of the effectiveness would be carried out the following August, when a second killing would give some information on the size of the remaining rat population.

It was estimated that 86% of the cereal crops in the region were lost to rodents prior to the campaig. It was also thought the area contained a rodent population of about 100,000. Four rodenticides were used in the campaign: zinc phosphide, hydrogen phosphide, warfarin, and chlorophacinone. In March, 80,920 rats were killed and in August 12,762.- Based upon these encouraging results the program was expanded to three zones in 1978, but results from this work are not yet available.

Cereal Treatment with Phostoxin and Malathion

In 1977-78, 50,000 tons of cereals were treated with Phostoxin and Malathion ULV 95%. Treatment was done under polyethylene covering and in air-tight storage areas. Results were positive.

HAZARDS AND PESTICIDE REGULATIONS

Because there is no control office, the sale of Pesticides is free. It is impossible to know even approximately how much is sold and the impact of their use on human health and the environment. In the control programs on insects, arthropods and rodents, tons of pesticides are used without taking into consideration the negative effects: intoxication, poisoning, death.

It is hoped that the DSPP (Department de la Sante Publique et de la Population) and DAR-NDR (Department de l'Agriculture, des Ressources Naturelles et du Developpement Rural) can collaborate to draft laws regulating pesticides by creating a control office and supervision of the use of such products.

Table 4 Pesticides currently available in Haiti

Insecticides:

Abate 500 E
Actellic 50%
Actellic 2% dust
Aldrin WP
Aldrin WP
Chlordane 40% WP
Cygon 4-E
Decis EC 25%
Decis EC 2.5% WP
DDT 75% WP
DDT 100% technical
Diazinon 40% EC
Diazinon liquid 60% EC
Diazinon 20% EC
Dieldrin WP
Dieldrin 50% EC
Dipterex SP
Dursban
Endrin
Kotrine
Lannate
Lethane
Lindamul 20% EC
Lindol Granules 0.6%
Malathion 57% EC
Malathion 25% WP
Malathion 50% ULV
Malathion 95% ULV
Nevarote (with pentachlorophenol)
Pocibam
Sevin 80% WP
Termide EC
Thimet
Vert de Paris (Copper arsenite)

Fungicides:

Arasan (Seed treatment)
Benlate
Captan
Copper sulphate ($Cu\ So_4$)
Dithane M-45
Dithane M-23
Ferbam 76%
Manege 80
Peltar
Terraclor Super-X
Terrazole 44%
Viricuivre (Copper oxychloride)

Nematicides:

Mocap
Nemacur

Molluscicides:

Mesurol (Methiccarb)
Metaldehyde technical concentrate
Moloss
One stroke
Slug Ancil Bait (Metaldehyde)

Rodenticides:

a) Acute Poisons

Chlorophacinone
Crimidine
1081
Phosphorous paste
Red Squill
Strychnine
Zinc phosphide

b) Anticoagulants and other rodenticides

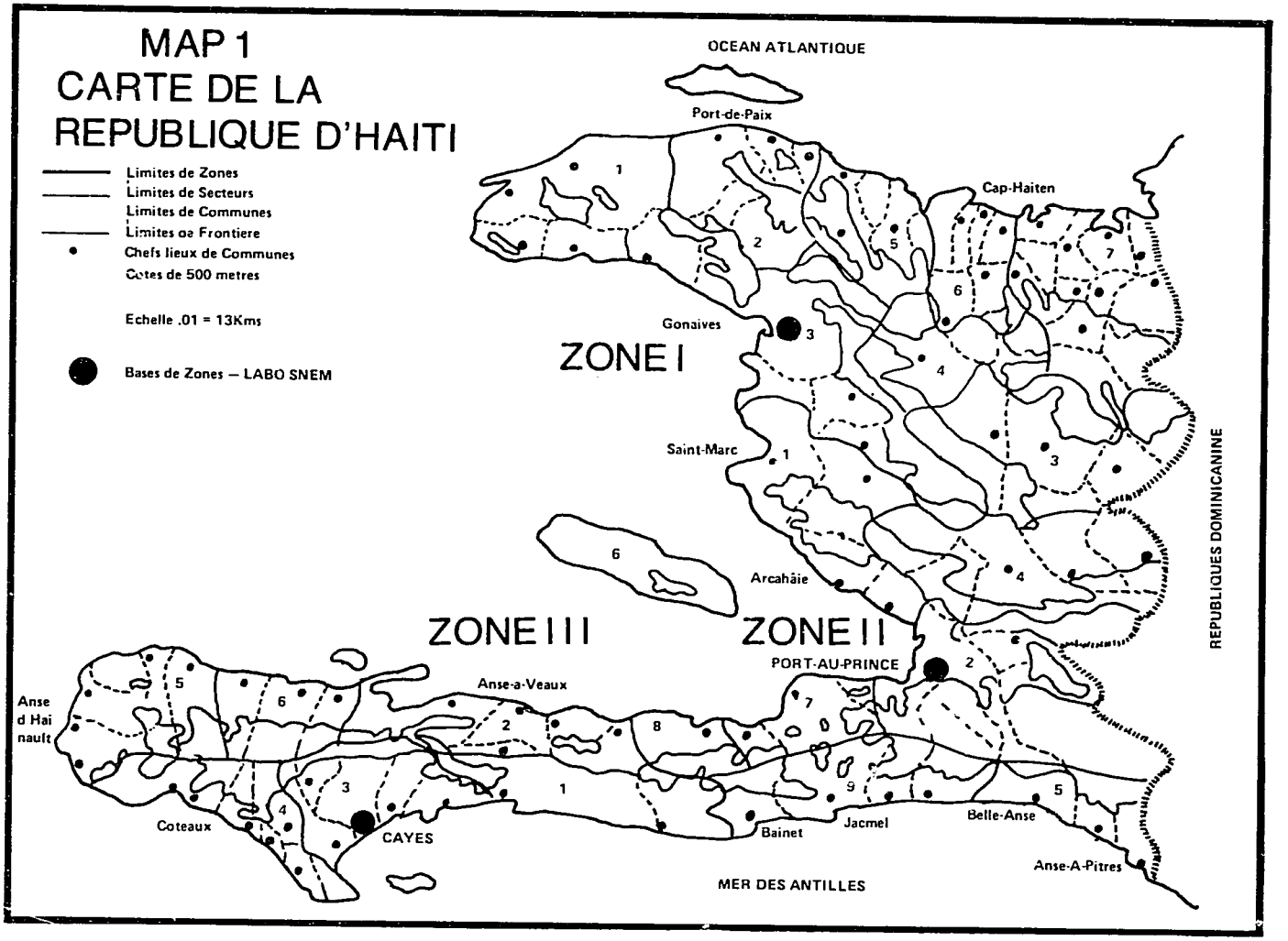
Antu
Bromadiolone
Compound 1080 (Fluorakil 100)
Coumachlor
Fumarin (Rattafin)
Gibbon
Racumen
Ratak
Raticate
Sodium chloroacetate
Turagil
Vacor
Warfarin
Yellow phosphide

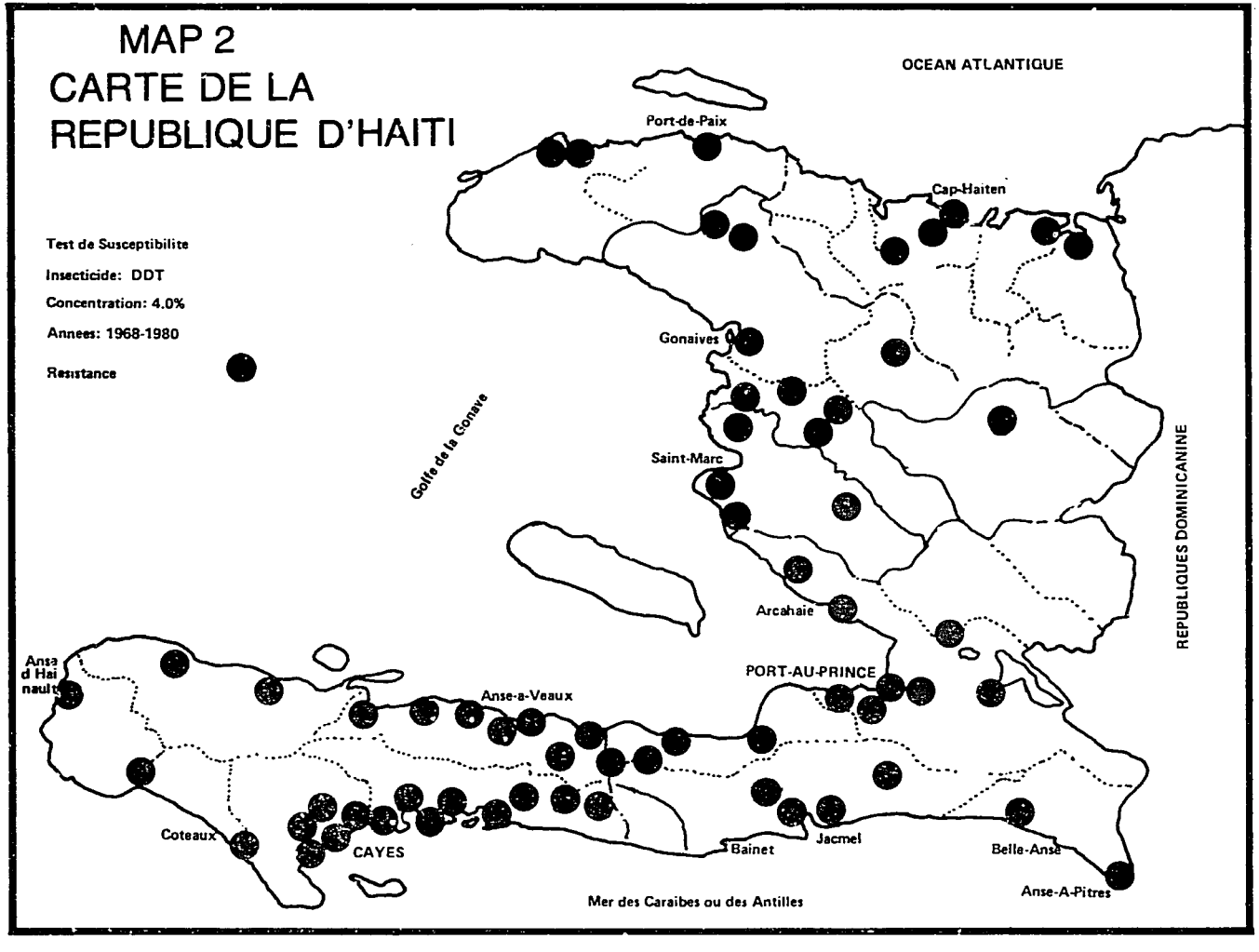
Smoke-Producers:

Fumisect
Phostoxin
Methyl bromide
Carbon tetrachloride

Health Services:

Baygon
Baytex
DDT 75% WP
DDT 100% technical
Fenitrothion 40% WP
Gamma BHC
Malathion 95% - 96% ULV
Shelltox
Spirale (coil) insecticide
Vapona 48


MAP 1
CARTE DE LA
REPUBLIQUE D'HAITI
Limites de Zones
Limites de Secteurs
Limites de Communes
Limites de Frontiere
Chefs lieux de Communes
Cotes de 500 metres
Echelle .01 = 13Kms
Bases de Zones — LABO SNEM
OCEAN ATLANTIQUE
Port-de-Paix
Cap-Haiten
Gonaives
ZONE I
Saint-Marc
Arcahâie
ZONE III
ZONE II
PORT-AU-PRINCE
Anse-a-Veaux
Anse d Hai nault
Coteaux
CAYES
Bainet
Jacmel
Belle-Anse
Anse-A-Pitres
MER DES ANTILLES
REPUBLIQUES DOMINICANINE


MAP 2
CARTE DE LA
REPUBLIQUE D'HAITI
Test de Susceptibilite
Insecticide: DDT
Concentration: 4.0%
Annees: 1968-1980
Resistance
OCEAN ATLANTIQUE
Port-de-Paix
Cap-Haiten
Gonaives
Golfe de la Gonave
Saint-Marc
Arcahaie
PORT-AU-PRINCE
REPUBLIQUES DOMINICANINE
Ansa d Hai nault
Anse-a-Veaux
Coteaux
CAYES
Bainet
Jacmel
Belle-Anse
Anse-A-Pitres
Mer des Caraibes ou des Antilles

11. JAMAICA

PEST AND PESTICIDE MANAGEMENT (HEALTH)

T.E. ALDRIDGE and MRS. ELLIE IRONS

CONTENTS

		Page
1.	INTRODUCTION	101
2.	PESTS IN JAMAICA	102
3.	PEST CONTROL PROGRAMMES	104
4.	PESTICIDE USAGE IN JAMAICA	106
5.	THE TRANSFER OF PESTICIDES TECHNOLOGY	108
6.	PESTICIDE HAZARDS & ENVIRONMENTAL IMPACT	108
7.	THE NATIONAL FRAMEWORK FOR THE MANAGEMENT OF PESTICIDES IN JAMAICA	111
8.	ALTERNATIVES	113
9.	RECOMMENDATIONS	113

1. INTRODUCTION

Jamaica is faced with the need for agricultural productivity at levels that the country has never experienced before. Regardless of a measure of success in family planning, urban and rural population growth rate is still relatively high and outpaces the rate of providing social and economic infrastructure. The quest for health demands that disease bearing pests be controlled and that people not succumb to poisonous chemicals. Several external and internal conditions impede satisfactory transfer or development of technological capability. The characteristics of the Jamaican environment and ecosystems are such that serious damage could result from careless use of pesticides. These are factors which have major implications for pest control and pesticide management in Jamaica during the rest of this century, and beyond.

The fact that Jamaica has experienced a reasonable degree of success in controlling pests is probably as much a matter of good fortune as of good management. It is therefore not surprising that while a great deal of credit can be given to the varying responses of health agencies, agricultural agencies, and others in Jamaica, future successful Jamaican response to the problem of pests and pest control will require improvements in critical areas.

Jamaica has begun to take account of the important considerations that pesticides are chemicals deliberately introduced into urban, rural, agricultural, domestic, industrial or other environments, and that pesticides have contributed to one of the most widespread and serious pollution problems in the world. It is expected therefore that this consideration will guide further advances in the Jamaican approach and arrangements for the control of pests and effective management of pesticides.

2. PESTS IN JAMAICA

In view of the scientific and legal aspects of pest control, reference is made to the definition of "pest" in the Jamaican Pesticide Act 1975:

"Pest means any insect, fungus, bacterium, nematode, weed, rodent, predatory animal or any other from of plant or animal life, including a virus, which may infest or be detrimental to vegetation, man, animals, or households, present in any environment where not desired, or which may be declared by the Minister, by order, to be a pest."

The Act further defines a "pesticide" as:

"Pesticide means any product, organism, substance or thing that is manufactured, represented, sold or used as a means of directly or indirectly controlling, preventing, destroying, mitigating, attracting or repelling any pest, and includes —

(a) any compound or substance that enhances or modifies or is intended to enhance or modify the physical or chemical characteristics of a pesticide, to which it is added; and

(b) any active ingredient used for the manufacture of a pesticide".

Table 1 indicates some common pests in Jamaica and their impacts on (a) health (b) material and (c) agriculture.

Table 1 Common Pests in Jamaica

Pest	Geographical Occurrence	Impact
	A. Mainly Health and Nuisance	
Mosquito	Urban & Rural Settlements, swamps etc. depending on specie.	Over 50 species identified in Jamaica most of which are nuisances, the important species with regards to health are:- i) *Aedes aegypti* — carrier of dengue and Urban Yellow Fever. ii) *Anopheles albimanus* — carrier of malaria iii) *Aedes taeniorhynchus* — carrier of equine encephalitis virus iv) *Culex quinquefasciatus* — carrier of filiariasis (rare).
Rats, mice most common species being *Rattus rattus*, *Rattus norvegicus*	Urban and Rural	Carriers of leptospirosis and augiostrongyliasis (rare).
Cockroach-several species, commonest- *Periplaneta americana*, *Blatella germanica* *Blatta orientallis*	Urban and Rural	Transmitters of several infectious diseases such as typhoid; nuisance.

(Table 1 Continued)

Pest	Geographical Occurrence	Impact
	A. Mainly Health and Nuisance	
Housefly	Common in most places	Transmitters of a number of infectious diseases; nuisance.
Fleas	Common in most places	Transmits plague, fleaborne typhus fever (rare); nuisance.
Tick	Common in most places	Transmits Q. fever, relapse fever (rare); nuisance to man and animals.
Lice	Common in most places	Transmit relapse fever (rare), nuisance.
Sandfly	Common in most places	Nuisance capable of transmitting sandfly fever (pappa faei fever).
Bedbug	Common in most places	Nuisance.
Spider	Common in most places	Nuisance.
Wasp	Common in most place	Nuisance.
Silverfish	Common in most places	Nuisance.
Lizard	Common in most places	Nuisance.
Scorpion	Common in most places	Some species produce toxic venom
Ant	Common in most places	Nuisance.
Worms, several species	Urban and rural but to a greater extent in rural communities	Round worm *(Ascaria lumbricodes)* cause ascariasis. Hook-worm – ancyclostomiasis, Pin worm *(Enterobius vermicularis)* – enterobiasis. Tapeworm-dephyllobethmiasis.
Virus: several species and strains)	Urban and Rural	Some common viral diseases are mumps, measles, poliomyelitis, influenza, chickenpox, epidemic and sporadic gastroenteritis.
Bacteria: several species and strains e.g. *Escherichia coli, Pneumococci, Mycobacterium leprae*	Urban and Rural	Some bacterial disease encountered are diarrhaea, pneumonia, pertussis (whopping cough), typhoid, leprosy. Food poisoning resulting from presence of *Clostridium perfringens, Staphylococcus, Clostridium botulinum.*

(Table 1 Continued)

Pest	Geographical Occurrence	Impact
	B. Destructive to Materials	
Termite	Urban and Rural	Destruction of furniture, houses (wooden), carpets.
Moths	Urban and Rural	Destruction of clothing.
Carpet beetles	Urban and Rural	Attack carpets.
	C. Agriculture	
Cricket	Predominantly Rural	Peel scarring such as in banana.
Grasshoppers	Predominantly Rural	
Slugs	Predominantly Rural	
Snails	Predominantly Rural	
Nematodes	Predominantly Rural	
Caterpillars	Predominantly Rural	
Aphids	Predominantly Rural	
Fungus (several species)	Predominantly Rural	Some fungal disease are black pod of cocoa (Downy mildew); diseases caused by *Mycophaerella musicola* affecting tobacco, tomato, pepper, egg plant, leaf spot disease in banana, smut in sugar cane (caused by *Ustilago scitaminea)* rust in sugar cane *(Puccina melano-cephala).*
Berry borers	Predominantly Rural	Eg. *Hypothenemus hampei.* Causes coffee berry disease.
Weevils (several species)	Predominantly Rural	Attack citrus and other crops.
Black fly termites	Predominantly Rural	Attack several agricultural crops.

(For more details see Paper No. 12 in this volume, by Watt)

3. PEST CONTROL PROGRAMMES

In Jamaica pest control activities are carried out by both public and private sector agencies as well as individual households, farmers, commercial operators, or others.

Public Sector Activities and Programmes

A. Ministry of Health

(i) **Epidemiological Unit** – The main function of this unit is the collection, collation, analysis and dissemination of information with specific interest in communicable diseases. The major pests encountered would be bacteria and viruses and the associated control measures would be preventative vaccinations and environmental control. In either case the unit alerts the

agencies concerned with the particular pest to be controlled. The unit is also responsible for certain quarantine activities and works in collaboration with the Environmental Control Division, with public health personnel in the parishes, and also with international agencies such as PAHO/WHO.

(ii) **Vector Control** – This section consists of a Senior Medical Officer of Health, an entomologist, Public Health Inspectors, spraymen, assistants and others. The main areas of concern at present are the *Aedes aegypti* and Mosquito Control Programmes. *Aedes aegypti* control is carried out at both the adult and larval stages. Adults are controlled by fogging operations carried out two hours after sunset daily for a duration of two weeks or until the pests are abated. A mixture of marine diesel oil, malathion and Lethane (94:3:3) is used for adult control. Larvicidal control is maintained by adding Abate granules (5ml/44 gal.) to domestic water supplies and covering water in marshes and swamps with a mixture of gas oil and crude oil. The Mosquito Control Programme has been in existence for a number of years.

Some activities are carried out in collaboration with the Environmental Control Division, especially when the contributions of environmental engineering or sciences might be considered useful.

(iii) **Environmental Control Division**

The setting up of an Environmental Control Division is a relatively recent development in Jamaica. The broad area of vector control has been stated by the Ministry to be the province of the Environmental Control Division, but this function is yet ot be developed as a systematic activity. The Division is currently giving some attention to the use and impact of pesticides in Jamaica. However the major relevant area of attention to date relates to bacteria, virus, and sometimes mosquitoes associated with water and wastewater, emphasis being placed on domestic water quality. An Environmental Health Inspector is assigned to each parish to monitor water quality. Actual treatment of water and wastewater is carried out by servicing agencies such as the National Water Commission and Parish Councils. The Environmental Control Division therefore monitors water quality in its capacity as a regulatory, advisory, and evaluating agency. It functions in a similar capacity with regard to the discharge of waste water into the environment, and the management and disposal of solid waste (inlcuding garbage) which are habitats for major pests.

(iv) **Health Departments**

Each parish has a Health Department with a Medical Officer of Health, Public Health Nurses and Public Health Inspectors on the staff. These Health Departments work in collaboration with the Environmental Control Division, Epidemiological Unit and the Ministry of Health, and are involved in several aspects of vector control and environmental sanitation.

(v) **Quarantine**

Quarantine Service is provided by the Ministry of Health at both international airports and wharves.

B. **Ministry of Local Government**

The Ministry of Local Government is the Central Government Ministry with broad responsibilities for local government affairs. Thus this Ministry as well as the Health Ministry is actively involved in any pest control activities carried out by the Kingston and St. Andrew Corporation and the 12 other local authorities.

C. **Ministry of Agriculture**

(i) **Crop Care Division**

This section operates under the Production and Extension Department both as an advisory body to farmers and providing services to farmers. It distributes pesticides and in some instances also applies pesticides, and lends equipment to farmers.

(ii) **Plant Quarantine**

This section is responsible for issuing of permits for all plants and plant materials entering the country. Inspectors stationed at the international airports and shipping wharves prevent the illegal entry of plants.

(iii) **Veterinary Division**

This section plays a major role in the control of livestock pests. In addition to giving preventive vaccination and applying insecticides to animals, Officers from this Division,

Animal Health Inspectors and Public Health Inspectors from the Health Departments, examine and certify all imported meat.

D. Ministry of Industry and Commerce

(i) Storage and Infestation Unit

The major function of this Unit is the prevention of insect infestation of stored grains and cereals. This is achieved by carrying out regular inspection of public storage facilities as well as private warehouses and applying the required pesticide where necessary. This is usually done by fumigation using methyl bromide. Attached to this Unit is a Research Branch which studies the storage life of selected crops.

Private Sector Activities in Pest Control

(i) Pest Control Operators

There are several Pest Control Operators offering their services for extermination of a large variety of pests ranging from fungi to lizards. There are over 22 well established companies in addition to small scale operators. The Pesticide Act of 1975 requires that all pest control operators should be licensed by the Authority. This however has been violated and employees in most cases are untrained in the area of pesticide usage.

(ii) Individual Effort

The Jamaican populace is very "pest" conscious. Hence most families control pests in their own enterprises, homes and gardens, using the numerous preparations available on the open market. These are available in different forms, for example powders, granules, aerosols and liquids. Small farmers will on their own initiative purchase and apply pesticides to their crops.

4. PESTICIDE USAGE IN JAMAICA

The 1980 Pesticide List shows over 312 different brands of pesticides approved for use in Jamaica by the Pesticide Committee. The vast majority of these pesticides are imported, the major countries of origin being United States of America (209), West Germany (30), United Kingdom (30) and Canada (15). There are over 26 local distributors of these products. The limited amount of pesticide manufacture in Jamaica is mainly a mixing/blending operation since raw materials are also imported. Below is a breakdown of the different types of registered pesticide (Table 2).

Table 2 Classification of pesticides registered for use in Jamaica

Insecticides	166
Nematicides	5
Rodenticides	14
Acaricides	2
Herbicides	65
Fungicides	53
Bactericides (agricultural)	1
Soil fumigants	3
Additives	3
Total	312

Bactericides for use in water supply, sewage and wastewater control, and general environmental sanitation have not been included. Table 3 indicates the amount of pesticides imported during the period 1975-1978. Locally manufactured pesticides are not included.

Table 3 Pesticides imported into Jamaica 1975-1978 (Kg.)

Pesticide	1975	1976	1977	(1978
Insecticide and Nematicide	2,592,201	944,094	895,664	911,101
Fungicide	3,690,415	6,113,342	4,667,759	5,379,107
Herbicide	434,880	240,563	188,840	1,621,175

At the end of the paper Tables 4, 5 and 6 give respectively a list of the registered, prohibited and restricted pesticides.

It is to be understood that the above classification of pesticides is only a basic categorization according to kind of pesticide and use. In order to satisfy the needs for effective management of pesticides in Jamaica it would appear that the information on a pesticide should include specifications or information on a pesticide should include specifications or information on chemistry, toxicity, hazard rating, international experience with the particular pesticide, its source of origin, on factors relating to its behaviour in the environment such as volatility, solubility, persistence, quantities used, and factors relating to its safe handling, storage and disposal, such as combustibility. The Jamaican regulations does in fact reflect a recognition of some of these needs, but does not cover them all.

Figure 1 which follows illustrates the importation of major categories of pesticides into Jamaica. The figure also gives a good indication of pesticide usage. Over the past four years severe economic hardships have contributed to a general reduction in imports into Jamaica. Nevertheless the general maintenance of import levels between 1975 and 1978, and the increase from 1977 to 78, demonstrate that there is an inclination towards increased use of pesticides in Jamaica, where per capita usage is equivalent to more than 2 kg per year.

Imported Pesticides metric tonnes

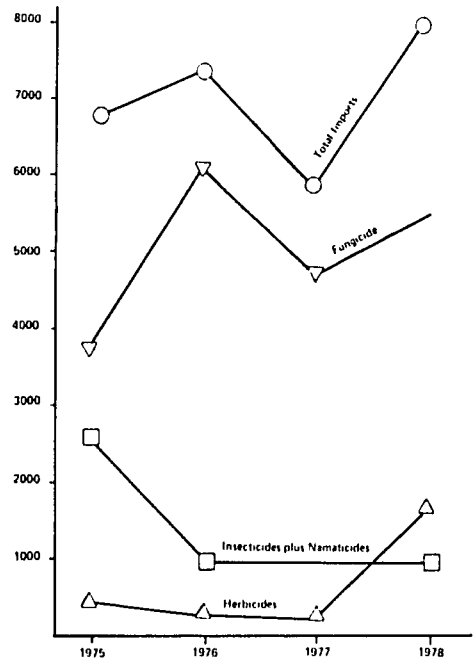


Figure 1 Imports of Pesticides into Jamaica, 1975-1978.

5. THE TRANSFER OF PESTICIDE TECHNOLOGY

Jamaica and other Regional countries have moved through the "first generation' 'pesticides such as botanicals and inorganic salts into the "second generation" of organochlorides, organophosphates, and other "broad spectrum" pesticides.

These as we know originate in industrialized countries but are commonly used in the Region. Indeed almost all aspect of Regional pesticides technology, desirable and undesirable, have sources external to the Region. Thus we are faced with several of the problems of technology transfer including the problem of limited access to full information on pesticide use, hazards, and alternatives.

We are prepared, sometimes delighted, to see pesticide manufacturing plants established in our territories, without always knowing the full implications of such a venture. It is not unheard of, to use in our territories, pesticides whose use has been prohibited in the industrialized countries from which they originate.

Jamaica sees the trasfer of pesticides technology as an area of concern where individual countries may wish to be able to make well informed choices and decision. Consequently among deficiencies that have been recognized in the country are:

- the need for adequate exchange of international information and data on pesticides and alternatives;
- the development of adequate local information and data on pesticides, pesticides use, and impact;
- the development of local expertise and personnel for effective pesticide management and surveillance.

6. PESTICIDE HAZARDS AND ENVIRONMENTAL IMPACT

General

The gaps in information on the impacts of pesticide usage in Jamaica are considerable. Only in the most glaring cases of intoxication or death from pesticide is there good documentation. Understandably there is even less information on the impact of pesticide usage on the Jamaican environment. Nevertheless it is possible to give some indication of the Jamaican experience and of actual or potential hazards and impacts.

Transporation Hazards

Two major transportation hazards from which Jamaica has suffered are:

(i) The transportation of pesticides in ships which subsequently or simultaneously carry foodstuff.

(ii) The transportation of pesticides within the island itself. It is not unusual practice in Jamaica for pesticides to be transported in the same vehicles with food stuff.

Human Intoxication and Deaths

Human intoxication resulting from pesticide is recorded under the broad heading of "Food Poisoning" which embraces microbiological poisoning, pesticide poisoning, as well as poisoning from organic substances occurring naturally in some foods such as ackee and mushrooms. It is not possible therefore to pick out pesticide poisoning from the numerous cases of poisoning which occur in Jamaica. Perhaps the most serious case of pesticide poisoning in Jamaica during the past 12 years is that which occurred in January, 1976. Counter flour imported from West Germany was contaminated by parathion (00-diethyl - 4 - nitrophenyl phosphorothioate) during transportation on the ship.* In this instance 19 fatalities were reported while 66 other victims

* Editor's Note: *Diggory et al. 1977, in "Fatal parathion poisoning caused by contamination of flour in international commerce", Am. Journ. Epidemology, 106, 2, state "Site inspections and review of shipping records suggested that the likely point of contamination was the European pest, where foodstuffs and insecticides were stored in the same warehouse."*

were hospitalized and treated. Further disaster was prevented only because the source was quickly identified and the contaminated flour withdrawn from the market. In a previous occurrence in 1968, 18 people died in the parish of Manchester after consuming flour contaminated by parathion, believed to have occurred during transportation.

There have been reported cases of localised pesticide poisoning as well. During the late seventies three people died after consuming a meal contaminated by methomyl. In this case the insecticide – nematicide was mistakenly used for common salt (sodium chloride) during the preparation of a meal. Recently three people died after using diazinon to wash their hair as a method of lice control. Control of lice by DDT was a relatively common practice in rural Jamaica during the sixties. However this practice has been discontinued and DDT is no longer sold on the open market. There have also been cases of young children ingesting pesticides (mainly baits for flies and rats) carelessly left around their homes. However statistics of this type of occurrence are not available.

Storage of Pesticides

Jamaica has not yet embarked on the regular and systematic surveillance of the storage of pesticide. Recently the escape of vapour or fumes from a storage compound was dispersed into the surrounding areas. The irritation from the vapour was great enough to alarm citizens who contacted the local Medical Officer (Health), who in turn referred the matter to the Environmental Control Division. It is probable that cases of improper storage are numerous.

Disposal

Recently the assistance of the Environmental Control Division was sought when a distributor of pesticides in Jamaica had a substantial quantity of pesticides which required controlled and environmentally sound disposal. Before the existence of the Environmental Control Division the pesticide would probably have been disposed of with less consideration of environmental consequences. In view of the fact that safe disposal techniques do not even exist for some pesticides in use in Jamaica, it is very likely that there are numerous recurrent cases of unsatisfactory disposal of smaller quantities of pesticides and residues, or washings.

Spills

No specific information is available for major or minor spills on shore in the waters around Jamaica. One must assume that some spillage occurs during transportation, storage, usage, and disposal on shore, and marine spillage may well be a significant potential problem.

Large Scale Application

In Jamaica large scale application of pesticides by aerial spraying assumes two forms: (i) the regular spraying of sizeable acreages of banana or other crop; (ii) occaisonal aerial spraying to combat an outbreak of dengue over urban countires and more populated rural areas. Because of several environmental and operational factors it may be difficult to restrict the impact of large scale spraying to a specific pest. There is as yet, no reliable information on impact of aerial spraying in Jamaica. During the last dengue outbreak the Environmental Control Division received a number of alarmed calls from citizens, groups, and agriculturalists whose concern must have been based, among other factors, on unconfirmed reports of the killing of bees during aerial spraying.

Small Scale and Individual Applications

A significant problem exists with respect to small scale applications of pesticides in Jamaica. Pesticides are used by a large number of small farmers, householders, and operators of small enterprises. Pest control operators are unlicensed and frequently untrained. In the absence of any significant public education or extension programmes dangerous practices are to be expected. Indeed reports and observations have been made of disturbing practices even in institutions which one might expect to be more careful. Furthermore, from time to time, banned pesticides have been found on supermarket shelves and in homes.

Environmental Impact

The actual environmental impact of pesticides in Jamaica has not been assessed as yet. However certain conditions contribute to a situation of some concern. Over one thousand surface and underground water supplies of various sizes exist in rural Jamaica. Many of these are in agricultural areas where large scale spraying is practised. In general urban and rural settlements are close to watercourses. Considerable runoff and soil erosion occurs into certain coastal marine areas such as Kingston Harbour. In view of the amount of pesticides in use, the nature of the Jamaican ecosystems, and deficiencies in pesticide application, environmental impact assessment

has been recognized by the Environmental Control Division as a high priority environmental action in Jamaica.

It is also anticipated that more and more attention will be given to "integrated" pest control which brings a wide range of old alternatives and existing new ideas to bear on pest control, so as to minimize environmental impact of the chemical pesticides. With the introduction of new plant diseases affecting crops such as sugar cane and tobacco, the question of alternatives becomes even more important.

Resistance to Pesticides

Unfortunately information has not been available on the development of resistance – recognized as an initial consideration in pesticide control.

7. THE NATIONAL FRAMEWORK FOR THE MANAGEMENT OF PESTICIDES IN JAMAICA

Institutions and Regulations

An interesting situation has developed with regard to institutions and regulations associated with pest control and pesticide management in Jamaica. The principal perceptions, attitudes, priorities, and institutional capabilities have come from:

(i) Health personnel, authorities, and institutions.

(ii) Agricultural personnel, authorities, and institutions.

(iii) Environmental personnel, authorities, and institutions.

(iv) The local authorities.

(v) Public Sector agencies concerned with marketing and commerce.

The Environmental Control Division is a relatively recent development in Jamaica, and the essence of its mandate and responsibility supports the practical need for increased agricultural productivity but upholds the necessity of safeguarding human health. Furthermore both agricultural productivity and the protection of human health must be kept in balance with environmental and ecological conditions and limitations.

It is not at all surprising that the earliest efforts at administering pesticide control measures were associated with the Health Ministry. Indeed an Advisory Pesticide Committee functioned under the Drugs and Poisons Board and was concerned mainly with registration issues. Obviously such a simplistic arrangement had severe limitations both in terms of the relevance and applicability of a Drugs and Poisons statute, and in terms of the conceptual and operational, institutional aspects of pesticide management and pest control.

Very significant acts of acknowledgement of the need for a more updates approach and specific institutional and legislative arrangements for pesticide management came in the early '70's which led to the passing of a Bill by the Jamaican Parliament in 1975. This Bill, to be cited as the Pesticide Act, 1975, sought to make provisions for the importation, manufacture, sale and use of pesticides, for the licensing of pest control operators and for matters related. Among the important features of the Act were:

(i) The identification of a number of functions required for pesticide management and provisions for a number of related regulations.

(ii) The setting up of a Pesticide Control Authority.

(iii) The recognition that a substantial machinery with a variety of disciplines and a high level of resources would be essential for proper operation and enforcement of the objectives of the Act.

Certain points can be made regarding the Act, namely that the Act was a worthwhile effort, but not enough attention was given to environmental monitoring and environmental impact

assessment. Further the penalties for infringements of the Act were inadequate and the important question of effective enforceability is not sufficiently emphasized.

The present position of the Act is somewhat uncertain. The Act itself has not yet been gazetted, nor has its administration yet been soundly established. The intention in 1975 was to have the Act administered by the Ministry of Agriculture. Indications are that this view and intention may be changing or may have changed. The Act itself could benefit from revision, restoration, and extension, particularly where it deals with the machinery for administering pest control and pesticide management. For example, it is unfortunate and ironic, that a 1977 amendment to the Act reduced the Pest Control Authority from a number of persons to one individual. The need for multi-disciplinary inputs and judgements in pest control and pesticide management is considerable. Consequently a one-man pesticide "authority" must be seen as a regrettable concession to expediency and a blow against the comprehensive multi-disciplinary approach.

At least as important as the Act itself is the need for improvements in the institutional framework, so that the management of pesticides in Jamaica allows full coverage, takes account of health interests, ecological-environmental interests, agricultural and other interests, permits application of an appropriate level of science and technology, and is set in a clear, unambiguous and uncontradictory framework for public sector regulatory – advisory – evaluatory bodies on the one hand, and on the other, for the operational bodies, whether public sector or private sector.

The following are among questions whose resolution would be extremely helpful to further advancement of the Jamaican framework:

What specific institutional arm of government by virture of structural conditions is the most appropriate for carrying out regulatory, monitoring, and evaluatory and research work?

What organization of disciplines and personnel promotes adequate consideration to all the places and occasions of urban, rural, agricultural, commercial and health-related pesticide issues?

It is not preferable to make a clear distinction between regulatory agencies and public sector and private sector operational bodies?

There is good reason to expect that questions such as these will be resolved in the future.

8. EXTENSION AND EDUCATIONAL PROGRAMMES

Extension and Educational Programmes exist at a low level. The Ministry of Agriculture's extension activities include distribution of pesticides and loan of equipment for application to some farmers, and the actual application of pesticides. These operations are, however, limited.

The Ministry of Health, the Environmental Control Division, and the Local Authorities do have a basic structure and personnel who could be more involved in a more comprehensive education programme. Up to the present time, however, educational efforts have been sporadic and directed at a particular damage or problem such as poisoning or alerting the country to the hazards of a specific prohibited pesticide.

Team Approach and Multidisciplinary Action

On the question of pesticides and pest control in Jamaica, a certain amount of communication takes place among involved public sector agencies. There are also occasions of interagency action. However the general level of interagency and interdisciplinary coordination and multidisciplinary behaviour needs to be improved. In the writers' view the matter of "team approach" is sometimes dealt with superficially. What seems to be critical is the development of a rational framework including the correct allocation of central and local responsibilities, the development of appropriate personnel, and resources activating good interagency contact at the official and personal levels, and actively developing understanding among the cooperating bodies themselves.

Wild Life

In pesticide management the consideration of wild life is crucial not only in terms of environmental-ecological-health impacts, but also in the application of alternatives. Wild species of flora

and fauna are important in themselves, are good indications of certain kinds of environmental impacts, and form an active link in the human – natural ecological chains involved in pesticide use and pest control. Thus information on wildlife, and Jamaica's Natural Resources Conservation Department, which is responsible for wild life protection, have significant places in a Jamaican framework. At the present time information on the effect of pesticides on wildlife is sparse.

Alternatives

In his paper (No. 12 in this volume) Watt gives examples of applications of cultural control in Jamaican agricultural practice, and of a limited number of attempts at the introduction of a number of predator species. In the control of rodents a certain amount of environmental engineering has been introduced into the management of garbage and other solid wastes and in attempts to control mosquitoes by varying water levels in coastal wet-lands.

The fact is, however, that more positive attention ought to be given to alternatives to chemical pesticides, and the Environmental agencies in Jamaica would advocate an active implementation of "integrated" pest control which involves the coordinated use of specific degradable or shortlived chemicals, cultural control, various biological methods, careful selection of plant species, and engineering and other techniques which are ecologically satisfactory.

9. RECOMMENDATIONS

A. Particular Relevance to Jamaica

(1) Jamaica is sensitive towards the question of pest control and pesticide management, and has a moderate degree of framework and legislation. However the effectiveness of Jamaica's efforts will be considerably enhanced by early adjustments in institutional framework, taking into consideration factors such as those discussed in this paper.

(2) An early assessment of the impact of pesticides on the Jamaican envrionment is is required. This should include measurement of pesticide residues in water, soil, food, and wildlife.

(3) Specific guidelines should be developed for the handling, use, storage, application, and environmentally accepted disposal of chemical pesticides.

(4) The Pesticides Act should be reviewed, updated and enforced.

(5) Programmes must be undertaken or extended in dissemination of information, education, and extension relating to pest control and pesticide management.

(6) A systematic and comprehensive programme for control and pesticide management should be developed taking into account multidisciplinary and other requirements.

B. Regional Relevance

(1) A network and process is desirable for the exchange of relevant international information on pest control and pesticides. This would entail links among territories in the Region and with external agencies.

(2) A system and guidelines should be developed for the satisfactory classification and designation of pesticides. This would take into account toxicity, behaviour in the environment, and several other factors such as those listed in Section 4 of this paper.

(3) Much attention should be given to environmental-ecological consequences in assessing the benefits of pest control. In view of the relationship of environmental quaity to health, to maintaining crop yields and productivity, to wildlife, the environmental quality might be considered as a focal point for pesticide management and pest control.

(4) Regional projects for the development of alternatives to pesticides should be undertaken. Simultaneous complementary activities could be carried out in various territories.

(5) Guidelines should be developed for a range of activities involved in pesticide use including handling, storage, application, and the current state of disposal technology

(6) Opportunities should be taken to participate in conventions to combat spillage or disposal of pesticides in the marine environment.

(7) Guidelines should be developed for assessing the potential environmental impact of pesticide industries in the Region, and taking appropriate precautions.

Table 4 Registered Pesticides in Jamaica

INSECTICIDES

Name	Active Ingredient
Abate 500E Emulsifiable Insecticide	Temephos: 0,0,0,0-Tetramethyl 0,0 thiodi-p-phenylphosphorothioate 44%
Abate 1-SG Granular Insecticide	Temephos: 1%
Abate WDP Insecticide	Temephos 50%
Agrothion 50	Fenitrothion: (0,0,Dimethyl-(4-nitro-m-tolyl) phosphorothioate) 50%
Albolineum	Highly regined Petroleum oils 80% w/w
Aldrin EM 4	Aldrin: 1,2,3,4,10,10-Hexachloro-1,4,4a, 5,8,8a-hexahydro-exo-1, 4-endo-5, 8-dimethanonaphthalene
Aldrin 48% EC	HHDN: Hexachloro-hexahydro-endo-dimethanonaphthalene 480 g/l
Ant Grub Killer	Chlordane
Anthio 33	Formothion: (0,0-Dimethyl S-(N methyl-N-formyl-carbamoylmethyl) phosphorodithioate) 33%
Azodrin 50% WSC	Dimethyl-l-methyl-2-methylcarbamoyl vinyl dimethyl-phosphate 75%
Basudin 0	Diazinon: (0,0-Diethyl 0-(2-isopropyl-4-methyl-6-pyrimidinyl) phosphorothioate) 40%
Basudin 25 BC	Diazinon 25%
Basudin 60 BC	Diazinon Technical 60%
Baygon Cockroach Bait	Baygon: 2-isopropoxy-phenyl-N-methyl-carbamate 2%
Baygon Dust	Baygon 1%
Baygon EC 20	Baygon
Baygon Flybait	Baygon 1%
Baygon Oil Base Spray	Baygon
Baygon Spray	Baygon 2%

(Table 4 Continued) Insecticides

Name	Active Ingredient
Baytex EC 50	0,0-dimethyl-0-(4-methylmercapto-3-methyl-phenyl) thiophosphate 50%
Bercotox	2,3, p-dioxanedithiol S,S, Bis-(0,0-diethyl-phosphorodithioate 30% Mehylated naphthalene 60%
Bioallethrin 80% EC	d-trans Allethrin: (dl-2-Allyl-4-hydroxy-3-methyl-2-cyclopenten-l-one of d-trans crysanthemum monocarboxylic acid).
C-5% D	Technical Chlordane 5.0%
Chlordane EM 8	Chlordane Technical 72.0% Petroleum distillate 21.0%
Chlordane 8-EC	Chlordane 72.0% Petroleum distillate 21.0%
Chlordane 50% (Emulsion)	Chlordane
Cooper Fly Killer	Pyrethrins 1.15% Piperonyl butoxide 2.0%
Coopermatic Fly Killer	Pyrethrins 0.81% Piperonyl butoxide 9.00%
Cooper Roach Killer	Diethyl 2-isopropyl-6-methyl-4 pyrimidinyl phosphorothionate 1% Pyrethrins 0.175% Piperonyl butoxide 0.875%
Coopertox	Toxaphene: (Technical chlorinated camphene) 60%
Crawl Tox	Baygon
Cutworm Dust or Spray	Chlordane
Cythion 57%	0, 0 dimethyl phosphorodithioate of diethyl mercaptosuccinate 57% w/w Xylene 30%
Cythion Technical Insecticide	Cythion 96%
D-Con Four Gone	Pyrethrins 0.50% Technical Piperonyl butoxide 1.00% N-Octyl Bicycloheptene Dicarboximide 1.67% Petroleum distillates 1.83%
D-Con Flying Insect Killer	d-trans Alletrhin 0.20% Piperonyl butoxide Tech 0.90% N-Octyl Bicycloheptene Decarboximide 0.50%
D-Con House & Garden Bug Killer	d-trans Allethrin 0.25% Piperonyl butoxide Tech 0.80% N-Octyl Bicycloheptene Dicarboximide 0.40% Petroleum distillate 8.05%

(Table 4 Continued) Insecticides

Name	Active Ingredient
D-Con Stayaway Fogger	d-trans Allethrin 0.10% Piperonyl butoxide Tech 0.50% Methoxychlor Technical 2.00% 2-Hydroxyethyl-n-oetylsulfate 1.42% Related Compounds 0.08% Petroleum Distillates 6.00%
D-Con Wasp & Hornet Spray	(5-benzyl-3-furyl)Methyl 2,2-dimethyl-3-(2 methylpropenyl) cyclopropane carboxylate 0.250% Related compounds 0.34% Petroleum distillate 69.384%
Diazinon 20E	Diazinon 160 g/l
Diazinon 60E	Diazinon 160 g/l
Diazinon Garden & Fruit Tree Spray	Diazinon
Dieldrin EM 1.5	Dieldrin: (Hexachloro-epoxy-octahydro-endo, exo-dimethranonaphthalene (principal constituent) 18.8%
Dieldrin 18% EC	HEOD: Hexachloro-epoxy-octahydro exo-dimethanonaphthalene 180 g/l
Dieldrin 50% WP	HEOD: 500 g/kg
Dimethoate 40 (Rogor 40)	0-0-Dimethyl S-(N-methylcarbamoyl methyl) phosphorodithioate
Dipterex SP 95	0.0-Dimethyl-(2,2,2-trichloro-1-hydroxy) ethyl phosphonate 95%
Dipterex Granular 2.5%	Dimethyl (2,2,2-trichloro-l-hydroxyethyl) phosphonate
Disyston Granular 10%	0,0-Diethyl S-2-(ethylthioethyl-ethyl) dithio-phosphate 10%
Dursban 1E	Chlorpyrifos: (0,0-diethyl-0-(3,5,6-trichloro-2-pyridyl) phosphorothioate)
Dursban 2E	Dursban 22.5% Aromatic petroleum derivative solvent 45%
Dursban 4E	Dursban 40.8% Aromatic petroleum derivative solvent 47.9%
D/V 217	Dursban 12%
Entacide Insecticide Vaporizer Spray (Formerly registered as ARRKEM ODOR CONTROLLED INSECTICIDE VAPORIZER SPRAY)	N-Octyl Bicycloheptene Discarboximide 0.5% Essential Oil Odor Control Agents 0.48% Technical Piperonyl butoxide 0.30% Pyrethrins 0.15% Petroleum Distillates 98.57%
Ficam W	2,2-dimethyl-1-3-benzodioxol-4-Q-l N-methyl-carbamate 80%

(Table 4 Continued) Insecticides

Name	Active Ingredient
Flair Flea and Tick Spray	Pyrethrins 0.025% Technical piperonyl butoxide 0.026% Rotenone 0.128%
Fly Blaster	Pyrethrins Piperonyl butoxide
Flytox House and Garden Aeresol	Pyrethrins Piperonyl butoxide
Folithion EC 50	0,0 Dimethyl-0-(4-Methylmercapto 3-methyl-phenyl) thiophosphate 50%
Gamatox	Gamma BHC: (gamma, 1,2,3,4,5,6-Hexa-chlorocyclohexane) 20%
Gammexane	Gamma BHC 16%
Gammexane	Lindane (Gamma BHC) 20%
(Gammexane)	Gamma BHC 24.7%
Gardona 75 WP	2-chloro-1-(2,4,5-trichlorophenyl) vinyl dimethyl-phosphate 75%
Heptachlor 40 WB	Heptachlor 40% Related Compounds 15.6% Heptachlorohydro 4,7-methanoindene
Holiday Tick & Flea Spray	Isopropoxyphenyl methylcarbamate
Hot Shot Brand Fly Mosquito Insect Killer	Pyrethrins 25% Technical piperonyl butoxide 80% N-Octyl bicycloheptene dicarboximide 40% Petroleum distillates 8.25%
Hot Shot Brand Indoor — Outdoor Formula House and Garden Spray	
Hot Shot Brand Roach & Ant Bug Killer	
I.C.I. Insect Spray	Gamma BHC Piperonyl butoxide Pyrethrins
Isotox Insect Spray	Metasystox R: (S-(2-ethylsulfinyl)ethyl) 0,0-dimethyl phosphorothioate.
Instant Kill Ant & Roach Killer, New Improved Insecticide	Piperonyl butoxide Tech. 0.26% Pyrethrins 0.025% Chlorpyrifos (Dursban) 0.5% Petroleum Distillate 68.737%
Kepone 5% Wettable Powder	Decacnloro-octahydro-1,3,4-methano-2H cyclobuta pentalene 5%
Kepone 50% Dust	Kepone 5%
Kepone 80% Concentrate	Kepone 80%

(Table 4 Continued) Insecticides

Name	Active Ingredient
Killzol	N-octylbicycloheptene dicarboximide .238% Technical piperonyl butoxide .238% Pyrethrins .095% Petroleum distillates 99.429%
Lannate	Methomyl: (S-methyl N-(methylcarbamoyl) oxythioacetimidate) 90%
Lebacyd EC 50	0,0 Dimethyl-0-(4-Methylmercapto 3-methyl-phenyl) thiophosphate 50%
Lethane 384	Betabutoxy betathiocyandiethyl ether 53% Petroleum distillate 47%
Mafu Spray	DDVP (0.0-dimethyl-0-(2,2-dichlorovinyl)-phosphate) 1%
Malathion 5E	0,0-dimethyl phosphorodithioate of diethyl-mercaptosuccinate 56.5%
Malathion 50 Insect Spray	Malathion 50%
Malathion 50 EC	Malathion 50%
Malathion 50%	Malathion 50% w/w
Malathion EM 5	Malathion 57.0% Aromatic petroleum derivative solvent 32.0%
Malathion 60 EC	Malathion 60%
Malathion Technical Insecticide	Malathion 96% w/w
Maladane	Chlordane Technical 37% Malathion 18% Aromatic Petroleum derivate solvents 40%
Master Mix Cygon 2E	Dimethoate: (0,0-dimethyl S-N-methyl carbamoylmethyl) phosphorodithioate 23.4%
Master Mix Fly & Mosquito Insect Killer	Pyrethrins 0.25% Technical Piperonyl butoxide 0.80% N-Octylbicycloheptene Dicarboximide 0.40% Petroleum distillate 8.25%
Master Mix Sugar Fly Bait	2-2-Dichlorovinyl dimethyl phosphate 0.46% Related Compounds 0.04%
Metasystox R EC 25	0,0-Dimethyl S-2 (4-Methylmercapto 3-methylphenyl) thiophosphate 50%
Morestan	6-Methyl-1,3-dithiolo (4,5-6) quinoxalin-2-one
Nankor 24 E	Ronnel: (0,0-dimethyl 0(2,4,5-trichloro-phenyl) phosphorothioate) Aromatic Petroleum Solvent 70.6%
Nothion 50 (Fenitrothion)	0,0-dimethyl-0-(4-nitro-m-tolyl) phosphoro-thioate 50%

(Table 4 Continued) Insecticides

Name	Active Ingredient
Ortho Ant Roach and Spider Spray	
Ortho Chinch Bug Spray	Aspon (=Chlordane)
Ortho Diazinon Insect Spray	Diazinon 25%
Ortho Dibrom 8	Naled: (1 2-dibromo-2, 2-dichloroethyl dimethyl phosphate). 58% Nylene 20%
Ortho Fruit and Vegetable Insect Control	Diazinon 25%
Ortho Hornet and Wasp Jet Spray	Baygon Pyrethrins Piperonyl butoxide
Ortho House & Garden Insect Control	
Ortho Household Insect Control	
Ortho-Klor 10 Chlordane Dust	Chlordane 10%
Ortho-Klor 44 Chlordane Spray	Chlordane 44%
Ortho-Klor 74 Chlordane Spray	Chlordane 74%
Ortho Liquid Sevin	Carbaryl 27%
Ortho Mosquito and Fly Insect Spray	
Ortho Rose and Floral Dust	Phalton (N-(Trichloromethylthio) phthalimide Malathion
Ortho Rose & Floral Spray	Phaltan Carbaryl
Ortho Sevin Garden Dust Insect Control	Sevin (Carbaryl): (l-Naphthyl N-methylcarbamate) 5%
Ortho Sevin Garden Spray Insect Control	Carbaryl 50%
Ortho Tomato & Vegetable Dust	Captan Methoxychlor
Oxford Blast M	Pyrethrins 30% Piperonyl bicycloheptene Technical 60% N-Octyl bicycloheptene Dicarboximide .100% Petroleum distillate 8.10%
Oxford Insects Jet Stream	Cyclopropane carboxylate 0.150% Related compounds 0.020% Aromatic petroleum hydrocarbons 0.274% Petroleum distillate 11.55%

(Table 4 Continued) Insecticides

Name	Active Ingredient
Oxford Kilz-M	O-Isopropoxyphenyl-methylcarbamate 1.00% N-Octyl bicycloheptene dicarboximide 0.17% N-Octyl sulfoxide of isosafrole and related compounds 0.10% Pyrethrins I & II 0.05% Petroleum Distillate 83.68%
Oxford Superbrand Insecticde Concentrate	N-Octyl bicycloheptene dicarboximide 0.60% Piperonyl butoxide of isosafrole and related compounds 0.18% Pyrethrins I & II 0.15% Allethrin 0.03% Isoparaffinic petroleum hydrocarbons 98.86%
Oc-o-cide	Piperonyl butoxide Technical 0.38% Pyrethrins 1 & 11 0.08% Petroleum hydrocarbon 99.54%
Perfekthion	Dimethoate 400 g/l
Phosdrin 24 EC	Dimethyl-2-methoxycarbonyl-l-methyl-vinyl phosphate 240g/l
Phosvel 50 WP	Leptophos: (0-(4-Bromo-2,5-dichlorophenyl) 0-methylphenylphosphonothioate) 50.0% Related products 5.6%
Phosvel 3 EC	Leptophos: 50%
Primicid 50 EC	Pirimiphos-ethyl: (2-Diethylamino-6-methyl-4-pyrimidyne diethyl phosphorothionate) 50%
Pulvex Dog Wash	Chlorfenvimphos: (2-Chloro-1-(2,4-dichloro-phenyl)-vinyl diethylphosphate)
Pulvex Flea Collars	Fospirate 15%
Pulvex Flea Spray for Dogs	Pyrethrins
Pulvex Flea & Tick Powder	1-naphthyl N-methylcarbamate 3.0% 2,2-methylene bis (4-chlorophenol) 0.5%
Pulvex Kitty Cat Flea Spray	Pyrethrins 0.06% Technical Piperonyl butoxide 0.48%
Pybuthrin 5/50	Pybuthrins Piperonyl butoxide
Pybuthrin 6/60	Pyrethrins Piperonyl butoxide
Pybuthrin 8/64	Pyrethrins Piperonyl butoxide
Pybuthrin 33	Pybuthrins Piperonyl butoxide

(Table 4 Continued) Insecticides

Name	Active Ingredient
Real Kill Ant & Roach Killer	Pyrethrins 0.045% N-Octyl sulfoxide of isosafrole 0.132% Related Compounds 0.01% 0,0-diethyl 0(2-isopropyl-6-methyl-4-pyrimidinyl) phosphorothioate 0.50% Petroleum distillate 96.230%
Real Kill Flying Insect Killer	
Real Kill House & Garden Bug Killer	Pyrethrins 0.27% Piperonyl Butoxide Technical 0.54% N-Octyl bicycloheptene dicarboximide 0.54% Petroleum distillate 4.50%
Real Kill Tropical Formula	Chlorpyrifos: (0,Odiethyl-0-(3,5,6-trichloro-2-pyridyl) phosphorothioate 0.500% N-octyl sulfoxide of isosafrole 0.132% Related Compounds 0.018% Pyrethrins 0.045% Petroleum distillates 96.272%
Rogor 40	Dimethoate 160 g/l
Screw Worm Smear	Ronnel, (0.0-dimethyl 0 (2,4,5-trichloro-phenyl)-phosphorothioate 5% Xylene 5%
Sevin 50% WP (Dust)	Sevin 50%
Sevin 85%	1-naphthyl-N-methylcarbamate 85%
Sheltox Ant and Roach Killer	Vapona: 2,2-Dichlorovinyl dimethyl phosphate 1250 g/l 0.5% Chlorpyrifos (Dursban) 1.0%
Sheltox Flying Insect Killer	Pyrethrins 0.2% Piperonyl butoxide 1.0% (0-0-dimethyl 2,2 dichlorovinyl phosphate) 0.37% Related compounds 0.03%
Skram Brand Insect Repellant	Gamma BHC
Sugar Bait Fly Killer	2,2-Dichlorovinyl dimethylphosphate 0.465%
Supona 20% EC	2 Chloro-1-(2-4 dichlorophenyl) vinyl-diethyl phosphate 20.9%
Teenex	2,2 Dichlorovinyl dimethyl phosphate 0.5% Dursban 5%
Thuricide H.P.	Bacillus thuringiensis 3.2%
Toxaphene EM 6	Technical Chlorinated Camphene 60% Xylene-range aromatic hydrocarbon solvent 32.0%
Trix Flea Collars	2,2-dichlorovinyl dimethyl phosphate 0.09% Related compounds 0.007%

(Table 4 Continued) Insecticides

Name	Active Ingredient
Vapona 48 EC	Vapona 480 g/l
Vapona 75 EC	Vapona 750 g/l
Vapona 125 EC	Vapona 1250 g/l
Vexol	0,0-diethyl 0,2,4-dichlorophenyl 3.0% Pentamethylbenzyl-p-rosaniline chloride 0.3%
Zeposector S Insecticide	N-Octyl bicycloheptene dicarboximide .94% Technical Piperonyl butoxide .56% Pyrethrins .28% Petroleum distillate 98.22%
Zep Roach & Ant Surface Spray	2-(1-methylethoxy) phenol methylcarbamate 0.50% Petroleum distillate 54.27%
FUNGICIDES	
Antracol WP 70	Zinc-Propylene-bis-dithiocarbanate 70%
Benlate	Benomyl: (Methyl 1-(butylcarbamoyl)-2-benzimidazolecarbamate) 50%
Citcop 4E	(Copper salts of Fatty & rosin acids 48% (Copper as Metallic 4%)
Cupravit Blue	Activated Copper hydroxide 35%Cu.
Daconil 2728 W-75	Chlorothalonil (=Bravo) (Tetrachloroisophthalonitrile) 75%
Difolatan 80% Wettable	Captafol (cis -N(1,2,2,2,-tetrachloroethylthio) -4-cyclohexene – 1 ,2-dicarboximide) 80%
Dithane M-45	A coordination of zinc ion and manganese ethylene bisdithiocarbamate 80% In which the ingredients are – Manganese 16% Zinc 2% Ethylene bisdithiocarbanate 62%
Karathane WD	Dinitro (1 methylheptyl) phenyl crotonate 22.5% Other nitrophenols & derivatives chiefly dinitro 2.5%
Kasumin	Kasugamycin
Maneb 80/85 WP	Maneb: Manganese ethylene bisdithiocarbamate Maneb 80% w/w
Manzate	Maneb 80%
Manzate D	Maneb 80%
Mertict Flowable	Thiabendazole (2-(4-Thiozolyl)-benzimidazole)

(Table 4 Continued) Fungicides

Name	Active Ingredient
Mertect 340	Thiabendazole
Morestan	6-Methyl-1,3-dithiolo (4,5-b) quinoxalin-2-one
Orthocide Garden Fungicide	Captan: (cis-N-(Trichlormethyl thio)-4-cyclohexene-1-2-dicarboximide) 50%
Orthocide 50 Wettable	Captan 50%
Ortho Rose and Floral Dust	Sevin (carbaryl) Kelthane
Phaltan Rose Garden Fungicide	Maltan: (N-(Trichormethyl thio) phthalimide) 75%
Plantvax – 75	Oxycarboxin: 5,6-dihydro-2-methyl-1 4-oxathiin-3 carboxanilide-4,4,-dioxide 75%
Polyram – Combi	Metiram 80%
Tri-Basic Copper Sulphate	Copper sulphate 53%
HERBICIDES	
Actril DS	Ioxynil+2,4-D Esters
Ansar 5-29 H.C.	Monosodium acid methanearsonate 47.74%
Aqua-Kleen 20	Butoxyethanol ester of 2,4-dichlorophen-oxyacetic acid 29.0% *Diuron 80%
Asulox 40	Asulox (Asulam) (Methyl sulfanilycarbamate) 40% w/w
Atrazine 80	Atrazine: (2-chloro-4-ethylamino-6-isopropy-lamino-1,3,5-triazine)
Balan	B-butyl-n-ethyl-trifluoro-2,6-dinitro-p-toluidine 19.4%
Banvel D	Dimethylamine salt of 2,4,5-trichloro phen-oxyacetic acide 34.25% Dimethylamine salt of 3,6-dichloro-o-anisic acid 12.37% Dimethylamine salt related acids 1.53% Dimethylamine salt of 2,4-dichloro-phenexy-acetic acid 37.17%
Banvel 4S	Dimethylamine salt of 3,6-dichloro-0-anisic acid (dicamba) 49.0% Dimethylamine salt of related acids 7.9%
Banvel T	Dimethylamine salt of dicamba 8.75% Dimethylamine salts of related acids 1.17%
Basfapon	Dalapon-Na: (Sodium salt of 2,2-dichloro-propionic acid) 85%

(Table 4 Continued) Herbicides

Name	Active Ingredient
Bladex 50% WP	2-(4-Chloro-6-ethylamino-s-triazin-2-ylamino) 2-methylpropionitrile 800 g/l
Chempar 2, – DLV	Iso-octyl ester of 2,4-dichloro-phenoxy acetic acid 95.4%
Daconate	Monosodium methanearsonate 35.41%
Dachthal 75% WP	Dimethyl tetrachloroterephthalate
DMA – 6	2,4-dichlorophenoxyacetic acid 69.5%
Diuron 80%WP	3-(3,4-Dichlorophenyl)-1,1-dimethyl urea
Dowpon	Sodium salt of dalapon: (2,2-dichloropropionic acid) 85%
Dowpon M	Sodium salt of dalapon: Magnesium Salt of dalapon 72.5% 12.0% 72.5% 12.0%
Dowpon S	Sodium salt of Dalapon 85%
Enide 50 W	Diphenamid: N,N-Dimethyl-2,2-diphenyl acetamide 50%
Eptam 5G	S-ethyl dipropylthiocarbamate 5%
Estemine 2,4-D	2,4-D acid 500 g/l l
Esteron Brush Killer	2,4-dichlorophenoxy acetic acid, propylene glycol butyl ether ester 36.0% 2,4,5-trichlorophenoxyacetic acid propylene glycol butyl ether ester 34.1%
Esteron Ten Ten	2,4-dichlorophenxyacetic acid, propylene glycol butyl ether ester 72.8%
Formula 40, 2,4-D Amine	Alkanolamine salts of the ethanol & isopropanol Series of 2,4-dichlorophenoxyacetic acid 65%
Gesapax-Combi 80	Ametryn Technical 40% Atrazine Technical 40%
Gesapax-Combi 500 GW	Ametryn Technical 25% Atrazine Technical 25%
Gesaprim 80	Ametryn Technical Atrazine: 2 chloro-ethylamino-S-isopropylamino-S-triazine 80%
Gesapax 50 GW	Ametryn: 2-(ethyl amino)-4-isopropylamino-6-methylthio-S-triazine 80% 480 g/l
Gesagard 50 WP	Prometryne-Technical: 2-4,bis(isopropylamino)-6-methylthio-S-triazine 50%
Gesapax 80	Ametryn 80%
Gesaprim 500 FW	Atrazine Technical 500 g/l

Table 4 Continued) Herbicides

Name	Active Ingredient
Gramevin	Sodium Salt of 2,2-dichloropropionic acid 85%
Gramoxone	Paraquat: (1,1-dimethyl-4,4-bipyridinium dichloride)
Hedonal 24-D720 LC	Amine Salt of 2,4-dichlorophenoxy acetic acid 720 g/l
Hyvar X	Bromacil: (5-bromo-3-sec-butyl-6-methyl-uracil) 80%
Iso-Spontox	2,4-D+2,4,5-T iso-octyl esters
Karmex	Diuron; 3-(3,4-dichlorophenyl)-1,1-dimethy-'-lurea 80%
Killer Weed Killer	Necoprop: (2-(4-Chloro-2-methylphenoxy)-propionic acid) 2,4-D Dicamba
Reglone	Diquat: dibromicd monohydrate salt of 1,1, ethylene-2-2-bypyridilium ion 300 g/l
Shell Brush Killer LV	2,4,5-trichlorophenoxyacetic acid 2,4-dichlorophenoxyacetic acid
Shell 2,4-D LV Ester	2-ethylbutyl ester of 2,4-dichlorophenoxy-acetic acid
Sodium TCA (Nata)	Sodium trichloroacetate 94%
Stam F – 34	Propanil: (3,4-dichloropropionanilide) 35%
Taluron D	Diruon 80%
Tillam 6E	S-propyl butylethylthiocarbamate 77.32%
TOK E 25	Nitrofen: 2,4, Dichlorophenyl p-nitro-phenyl ether 25%
TOK WP 50	Nitrofen 50%
Tordon 101	4-amino-3,5,6-trichloropicolinic acid as the triisopropanolamine salt 10.2% 2,4-dichlorophenoxyacetic acid 39.6%
Tordon 155	4-amino-3,5,6-trichloropicolinic acid, as the propylene glycol butylether ester 63.4%
Treflan	Trifluralin
U 46 D-Ester LV	Iso-octyl ester of 2,4-dichlorophenoxyacetic acid
U 46 Special HV 720 GL	Isobutylester of 2,4-dichlorophenoxy-acetic acid and isobutylester of 2,4,5-trichloro-phenoxyacetic acid

(Table 4 Continued) Herbicides

Name	Active Ingredient
U 46 Special 80 GL	Isobutylester of 2,4-dichlorophenoxy-acetic acid and iso-octylester of 2,4,5-trichloro-phenoxyacetic acid
Weedar 64	2,4-D
Weed — B-Gon	2,4-D Silvex: 2-(2,4,5-trichlorophenoxy) propionic acid
Weedone BK 64	2,4-D
Weedone IBK	2,4-D
Weedone LV 4	Butoxyethanol ester of 2,4-dichlorophen-oxyacetic acid, 62.5%
Weedone LV 6	Butoxyethanol ester of 2,4-D 87.83%
Weed-No-More 24 DLV	2,4-D Ester

NEMATICIDE

Name	Active Ingredient
Nemacur Granular 10%	0-ethyl-0-(3-methyl-4-methylthiophenyl isopropylamido-phosphate 10%
Namagon 75% EC	1,2 dibromo-3-chloropropane 82.2%
DD Soil Fumigant	1,3-dichloropene, 1,2-dichloropropane, and related chlorinated hydrocarbons

RODENTICIDES

Name	Active Ingredient
Diphacin 110	Diphacinone: 2-Diphenylacetyl -13-indan- - dione
Golden Marlin Fly Bait	2,2-dichlorvinyl dimethyl phosphate 0.093% Related Compounds 0.007% Ronnel (0,0-dimethyl 0-2-5-trichlorophenyl phosphorothioate 0.250%
Master Mix Blue Death Throw Pak	2-(alpha-acetonyl furfuryl-4-hydroxy-coumarin)
Master Mix Mouse & Rat Throw Pak	Diphacinone .005%
Master Mix Prolin Rat Bait	N-(2-Quinoxalinyl) sulphanilamide 0.025%
Racumin Powder	3-(a-tetralyl)-4-hydroxycoumarin
Racumin Rat Bait	3-(a-tetralyl)-4hydroxycoumarin 0.0375%
Ramik Green	Diphacinone 0.005%
Ramik Throw Pak (Pellets)	Diphacinone: 0.005%

(Table 4 Continued) Rodenticides

Name	Active Ingredient
Rattex	Warfarin
Trax Rat & Mouse Bait	Warfarin 0.025% Sulfa quinoxaline 0.025%

ACARICIDES

Name	Active Ingredient
Kelthane AP	Dicofol: 1, 1-bis (chlorophenyl) 2,2,2-trichloroethanol
Morestan	6-Methyl-1, 3-dithiolo (4,5,6) quinoxalin-2-one

SPREAD-BINDERS & SPREAD-STICKERS

Name	Active Ingredient
Citowett	Alkylarylpolyglycol ether 100%
Surfactant WK	Dodecyl ether of polyethylene glycol
Triton B-1956	Modified phthalic glycerol alkyl resin 77%
Triton CS – 7	Blend of alkylaryl polethoxylate & Sodium salt of alkylsulphonated alkylate 60%

FUMIGANTS

Cyanogas	Calcium Cyamide 42% minimum
Dowfume MC – 2	Methyl Bromide 98% Chloropicrin 2%
Dowfume W-85	Ethylene dibromide 83%
Nemagon 75% EC	1,2-dibromo-3-chloropropane 82.2% Other halogenated C_3 Compounds 4.3%
Vapam	Sodium methyl dithiocarbamate 32.7%

BACTERICIDE ANTIBIOTIC

Agrimycin 17	Streptomycin Sulphate 21.2%

(Table 4 Continued)

MISCELLANEOUS PROPRIETARY PREPARATIONS

Name	Active Ingredient
Blitzem	Metaldehyde
Bromo-gas	
Bug-Geta Snail and Slug Bait	Mesurol: 3,5-Dimethyl-4-(methylthio) phenol methylcarbamate
Captan	Captan 500 g/kg
Daconil 2787	Chlorothalonil: Tetrachloro-isophthalonitrile 75%
Danathion 50% EC	
Difolatan 4F	CIS-N-(1,1,2,2-tetrachloroethyl) thio-4-cyclohexane-1,2-dicarboximide 4 lb/gal
Dursban 4S	
Garden Master	Carbaryl 100 g/kg Maneb 128 g/kg Sulphur 120 g/kg Dicofol 44 g/kg Maldison (Malathion) 60 g/kg
Grow Wettable Powder	Sulphur 95%
Holiday Flea Stop Drops	Delvin and Pyrethrins
Holiday Tick Stop	Sevin and Pyrethrins
Kelthane EC	Dicofol: 1,1-bis (chlorophenyl)-trichloroethanol
Kocide 101	
Kur Mange	Rotenone
Luxan Anti-Sprout SC	Propham & Chlorpropham
Mesurol Snail Bait	3,5-dimethyl-4-methyl-mercaptophenyl-N-methyl carbamate 4%
Metaldehyde	
Ortho Leaf Polish	
Ortho Pruning Paint	
Ortho Spray Sticker	Alkyl olefin aromatic polymers 45%
Pestmaster	
Phostoxin Pellet	Aluminium phosphide formulated with ammonium carbamate and hard pharmaceutical paraffin
Phostoxin Tablets	

(Table 4 Continued) Miscellaneous Proprietary & Preparations

Name	Active Ingredient
Rootone F	2-methyl-l-naphthalene acetic acid 0.333% Indole-3-butyric acid 0.057% Naphthylacetamide 0.67% 2-methyl-l-naphthylacetamide 0.015% Thiram 4.000%
Rose Spray	Lindane 2% Captan 12% Malathion 6% Sulphur 12%
Shell Drite Aerosol	
Shellgard	
Shell White Oil	
Tabard	

Table 5 Prohibited Pesticides

aldicarb (Temik)	fonofos (Dyfonate)
azinphos-ethyl (Gusathion A)	Gophacide
azinphos-methyl (Gusathion M. Guthion)	parathion
demeton (Systox)	parathion-methyl
dicrotophos (Bidrin)	phorate (Thimet)
dimefox (Pestox XIV)	schradan
DNOC	sulfotep
EPN	TEPP
fensulfothion (Dasanit, Terracur P)	thionazin (Nemofos, Zinophos)
fluenetil (Lambrol)	Zectran

Table 6 Restricted Pesticides

Abate	arsenates, lead, copper and calcium
acrylonitrile	arsenites, sodium and potassium
aldrin	binapacryl (Morocide)
alpha naphthyl	carbofuran (Furadan)
thiourea (Antu)	carbon disulphide
Aluminium phosphide	carbophenothion (Trithion)

(Table 6 Continued)

chlordecone (Kepone)

chlorfenvinphos (Birlane, Sapecron)

chloropicrin

coumaphos (CoRal)

cyanides (Inorganic)

cycloheximide (Actidione)

DDT

demephion (Cymetox, Atlasetox)

dichloropropane and/or

dichloropropene (D-D, Telone)

dichlorvos (DDVP, Vapona)

dieldrin

dinoseb, dinoseb acetate

dinoterb

disulfoton (Disyston)

Dursban

endosulphan

endrin

ethion

ethylene dibromide

ethylene dichloride

ethylene oxide

heptachlor

mecarbam (Murfotox)

medinoterb acetate

mercuric chloride

all organomercury compounds

mercurous chloride

methamidophos (Monitor, Tamaron)

metham-sodium (Vapam)

methomyl (Lannate)

methyl bromide

Methyl trithion

mevinphos (Phosdrin)

Mocap (Prophos)

monocrotophos (Azodrin, Nuvacron)

Nemacur

nicotine sulphate

oxydemeton-methyl (Metasystox-R)

oxydisulfoton (Disyston-S)

paraquat (Gramoxone)

Paris Green

Pentachlorophenol

phosphamidon (Dimecron)

propoxur (Baygon, Unden)

prothoate (Fac)

red squill

sodium fluoride

sodium fluoro acetate ("1080")

strychnine

TDE (DDD)

thallium sulphate

toxaphene

Vorlex, Trapex, Di-Trapex

White arsenic

White phosphorus

zinc phosphide

12. JAMAICA

PEST AND PESTICIDE MANAGEMENT (AGRICULTURE)

ERIC I. WATT

INTRODUCTION

The use of pesticides is an agricultural technology that takes priority in the production of crops and livestock.

In Jamaica, there is a dichotomy in the use and management of pesticides. On large, well established farms pesticide application is an important input that is scheduled in production programmes, the usage sometimes properly supervised.

On small peasant farms, pesticides are almost never used (except for the growing of export crops) due to an innate fear of pesticides, the inability to purchase material and equipment, and the cost benefit to be derived not fully understood.

There is a vital need for more educational programmes on the use of pesticides, the disposal of empty containers, worker exposure and the impact on the environment. A dangerous trend is the large numbers of pest control operators, who offer their services for a fee and who are not trained in the use of handling pesticides.

There is clearly the need for revision of the laws to regulate the indiscriminate use of pesticides. These regulations should be so structured that members of research and service organizations in both the Public and Private Sectors play a more positive and dynamic role to ensure safer usage of pesticides by the farming community.

In the first part of this paper a brief account is given of the livestock and crops affected by pests, and the control measures employed; in the second part pesticides and their management are considered in more detail.

PART I. AGRICULTURAL PRODUCTS

I. LIVESTOCK

The production and care of livestock in Jamaica are achieved by large scale farming and by peasant farming. On large farms, proper management, including health care, is maintained. On peasant farms livestock is confined to small areas or allowed to roam freely and health care is administered only in cases of emergency.

Recently, the fifth meeting of Directors of Livestock Research and the Third Biennial Livestock meeting were held at the New Kingston Hotel in Kingston, Jamaica. These meetings brought into focus the seriousness with which the breeding, development and health care of livestock are regarded in Jamaica. For example, Jamaica has developed and is a major producer of tropically adapted beef and dairy cattle, sheep, goats and pigs.

The Veterinary Division of the Ministry of Agriculture is responsible for livestock health care. This division is divided into research and service. The research section is situated at Hope, Kingston and each parish has at least one Veterinary Officer and several Animal Health Assistants.

1) Cattle

A PAHO sponsored "Animal Health Programme" is funding a Brucellosis and Tuberculosis Eradication Programme. The objective of the programme is to eradicate these two diseases of cattle from Jamaica.

Other diseases present in Jamaica affecting cattle are, anaplasmosis, piroplasmosis, cattle blackleg, leptospirosis, pasteurella pneumonia, mastitis, vibrio and anthrax. Preventive vaccination is available for blackleg, vibrio and anthrax.

2) **Sheep**

These animals are not popular in Jamaica. Diseases affecting them are nematodes, clostridial infection and blue tongue. Clostridial vaccination is available.

3) Goats

The animal is reared mainly for its meat, and to a lesser extent, its milk. The approach to husbandry on peasant farms is usually casual. In the urban areas, the herd is allowed to roam freely, foraging for food. Diseases associated with goats are blue tongue, shake head and flukes.

4) Pigs

Pigs are usually reared in pens, are properly fed, and have access to veterinary service on the large farms. However, on peasant farms, pigs are allowed to roam freely. Diseases associated with pigs are erysipelas, pasteurella pneumonia, colibacillosis. Preventative vaccination is available.

5) Horses

The most serious disease associated with horses is the eastern equine encephalomyelitis disease, which is transmitted by *Aedes taeniorhynchus*.

6) Poultry

The poultry industry in Jamaica is well established. Birds are reared for meat and eggs, which are supplied to large poultry distributors in Kingston.

All birds are vaccinated as 'day-old' chicks against most diseases affecting poultry. Diseases are fowl pox, infectious bronchitis, newcastle disease and Marek's disease.

The control of insect pests associated with livestock are chiefly for tick and lice. Drugs used are: Asuntol, Bercotox, Carlo 4-3-3 (Diazinon), gamma isomer BHC, Tetmosol, Ascarbiol.

Animal Quarantine

The importation of livestock, meat and meat products are strictly controlled. The schedule of entry for each country are as follows:

Animals:-	Dogs and Cats:	Allowed from United Kingdom only.
	Pigs:	Canada with special certificate.
	Cattle, Horses, Sheep:	United Kingdom, Canada and U.S.A. and are subjected to quarantine.
	Poultry:	Eggs are permitted to enter from U.S.A. and Canada with certificate: also applicable to ducks and turkeys.
	Birds (pets):	Allowed in from United Kingdom, Canada, U.S.A., after obtaining a permit for entry and accompanied by a certificate of health from the exporting country.
Meats & Meat Products:-		U.S.A., Canada, New Zealand and Australia. Fresh pork is not allowed due to the possible introduction of the African Swine Fever.

All ships entering Jamaica are inspected by Health Officers for the illegal entry of meats, meat products, and live animals. Similar checks are carried out at the international airports.

Table 1 summarises the pests and diseases of livestock and the control measures normally applied.

Table 1 Important Diseases and Insect Pests of Livestock and their control in Jamaica

Animal	Livestock Disease/Pest	Control
Cattle	anaplasmosis	control vector
	piroplasmosis	control vector
	cattle blackleg	vaccinate
	leptospirosis	rodent control
	pasteurella pneumonia	vaccinate
	mastitis	hygiene
	vibrio	vaccinate
	anthrax	vaccinate
Sheep	blackleg	vaccinate
	nematodes	routine drench
	clostridial infection	vaccinate
	blue tongue	no studies
Goats	blue tongue	no studies
	shake head	vitamin B & remove animal from area
	flukes	routine drench
Pigs	erysipelas	vaccinate
	pasteurella pneumonia	vaccinate
	colibacillosis	vaccinate
Poultry	fowl pox	vaccinate
	infectious bronchitis	vaccinate
	newcastle disease	vaccinate
	mareks disease	vaccinate

II. CROPS

Efficient crop production is of utmost importance to the Jamaican economy, in that crops are grown for export and for local consumption. Crops grown for export receive priority with regards to management, government subsidy and the negotiation of "safe" markets.

In recent years two new diseases and two insect pests were introduced into Jamaica. This resulted in the loss of millions of dollars in terms of production and man-hours. The diseases and pests are smut and rust of sugar cane, the tomato pinworm and the coffee berry borer.

Crop production for the entire island comes under the direct management of the Ministry of Agriculture. Export corps are administered by statutory boards.

1) **Sugar Cane** *(Saccharum officinarum)*

Sugar production is one of the main foreign exchange earners of the Jamaican economy. However, in recent years, there has been a serious decline in production due to the ravages of disease and insect pests of the sugar cane plantations.

In 1976, smut of sugar cane, *Ustilago scitaminea*, was discovered on a farm in Innswood Sugar Estate, and since then the disease spread rapidly to all the sugar growing areas island-wide. When the smut appeared in Guyana two years earlier, a preparedness programme was instituted in Jamaica. The programme consisted of lectures, dissemination of pamplets and advice to farmers to alter their current planting patterns, and a pool of resistant varieties was also available for replanting. When smut did appear in Jamaica it decimated the susceptible varieties which

occupied 42% of the island's cane acreage. A control programme was immediately instituted and consisted of:

(a) finding the disease as quickly as possible by regular field surveys;
(b) reducing the amount of infectious material by roguing;
(c) replanting susceptible varieties with resistant ones.

Rust of sugar cane, *Puccina melanocephala*, appeared in Jamaica nearly two years after the smut. The damage to sugar cane was only 15% of the island's sugar cane acreage. The intensity of the rust infection is related to varietal susceptibility, to the age of the sugar cane, soil infertility, poor weed control and moisture stress. Therefore if the cane is in good physical condition, the effect of rust is minimised.

Control consists of:

(a) replanting with approved resistant varieties;
(b) applying fungicide, using Dithane or Manzate at 0.5 kg/ha.

Insects and other pests affecting sugar cane production are termites and rats. Termites *(Isoptera)* are frequently called white ants, duck ants and wood ants. Two species, *Nasutitermes nigriceps* and *N. rippertii*, attack sugar cane in Jamaica. Control consists of destroying the nests by burning or by the application of a pesticide (chlordane).

Damage by rats to sugar cane cultivation can be very extensive in that they provide entry for disease pathogens by chewing on the stalks of the cane. Damaged cane become infected with red rot, *Physalospora tucumanensis*, which reduces the sucrose content. The control of rats in sugar cane fields is done by the mongoose, *Herpestes javanicus*, introduced in Jamaica from India in 1872. Other means of control are by the use of pesticides.

2) Banana *(Musa sapientium vars)*

Banana is another of the main foreign exchange earners. There are presently 30,000 ha. under banana cultivation. Of this, 25,000 ha. are planted for export and include varieties such as Valery, Lacatan, Robusta, and Williams hybrid. The major pests affecting banana are leaf spot or sigatoka disease, banana weevil borer, *Cosmopolites sordidus*, nematodes, and peel scarring pests, which include crickets, grasshoppers, slugs and snails.

Leaf spot or sigatoka disease is caused by the fungus *Mycosphaerella musicola*, and seriously affects banana production. Regular spraying is of vital importance in order to control the disease. The control programme consists of both aerial and ground spraying using light aircraft and mistblower respectively.

Spraytex CT, a light paraffinic oil, is used at 18-22 l/ha. Benlate (benomyl) at 0.2 kg/ha. is added to the oil. The average number of spray cycles per year is 11 to 17. All aspects of leaf spot control are monitored by a team of leaf spot officers. The officers are involved with surveying fields for leaf spot incidence and severity, and checking oil coverage within 48 hours of application, certifying the acreage sprayed and the application rates.

The banana weevil borer is the main insect pest of the banana. The insect tunnels its way into the corm thereby providing entrance for disease pathogens. The weevils can be controlled by chemical, cultural and biological means.

Chemical control involves the use of Mocap at 30 grams per mat placed in a circular band. At planting time 15 grams of Mocap 10G is placed in the holes. Cultural control involves the use of clean seeded planting material. As an attempt at biological control, the black histerid beetle, *Plaesius javanus*, was imported into Jamaica from Java and liberated on banana plantations. These beetles have never reduced the infestation of the banana weevil borer to any significant level.

Damage done to the fruit by peel scarring pests do not affect the quality, but rather the appearance of the fruit. Poor appearance of fruit causes rejection for export standards. Control consists of removal of the corbata, detrashing of plants, and sleeving 14-21 days after shooting. Snails and slugs are controlled by using 5% metaldehyde in coir dust or sawdust placed in the "throat" of plants. Field sanitation and proper pruning is also important.

3) **Tobacco** *(Nicotiana tabacum)*

Tobacco is grown in Jamaica for the quality of leaves, which are used in the manufacture of cigars for export and cigarettes for local consumption.

In November 1979, the blue mould or downy mildew of tobacco, *Peronospora tabacina*, was identified in several tobacco fields. The fungus attacks seedlings and in some instances older plants. The pathogen survives on other solanaceous crops, e.g. tomato, pepper and egg plant. Control of the disease is obtained by the use of redomil and zineb used alternately.

Nematodes also attack tobacco plants and cause extensive damage. *Rotylenchulus* spp is associated with unthriftyness in tobacco and is controlled by crop rotation and application of DD at the rate of 330-440 l/ha. or mocap 10G at 70-90 kg/ha.

4) **Coconut** *(Cocos nucifera)*

Coconut is an important crop for the following reasons:

a) it is the only source of edible oils,
b) there are many areas along the coast line where the soil is poor and nothing else will grow economically,
c) many peasant farmers depend on the sale of nuts for their only source of income.

The present coconut population in Jamaica consists of

(i)	Malayan dwarf and hybrids	18,800 ha.
(ii)	Jamaica tall	14,000 ha.
(iii)	Panama tall and Mapan hybrids	4,500 ha.

Coconut suffers from the attacks of many diseases and insect pests, but lethal yellowing, since its appearance in Jamaica in 1940, completely destroyed the industry. The symptoms of lethal yellowing are leaf yellowing, nut fall, infloresence and spear necrosis, followed by the death of the plant within 3-4 months. Jamaica has lost some 4.5 million out of 6 million trees since 1961 as a result of lethal yellowing.

Research into the cause and possible control of the disease has been an on-going project since 1940: it is currently believed that the cause is a mycoplasma transmitted by leafhoppers, one of which is probably *Myndus crudus*. A range of varieties and hybrids have been tested and presently the Malayan drawf and Maypan F-1 hybrid are being used for replanting.

5) Coffee

Adams (1972) reports that there are three species of coffee growing in Jamaica:

i) *Coffea liberica* Bull ex Hiern – Liberian coffee
ii) *C. canephora* Pierre ex Frohner – Robusta coffee
iii) *C. arabica* L. – Arabian coffee

C. arabica is the only species grown locally for commercial production.

The most important insect pest affecting coffee is the coffee berry borer, *Hypothenemus hampei* (Ferr), which was discovered three years ago. This pest has caused severe crop damage, reducing production extensively.

A control programme was initiated involving the Coffee Industry Board and the Crop Care Section of the Ministry of Agriculture. The programme started in 1978 and consists of three phases:

Phase I: Survey to determine the spread and level of infestation.

Phase II: Post harvest field sanitation, designed to obtain a drastic step in the pest population. This is achieved by:-

a) stripping trees of all berries,
b) cleaning fields,
c) destroying debris and refuse by burying or burning, and the application of an insecticide (chlordane) to the ground surface of coffee fields,

d) education through field days and demonstration, and the motivation of farmers to become aware of the gravity of the problem.

Phase III: Foliar preventive spraying, the objective being to protect the developing crop and reduce the level of damage and infestation. This is achieved by the application of insecticides, specifically edosulfan (Thiodan) at the rate of 800 ml per 230 l of water. There should be at least two applications during the crop, starting when 50% of the berries are two months old, the 2nd, 4-6 weeks after. A third application may be made in localized areas where infestation is high. A systemic insecticide, dimethoate (Rogor), is added to alleviate very high infestation. A copper fungicide is added (Kocide or Cupravit) to this mixture as a preventative against the disease.

6) **Citrus**

Citrus grown in Jamaica are mainly for the export of fresh fruits, canned juices and other by-products. The more popular species grown locally include:-

Citrus sinensis (L.) Osbeck –	orange
C. reticulata Blanco –	mandarin, tangerine
C. aurantium L. –	seville or sour orange
C. paradisi Macf. –	grapefruit
C. grandis (L.) Osbeck –	shaddock
C. limon (L.) Burm. –	lemon
C. medica L. –	citron

There are a number of hybrids which have been developed in Jamaica and are popular in the U.S.A. and Canada because of their taste –

C. paradisi x C. reticulata –	tangelos, ugli
C. reticulata x C. sinensis –	ortanique
C. reticulata x Fortunella sp –	calamondin

Citrus suffers from a number of insect pests and diseases, the most important being the citrus weevil of Jamaica and the Black Fly of Citrus, *Aleurocanthus woglumi*. VanWhervin (1968) reported the following six species of citrus weevil in Jamaica:

1. *Exophthalmus vittatus* L.
2. *E. viridipupillatus* Cockl.
3. *E. Similis* Drury
4. *E. farr* Vaurie
5. *Pachnaeus citri* Marsh
6. *Lachnopus aurifer* Drury

He noted that citrus weevil was observed on twenty five host plants, including hardwood plants, ornamentals, fruit trees and vegetables. Seven species of wasps were also observed, which are natural enemies of the citrus weevil and include:

- *Tetrastichus haitiensis*
- *Horismenus* spp
- *Fidiobia* spp

James (1954) reported that Dougal Campbell ant, *Cremastogaster brevispinosa*, was released in citrus groves to control the Black Fly of citrus, but this practice was discontinued when it was observed that the ants fostered and disseminated the green scale *Coccus viridis*.

7) **Cocoa** *(Theobroma cacao)*

Cocoa is grown for the production of the beans, which are processed and sold for the manufacture of chocolate drinks and bars.

Cocoa plantations are decimated by the Black Pod disease of cocoa, *Phytophthora palmivora*. Under wet conditions, which are favourable for the spread of the fungus, the crop loss may be in excess of 75%. To control the disease, the plants must be sprayed with a copper fungicide e.g. Kocide, Cupravit Blue or Peronox at 1.5 – 1.75 kg/450 l. water.

8) **Vegetables**

Vegetables are grown all year round mainly for local consumption, for the Tourist Industry and in exceptional cases, for the winter market in New York, Toronto and Miami. Some of the more important vegetables grown are:

Lycopersicon esculentum –	tomato
Brassica oleracea –	cabbage
Sechuim edule – –	cho cho
Lactuca sativa –	lettuce
Amaranthus spp –	calalu
Allium cepa –	onion

Several diseases such as, damping off, Sclerotium wilt, Fusarium wilt and root knot nematode affect most vegetables, often starting in the seed bed. Pests such as tomato pin worm, diamond back moth, aphids, cutworm, cabbage looper, all contribute to a decline in production.

Tomato pinworm, *Keiferia* sp, since its appearance in Jamaica has caused losses sometimes as high as 60% of the crop. Control is obtained by using Surecide or Lannate (methomyl) for a quick "knockdown". Other crops affected by the tomato pinworm include Irish potato, pepper, tobacco and eggplant.

Diamond back moth, *Plutella xylostella*, attacks nearly all cruciferous crops, causing extensive damage. Control is achieved by applying Thuricide, Phosdrin, or Azodrin.

Weed control also plays an important role in the production of vegetables. It is therefore incumbent on the farmer to control weeds in order to achieve maximum production. On small farms, control is usually obtained by the use of a hoe, machete or by hand weeding, whereas on large farms weeds are controlled by herbicides.

Several weed species have become important in vegetable production, due to their persistence. Nutgrass *Cyperus rotundus*, white top, *Parthenium hysterophorus*, and Johnson grass, *Sorghum halepense*, are the three most persistent weeds found in Jamaica. The control of nutgrass may be obtained by the use of glyphosate at the rate of 3.5 kg/ha., EPTC applied pre-plant at 5 kg/ha., white top and Johnson grass can be controlled by the use of 2,4,5-T applied post-emergence.

Plant Quarantine

Fruits and vegetables, rooted plants, bulbs and other plant parts are capable of carrying diseases and insect pests from one country to another. To prevent introduction of diseases and insect pests into the island, restrictions are placed on the importation of plant and parts of plants.

The Plant Quarantine Section under the Ministry of Agriculture, is responsible for the issuing of permits for all plant and parts of plants entering Jamaica. Officers carry out inspection of plants, plant parts and fruits entering the island via the airports and shipping wharves, ensuring that phytosanitary certificates accompany each shipment.

Plants, fruits, vegetables and root crops are allowed entry into the island from areas where there is little risk of introducing pests or disease causing organisms.

Crop Care

The Crop Care Division offers the following assistance to the family community:

a) Service – The principal service offered is the application of pesticides to control insect pests and diseases in crops. A minimal charge of $3.00 per acre is attached to the service provided. There is no charge for labour.

b) Distribution of Pesticides – Pesticides are distributed to farmers who have their own equipment and have experience in applying pesticides. There is no charge for the pesticide and no limit as to the amount of pesticide the farmer receives.

c) Loan of Equipment – Any farmer who has a working knowledge of agricultural equipment and is in need of such equipment, is provided with equipment to com-

plete his job. There is no charge for this service. Table 2 summarises the crops, pests and control methods usually undertaken.

Table 2 Important Insect Pests of Crops in Jamaica and Control Methods

Vegetable	Insect	Control
a) Crucifers	*Plutella xylostella*	Thuricide, Phosdrin
	Trichoplusia ni	Thuricide, Surecide
	Brevicoryne brassicae	Malathion, Dimethoate, Diazinon
	Agrotis spp.	Chlordane, Diazinon
b) Cucurbits	*Tetranychus* spp.	Dimethoate, Kelthane
	Diabrotica balteata	Dipterex, Diazinon
c) Solanaceae	*Keiferia* spp.	Azodrin, Lannate
	Phyllotreta spp.	Diazinon, Agrothion
	Heliothis spp.	Dipterex, Sevin
d) Onion	*Thrips tabaci*	Malathion, Dimethoate
Legumes	*Fundella cistipennis*	Supona, Surecide
	Nezara viridula	Azodrin, Diazinon
	Heliothis zea	Dipterex, Sevin, Azodrin
	Empoasca fabae	Dimethoate, Diazinon
Root Crops		
a) Sweet Potato	*Cylas formicarius*	Cultural control – rotation, prompt harvesting
b) Cassava	*Silba pendula*	Not generally controlled
c) Irish potato	*Agrotis* spp.	Soil treatment
	Phyllophaga spp.	Soil treatment
	Exophthalmus spp.	Soil treatment
Coffee	*Hypothemus hampei*	Dimethoate, Kocide

Table 3 Important Diseases of Crops in Jamaica

Crop	Disease	Pathogen	Control
Banana	Leaf Spot	*Mycosphaerella musicola*	– Maneb, oil, Kocide, Benlate
Citrus	Citrus Scab	*Elsinoe fawcetti*	– Benlate
	Stem Knot of Lime	*Sphaeropsis* spp.	– Pruning
Coconut	Lethal Yellowing	mycoplasma	– Tetracycline injection & replanting with resistant variety
Sugar Cane	Rust	*Puccina melanocephala*	– Replanting with resistant variety
	Smut	*Ustilago scitaminea*	
Coffee	Anthracnose	*Glomerella cingulata*	– Difolatan, Kocide
Pimento	Rust	*Puccinia psidii*	– Maneb, Zineb
Vegetable:			
Cabbage	Downy Mildew	*Peronospora parasitica*	– Zineb, Dithane
Carrot	Leaf Blight	*Alternaria dauci*	– Manzate, Zineb
Lettuce	Leaf Spot	*Cercospora longissima*	– Antracol, Maneb
Onion	Leaf Disease	*Alternaria porri*	– Maneb, Zineb
Tomato	Fusarium Wilt	*Fusarium oxysporium*	– Rotation
	Southern Blight	*Sclerotium rolfsii*	– Soil treatment
Legume:			
Cow Peas	Moasaic	virus	– Clean seed
Peanut	Rust	*Puccinia arachidis*	– Kocide, Maneb
Soyabean	Anthracnose	*Glomerella glycinea*	– Maneb, Kocide
Root Crop:			
Cassava	Black rot	*Rosellinia* spp.	– Rotate crop
Irish Potato	Late Blight	*Phytophthora infestans*	– Maneb, Zineb
	Early Blight	*Alternaria solani*	– Use resistant varieties
Yam	Black rot	*Rosellinia* spp.	– Kocide, Perenox
Cereal:			
Corn	Leaf Blight	*Helminthosporium turcicum*	– Seed treatment
	Leaf Spot	*Cercospora sorghi*	– Maneb, Zineb
Rice	Blast	*Pyricularia oryzae*	– Thiram, Captam
Sorghum	Rust	*Puccinia purpurea*	– Rotate crop
Misc. Crop:			
Tobacco	Blue Mould	*Peronospora tabacina*	– Redomil, zineb
Pineapple	Heat & Root Rot	*Phytophora parasitica*	– Difolatan
	Base or Butt Rot	*Ceratocystis paradoxa*	– Difolatan

PART II. PESTICIDES AND THEIR MANAGEMENT

THE PESTICIDES

There were 312 pesticides registered for use in Jamaica up to August 1980, which are classified as follows (Table 4):

Table 4 Classification of Pesticides Registered for use in Jamaica

Insecticides	166
Herbicides	65
Fungicides	53
Rodenticides	14
Nematicides	5
Acaricides	2
Bactericides	1
Soil fumigants	3
Additives	3
Total	312

Many of these have been indicated by name in Table 2.

Jamaica imports almost all its requirements of pesticides. Countries of origin are shown in Table 5, and in Table 6 the amount expressed in kilograms and Jamaican dollar value of pesticides imported for the period 1975-1978 are shown. The figures show that the total imports of pesticides have remained fairly constant at about 7 million kg/year: a sharp fall in insecticides has taken place, but an increase in herbicides.

Table 5 Countries of Origin of Pesticides Imported into Jamaica
(The figures indicate the number of different pesticides)

U.S.A.	209
United Kingdom	30
West Germany	30
Canada	15
Switzerland	13
New Zealand	6
Guatemala	3
France	2
Japan	1
Holland	1
Barbados	1
Jamaica	1
Total	312

PESTICIDE HAZARDS

The storage and transportation of pesticides pose serious health hazards. There are several incidents in which people have died tragically as a result of food stuff contaminated with pesticide either in storage or during transportation. Other incidents of pesticide poisoning involved the use of pesticides as a delousing agent.

Pesticides are imported into Jamaica by any of approximately 20 local distributors. These distributors sell wholesale to retail outlets, or operate their own retail outlet. There is no restriction on the sale of pesticides, regardless of their dermal or oral toxicity. However, there are restrictions on the importation and distribution of certain pesticides, but although there are so many pesticides registered, it is not unusual to see unregistered pesticides being sold in retail outlets — another obviously dangerous practice.

Table 6 Pesticides imported into Jamaica, 1976-1978

Pesticides	1975		1976		1977		1978	
	Ja. $	Kg.	Ja. $	Kg.	Ja. $	Kg.	Ja. $	Kg.
Insecticide/ Nematicide	2,341,126	2,592,201	2,327,971	994,094	2,774,713	895,664	3,914,392	911,101
Fungicide	897,327	3,690,415	1,864,083	6,113,342	1,534,327	4,667,759	2,192,635	5,379,107
Herbicide	1,490,978	434,880	747,529	240,563	667,491	188,840	1,375,512	1,621,175

Figures obtained from the Department of Statistics — Kingston, Jamaica.

PESTICIDE REGULATIONS

The importation, manufacture, sale, registration and usage of pesticides in Jamaica need re-examination and more stringent laws passed to regulate control.

Prior to 1975, there were no specific laws regulating the use and importation of pesticides in Jamaica. At that time, these functions came under the Drugs and Poisons Board in the Ministry of Health and Environmental Control. An Advisory Pesticide Committee reporting directly to the Drugs and Poisons Board, carried out the following functions:

- registration of old pesticides,
- registration of new pesticides,
- registration of premises to sell wholesale,
- registration of premises to sell retail,
- registration of pest control operators.

Under the present Drugs and Poisons Laws, no provisions have been made to cover the importation and usage of pesticides. The law only covers drugs and poisons as related to human beings and animals.

In March 1975, a bill was signed in Parliament and became known as the Pesticides Act (Act 6 of 1975), which seeks to give legality to a "Pesticide Control Authority". The "Authority" was intended by law to be placed as a "Unit" in the Ministry of Agriculture under the direction of the Minister, and to deal with pesticides as indicated by the "forms" through which control was affected.

1) Form A – Regulation 4 (1) – Application for registration of pesticides

2) Form B – Regulation 5 (2) – Certification of registration of pesticides

3) Form C – Regulation 9 (1) & (2) – Application and licence to import pesticides

4) Form D – Regualtion 9 (3) – Application and licence to manufacture and/or process pesticides

5) Form E – Regulation 10 (1) – Application for registration to sell restricted pesticides and for registration of the premises in which these pesticides will be sold

6) Form F – Regulation 10 (8) – Certificate of Registration as an authorised seller of restricted pesticides and for the premises in which these pesticides will be sold

It became apparent that the setting up of such a "Unit" would be more complex than anticipated and it was therefore decided to amend the Pesticides Act (1975), and this was done by the "Pesticides (Amendment) Act (1977). Under the amendment the definition of the "Authority" was changed to mean a "Public Officer" so designated by the Minister of Agriculture. The amendment to the Pesticides Act has so far not been gazetted and the functions are still being performed in the Ministry of Health and Environmental Control.

PESTICIDE ALTERNATIVES

Investigations into the efficacy of new pesticides are presently being conducted. Associated with this is the investigation of alternative means of pest control.

The Banana Company of Jamaica was involved in the biological control of the banana weevil borer, though this proved unsuccessful. The Coconut Industry Board has bred hybrid coconut plants, resistant to the lethal yellowing disease of coconut. Scientists from the Ministry of Agriculture and CARDI are currently involved in investigating cultural and genetic means of pest control.

Hutton (1977) reported on nematodes associated with poor growth and development in such crops as plantain, pineapple, yam *(Dioscorea* spp*)*, tobacco, vegetable and ornamentals. Control

of nematodes involves crop rotation, replanting, the use of clean healthy material and planting of resistant varieties.

Thompson (1979) crossed the 10R3, a semi-prostrate red seeded cowpea with Blackeye No. 25, an erect, early maturing cowpea to control the Cowpea Mosaic Virus (CPMV). The F3 generation proved highly resistant.

Methods of weed control being investigated in the cultivation of peanut are spacing and plant population density. Both methods have proved successful in the control of many broad-leaf weeds.

EXTENSION AND EDUCATIONAL PROGRAMMES

Programmes involving pest control are arranged at different levels by the Training Division, Crop Care, and the Parish Extension staff of the Ministry of Agriculture. The Training Division conducts residential courses which include pest control management. These courses are held at special training centres, and involve agricultural field and livestock officers and farmers. At the divisional level, crop and animal care programmes are given through lectures, field days and demonstrations, which deal with specific problems. For immediate dissemination of a technique designed to control a specific problem, the Parish Managers conduct demonstrations on farm holdings. On some occasions specialists from other Government departments and pesticide distributors also assist in lectures and demonstrations.

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13. MONTSERRAT

PEST AND PESTICIDE MANAGEMENT

J.G. LYNCH and C. BROWNE

INTRODUCTION

Montserrat is a small island in the Eastern Caribbean located near latitude 16.8°N and longitude 62.2°W. It covers an area of 39.6 sq. mls. or 103 km^2 and has a population of 12,073. The island is of volcanic formation and is therefore rather mountainous. Because of the mountainous terrain only 5,500 acres or 2,225 hectares of the area are regarded as cultivable.

The temperature ranges between 73 and 79°F and there is an average annual rainfall of 60 ins. which contributes to the lush green appearance throughout most of the year, and hence the island is referred to as the "Emerald Isle of the West." The size and terrain do not facilitate any natural collection of surface water in terms of streams, rivers, or ponds and these are practically non-existent. The sources of water supplies are springs and deep wells. Montserrat, like all other human settlements, has its fair share of pests and probably more than its share if we consider weeds and the economics of weed control. Therefore, like other human settlements, we depend largely on the use of chemical pesticides.

THE PESTS

The major pests affecting the urban, health and agricultural sectors and their method of control are shown in Table 1. The most prevalent pests in the island are mosquitoes, flies, cockroaches, rats, green stink bugs, aphids, beetles, leaf miners, ticks and mites. There is also a fairly serious termite problem; this is mainly in the urban areas but termites are also common in the agricultural regions. Nematodes are pests of major importance but it is difficult to get farmers involved in nematode control.

The Ministry of Health carries out an *Aedes aegypti* eradication campaign as part of its routine work. From time to time other campaigns are carried out and recently the Ministry of Agriculture organised a livestock internal and external parasite control campaign and a rodent control campaign. There was collaboration with the Ministry of Health in the latter, as this campaign was conducted both in the homes and in the fields.

THE PESTICIDES

The pesticides available for use on the island are shown in Table 2 (at end of paper). Although the Government has almost total control over the amounts and rates of pesticides applied, accurate statistics on these cannot be obtained. This is due to faulty recording systems; these are being examined with plans to rectify them.

Most of the pesticides are applied by the Pest Control Inspectors of the Ministry of Health and the Crop Protection Team within the Ministry of Agriculture. These workers receive instructions in the basic principles of Pest Control, especially the safe use of pesticides and safety precautions to be observed when using pesticides.

With the exception of the *Aedes aegypti* campaign, which is on an island wide basis, pesticide application by the Pest Control Inspectors is restricted to refuse dumps and a few Government buildings. Pesticide application by the Crop Protection Team takes care of about 90% of the farming community.

The major importer of pesticides in the island is the Development Finance and Marketing Corporation (DFMC). However, there are two private entrepreneurs involved in pesticide application to the domestic sector who import some of their pesticides, and there is also an ornamental plant concern which imports its own. These, along with the commercial business houses which import aerosol containers of pesticides for home use, make up the total of pesticides imported into Montserrat.

Although accurate statistics cannot be obtained about the kinds and amounts of pesticides used, there are certain trends indicated. Among the insecticides, Systoate, Malathion, and Sevin are the most widely used. Malathion is used both by the health and agricultural sectors while

the other two are largely restricted to the agricultural sector, although Sevin is quite commonly used against cockroaches in the homes. However, Sevin is losing its popularity as an ixodicide (acaricide) and more and more livestock owners are turning to Supona for tick control.

The most commonly used fungicides are Kocide and Dithane. A moderate amount of Benlate and Rovral are used by Leeward Islands Plants Ltd. (the producers of ornamentals). The miticide/fungicide Karathane was once fairly widely used but workers do not like using it and its place has been taken by the miticide Kelthane.

Gramoxone is the most commonly used herbicide. There is a serious nut grass *(Cyperus rotundus)* problem on the island and Round-up has proven to be the most effective herbicide for its control. However, because of its high price the farming community are reluctant to use it, so its rise in popularity is slow. Livestock farmers use a fair amount of 2, 4, 5-T for controlling broad leaved weeds in pastures.

Fumigants and nematicides are not very widely used. Carbon disulphide and methyl bromide are used for fumigating cotton seed and Temik is used as a nematicide by Leeward Islands Plants Ltd.

The use of pneumatic hand sprayers, knapsack sprayers, thermo-fogging on a very limited scale, and spot baiting of rats and mice are the main modes of pesticide application, plus the use of the mist blower which is used only by the Agricultural Department.

PESTICIDE HAZARDS

No medical examination of workers is done prior to their employment. While this is considered desirable the particular tests cannot be done locally. However, Health Department workers are entitled to free medical treatment whenever they report ill. This is not the case in the Agricultural sector as workers must first prove that their illness was caused as a result of their occupation. However, absenteeism due to illness is not a frequent occurence.

Certain protective clothing is provided for use when handling concentrates, viz: respirators, reinforced rubber gloves and goggles. Unlike the Agricultural Department, where overalls are provided, the Health Department does not provide any but pays a laundry allowance in order to encourage and facilitate the regular and frequent washing of clothes that have become soiled with pesticides.

The only noticeable environmental impact at present is the effect of Hyvar X on trees and plants adjacent to plots treated with this herbicide. Other hazards not apparent to the naked eye may well be present but are impossible to certify due to the absence of any quality control facilities and a general lack of control management.

PESTICIDE REGULATIONS

The Pesticides Control Ordinance was brought into force in April 1975 to regulate the importation, sale, storage and use of pesticides, but to date this ordinance seems to be non-operative, and commercial houses and individuals appear free to import and use pesticides as they wish.

PESTICIDE ALTERNATIVES

Mosquitoes, flies, rats and mice are effectively controlled by improved refuse storage, collection and disposal. The same principle of effective post harvest clean up after crops is advocated by the Agricultural Department for certain crops e.g. cotton and cabbage. Cotton has legislative support to control this post harvest clean up. In the case of livestock, rotation of animals on pastures and proper sanitation in pig rearing is encouraged to reduce the possibility of parasite infestation.

There are several examples of biological control on the island some of which are highlighted below:

(a) Fresh water fish were recently introduced to a newly constructed irrigation dam to control mosquito breeding.

(b) The white cattle egret controls ticks on livestock.

(c) Lady bird beetles control aphids on plants.

(d) The Bengal bean which was commonly used as a green manure was found to control nematodes. Farmers are encouraged to re-introduce the use of the begal bean but there are problems involved in incorporating it into the soil by tillage implements.

EXTENSION AND EDUCATIONAL PROGRAMMES

There are ongoing educational programmes in both Departments geared to impart knowledge and change attitudes with regards to factors associated with pest control and the economy and hazards of chemical agents.

AGROMEDICAL TEAM APPROACH

While there is a limited formal approach to pesticide management and pest control between the two Ministries, it is worthwhile to note that the board of control as set out in the Pesticides Control Ordinance of 1975 should consist of the Chief Medical Officer and the Director of Agriculture.

There has been a joint approach in a recent rodent control campaign and there is provision for the exchange and sharing of information in matters of this nature.

CONCLUSION

Montserrat is in a unique position in that most of the pesticides used are applied by persons with some basic training and under experienced supervision. This reduces the risk of pesticides becoming a health hazard or being of any danger to the environment.

However, because of the laxity in which pesticides are imported into the island there is always a risk of something disastrous happening. Much of this can be put right if the Ordinance of 1975 is set in motion. There would still exist a problem, however, because most of the supporting legislation e.g. Plant Protection, Quarantine, Animals (Diseases & Importation) etc. is outdated. In some cases attempts are being made at revising the laws, in others the laws may be adequate but because of lack of infrastructure and/or lack of adequate trained personnel they are not enforcible.

Table 1 Crops, Pests and Diseases, and Control Methods

AGRICULTURE

Crop	Pest/Disease	Pesticide/Method of Control
Cotton	Aphid *(Aphis gossypii)*	Systoate
	Hardback	Sevin
	Boll Weevil *(Heliothis armigera)*	Sevin, Thiodan
	Red spider mite *(Tetranychus* sp.*)*	Systoate
	Cotton stainer *(Dysdercus* sp.*)*	Sevin, Thiodan
	Leaf eating caterpillar	Sevin
	Black boll	Kocide, Dithane
Hot pepper	Leaf miner	Systoate
	Greeen stink bug *(Nezara viridula)*	Sevin, Malathion
	Pepper bud moth	Systoate, Diazinion, Malathion
	Anthracnose	Benlate
	Southern blight	Rogue and burn
	Mosaic virus	Rogue and burn

(Table 1 Continued)

Crop	Pest/Disease	Pesticide/Method of Control
Cabbage	Diamond back moth	Dipterex
	Cabbage looper	Dipterex
	Cabbage white butterfly	Diazinon, Malathion
	Black rot	Dithane
	Tip burn	Dithane, rogue
Tomato	Leaf miner	Systoate
	Mite	Kelthane
	Green stink bug	Sevin, Malathion
	Cutworms	DDT-toxaphene, Dipterex
	Root knot nematode	Furadan, Nemagon
	Southern blight	Rogue and burn
Peanuts	Mite	Kelthane, Karathane
	Southern blight	Rogue and burn
Onion	Thrips	Sevin
	Cutworms	DDT-toxaphene, Dipterex
Corn	Fall army worm	Dipterex, Systoate
	Corn smut	Rogue and burn
Beans	Beetles	Sevin, Malathion
	Aphids	Systoate, Malathion, Diazinon
	Mealy bugs	Malathion, Diazinon
	Cercospora leaf spot	Kocide, Dithane
	Tobacco mosaic virus	Rogueing
Eggplant	Leaf miner	Systoate
	Mites	Kelthane, Karathane
	Lace bug	Sevin, Malathion
Cucumber	Leaf eating caterpillars	Diazinon, Malathion
	Powdery mildew	Kocide, Dithane
Carrots	Southern blight	Rogue and burn
	Soft rot	Improve drainage system
Sweet potato	Silas weevil	Sevin, rogue
Animal	**Pest/Disease**	**Pesticide/Method of Control**
Cattle	Tick *(Amblyoma cajenense Boophilus microplus)*	Sevin, Supona
	Biting fly *(Dermatophilus congolensis)*	Sevin Penicillin-Streptomycin
Sheep	Tick *(Amblyoma cajenense)*	Sevin, Supona
	Mite	Lindane
Goat	Tick *(A. cajenense)*	Sevin, Supona
	Mite	Lindane
Rabbit	Ear mite	Aurimite
Poultry	Lice	

(Table 1 Continued)

Animal	Pest/Disease	Pesticide/Method of Control
Dog	Tick *(Rhipicephalus* sp.*)*	Aurimite, Sevin, Supona
	Mite *(Demodex canis)*	Aurimite
	Flea	
Cat	Lice	
	Flea	

PUBLIC HEALTH

Pest	Pesticide/Method of Control
Mosquito (18 spp.)	Malathion, Abate, Baytex, Baygon, Sheltox, Airkem, Raid, Mosquito Coil
Flies	Malathion (residual and fogging), Floret, Baygon
Cockroaches	Malathion, Abate
Rats and Mice	Warfarin, Ratak, Racumin, Biotrol, Parablox
Termites	Aldrin, Lindane

Table 2 Pesticides available in Montserrat

INSECTICIDES

Organochlorines	Organophosphates	Carbamates
Acarin	Abate	Nudrin
Aldrin	Baytex	Baygon
Arkotine	Diazinon Orthene 75S	Sevin
Chlordane	Diptere::	
DDT-Toxaphene	Gardona	
Kelthane	Gusathion	
Lindane	Maladrex	
Thiodan	Malathion	
Thionex	Sheltox	
	Supona	
	Systoate	

Spore Pathogens	Pyrethroids	Miscellaneous
Dipel	Airkem	Albolinium
Thuricide	Ambush	Raid
	Decis	Triona
	Floret	

(Table 2 Continued)

FUNGICIDES

Copper

Copper A
Kocide

Carbamates

Benlate
Dithane
Ficam
Rovral
Tri miltox forte (+ Cu)

Aromatic Compounds

Karathane

Sulphur

Captan
Elvaron

Miscellaneous

Bravo

FUMIGANTS AND NEMATICIDES

Fumigants

Carbon disulphide
Methyl bromide
Nemagon

Carbamates

Furadan
Temik
Vapam

Organophosphates

Disyston

Organochlorines

Shell D D

RODENTICIDES

Biotrol
Parablox
Racumin
Ratak
Warfarin

HERBICIDES

Triazines

Gesapax (ametryne)
Gesaprim (atrazine)
Simazine

Diazines

Hyvar X (bromacil)

Substituted Ureas

Cotoran (fluometuron)
Dybar (fenuron)
Karmex (diuron)

Thiocarbamates and Dithiocarbamates

Eptam (EPTC)
Vernam (vernolate)

Phenoxy Compounds

2, 4-D
2, 4, 5-T

Quarternary Ammonium Compounds

Gramoxone
Millquat
Reglone

Benzoic Acids

Amiben (chloramben)

(Table 2 Continued)

Amides

Enide (diphenamid)
Lasso (alachlor)

Miscellaneous

Ansar (Ammonium methanearsonate)
Conso weed killer
Dacthal (chlorthal dimethyl)
Dow Sodium TCA
Kerb 50 W (pronamide)
Round up (glyphosate)
Tok E 25 (nitrofen)

14. ST. KITTS-NEVIS

PEST AND PESTICIDE MANAGEMENT (HEALTH)

J. A. STEVENS

INTRODUCTION

During the past 60 years or more, there have been significant changes in the use of Pesticides. These developments have resulted in vast increases in production of food, and the control of insect-borne diseases, such as, malaria, yellow fever, plague, typhus and encephalitis. In earlier years, Public Health workers relied mainly on the arsenicals, sulphur, petroleum oils and pyrethrum as insecticides. Although these continue to be widely used, today the emphasis is on the organophosphate, carbamate and chlorinated hydrocarbon insecticides, which were developed since World War I. Some of these, particularly a few of the chlorinated hydrocarbons such as DDT, remained in the environment for years, and entered non-target organisms, thus affecting the food chains of mammals, birds and fishes. As a result of this, some countries have enacted legislation restricting or abolishing the use of some of these pesticides.

Pest control programmes today should therefore focus attention on integrated control. We of the Environmental Health Agency, consider that the most effective pest control programmes have resulted from a combination of biological, environmental and chemical methods, rather than from the use of insecticides alone. In St. Kitts/Nevis, for example, over the past years, the Department of Health based its mosquito control programme on proper water management rather than emphasis on insecticide application. Similarly, the control of flies has been achieved particularly by proper environmental sanitation of premises etc., rather than by pesticides.

We are now concerned not only with the control of insect vectors/pests, but also with the conservation of the entire environment. Chemical control supplements, but does not supplant other control measures.

THE PESTS

Only those of particular importance to Environmental Health and the Department of Health are considered. Mosquitoes are the most serious, in particular the continued presence of *Aedes aegypti*, the vector of yellow fever and dengue. *Anopheles aquasalis*, the vector of malaria, is present in Nevis. *Culex fatigans* and *C. quinquifaciatus*, vectors of filariasis, occur in both islands, and also a salt marsh mosquito, *Aedes taeniorhynchus*, which has a very painful bite.

Sand flies *(Culicoides furens)* and house flies are also serious pests. and to a lesser extent cockroaches, bed bugs and lice. There are also pests of stored food products, weevils and beetles, especially in warehouses and storerooms.

There is also concern for the alarming rodent (rats and mice) population which will have to be given very serious and urgent attention by both Departments of Agriculture and Health.

At the present time the Department of Health of St. Kitts/Nevis has no specific programme in respect of either mosquito or rodent control, but propsals have been submitted to Government to revive the *Aedes aegypti* eradication programme which was instituted in the 1950's, but which was not completed due to various factors. Proposals were also submitted to undertake an organised rodent control programme, but to date this has not been achieved.

THE PESTICIDES

The use of pesticides generally by the Department of Health is on a very limited basis, and the pesticide used by the Department may be classified as follows:-

Adulticides	Larvicides	Rodentcides
Residual Sprays	Solutions	Baits
Fogs	Emulsions	
Mist		
Dusts		

The difference between Public Health and agricultural use of pesticides may be summarised briefly (Table 1).

Table 1 Comparison of Agricultural and Public Health use of pesticides

	PUBLIC HEALTH		AGRICULTURE
PESTS			
i)	A few, well defined species, predominantly insects.	i)	A wide variety, including insects, mammals and plants.
PESTICIDES			
i)	Usually of low or moderate toxicity.	i)	Widely varying toxicity.
ii)	Persistence usually sought.	ii)	Persistence less important.
iii)	There is considerable exposure of the general public.	iii)	There is minor exposure of the public if properly used.
iv)	There is a regular cycle of application, usually of a single pesticide.	iv)	May be irregular or sequential application.

The types of insecticide used by the Department of Health consist of:

(i) Organophosphates

Malathion and Diazinon have generally replaced the chlorinated hydrocarbons such as DDT, because they control resistant insects, and do not contaminate the environment. Malathion is the insecticide most widely used by the Health Department, especially for the control of adult mosquitoes and sandflies. It is used in proportions of 2.5 – 5 per cent sprays or as a fog or mist in space-spraying. Malathion 57 per cent emulsifiable formulation is used for making up the spray solutions. Diazinon is used to control cockroaches, fleas, spiders and many other household insects. Since it is more toxic to human beings than Malathion it is used at lower concentrations. Only 0.5 per cent spray is used in the home for cockroach control. It is believed that Diazinon resistant strains of cockroaches have developed in some countries.

(ii) Carbamates

Carbaryl (Sevin) is normally used as dusts at a 2 – 5 per cent concentration to kill fleas and ticks on dogs and cats, and to control cockroaches, centipedes, ants and many other arthropods.

Baygon is used in the control of Cockroaches. Houseflies etc. It has not only a residual and long-lasting effect as an insecticide, but also as a rapid knock-down action.

(iii) Mineral Oils

Petroleum oils such as kerosene and diesel oil have been used as mosquito larvicides for many years. Diesel oil is the commonest solvent for the synthetic insecticides such as Malathion used for larviciding, fogging or misting. Triton X is added as a spreading agent, which increases the quantity of solvent used in relation to the coverage, e.g. it will be possible to use only 2 – 3 galls of Diesel Oil per acre.

PESTICIDE HAZARDS

Harm to Man. Most pesticides can cause severe illness, or even death, if misused, but every registered pesticide can be used safely if used correctly. Many accidental pesticide deaths are caused in some countries by eating or drinking the product, but some applicators die or are injured when they breathe a pesticide vapour or get a pesticide on their skin. Repeated exposure to small amounts of some pesticides can cause severe illness.

Harm to Environment. Fine mists of herbicides can drift to nearby crops or landscape plants and kill them. Bees and other pollinators can be killed if crops are treated with a pesticide while they are in the field, or the natural enemies of insect pests can be killed.

Life in streams or ponds can be wiped out by:-

(a) accidental spraying of ditches,
(b) run-off from sprayed fields,
(c) careless tank filling or draining,
(d) careless container disposal.

Not all pesticides act the same way afte. they are applied. Most pesticides break-down quickly and remain in the environment only a short time before changing into harmless products. Others break-down slowly, and may stay in the environment without change for lengthy periods. These are known as persistent pesticides. In addition, some persistent pesticides can build up in the bodies of animals, including man, and these are spoken of accumulative.

Pesticides become problems when they move off target such as:-

(a) drifting out of the target area in the form of mist or dust,
(b) moving on soil particles by erosion,
(c) leaching through the soil and contaminating sources of water supplies,
(d) being carried out as residues in crops and live-stock, or evaporating and moving with air currents.

PESTICIDE REGULATIONS

The Government of the State of St. Kitts/Nevis has enacted legislation relating to Pesticides, known as the Pesticides Act No. 20 of 1973. The arrangements of the relevant sections deal with (1) Short Title, (2) Interpretation, (3) Regulations, (4) Pesticides Board and assignment of Inspectors, (7) Offences and Penalties, (8) Taking of samples for analysis, (9) Expenses, (10) Crown, (11) Commencement.

In the exercise of the powers conferred upon the Minister of Agriculture by section II of the Pesticides Act 1973, notice was given and cited the 1st day of February 1974 as the appointed day on which the Act went into operation. Similarly, Regulations were made and cited as the Pesticides (Labelling and Storage of containers) Regulations, Statutory Rules and Orders No. 18 of 1975.

Since the provision of such legislation (The Pesticide Act) the Ministry of Agriculture circulated for informalation and guidance of a list of Pesticides of very high mamalian toxicity, and advised against the importation of such pesticides into the State of St. Kitts/Nevis. These pesticides were Parathion, Endrin, T.E.P.P., Aldrin, Dieldrin, Phosdrin, Antak, Bidrin, Dinoseb, Calcium arsenate, Furadan, Lannate, Lindane, Systox, D.D.T., D.D.V.P., Thimet, Isolan and Isodrin.

PESTICIDE ALTERNATIVES

If more than one pesticide will control the pest, the one that is the least hazardous to the environment, and most useful for the particular situation should be chosen. Whatever methods are proposed for pest control should be subjected to the same searching examination for potential toxicity to man as is applied to the synthetic pesticides. It may be very difficult to provide satisfactory criteria for testing the safety of such agents as novel viruses or bacteria.

Environmental Sanitation, particularly proper storage and disposal of garbage and animal wastes, is of primary importance in fly control programmes. Similarly in mosquito control, only a limited amount of insecticidal application is necessary if adequate water management practices are maintained.

There has recently been extensive research in such areas as insect parasites, insect sterility etc. Hundreds of species of parasites attack Arthropods of Public Health Importance, but there is so far no agent available on an operational basis. Insect sterility research has been focused on the sterile male technique using irradication, chemosterilants and genetic control. However, so far as Public Health is concerned, these also are not yet of operational importance.

It must be clearly understood that any pest control measure, including the use of pesticides, will have effects other than its intended use. Such side effects may prove to be good or bad,

they may be gross or minimal, temporary or permanent, localized or dispersed widely. The importance of an integrated pest control management is to try and choose such pest control measures as will minimize harmful effects and maximise beneficial ones. Neither pesticides nor any other control measures should be abused to the extent that they serve no useful purpose, but instead adversely affect man and his environment.

AGROMEDICAL TEAM APPROACH

The only collaborative aspect that has been established in this area is the fact that the Chief Medical Officer is a member of the Pesticide Board appointed by the Minister of Agriculture, which includes also the Chief Agricultural Officer as Chairman, the Labour Commissioner, the Government Analyst and a secretary. However, there seems to be little doubt that with the growing concern for the safe use of pesticides, a more concerted team approach between the Ministries will be established in the near future.

15. ST. KITTS-NEVIS

PEST AND PESTICIDE MANAGEMENT (AGRICULTURE)

JEROME THOMAS

INTRODUCTION

This paper briefly outlines the Agricultural aspects of Pest and Pesticide Management in St. Christopher-Nevis; Public Health aspects are considered elsewhere in this volume (Stevens: Paper No. 12). The discussion is limited to insect pests and insecticides, though it is noted (Table 1) that herbicides are the chemicals used in the greatest quantity, and small quantities of fungicides are also imported. As is so often the case, Government practices (NACO and Government Farms) are far ahead of small farms in this technology, and although there is no planned extension programme involving pesticide use and safety, the need is obvious.

THE PESTS

Sugar cane is the major crop, occupying over 4,000 hectares. The sugar cane moth, *Diatraea saccharalis*, is the most serious pest of the crop. The larva bores horizontally and the fully formed larva pupates within the stalk, leaving a fine film of plant tissue covering the pupal chamber. The severity of borer attack is assessed as a percentage joint infestation of mature cane. The economic threshold level used is 5%.

The current management practice is a continuation of the biological control programme which began in 1932 with the release of the Cuban Fly, *Lixophaga diatraeae* (Tachinidae). In 1969 two further parasites, *Apanteles flavipes* and *Metagonistylum minense*, were released. The most recent releases of *A.flavipes* were made in 1970, 1971, 1972 and 1973. The borer survey done in 1978 gave the island-wide level of *Diatraea* infestation as 7.6% (Yanseen 1978). Further releases of *Apanteles* spp. are planned for the near future.

Peanuts occupy over 120 hectares of land under the National Agricultural Corporation's (NACO) diversification programme. This crop, which is traditionally a small farmer's cash crop is attacked by two major pests. *Spodoptera eridenia*, the army worm, is the most destructive pest and can travel great distances at night. The green worm, *Anomis argillacea*, which wriggles violently when disturbed, is the other major pest.

The yellow to greenish-yellow velvet bean caterpillar, *Anticarsia gemmatalis*, occasionally appears in damaging numbers.

Small farmers seldom attempt any control of pests. NACO practices a regular spray programme approximately once every ten days, alternating Orthene with Belmark.

Vegetables are traditionally grown by small farmers, especially during the cooler months of the year. The major pests attacking most vegetable crops are army-worms, *Spodoptera* spp., and cut-worms, *Agrotis* spp.

The major pests of the Cruciferae are the diamond-back moth *Plutella xylostella*, and the cabbage budworm *Hellula rogatalis*. Tomato is the other major vegetable crop grown that has specific pest problems viz. green stink bugs *Nezera viridula* and tomato fruit worm, *Heliothis* spp.

Most farmers obtain their pesticides from the Agricultural Department. Generally, pesticides are not used on a regular basis. Sevin and Orthene are sold to the farmers by the department. On the two hectare vegetable farm being operated by the National Agricultural Corporation, pesticide spraying is done on a regular basis. Alternation of the chemicals used in practised on this farm.

There are a few medium size livestock farms on St. Kitts-Nevis. Most farmers keep their livestock in their yards overnight and take them out for grazing during the daytime. Mange mite, *Sarcoptes scabiei* var. *suis*, is the major pest of pigs, and is more prevalent on the large white pigs than on the local black pigs.

The major pests found on cattle are the ticks, *Boophilus microplus* and *Amblyomma* spp. *B. microplus* is the more common tick. Horn flies, *Siphona irritans*, is the other common pest.

For ticks, there is generally a haphazard control programme by the small farmers. On the government farms a regular spray programme is practised on a once per fortnight cycle, in which sevin and supona are alternated.

THE PESTICIDES

Table 1 gives the gross imports of pesticides into St. Kitts-Nevis during the three years 1977 and 1979, and table 2 the actual chemicals used (by trade names).

Table 1. Pesticide Imports (kg)

Year	1977	1978	1979
Insecticides	19,538	36,986	32,333
Fungicides	1,541	1,068	225
Weed-killers	41,054	19,769	50,852

Source: Government Statistical Department

Table 2. Pesticides used in St. Kitts-Nevis

Insecticides	Fungicides	Herbicides
Belmark	Benlate	Actril DS
Dipel	Kocide	Asulox 40
Dipterex		Gesagard 500
Dithane		Gesapax 500
Orthene		Gesapax Combi
Sevin		Gesaprim
Supona		Gramoxone
		Hyvar-X
		Round-up

PESTICIDE HAZARDS

The statistics department of the Ministry of Health has no records of human intoxication or deaths from pesticides.

PESTICIDE ALTERNATIVES

As is mentioned above biological control measures are well established in the Sugar Industry. No pesticide is used in the control of the moth borer.

NACO has recently introduced biological control measures on a limited scale for the control of armyworms in the peanut crop. The following parasites were recently received from the Caribbean Institute of Biological Control in Trinidad:- *Campoletis flavicineta, Telenomus remus T. nawai* and *Chelonus formosanus.*

EXTENSION AND EDUCATIONAL PROGRAMME

There is no planned programme involving pesticide use and safety. The limited extension service that exists at present encourages the use of pesticides wherever feasible.

REFERENCES

YASEEN, M. (1978). Report on a survey of the moth borer *Diatraea saccharalis* and its introduced parasites in St. Kitts, CIBC Report (Cyclostyled).

16. ST. LUCIA

PEST AND PESTICIDE MANAGEMENT

F. FLETCHER and F. GRIFFITH

St. Lucia is a small Island (238 sq miles) in the Caribbean sea and is situated between 13° 40' North Latitude and 60° 05' west Longitude which is approximately half way between the French Island Martinique to the North and St. Vincent to the South.

The Island is volcanic in origin, very rugged and mountainous, the highest peak is 3145 ft. A central mountain range runs north to south roughly dividing the island; lateral ridges extend easterly and westerly with numerous streams of water intercepting the mountains and spurs. The sudden dips and rises in the land are spectacular. The combination of mountains, sea, coastal plains and tropical vegetation especially when viewed from an elevation provides great scenic beauty and variety.

Notwithstanding the ruggedness of the Island there are plains on the east and west coasts and to a larger extent at the northern and southern ends of the Island, which provide suitable pasture lands for the raising of animals. These plains and in particular that of the south which is extensive and low lying, provide suitable places for mosquitoes breeding (ponds and marsh areas) and are well known for producing cattle suffering from fascioliasis (problems which face both the Health and Agricultural department and are yet to be tackled).

Narrow coastal valleys provide the location for most villages and towns. The Capital is the city of Castries; the other important towns are Soufriere and Vieux-Fort.

The population is approximately 120,000 mainly of African descent; there are a few East Indians, and Whites of British and French descent; a remnant of the original Caribs still exist but no trace of the Arawaks.

English is the official language, but patois, which is a broken French, is commonly spoken especially by the rural communities and the illiterate.

The Island has a tropical climate with temperatures ranging from 70° to 90° (21 - 36°C). There is a dry and wet season with an average annual rainfall ranging from 50 - 150 inches, being lowest in the northern and southern ends of the Island and highest in the central mountainous areas.

The Island's economy is predominently based on agriculture, industry and tourism. Approximately 70% of the agriculture is bananas, with coconuts the second most important crop. Approximately 41,646 acres are under agricultural production. The onslaught of hurricane Allen on the 4th August 1980 seriously affected agriculture, completely destroying the banana crop, and damaging most others, leaving the island temporarily dependent upon tourism and industry. However, programmes for the rehabilitation of the agricultural sector are in progress.

MAJOR PESTS OF THE AGRICULTURAL SECTOR

The current control programme for management of pests in the Agricultural and Health sectors in St. Lucia embraces the use of pesticides, as well as good sanitation, drainage and in case of agriculture, crop nutrition.

WINBAN has established methods for pest management in bananas, and several major pests have been identified. Much work needs to be done on the forecasting and monitoring of pest outbreaks.

Studies from a recent survey on the plant pests and diseases and their status have been reported by Mr. Alam and Dr. W. Small of CARDI (May 1980).

The major pests are listed below, along with the recommended pesticides and control measures.

Table 1 Major pests, control measures and pesticide recommended

LIVESTOCK PESTS

A. Cattle:

1. Ticks: *Boophilus microplus; Amblyomma* sp.
   Control: spray animal with used motor oil at 10 - 14 days intervals: burning pastures: Rotational grazing systems

2. Biting flies: (a) Horn flies
   (b) Blow flies

B. Sheep:

Ticks: *Boophilus* sp.
Mange Mites: Sarcoptic mites and Demodex sp.
Control: Disinfect with BHC solution: spray or hand dress with Gamatox (gamma isomer BHC).

C. Goats:

Ticks: *Amblyomma* sp. and *Boophilus microplus*
Mites: (a) Sarcoptic
(b) *Demodex* sp.
Control: Spray with BHC solution or Gamatox

D. Swine:

Mites: Sarcoptic
Demodex sp.
Control: Gamatox

CROP PESTS

Crop	Pest	Status	Recommended Pesticide & Control Measure
Cabbage *Brassica oleracea*	*Plutella xylostella*	***	Decis, Ambush, Lannate,
	Trichoplusia sp.		Lannate, Diazinon,
	Ascia monuste	***	Malathion, Dipterex, Lannate
	Hellula phidilealis	***	Toxaphene, Lannate, Dipterex.
	Brevicoryne brassicae	**	Malathion, Perfekthion, Dipterex
	Xanthomonas campestris		
	Damping off fungi		Hot water treatment — Captan
	Erwinia carotovora		
	Fusarium yellows	***	
Okra	Tipburn	***	
Hibiscus esculentus	*Anomis illita*	*	Lannate, Dipterex, Decis.
	Aphis gossypii	*	
	Tetranychus sp.	*	Perfekthion
	Empoasca sp.	*	Perfekthion
	Spodoptera eridania		

(1) Status: *** = serious
** = moderate
* = slight

Table 1 (Continued)

CROP PESTS

Crop	Pest	Status	Recommended Pesticide & Control Measure
Maize			
Zea mays	*Spodoptera frugiperda*		Sevin, Lannate
	Peregrinus maidis		Malathion, Perfekthion
	Thrips		Perfekthion
	Tetranychus sp.	***	
Cucumber			
Cucumis sativus	*Liriomyza* sp.	***	Dipterex
	Aphis gossypii		Diazinon, Dipterex
	Margaronia hyalinata	*	Lannate, Dithane, Dipterex, Decis
	Diabrotica sp.		Sevin
	Empoasca sp.		
	Tetranychus urticae		Perfekthion
	Nezara viridula	*	
	Lepidopterous leaf stitcher		
	Powdery mildew		
	Colletotrichum sp.		
	Angular leaf spot		
	(1) Status: *** = serious ** = moderate * = slight		
Tomato			
Lycopersicum esculentum	Lepidopterous fruit borer		Dipterer, Diazinon, Decis
	Liriomyza pusilla	**	Dipterex, Diazinon
	Nezara viridula	*	Sevin
	Myzus persicae		Malathion, Diazinon
	Pseudococcus sp.		Perfekthion, Malathion
	Trichoplusia ni	*	Perfekthion, Malathion
	Cryptopeltes nu		Malathion
	Epitrix parvula	*	
	Fusarium oxysporium	***	Rogue infected plants
	Alternaria solani	***	Kocide, Cupravit blue
	Sclerotium rolfsii		Rogue infected plants
	Blossom end rot	***	Lime
	Nematodes		Furadan
Sweet Potato			
Ipomoea batatas	*Spodoptera eridania*	**	
	Empoasca sp.	***	Perfekthion, Malathion
	Brachmia emigrans	*	
	Calycomyza ipomaeae		Dipterex
	Megastes grandalis	**	Lannate, Sevin
	Cyclas sp.	***	Heptachlor
Beans	*Liriomyza* sp.	**	Dipterex
Phaseolus vulgaris	*Zinckenia fascialis*		
	Nezara viridula		Malathion, Sevin, Dipterex
	Tetranychus sp.		Malathion, Sevin, Dipterex
	Urbanus proteus		Malathion, Sevin, Dipterex
	Uromyces phaseoli	*	
	Xanthomonas phaseoli	**	Dithane

Table 1 (Continued)

CROP PESTS

Crop	Pest	Status	Recommended Pesticide & Control Measure
Citrus *citrus* spp.	*Coccus viridis*	***	Folithion
	Planococcus citri	**	Metasystox
	Diaprepes familicus	**	Chlordane, Heptachlor, Folithion
	Veronicella sp.	***	Metaldehyde
	Atta sp.	**	
	Elsinoe fawcetti		Cupravit blue, Kocide
	Mycosphaerella citri	***	Cupravit blue, Kocide
	Diaporthe citri	***	Cupravit blue, Kocide
Coconuts *Cocos nucifiera*	*Aspidiotus destructor*		Field sanitation
	Cholus zonatus	**	Field sanitation
	Phytophora palmivora	**	Field sanitation
	Yellowing		
	Oryctes rhinoceros	**	Field sanitation
	Rhynchophorus palmarum		Field sanitation
	Rattus rattus	***	Ramik, Ratak, Ratex Blocks
Avocado *Persea americana*	*Phytophthora*	**	
	Colletotrichum sp.		Benlate, Captan dip
	Cephaleuros sp.		
Carrot *Daucus carota* L.	*Rhizoctonia* sp.		
	Alternaria sp.	***	
	Cercospora sp.	***	
	Aster yellow		
	Jassids		Malathion, Perfekthion
	Mirids		
Onion *Allium* sp.	*Liriomyza* sp.	***	Dipterex, Decis
	Thrips tabaci	**	Rogor, Metasystox
	Dieback	**	Malathion, Rogor, Diazinon
Celery	*Septoria* sp.	***	Kocide, Cupravit blue
Sweet pepper *Capsicum annuum*	*Cercospora* sp.	***	Dithane, Kocide
	Phthorimaea capsicus	**	
Dasheen and Eddoes *Colacasia esculenta*	*Corythuca gossypii*	**	
	Aphis gossypii	*	
	Tetranychus sp.		Perfekthion
	Tetraleurodes ursorum		
Tannia *Xanthosoma sagittifolium*	Burning disease	***	(Cause at present unknown)
	Aphis sp.	*	

Table 1 (Continued)

CROP PESTS

Crop	Pest	Status	Recommended Pesticide & Control Measure
	Colletotrichum sp.	**	
	Cercospora sp.		
	Sclerotium rolfsii		Rogue
	Powdery mildew	***	
Pigeon Peas			
Cajanus indicus	*Heliothis virescens*	**	Ambush, Decis, Belmark
	Fundella pellucens	**.	Ambush, Decis, Belmark
	Ancylostomia stercorea	**	Ambush, Decis, Belmark
	Rust		
Bananas			
Musa CVS	*Micosphaerella musicola*	**	Benlate + mineral oil
	Colletotrichum musae	**	Dithane, TBZ
	Nematodes	**	Mocap, Furadon
	Thysanoptera	**	Sleeving with polytheme
	Cosmopolites sordidus	***	Field sanitation
Cocoa			
Theobroma cacao	*Phytophora palmivora*	*	Kocide, Cupravit Blue
	Marasmius perniciosus	*	Remove diseased areas
	Thysanoptera		Malathion, Dipterex, Diazinon
	Coleoptera		Malathion, Dipterex, Diazinon

MAJOR WEEDS

The major weeds found in agricultural crops are listed below (Table 2). These weeds occur in bananas, coconuts, citrus, avocado and other crops, and generally throughout the Island. Gramoxone is the most commonly used herbicide.

Table 2 Major weeds and recommended herbicides

Weeds	Usual Herbicides
Commelina sp.	Gramoxone
Paspalum fasciculatum	Gesapax
Panicum muticum	Dalapon
	Maloran
Ipomoea tiliacea	2,4-D
Cyperus rotundus	Dacthal
Achyranthes indica	Simazine
Mimosa pudica	Gesaprim
Cleome sp.	Gramoxone
Anonopus compressus	Gramoxone
Parthenium sp.	Keep field weed free
Sporobulus indicus	Gramoxone
Aramanthus sp.	Keep field weed free
Canna coccinea	Keep field weed free
Solanum sp. (Buru Buru)	Keep field weed free
Sorghum halipense	Gramoxone

PESTS OF PUBLIC HEALTH IMPORTANCE

The major pests of Medical importance in St. Lucia are the mosquitoes, flies, sandflies and rodents. **Bodylice** *(Pediculus humanus humanus)* **headlice** *(Pediculus humanus capitis)*, **crablice** *(Phthirus pubis)* and **bed bugs** *(Cemex lectularis* and *Cemex hemipterus)* are all known in St. Lucia, but at present are not plentiful and do not present a health problem.

Mosquitoes are plentiful and do present a problem to the Health Department; the most important species are *Aedes aegypti* and *Culex* sp. *Anopheles* mosquitoes are few and do not specifically engage the attention of the Health Department as malaria was eradicated from the Island some eleven years ago. An Aedes aegytpi eradication programme is now ongoing.

Flies: there has been no specific programme for the control of flies in St. Lucia, but the Environmental Health Branch of the Ministry of Health deals with any problems as they arise. The most common flies are the house flies *(Musca domestica)* and the sandflies *(Phlebotomus)* which are continual nuisances, especially along the coastal areas where they affect mainly the villages and beach resorts.

Cockroaches. The common cockroaches *(Blatta orientalis)* are plentiful and the German cockroach *(Blattella germanica)* are few. No control programme is carried out by the Health Department, but individual householders take their own action against these annoying pests.

Insecticides used by the Health Department against any of the above mentional pests are basically Malathion 95%; Abate 1% granules, Malarioil and Diesel; operations include fogging, ULV spraying, hand pump spraying, and larvicidal hand applications.

Rodents. There are two species of rat in St. Lucia, the Norway rat *(Rattus norvegicus)* and the roof or tree rats *(Rattus rattus)*. There is also the house mouse *(Mus musculus)*. It is said that these three species of Rodent were introduced into St. Lucia during the early days of colonisation. Most of the damage to coconut plantations is caused by the white bellied *Rattus norvegicus frugivenus.*

Also present is the mongoose *(Herpestes javanicus)* which is believed to have been introduced into St. Lucia to control the rat population. This could only have been of some significance against *R. norvegicus* in the canefields but certainly is of no importance today since St. Lucia is no longer a cane producing country and neither can the mongoose climb trees in which rats frequently nest.

No effort has been made by the Health Department to control the mongoose population since it does not present any immediate health problem. However, the Health Department has undertaken a control programme against rats and mice, which started in 1975; this programme is limited in that operations do not go beyond the limit of the city and town and villages.

THE PESTICIDES

The statistics available represent quantities of chemicals requested for one year by the Agricultural and Public Health Sectors. The figures below (Table 3) are approximate annual averages.

Table 3 Annual use of pesticides in St. Lucia

INSECTICIDES (for agricultural use).

Chemical	Quantity Litres	Kg	Use and Pests controlled
Chlordane	95	-	Soil insects: cutworms, leaf hoppers, ants
Diazinon	126	150	Vegetables, citrus, corn: mites, moths, aphids, scale, corn earworm, leaf hopper, caterpillars, ticks, lice

(Table 3 Continued)

INSECTICIDES (for agricultural use).

Chemical	Quantity Litres	Kg	Use and Pests controlled
Folithion	152	-	Vegetables: aphids, leaf hoppers, scale, thrips, mites, borer, mealy bugs, caterpillars
Malathion	2,446	-	Vegetables, citrus, corn, legumes, guava, avocado cattle, sheep, goats, poultry; aphids, mites, scale, leaf hoppers, leaf miners, loopers, mealy bugs, corn earworm, caterpillars, bugs, ticks, lice, flies
Metasystox	76	-	Vegetables, aphids, thrips, leaf hoppers, mites
Primicid	380	-	Bananas, vegetables: banana borers, caterpillars, stink bugs, thrips.
Sevin		690	Orchard tree crops, vegetables, sweet potatoes, cats, dogs, poultry: wide range of insect pests including ticks, lice, fleas
Toxaphene	57	-	Citrus fruit, vegetables: leaf hoppers, army worm, cutworms, aphids, leaf miners, thrips.
Totals	3,332	840	

INSECTICIDES (for Public Health use)

Abate	-	3,665	Mosquitoes
Diesel oil	3,648	-	Mosquitoes
Malariol	15,390	-	Mosquitoes
Totals	19,038	3,665	

HERBICIDES

Chemical	Quantity Litres	Kg	Use and Pests controlled
2,4-D	76	-	Broad leaf weeds; brush killer
Daconate	684	-	Plantation crops: water grass, Johnson grass, etc.
Dacthal	-	111	Vegetables: a wide range of weeds
Dalapon	-	4,159	Banana, citrus, cocoa; Para grass, Johnson grass, perennial and annual grasses.
Gesapax	-	2,218	Citrus, avocado, banana, cocoa, coconut; Para grass, water grass
Gramoxone	46,990		Citrus, avocado, banana, cocoa, coffee: annual weeds and grasses

(Table 3 Continued)

HERBICIDES

Chemical	Quantity Litres	Kg	Use and Pests controlled
Malaron	-	1,669	Bananas; weeds
Round-up	1,140	-	Johnson grass, Bermuda grass
Totals	48,890	8,157	

FUNGICIDES

Antracol	-	45.4	Citrus, vegetables; leaf spot, powdery and downy mildew, early and late blight
Benlate	-	5,448	Vegetables, citrus, avocado, and mixed with mineral oil in bananas; leaf spot, banana black rot, stem rot, *Fusarium*, *Cercospora* crown rot, *Botrytis*
Captan	-	45.4	Vegetables, citrus, avocado, mango
Cupravit blue	-	318	Vegetables, avocado, citrus, mango, cocoa, coffee; anthracnose, leaf spot, leaf curl, bacterial blight, early and late blight, downy mildew
Dithane M45	-	130	Vegetables, citrus, mango, avocado, cocoa; anthracnose, leaf spot, scab, black rot, rust, early and late blight
Kocide	-	91	Vegetables, citrus, avocado: Cercospora leaf spot, anthracnose, other leaf spots, bacterial blight.
Mildothane	-	509	Banana; anthracnose, black spot, leaf spot, stem rot, post-harvest decay
Mertect (TB2) and TBTO	3,140	-	Banana crown rot, stem-end rot, *Cercospora* leaf spot
Totals	3,140	6,586.8	

NEMATICIDES

Furadan	-	2,722	Banana, vegetables; nematodes and soil insects
Mocap	-	2,012	Banana, vegetables; nematodes
Totals		4,734	

RODENTICIDES

Ramik	-		
Ratak	-	32,317	Rats
Ratax blocks	-		

(Table 3 Continued)

RODENTICIDES

Chemical	Quantity Litres Kg	Use and Pests controlled

MOLLUSCIDES

Slugit liquid	300	Vegetables and other crops; slugs
Bayluscide	400	Freshwater snails
Totals	700	

LIVESTOCK CHEMICALS

(Acaricides)

Becotox	760	Cattle, sheep, goats; ticks
Gamatox	76	Cattle, sheep, goats; fleas, mange, mites
Totals	836	

OVERALL QUANTITIES OF CHEMICALS USED

Insecticides, Molluscicides and Nematicides

Agriculture:	3,622 litres	5,574 kg
Public Health:	400 litres	3,665 kg (+ 19,038 litres of Diesel oil and Malariol)
Herbicides:		
Agriculture	48,890 litres	8,157 kg
Fungicides:		
Agriculture	3,140 litres	6,587 kg
Rodenticides:		
Public Health	-	32,317 kg
Totals	56,052 litres	53,300 kg

Trends. There is a substantially greater use of herbicides than of insecticides in the agricultural programme. There has in recent years been some replacement of other namaticides. by Furadan in banana cultivation. The banana industry is the major user of herbicides and relies heavily on Gramoxone (paraquat).

PESTICIDE HAZARDS

There have been no alarming reports as to human intoxication or deaths from pesticides. The Annual Report of the Division for the year 1978 discloses one death from herbicide ingestion. However, there is a host of problems connected with the use of pesticides in both Public Health and agriculture.

1. The inability of some farmers to read and write creates a major hazard in the use of poisonous chemicals. Patois (French creole) is mostly spoken by those people actually handling and spraying the chemical.

2. Inadequate equipment for measuring and application of pesticides: eg. dealers send short plastic scoops for use of Furadan – one of the most dangerous chemicals used in the Island.

3. Sprayer operators do not always wear protective clothing, very few farmers use masks or respirators whilst spraying.

4. Poor methods of chemical application, allowing drift of chemicals onto the operators.

5. Washing of sprayers, and disposal of residues in nearby rivers.

6. Blockage of nozzles when spraying mixtures of powder and water.

7. Indiscriminate use of gramoxone as fish poison.

8. Loss of fish due to dispcsal of organo-chlorides in the open sea.

9. Loss of bees due to spraying for control of mosquitoes.

10. Reports from studies carried out by WINBAN research 1975-1977, showed resistance of the banana borer to the organochloride heptachlor.

From the overall survey results, there was a twofold increase in the level of borer resistance from 1975-1977. (Reference: Borers and Windward Island banana grower, WINBAN Research and Development. Report to the Association, January 1978). Granular nematicide/insecticides have since replaced the use of heptachlor.

PESTICIDE REGULATIONS

The Pesticides Control Act was passed in the House of Assembly in March 1975. This Act makes provision for the control of the manufacture, importation, sales, storage and use of pesticides. A Pesticide Control Committee was also formed.

The Act has not yet being proclaimed, and so these regulations are not at present enforced.

Provisions of Regulations

1. Controlling the quality of pesticides which may be imported or manufactured, the type of container in which such substances may be imported, transported, offered for sale or otherwise distributed.

2. Controlling the labelling of containers, their subsequent disposal, and disposal of unwanted stocks of pesticides.

3. Requiring the keeping and inspection of records and the furnishing of returns and other information with respect to pesticides.

4. Restricting or prohibiting the use of particular pesticides or classes or pesticides.

5. Imposing restrictions on pest control operators and their servants or agents.

6. Imposing duties on employers of workers, on workers themselves, and others.

7. Requiring the provision and maintenance of protective clothing, proper equipment, facilities for washing and cleaning other things needed for protecting persons, such as clothing, equipment and appliances, from contamination by pesticides or for removing sources of contamination there from.

8. Requiring the use of devices by employers to warn against poisoning by chemicals; to ensure proper use of the apparatus and facilities provided in pursuance of the regulations. To warn against eating, drinking, and smoking where there may be risk of poisoning by pesticides.

9. Providing limits to periods of exposure of workers to pesticides and the length of the intervals between periods of exposure.

10. Requiring special precautions to be taken by employers in the case of workers, who because of their state of health, age or other circumstances are subject to particular risks of poisoning by pesticides.

11. Imposing prohibition and restriction, whether temporary or permanent, regarding employment of the class of workers mentioned in paragraph ten.

12. Prescribing measures for investigations and detecting cases in which poisoning of workers by pesticides has occured or may reasonably be thought to have occurred, including medical examination, the collection of samples and blood testing.

13. Requiring employers to provide proper facilities for first aid treatment and safety of workers.

14. Requiring employers to ensure that workers submit to instructions and training in the use of apparatus and facilities provided in pursuance of the regulations.

15. Prescribing standards for the composition of pesticides.

16. Making it necessary to obtain a licence to manufacture, import, package, sell or otherwise distribute or use any pesticide or to operate as a pest control operator, and to provide for exemptions from such regulations.

17. Prescribing the manner for application and grant of licences necessary under paragraph seven, and grounds for revocation of such licences.

PESTICIDE ALTERNATIVES

The unavailability of particular pesticides recommended in the past management system and the increasing costs of these chemicals have led us to look to other methods of protecting crops. Alternative methods practised in the agricultural programme include cultural practices and biological control.

Cultural practices. In the current management programme for bananas, a major export crop of the Island, recommendations by WINBAN include:-

1. Clean planting material
2. Clean fields
3. Sleeving with blue polythene
4. Removal and detrashing of leaves and pseudostem
5. Good weed control
6. Good crop nutrition

Alternative control measures for protection against pests of seeds, consists of hot water treatment especially for avocado, cabbage, and other vegetable seeds. Non-chemical alternative methods of weed control include hand pulling, hoeing, cutlasing, and use, on a very small scale of tractor drawn implements.

The management of all crops includes general field sanitation, drainage and weed control, as part of the control programme.

Biological control

The Commonwealth Institute of Biological Control (CIBC) has carried out control of pests by the release of a number of parasites.

The major crops for which biological control has been attempted are coconuts, bananas, cabbage, corn, Honduras mahogany and citrus. (see Table 4).

The small amounts of parasites released cannot establish population levels high enough to give effective and contineous control, although successful control has been achieved in some cases. Consideration is being given to studies on host attraction by borer preference to crops other than bananas. The intercropping of bananas with dasheen, tannia, sweet potato and other root crops and the preference of borer for these root crops is to be considered at the WINBAN Research Centre.

In the Public Health field the only biological control methods in use against any insect pest is the seeding of fish in ponds and other suitable water bodies as a measure against the breeding of mosquitoes.

Table 4 List of crops, pests and the parasites released by C.I.B.C.

Crop	Pest	Parasite	Date
Cabbage	*Ascia monuste*	*Pteromalus puparum*	1950
	Plutella xylostella	*Apanteles vestalis*	1971
		Apantles plutellae	1971
Honduras machogany *Swietenia macrophylla*	*Hypsipyla grandella* shoot borer	*Tetrastichus spirabilis*	1971
		Antrocephalus renalis	1971
		Tricogrammatoidea nana	1971
		Phanerotoma sp.	1971
Banana *Musa cvs.*	*Cosmopolites sordidus* banana borer	*Hololepta quadridentata quadridentata*	1950
		Plaesius javanus	1950
		Dactylosternum spp.	1950
Citrus spp.	1. *Icerya purchasi* cottony cushion scale	*Rodolia cardinalis*	1970
Coconut *Cocos nucifera*	*Rattus rattus*	*Herpestes javanicus*	1970
	Aspidiotus destructor coconut scale	*Rhizobius pulchellus*	1971
Maize *Zea mays*	*Heliothis armigera* corn earworm	*Ecphoropsis perdistinctus*	1971
	Spodoptera spp.	*E. perdistinctus*	1971

Some exotic natural enemies have been identified for crop pests and from a recent survey made by entomologist Mr. Munir Alam (CARDI, May 1980) some possible introductions might be made.

Telenomus remus, against *Spodoptera* sp.

Trichogramma fasciatum against *Diatraea* spp.

Apanteles flavipes against *Diatraea* spp.

Chelonus sp. *mexicanus*, and *Bracon* spp. against *Hellula phidilealis*.

Exochomus lituratus and *Chilocorus cacti* against *Planococcus citri* and *Coccus viridis.*

Litomastix nr. *truncatellus*, against *Trichoplusia ni.*

Eiphosoma annulatum against *Margaronia hyalinata.*

Level of Expertise

Available at the Union Research Centre of the Ministry of Agriculture is an agronomist involved in crop protection; and at the Winban Research Centre, an entomologist-nematologist and pathologist. These have to some extent, assisted the Commonwealth Institute of Biological Control in monitoring the release of parasites in the field.

EXTENSION AND EDUCATION PROGRAM

The extension officers play an important role in the management of pests and use of pesticides on farms. The programme involves the distribution of information on pests affecting crops and systems of management. The Agricultural Information Officer also helps in the distribution of such information on radio, and by the use of bulletins.

The extension service works directly with the research centres, which identify pests and make recommendations as to the pesticides that should be used and how they should be applied and handled. Collection of pests and monitoring of experiments are duties of the extension officer, and he is also responsible for teaching and training the farmer in pest management practice, use of the correct pesticide at recommended rates, and at the proper time. It has also been stressed in the programme that officers must be vigilant in the use of pesticides, in view of the farmers' shortcomings (eg. not being able to read and write).

Extension staff have been trained in the use of pesticides, and bulletins on subject issued. In service Training Courses have also been scheduled for officers.

The Winban Research Centre has issued leaflets concerning safety in the use of chemicals.

AGROMEDICAL TEAM APPROACH

There is need for team collaboration between Agriculture and the Health Department in pesticide management which is presently lacking. However, we hope and earnestly look forward to this Seminar as a means and beginning of this collaboration.

17. ST. VINCENT

PEST AND PESTICIDE MANAGEMENT

GLENROY BROWNE and J. LEWIS

PREFACE

This paper, the first of its kind to be attempted on St. Vincent, sets out to outline the major agricultural and uraban pests and the management of these pests and the pesticides used in their control.

The paper is not an exhaustive one. It attempts to give a comprehensive over-view of the topic which could serve as a basis for deeper and more exhaustive presentation. The shortcomings of the paper are indeed a manifestation of the lack of information available locally on this area of agricultural technology and should indicate the need for training both at the profession and technical levels.

INTRODUCTION

St. Vincent and the Grenadines, a small island state, lacks known mineral resources which can be worked commercially. However, its moderate tropical climate and rich deep volcanic soils allow for the development of a well diversified agriculture. Agriculture is the backbone of the island's economy, employing the largest percentage of the labour force and providing the largest percentage of the economy's foreign exchange earnings.

Agricultural activities are involved with the cultivation of over sixty different types of crops, the chief of which is bananas. According to the 1972-1973 Agricultural Census these crops are grown on some 7088 holdings totalling 34,355 acres of arable lands.

Much of the agricultural production is carried out primarily to satisfy the export market and then for local consumption. The principal export crops are bananas 5,000 acres, plantains 1,000 acres, arrowroot 500 acres, coconuts 7,000 acres, tannias, eddoes and dasheen 830 acres, sweet potatoes 705 acres, peanuts 672 acres. Several other fruit and root crops are exported but in very small quantities, most being consumed locally.

The management practices followed in the production of the various crops grown are directly related to the monetary returns accruing to the farmer. The crop which earns the highest on the export market generally enjoys the highest levels of management, e.g. bananas and more recently, tobacco. There are usually spin-off crop care benefits, however, to the other crops in the form of fertilizer, pesticide and management skills generally. For example control of weeds using chemicals has now become accepted and commonplace, thanks to the widespread use of gramoxone by banana farmers. Similarly, the use of chemicals for the control of leaf roller *(Calpodes ethlius)* in arrowroot has drawn to the attention of arrowroot growers the usefulness of pesticides in control of destructive insects.

Today, a variety of pesticides is available. The national thrust to produce demands the cultivation on an ever larger scale crop plants of similar germplasm. Weather conditions, especially during the rainy season, coupled with the available large quantity of similar germplasm, favour rapid pest growth of pests.

This situation therefore demands improved pest management. Central to any pest management program is the use of pesticides, with their attending potential dangers to the environment and human population. It is therefore vital that in St. Vincent, where the use of pesticides is now becoming an integral part of agricultural technology, great care be taken in the management of these chemicals to avoid their abuse and misuse.

CROPS, THEIR PESTS AND CONTROL METHODS

Arrowroot

Major Pest: Leaf roller – *Calpodes ethilus*

Management Practice: Application of chemical sprays at the first sign of attack by the pest. Malathion, carbaryl, tetrachlorvinphos, systoate, diazinon and primicid have been used with little success. Decis used this year for the first time has proved quite successful.

Investigations into the use of biological agents are currently in progress.

Sugar Cane

Major Pests: Sugar cane moth borers – *(Diatrea saccharalis, Diatrea centrella).*

Management Practice: Biological control using imported natural enemies. In February 1978, a survey of the major insect pests attacking this crop was carried out by Munir Alam of CARDI. The survey showed average stalk and joint injestation to be 73.7% and 53.3% respectively. The larval parasite *Apanteles flavipes* was introduced against *Diatrea saccharalis.* One month later the parasite was recovered and the level of parasitism was 20%. Observations since then revealed that the parasite has become well established and its population is increasing.

Coconut

Major Pests: Rhinocereos beetle *(Stretegus titanus),* the vector of Red Ring nematodes.

Management Practice: Chemical control by injection of trees twice a year: Azodrin at the rate of 1½ pints/acre is used.

Carrots

Major Pests: Southern blight *(Sclerotium rolfsii)*
Cercospora leaf spot *(Cercospora carotae)*
Alternaria leaf spot *(Alternaria sp.)*
Root knot nematodes *(Meloidgyne* spp.*)*

Mangement Practice: Most farmers sow their seeds with a dressing of sevin or preferably aldrin powder. No fungicide has been used at planting. Farmers are now encouraged to apply a soil treatment of 2-4 quarts/acre of diazinon to control all soil insects and 8 pounds/acre captan (Orthocide) to control damping off disease and southern blight. Subsequently, fortnightly foliar sprays of diazinon ¾-1½ pints/acre and captan 6 lbs/acre are recommended.

In 1978 on request by the Department of Agriculture Dr. Singh, CARDI's nematogologist, carried out a very extensive survey on nematodes in St. Vincent's carrot growing area. Soil acidity, levels of nematode population, and relation of weed population to nematode incidence were examined. Based on the findings of these surveys nematicidal and crop rotational trials were commenced to determine suitable application rates for commercial nematicides and crop rotation systems which would bring about control of the nematode that are ravaging this crop.

Peanuts

Major Pests: Cercospora leaf spot *(Cercosporidium personatum)*
Southern Blight *(Sclerotium rolfsii)*
Fall Army Worm *(Spodotera frugiperda)*
Bud Worm *(Heliothis zea)*
Corn Ear Worm *(Rhopaea magnicorni)*
Rats *(Rattus rattus)*

Management Practices: Farmers do not carry out any soil treatment to control soil borne diseases and insects. However, they are encouraged to treat seeds before planting with captan or thiram at the rate of 2 oz/lb of seed. At four to six weeks after germination foliar sprays of Benlate of 2 lb/acre are applied, and Orthene or diazinon or Decis at rates of 1 lb/acre, 1½ pints/acre and 4 oz/acre respectively in fortnightly spray cycles.

Pigeon Peas

Major Pests: Rust *(Uredo cajani)*
White flies *(Empoasca* spp.*)*

Management Practice: Chemical control using malathion, Azodrin, diazinon or Decis at the rates of 1½ pint/acre, 1 pint/acre, 1½ pints/acre, 4 oz/acre respectively, depending on availability of chemical. Benlate at the rate of 2 lb/acre is recommended for the control of rusts. The application of these chemicals is carried out by the Crop Protection Unit of the Department of Agri-

culture once per year as a service to pigeon pea farmers.

Corn

Major Pests: Fall army worm *(Spodoptera frugiperda)*
Corn ear worm *(Rhopaea magnicornii)*
Aphids *(Aphis gossypii)*

Management Practice: Chemical control using sevin at 1 lb/acre or Basudin 1 pint/acre. Biological control of fall army worm is now being attempted with the introduction of the egg parasite *Telenomus remus* which is now established in St. Vincent. The first release was made in 1978 by Munir Alam of CARDI.

Beans (String Beans)

Major Pests: Bacterial blight *(Xanthomonas phaseoli)*
Rust *(Uromyces appendiculatus)*
White flies *(Empoasca spp.)*
Aphids *(Aphis gossypii)*

Management Practice: Most farmers carry out no control programme for these pests. It is however recommended by the Department of Agriculture that a weekly spray of Kocide or Cupravit or Benlate be applied to control these diseases. For control of insect pests Diazinon at 1 pint/acre or Decis at 4 oz/acre are recommended.

Cowpea (Black-eye pea)

Major Pests: Mosaic *(Cowpea Mosaic Virus)*
White flies *(Empoasca* spp.*)*
Aphids *(Aphis gossypii)*

Management Practice: Chemical control using diazinon at 1 pint/acre or Decis at 4 oz/acre. The control of the above insect pests will ensure the control of mosaic, since these insects are vectors of the mosaic virus.

Cucumbers

Major Pests: Powdery Mildew *(Erysiphe cichoracearum)*
Melon worm *(Margaronia hyalinata)*
Leaf miner *(Liriomyza munda)*

Management Practices: Chemical control for the insect pests. Diazinon at 1 pint/acre is used at the first sign of infestation. Milcurb at 1 pint/acre or Benlate at 2 lbs/acre are used to control the fungal pests.

Eddoes, Dasheen, Tannias

Major Pests: Burning disease - cause unknown
Aphids *(Aphis gossypii)*
White flies *(Empoasca spp.)*

Management Practice: Most farmers do not carry out any pest management practices. Burning disease is prevalent and wide spread especially on tannias. Whenever requests are made for the control of insect pests Diazinon at 1 pint/acre is recommended.

Tomatoes

Major Pests: Early blight alternaria leaf spot *(Alternaria solani)*
Bacterial wilt *(Pseudomonas solanacearum)*
Fusarium wilt *(Fusarium oxysporum)*
Stink bug *(Nezara viridula)*
Cotton stainers

Management Practice: Most farmers practice crop rotation. Soil used for nurseries is not generally treated resulting in high loss of seedlings particularly during the rainy season.

Control of early blight is achieved by spraying with Dithane every ten days at rate of 2 lbs/acre. The insect pests are controlled by spraying with Diazinon and Orthene in weekly rotation at the rate of 1 pint/acre and ¾ lb/acre respectively.

Cabbages

Major Pests: Black rot *(Xanthomonas campestris)*
Diamond back moth *(Pluetella xylostella)*

Management Practice: Black rot is not very prevalent at the moment and no hot water treatment service is carried out at the moment. Farmers are shifting, though slowly, to resistant hybrids. Some control of Diamond back moth is being achieved by application of Orthene ¾ oz/acre and Decis 4 oz/acre in rotation every seven days. Efforts at biological control of Diamond back moth have been made by CARDI. Releases of *Apanteles plutella* brought from Barbados were made on several occasions since 1978, and this parasite is now established in St. Vincent. Further work in this area of control is greatly needed.

Mangoes

Major Pests: Anthracnose *(Gloeosporium mangiferae)*
Striped fiddler beetle *(Prepodes vittatus)*

Management Practice: Farmers do not usually attempt to control these pests. The aerial application of Benlate for control of sigatoka leaf spot disease of bananas has helped in the control of anthracnose on mangoes in some localities. The striped fiddler beetle is controlled by foliar application of Diazinon at 1½ pints/acre.

Citrus

Major Pests: Anthracnose *(Colletotrichum gloeosporioides)*
Striped fiddler beetle *(Prepodes vittatus)*
Black blight

Management Practice: Citrus orchards are sprayed prior to flowering or at the onset of the rainy season with a mixture of Kocide or Perenox, Albolineum and Diazinon at the rate of 1½ lbs/acre, 1½ lb/acre, 1½ pints/acre and 1 pint/acre respectively. Subsequently, applications of Diazinon at 1 pint/acre are made at the first sign of striped fiddler beetle infestation.

LIVESTOCK: PEST AND CONTROL METHODS

Cattle

Major Pests: Ticks *(Boophilus* spp.*)*
Strongylids *(Helminthes* spp.*)*

Management Practice: Ticks – wash skin with Sevin 5% solution. Sevin 75% is also used at the rate of 1 oz/gal. Ripercol and Nilverm are given as dewormers once every two months.

Sheep and Goats

Major Pests: Strongylids *(Helminthes* spp.*)*
Mange *(Sarcoptes scabei)*

Management Practices: The veterinary Unit in collaboration with the Extension Division of the Department of Agriculture carry out regular deworming clinics during the rainy season.

Pigs

Major Pests: Strongylids *(Helminthes* spp.*)*

Management Practices: Nilverm pig wormer and Panacur given.

PESTS OF URBAN & HEALTH SECTORS

Mosquitoes: The *Aedis aegypti* mosquito is the most serious pest. An eradication programme is currently being carried fogging using a malathion oil mixture. Temephos is also placed in vases and in any container of standing water.

Cockroaches: Householders and public health departments use propoxur (Baygon).

Bed Bugs: In the institutions, particularly the prisons, Malathion and propoxur (Baygon) are used.

Rats: Rat control is carried out using several rodenticides e.g. Ratek, Racumin, Rat cake, Ramiks. Rat traps are in general use.

PESTICIDES

Information on the amount of pesticide used in St. Vincent and the Grenadines has been obtained from two sources — the Government Statistical Officer and the St. Vincent Banana Growers Association. The Government Statistical Officer provided information on total amounts imported, which is available under four general headings, viz:—

(1) Insecticides
(2) Fungicides
(3) Weedicides
(4) Vermin Killers

The data are given in Table I for 1976 — June 1979.

Table 1 Quantities and value of agricultural chemicals imported into St. Vincent during the period January 1976 — June 1979

	1976			1977			1978			1979 (Jan - June)		
	Source	lb	Value ($EC)	Source	lb	Value ($EC)	Source	lb	Value ($EC)	Source	lb	Value ($EC)
Insecticides	U.K.	33,267	101,318	U.K.	30,640	121,802	B'dos	11,714	72,044	B'dos	12,464	66,364
	Guyana	16,800	34,328	Guyana	17,950	32,595	U.K.	27,725	78,755	U.K.	8,288	33,539
	Trinidad	314,904	62,293	Trinidad	617,604	118,939	Trinidad	261,036	79,125	Canada	1,400	17,215
	U.S.A.	4,271	15,696	U.S.A.	7,851	28,537	H. Kong	13,514	51,746	Trinidad	168,477	50,249
	Brazil	20,000	28,000	Holland	3,830	14,276	U.S.A.	13,722	64,587	U.S.A.	2,726	12,977
	W. Germany	12,781	49,851	Hong Kong	8,385	25,772	Holland	4,652	18,337	Holland	2,299	10,671
	E. Germany	1,362	15,038	W. Germany	22,764	94,097	Guyana	7,200	14,310	W. Germany	3,581	6,570
	Other countries	19,232	55,628	Other countries	9,953	29,515	Other countries	3,932	15,124	Other countries	182	3,888
	Total insecticides	422,617	362,152		719,177	464,533		343,495	394,028		199,417	201,473
Fungicides	U.K.	242,168	294,764	U.K.	111,786	467,116	U.K.	259,294	410,805	U.K.	5,120	25,600
	U.S.A.	1,226	19,993	U.S.A.	7,854	107,551	U.S.A.	5,982	116,300	U.S.A.	73,838	129,113
				Other countries	31,821	59,226	Other countries	4,851	22,640	Puerto Rico	770	4,743
	Total fungicides	243,394	314,757		151,461	633,893		276,127	549,745		79,728	159,456
Weed-killers	U.K.	38	228									
	U.S.A.	7,923	18,697	U.K.	8,485	35,805	U.K.	40,118	43,544	U.K.	3,098	12,562
	Switzerland	40,700	3,522	U.S.A.	4,012	9,701	U.S.A.	3,160	11,257	U.S.A.	3,330	7,935
	W. Germany	660	3,086				Other countries	55	391	Trinidad	80	100
	Total weed killers	49,321	25,533		12,497	45,504		43,333	55,192		6,508	20,597
Vermin Killers	(not stated)	2,232	2,778	B'dos	969	3,724	B'dos	5,300	2,190	B'dos	1,000	1,260
	" "	2,240	3,161	Jamaica	2,200	2,442	U.K.	1,255	4,468	U.S.A.	1,145	2,786
	" "	56	279	U.S.A.	1,610	3,648	Other countries	833	2,033			
				Other countries	55	329						
	Total vermin-killer	4,528	6,218		4,834	10,143		7,388	8,691		2,145	4,046
	Total all chemicals	719,860	708,660		887,969	1,154,073		670,343	1,007,656		287,798	380,572
	(kg)	326,528			402,798			304,080			130,545	

Source: Government Statistical Service

Statistics obtained from the St. Vincent Banana Growers Association provide information on the amounts distributed. The Association is the largest user of pesticides in St. Vincent.

Table 2 Pesticides distributed to Banana Farmers during the period January 1978 – June 1980

		1978	1979	Jan – June 1980
Daconate	(galls)	221	219	60
Furadan	(lbs)	9,460	19,085	13,290
Gesapax	(lbs)	2	-	-
Gramevin	(lbs)	550	550	-
Gramoxone	(litres)	10,665	11,254	8,320
Maloran	(lbs)	5,808	5,236	1,804
Mocap	(lbs)	420	420	297
Namagon	(galls)	2,140	600	98

Table 3 List of Pesticides on sale in St. Vincent

Insecticides	Fungicides	Weedicides
Abolineum	Aretan	Atrazine
Aldrin	Benlate	Brush Killer
Baygon (propoxur)	Captan	Daconate
Chlordane	Cupravit Blue	Dacthal
Conqueror	Dithane M45	Gesagard
Decis	Kocide	Gesapax
Diazinon 60 Ec	Milcurb	Gramevin
Dipterex	Perenox	Gramoxone
Folithion		Maloran
Fosferno 50		Tok WP
Furadan		2,4-D amine
Gardona		2,4,5-T
Heptaclor		
Malathion		
Menazon		
Metasystox		
Mocap		
Namagon		
Nudrin		
Orthene		
Parathion		
Pirimor 60 G		
Primicid		
Sevin		
Timbex brown		
Rodenticides	**Fumigant**	
Racumin	Dowfume MC-2	
Ramick	EMC-2 Fumigant	
Ratak		
Rat Cakes		

PESTICIDE HAZARDS

For the period 1977 to June 1980, six cases of death due to pesticide poisoning were reported. Five of thsese were suicide cases and occured in the banana growing area of Marriaqua. The other was accidental – a toddler ingested what appears to have been an organophosorus compound. In September of 1979 it was reported that thousands of crayfish were crawling out of the Rabacca river and dying along its banks. Investigation revealed that Systoate had been dumped into the river.

Banana cultivation has been extended far into the mountains. Some farmers have cultivated in and around catchment areas, but several have been evicted by the water authority. Cultivation of bananas in such areas can lead to contamination of drinking water due to leaching of pesticides, especially when those with long-persistence are used.

In most areas of St. Vincent rivers, streams and springs are the principal sources of water used for the mixing of chemicals, thus the chance of contamination of the water is ever present. Yet no major mishap has so far occurred. In an effort to eradicate *Aedes aegypti* (mosquito), a programme of fogging using malathion is being carried out. This is often done at rush hour periods, 8.00 a.m.-9.00 a.m. and is causing some concern. Fortunately, only one case of intoxication has been reported.

PESTICIDE ALTERNATIVES

Biological control of insect pests was first tried in St. Vincent several years ago. Information from the Department of Agriculture shows that work was done through the Commonwealth Institute for Biological Control in collaboration with the Department.

These efforts included attempts at the control of the mahogany shoot borer, the arrowroot leaf roller *(Calpodes ethlius)*, the sugar cane moth borer, *(Diatraea saccharalis)* by *Apantales flavipes*, and the diamond back moth *(Plutella xylostella)* by *Apantales plutellae*.

This work was restarted in 1978 when the services of Mr. M. Alam was provided by CARDI at the request of the Department of Agriculture to investigate the high incidence of moth borer infestation of sugar cane. *Apanteles flavipes* was re-introduced in 1978 and has now been successfully established with resultant reduction in the pest population. A very small number of Cuban flies were also introduced. Investigations were also carried out on vegetables, corn and arrowroot; *Telenomus remus* and *Apanteles plutellae* were introduced for control of army worm *(Spodoptera frugiperda)* and diamond back moth *(Plutella xylostella)* respectively.

The investigations carried out by Dr. Alam have revealed that there are many natural enemies of the main pests of agricultural crops. However, injudicious use of pesticides, particularly contact insecticides, can decimate the population of natural enemies. In view of this, and also taking into account the rising costs of pesticides (as can be seen in Table 1), the Department of Agriculture has been encouraging the use of resistant varieties of crops and the improving of cultural practices, particularly field sanitation.

The system of multiple cropping which has been traditional for small farmers in St. Vincent is now under investigation by CARDI. The author hopes that these investigations would include surveys of pest populations and their natural enemies, so that recommendations can be made for an appropriate integrated pest control programme.

PESTICIDE REGULATIONS

The Pesticide Control Act of 1973 provides for the control of the importation, sale, storage and use of pesticides. It empowers the Governor General to make regulations for carrying into effect the provisions of this Act and in particular to make regulations relevant under the Act and for the appointment of Inspectors. The regulations make provision for the establishment of a Pesticide Control Board, whose function should be to advise the Governor General in making Regulations under the Act and to put into effect these provisions.

Unfortunately, the Board was never established and the above mentioned regulations neither created nor enforced. However, the Chief Agricultural Officer may from time to time, on the

advice of the Crop Protection Officer, petition Cabinet or the Minister to make rulings on some of these matters.

EXTENSION AND EDUCATION PROGRAMMES

The extension staff is involved in pest control programmes. They provide to farmers in their respective districts diagnostic information on pests and diseases, and recommended possible treatments. They also report any pest and disease problems which may be new to them to the Crop Protection Officer. They organise annually in collaboration with the Crop Protection Unit of the Department of Agriculture, the chemical control of *Empoasa* sp. infestation of pigeon peas *(Cajanus cajan)*, thrips and black pod infestation of cocoa, and *Calpodes ethilus* infection of arrowroot.

Pesticide use and safety always feature as an important topic at farmers' training seminars. At least one such seminar is held every year for farmers in each of the agricultural districts on St. Vincent's mainland. Similar seminars are held for banana farmers by the St. Vincent Banana Growers Association. Earlier this year the Plant Protection Officer was invited to lecture to medical and nursing personnel on "Pesticide Poisoning". This is expected to be an annual feature. It is hoped that the target audience will soon include the wider public, children and adolescents in particular. The effectiveness of these programs can be greatly enhanced by the ongoing intraining of extension staff in detection of pests and diseases.

AGROMEDICAL TEAM APPROACH

There is no agromedical team approach save for infrequent consultations whenever emergencies arise, such as pesticide intoxication or death. The invitation by the Nurses' Association to the Plant Protection Officer to lecture to Nurses and Medical personnel on "Pesticide Poisoning" may indicate an increased awareness in this area.

18. TRINIDAD AND TOBAGO

PEST AND PESTICIDE MANAGEMENT

R.M. BARROW

PART I PUBLIC HEALTH SECTOR

The Public Health Sector has been dealt with in some depth by Tikasingh (1980) and will not be considered in detail in this paper. Table 1 below summarises the most important pests in this sector, along with control methods employed.

Table 1 Main Public Health Pests of Trinidad and Tobago and Control Measures

Pest	Diseases carried or other effects	Control
Mosquitoes		
Anopheles spp.	Malaria	Adults: perifocal spraying with malathion: Larvae: 1% Abate sand granules in potable water, bird baths, animal drinking containers, etc.
Aedes aegypti	Yellow fever, dengue	
A. taeniorhynchus	Eastern equine encephalitis	
Culex fatigans	Filariasis	
Lutzomyia sp.	Leishmaniasis	
Flies	Household pests	
Cockroaches	Household and warehouse pests	Baits containing boric acid powder: Baygon
Periplaneta americana		
Blatta sp.		
Termites	Subteraneam	
Heterotermes sp.	Subteraneam	Treat nest with cyclodiene compounds, eg, aldrin, dieldrin, chlordane, heptachlor
Cryptotermes brevis	Drywood	Fumigate with methyl bromide (Dowfume)
Sandflies		
Culicoides sp.		
Leptoconops sp.		
Ants eg.		
Monomorium sp.		Baits containing boric acid: Baygon
Ticks eg.	Irritants	
Amblyomma cajennense		
Mites		
Sarcoptes scabei	Scabies	
Rodents		
Rattus rattus	House and warehouse pests	Baits containing anticoagulants, eg. Racumin, Warfarin

(Table 1 Continued)

Pest	Diseases carried or other effects	Control
Bats		
Free tailed house bats *(Molossus* sp*)*		Application of chlorinated hydrocarbons (eg. Lindane, heptachlor) to roosting area
Vampire bats *(Desmodus rotundus)*	Rabies	Diphacinone (anticoagulant) Strychnine on wounds inflicted by bats on animals; poisons bat on its return to the wound.
Birds		
Pigeons	Crop and household pests	Sterilisation of both males and females by treating feed materials with hormones

Source: from the author with additions from Tikasingh (1980).

It is reported (Tikasingh 1980) that Malaria has been eradicated, but dengue fever is still present, with 330 cases in 1978 and 38 in 1980.

PART II AGRICULTURAL SECTOR

PESTS AND DISEASES

Tables 2, 3 and 4 (at end of paper) list the more important pests and diseases of crops and livestock. Particularly worthy of note is the Froghopper *(Aneolamia varia)*, which attacks both roots and leaves of sugar cane. There has been an increase in the intensity of sugar cane borer *(Diatraea saccharalis)* thought to be due to the reduction of its natural predators by chemical sprays (Pollard 1980). For several years (since 1966) frog-hopper has been attacked by aerial spraying, and has developed resistance to all three major classes of insecticides, and is beginning to show resistance to the synthetic pyrethroids (for details see Pollard, op. cit).

THE PESTICIDES

Insecticides

It will be noted from the list of chemicals given (Table 5 at end of paper) that the majority of insecticides now in use are organo-phosphates, carbamates, and since 1976 the synthetic pyrethroids. Although the present trend indicates a reduction in use of the organo-chlorines, farmers still employ compounds of the cyclodiene group – aldrin, dieldrin, heptachlor etc. – in the control of soil-inhabiting pests e.g. mole crickets, cutworms and ants. The organo-chlorines tend to have longer residual activity in the soil than any other pesticides. Pest control operators also use the cyclodiene compounds in the control of subterranean termites.

Although the organo-phosphates and the carbamates have a narrower range of activity against insects than the organo-chlorines, they are less persistent and have a lower order of toxicity to mammals. Malathion and Sevin are two of the most widely used pesticides locally. A feature of some organo-phosphates e.g. Folithion, Gusathion, etc. and carbamates e.g. Furadan, Lannate, Temik, is their systemic activity which make them effective against sucking insects. Baygon, another carbamate, is highly effective against cockroaches and other household insects.

The synthetic pyrethroids have been found to be useful against pests of market garden crops e.g. cabbage looper and diamond back moth, while the microbials, Dipel and Biotrol, are recommended for use against lepidopterous pests. So far when these latter insecticides are

used singly the results have not been encouraging.

The fumigants – Dowfume, Bromofume, and Phostoxin are important in the control of storage pests e.g. *Calandra oryza*, *Ephestia* sp. etc. and also for the sterilisation of soil.

Fungicides

Although there is a marked reduction in the use of the inorganic fungicides, the copper compounds are still required to control black pod (*Phytophthora* sp.) in cacao. The organic fungicides are less toxic and the dithiocarbamates, e.g. Dithane M45, and the dicarboximides, e.g. captan, are widely used as foliage protectants. Captan is also a very effective seed dressing. Systemic fungicides, e.g. Benlate, are known to provide economic control of a broad spectrum of diseases including *Sclerotinia*, *Botrytis* and the powdery mildews. PCP and PCNB are no longer available for use.

Herbicides

Herbicides in recent years have become increasingly important to the farmers due to the high cost and shortage of farm labour. Herbicides such as 2,4-D and paraquat are used in orchards and plantation crops where it is easy to avoid applying them to the cultivated crops. Soil applied herbicides such as diuron and the triazine compounds, e.g. Gesaprim and Gesagard, are in wide use in maize, sugar-cane and rice.

Importation of Pesticides

Table 1 below shows the amounts of pesticide by category imported into Trinidad and Tobago in 1978 and for the period Jan – August 1979, giving a total for 1978 of 1,779 tonnes.

Table 6 Imports of pesticides into Trinidad

Category of Pesticides	Amount in kg	
	1978	Jan-Aug 1979
Insecticides	1,186,391	637,463
Fungicides	95,649	37,944
Herbicides	371,029	130,321
Other pest killers, e.g. rodenticides, molluscides etc.	126,002	
Total	1,779,071	805,728

N.B. Pollard (1980) quotes figures from 1976-1977, the total in the latter year being 983 tonnes. The great increase in 1978 should be noted and adds considerable force to Pollard's arguments (Ed).

PESTICIDE HAZARDS

Statistics on human intoxication or deaths from pesticides are not readily available. However, there is reliable information from the Ministry of Health that the data as shown in Table 7 on suicides caused by adverse chemical substances (medicinal and non medicinal) may be mainly attributed to pesticide poisoning.

Table 7 Adverse effects of chemical substances

No. of Suicides			
Year	Total	Due to adverse effects of chemicals	% of Suicides due to chemicals
1972	102	68	66.7
1973	104	83	79.8
1974	75	49	65.3
1975	91	68	74.7
1976	98	71	72.5

Source: Population and Vital statistics Digest (1972 - 76)
compiled by Central Statistical Office, Trinidad and Tobago.

In the recent past there has been only one report of alleged chemical pollution, i.e. in the Chaguaramas Bay area where there was a high incidence of fish kill, though no firm evidence was available to link this with chemicals used in the nearby region. It is expected that pesticide spills will be dealt with by the Pollution Control Council.

There have been no reports with regard to hazards caused by the disposal of pesticides and pesticide containers. Efforts are underway by the recently formed company, The Solid Waste Disposal Company, to oversee the proper disposal of pesticide and pesticide containers.

Pesticides are applied as dusts, granules or liquid. The liquid formulation, which includes wettable powders and emulsifiable concentrates, is the most extensively used. Mist blowers, knapsack sprayers – low volume, ultra low volume (ULV) – are the commonest means of applying chemicals. Aerial application of pesticides is employed in the sugarcane industry for the control of the froghopper, *Aeneolamia varia*, also in the control of locusts, *Coscineuta virens*, *Tropidacris dux*, and *Osmilia* sp. that feed on several cultivated crops in South Trinidad, and in the anti-yellow fever campaign to control the vector of the disease, the mosquito *Aedes aegypti*.

Incidence of pest populations developing resistance or tolerance to pesticides has not been documented. In the frequent visits and meetings that the Ministry of Agriculture, Lands and Fisheries personnel have had with the vegetable farmers in the Aranguez area (north Trinidad) over the years, it would, however, appear that some economic pests have developed tolerance or resistance to the chemicals applied. This may be attributed to the fact that the Aranguez farmers tend to do insurance spraying i.e. the application of chemicals routinely and not based on the incidence of pests. Recently there have been reports that the cabbage looper, *Trichoplusia ni*, the diamond back moth, *Plutella xylostella*, and the budworm, *Hellula phidilealis*, have shown tolerance to Tamoron. Similarly mole crickets, *Scapteriscus vicinus* have evidenced marked tolerance to cyclodience pesticides. The case of froghopper (*Aneolamia varia*) has already been mentioned and is discussed in some detail by Pollard (1980).

PESTICIDE REGULATION

An Act entitled the Pesticide and Toxic Chemicals Act was enacted by the Parliament of Trinidad and Tobago on December 17, 1979. This Act purports to regulate the importation, storage, manufacture, sale, use and transportation of pesticides and toxic chemicals, and to provide for the establishment of a Pesticides and Toxic Chemicals Control Board, and for matters incidental thereto.

Regulations covering registration for use, labelling, storage, advertisement, transport, packaging and licensing of premises for sale of pesticides have been drafted.

The Pesticides and Toxic Chemicals Control Board has been appointed and the members are in the process of drafting further regulations concerning disposal, licensing of pest control operators, etc.

The regulations under the Act have not so far been enforced, and final approval of the draft regulations is awaited.

PESTICIDE ALTERNATIVES

Biological Control

Biological control of *Hypsipyla* spp. (Phycitidae; Lepidoptera), is being attempted. This phycitid is a pest of cedar and mahogany. Biocontrol agents, parasites of *H. robusta*, have been imported from India for the control of this pest. These were *Antrocephalus renalis*, *A. destructor* and *Tetrastichus spirabilis*.

For the past four years biological control agents have been used in the control of fruit flies (*Anastrepha* sp) on 'soft' fruits e.g. sapodilla (*Achras sapota*), guava (*Psidium guajava*) and pomerac (*Eugenia* sp.). Pupal parasites, *Dirhinus giffardi*, and larval-pupal parasites, *Trybliographa daci*, obtained from Florida, were used in this exercise.

Integrated Pest Management Programme

Experiments have been conducted on the development of an integrated pest management programme for corn. A combination of parasites and chemicals were used to control the armyworm, *Spodoptera* sp., and the earworm, *Heliothis zea*, on corn. Similar experiments have been conducted on cabbage and cauliflower to control the pests of economic importance on these crops. The IPM was effective in the control of *Trichoplusia ni* and *Plutella xylostella*. Only chemicals proved effective in the control of the budworm, *Hellula* sp.

Work on the IPM system for the control of the pinworm, *Keiferia* sp. on tomato has met with partial success. *Apanteles dignus*, a parasite obtained from Hawaii and Florida, has been recovered from samples of pinworm taken at the experimental site. In 1980 the level of pinworm incidence has been insignificant.

In all operations where biocontrol agents were used Ministry of Agriculture, Lands and Fisheries personnel worked in collaboration with the Entomologist from the Commonwealth Institute of Biological Control with headquarters in Trinidad.

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Table 2 Pests of Economic Crops of Trinidad and Tobago

Avocado	*Argyotaenia amantana* *Oiketicus abbotti*
Banana (*Musa* sp)	*Cosmopolites sordidus* *Colaspis* sp.
Bean (*Phaseolus vulgaris*)	*Cerotoma arcuata* *Diabrotica* sp. *Systena* sp.
Cabbage (*Brassica oleracea*)	*Hellula phidilealis* *Plutella xylostella* *Trichoplusia ni*
Cacao (*Theobroma cacao*)	*Steirastoma breve* *Selenothrips rubrocinctus* *Xyleborus* sp.
Cassava (*Manihot utilissima*)	*Lonchaea* sp. *Iatrophobia brasiliensis* *Tetranychus* sp.
Cauliflower (see cabbage)	
Citrus (*Citrus* spp.)	*Atta cephalotes* *Toxoprera aurantii* *Selanaspidus* sp.
Coconuts (*Cocos nucifera*)	*Rhyncophorus palmarum* *Brassolis sophorae* *Aspidiotus destructor*
Coffee (*Coffea* sp.)	*Xyleborus* sp.
Corn (*Zea mays*)	*Spodoptera* sp. *Heliothis zea*
Cowpea (*Vigna unguiculata*)	See Bean
Cucurbits (cucumber, pumpkin, watermelon)	*Diaphania hyalinata* *D. nitidalis* *Diabrotica* sp.
Grass (Guinea, pangola)	*Scapteriscus vicinus* *Blissus leucopterus* *Aeneolamia varia*
Melongene (*Solanum melongena*)	*Corythuca gossypii* *Epitrix* sp. *Alcidion* sp.
Ochro (*Hibiscus esculentus*)	*Steirastoma breve* *Dysdercus* sp. *Ceresa minor*
Onion (*Allium* sp.) (including chive)	*Thrips tabaci* *Cyrtonemum* sp.

(Table 2 Continued)

Papaya *(Carica papaya)*	*Toxotrypana curvicauda*
Patchoi *(Brassica chinensis,*	See cabbage
Pepper *(Ananas comosus)*	*Keiferia lycopersicella* *Contarinia* sp. *Diabrotica* sp.
Pigeon pea *(Cajanus cajan)*	*Ancylostomia sterrorea* *Diphaulaca* sp. *Heliothis virescens*
Pineapple	*Dysmicoccus brevipes* *Thecla basilioides*
Rice *(Oryza sativa)*	*Oepalus poecilus* *Rupela albinella* *Diatraea saccharalis* *Conocephalus* sp.
'Soft Fruits' Guava, Sapodilla, Pomerac	*Anastrepha mombinpraeoptans* *A. striata* *A. serpentina*
Sorrel *(Hibiscus sabdariffa)*	See pests on ochro
Sugar Cane *(Saccharum officinarum)*	*Aeneolamia varia* *Diatraea saccharalis*
Sweet Potato *(Ipomea batatas)*	*Megastes grandalis*
Tannia *(Xanthosoma sagittifolium)*	*Ligyrus ebenus* *Aphis gossypii*
Tomato *(Lycopersicon esculentum)*	*Contarinia lycopersici* *Keiferia lycopersicella* *Liriomyza* sp.
Mainly food crops	Army worm *(Spodoptera* sp.), Ants *(Azteca* sp), Mole cricket *(Scapteriscus vicinus)*
Many tree crops	Locusts *(Coscineuta virens,* *Tropidaeris dux,* *Osmilia flavolinetis)*
Stored Products Pests	
Tobacco	*Lasioderma serricorne* *Rhizopertha dominica*
Cacao	*Anagasta (Ephestia)* sp.
Peas and beans	*Bruchus* spp. *Tribolium castaneum*

(Table 2 Continued)

Rice	*Calandra oryzae* *Rhizopertha dominica*
Stock Feed	Psocidae *Sitotroga* sp. *Laemophalus* *Sitophilus granarius*
Cork liners	*Monomorium destructor*

Miscellaneous pests

Bats. There are several genera of fruit-eating bats in the country. The two most abundant genera are *Artibeus* and *Carollia* — these feed on a wide range of fruits including mango, papaya etc.

Birds. The following genera of birds are important as agricultural pests on the crops noted:

Fringillidae: (Finches) — Dick Cissel *(Spezia americana)* — rice

Icteridae (Orioles) — Cowbird (*Molothrus* sp.) — rice
— Cornbird (*Psarocolius* sp) — corn, citrus, cocoa
— Blackbird *(Azelains icterocephalus)* — rice

Pscittacidaes (Parrots) Green Parrot *(Amazona amazonica)* — cocoa
Parrakeet *(Forpus passerinus)*.— sorrel

Cracidae Cocrico *(Ortalis ruficauda)* — cocoa, pigeon pea, cassava

Molluscs Slugs and Snails —*Marisa* spp. feed on rice, grass, lettuce

Table 3 Pests of Economic Importance on Livestock in Trinidad and Tobago

Host	Pest	Control
Cattle (Bovine)	Ticks – *Boophilus microplus* *Amblyomma cajennense*	Sevin (carbaryl) wettable powder Asuntol (coumaphos) Bercotox
Goats & Sheep	Mite – mange mite *Sarcoptes scabei*	Supona (chlorfenvinphos) Kelthane Tetmosol
	Tick – *Boophilus microplus*	Sevin wettable powder Asuntol Bercotox
Swine	Mite – mange mite *Sarcoptes scabei*	See above
Poultry	Lice Body louse – *Eomenacanthus* sp. Shaft louse – *Menopon gallinae*	Malathion E.C. Sevin wettable powder Coumaphos dust for treatment of litter.
	Mite red mite – *Dermanyssus* sp. scaly leg mite – *Cnemidocoptes* sp.	Sevin Kelthane no treatment
Rabbit	Mites Ear mites (canker) *Psoroptes communis* var. *cuniculi* *Chorioptes cuniculi*	Disinfect cages. Use miticide in oil solution to treat ears of rabbits Lindane (Gamma BHC)

The incidence of ectoparasites on all livestock with the exception of cattle is not significant.

Table 4. List of Diseases known or reported to be present in Trinidad and Tobago

Crop	Disease	Organism
Avocado *(Persea americana)*	Anthracnose Fruit rot Root rot	*Elsinoe perseae* *Phytophthora cinnamoni* *Phytophthora cinnamoni*
Banana *(Musa* spp.*)*	Crown rot	*Collectotrichum* spp. *Fusarium* spp. *Gladosporium* spp.
	Moko disease Panama disease	*Pseudomonas solanacearum* *Fusarium oxysporum* f. sp. *cubense*
	Leaf spot Tip. Rot (fruit) Root damage	*Mycosphaerella musicola* *Fusarium fujikuroi* *Radopholus similis*

(Table 4 Continued)

Crop	Disease	Organism
Bean (*Phaseolus vulgaris*)	Mosaic	Bean Common Mosaic Virus
	Mosaic	Bean Yellow Mosaic Virus
	Southern blight	*Sclerotium rolfsii*
	Rust	*Uromyces phaeseoli*
	Angular leaf spot	*Isariopis griseola*
	Bacterial blight	*Xanthomonas phaseoli*
	Stem rot	*Pythium butleri*
Cabbage (*Brassica oleracea*)	Black rot	*Danthomonas campestris*
	Leaf spot	*Pseudomonas maculicola*
	Leaf spot	*Cercospora* spp.
	Leaf spot	*Alternaria* spp.
	Soft rot	*Erwinia carotovora*
	Downy mildew	*Peronospora parasitica*
Cacao (*Theobroma cacao*)	Black pod	*Phytophthora palmivora*
	Wilt	*Ceratocystis fimbriata*
	Witches' broom	*Crinipellis perniciosa*
	Brown pod rot	*Botryodiplodia theobromae*
	Anthracnose	*Colletotrichum* spp.
	Virus	Cocoa Trinidad Virus (C.T.V.)
	Root disease	*Rosellinia* spp.
Carrot (*Daucus carota*)	Alternaria blight	*Alternaria dauci*
	Soft rot	*Erwinia carotovora*
	Leaf blight	*Xanthomonas carotae* (Suspected)
Cassava (*Manihot esculenta*)	Bacterial blight	*Xanthomonas manihotis*
	Mildew	*Oidium* spp.
	Rust	*Uromyces* spp.
	Brown leaf spot	*Cercospora hemingsii*
	White leaf spot	*Cercospora caribea*
	Blight leaf spot	*Cercospora viscosae*
Cauliflower (*Brassica oleracea*)	Black rot	*Xanthomonas campestris*
	Leaf spot	*Pseudomonas maculicola*
Celery (*Apium graveolens* var *dulce*).	Leaf spot	*Cercospora appii*
	Heart rot	Physiological
	Root knot	*Meloidogyne* spp.
	Mosaic	Western Celery Mosaic Virus (strongly suspected).
Citrus (*Citrus* spp.	Melanose	*Diaporthe citri*
	Areolate leaf spot	*Corticium areolatum*
	Greasy spot	*Mycosphaerella citri*
	Wither tip	*Gloeosporium limetticola*
	Anthracnose	*Colletotrichum gloeosporioides*
	Gummosis (foot rot)	*Phytophthora parasitica* *Phytophthora citrophthora*
	Damping-off	*Pellicularia salmonicolor*
	Sour orange scab	*Elsinoe fawcetti*
	Brown rot	*Sclerotium rolfsii*
	Thread blight	*Corticium stevensii*
	Citrus nematode	*Tylenchulus semipenitrans*

(Table 4 Continued)

Crop	Disease	Organism
Coconuts *(Cocoa nucifera)*	Red ring disease	*Rhadinaphelenchus cocophilus*
	Cedros wilt	Suspected *Phytomonas* spp.
	Bronze leaf wilt	Physiological
	Little leaf	Physiological (suspected)
	Bud rot	*Phytophthora palmivora*
Coffee *(Coffea* spp.*)*	Anthracnose	*Colletrotrichum coffeanum*
	Thread blight	*Corticium koleroga*
	Brown eye spot	*Cercospora coffeicila*
	American leaf disease	*Hycena citricolor*
	Root and bark rot	*Rosellinia* spp.
Cowpea *(Vigna unquiculata)*	Leaf spot	*Cercospora canescens*
		Cercospora cruenta
	Mosaic	Cowpea Mosaic Virus
	Powdery mildew	*Oidium* spp.
	Stem rot and wilt	*Pythium butleri*
	Dry stem rot	*Fusarium solani*
Cucumber *(Cucumis sativus)*	Downy mildew	*Pseudoperonospora cubensis*
	Powdery mildew	*Oidium* spp.
		Erysiphe cichoracearum
	Angular leaf spot	*Pseudomonas lachrymans*
	Mosaic	Cucumber mosaic virus
Guinea grass *(Panicum maximum)*	Leaf spot	*Cerospora* spp.
Mango *(Mangifera indica)*	Anthracnose	*Colletotrichum gloeosporioides*
Melongene *(Solanum melongena)*	Bacterial wilt	*Pseudomonas solanacearum*
	Anthracnose	*Colletotrichum melongenae* (*C. gleosporioides* var. *melongenae*)
	Fruit rot	*Phytophthora* spp.
	Root knot	*Meloidogyne* spp.
Ochro *(Hibiscus esculentus)*	Leaf spot	*Cercospora* spp.
	Mosaic	Suspected virus etiology
Onion *(Allium cepa)*	Damping-off	*Pythium* spp.
	Purple blotch	*Alternaria porri*
	Southern blight	*Sclerotium rolfsii*
Pangola grass *(Digitaria decumbens)*	Rust	*Puccinia* sp.
Papaya *(Carica papaya)*	Anthracnose	*Colletotrichum gloeosporioides*
	Internal blight	*Cladosporium* spp.
		Alternaria spp.
		Penicillium spp.
		Fusarium spp.

(Table 4 Continued)

Crop	Disease	Organism
	Bunchy top	*Mycoplasma*
	Distortion veinal mosaic	Virus (suspected)
	Ringspot virus	Papaya ringspot virus
	Stem canker	*Erwinia caricae*
Patchoi (*Brassica chinensis*)	Leaf spot	*Cercospora albomaculans*
	Leaf spot	*Phoma* spp.
Pepper (hot) (*Capsicum annum* var. *abbreviatum*)	Anthracnose	*Glocosporium piperatum*
	Mosaic	Tobacco Mosaic Virus
	Blight	*Phytophthora capsici*
Pepper (Sweet) (*Capsicum annum* var. *grossum*)	Foot rot and wilt	*Sclerotium rolfsii*
	Mosaic	Potato Virus y
	Anthracnose	*Colletotrichum phomoides*
	Blight	*Phytophthora capsici*
Pigeon Pea (*Cajanus cajan*)	Canker	*Phoma* spp.
	Southern blight	*Sclerotium rolfsii*
	Rust	*Uredo cajani*
Pineapple (*Ananas comosus*)	Root knot	*Meloidogyne* spp.
	Mealy bug wilt	*Pratylenchus* spp.
	Nematode	*Helicotylenchus* spp.
Pumpkin (*Cucurbita pepo*).	Powdery mildew	*Oidium* spp.
	Mosaic	*Erysiphe cichoracearum*
	Mosaic	Cucumber Nosaic Virus
	Stem rot	Squash mosaic virus
		Pythium spp.
Rice (*Oryzae sativa*)	Blast	*Pyricularia oryzae*
	Leaf spot	*Helminthosporium oryzae*
	Smut (Kernel)	*Tilletia barclayana*
	Leaf smut	*Entyloma oryzae*
Sorrel (*Hibiscus sabdariffa* var. *sabdariffa*)	Collar rot	*Phytopthora nicotianae* var. *nicotianae*
	Leaf spot	*Colletotrichum* spp.
	Zonate Leaf spot	*Cercospora* spp.
Soyabean (*Glycine max*)	Mosaic	Soybean Mosaic Virus (strongly suspected)
	Root rot	*Phytophthora* spp. (strongly suspected)
	Mosaic	Cowpea Mosaic Virus

(Table 4 Continued)

Crop	Disease	Organism
Sugar-cane (*Saccharum officinarum*)	Smut	*Ustilago scitaminea*
	Leaf Scald	*Xanthomonas albilineans*
	Leaf spot	*Helminthosporium sacchari*
	Red stripe	*Xanthomonas rubrilineans*
	Top rot	*Xanthomonas rubrilineans*
	Pokhah beong	*Gibberella moniliformis*
	Rust	*Puccinia erianthi*
Sweet potato	White rust	*Cystopus ipomoea-panduranoe*
(*Ipomea batatas*)	Leaf spot	*Phyllosticta batatas*
Tannia (*Xanthosoma Sagittifolium*)	Leaf spot	*Alternaria* spp.
	Mosaic	Dasheen mosaic virus
Tomato (*Lycopersicon esculentum*)	Bacterial wilt	*Pseudomanas solanacearum*
	Southern blight	*Sclerotium rolfsii*
	Early blight	*Alternaria solani*
	Grayleaf spot	*Stemphylium solani*
	Greyleaf mold	*Cladosporium fulvum*
	Mosaic	Tobacco Mosaic Virus
	Black leaf spot	*Septoria* spp.
	Root knot	*Meloidogyne* spp.
Watermelon (*Citrullus vulgaris*)	Foot rot and wilt	*Sclerotium rolfsii*
	Blossom-end rot	Physiological
Yam (*Dioscorea alata*)	Leaf spot	*Cercospora carbonacea*
	Leaf spot	*Phyllosticta* spp.
	Anthracnose	*Colletrotrichum gloespo-rioides*
	Internal brown spot	Virus
	Mosaic	Virus

Table 5 Pesticides commonly used in Trinidad and Tobago

INSECTICIDES

Botanicals

Pyrethrins, Cinerins.

Inorganics

Lead arsenate

Chlorinated hydrocarbons

Agrocide (gammexane)
chlordane
heptachlor
aldrin
dieldrin
Thiodan (endosulfan)
toxaphene
mirex
Kelthane (dicofol)

(Table 5 Continued)

Carbamates

Unden (propoxur)
Mesurol (methiocarb)
Famid (dioxacarb)
Sevin (carbaryl)
Furadan (carbofuran)
Lannate (methomyl)
Vydate (oxamyl)
Padan (cartap)

Organophosphates

Aliphatic derivatives of Phosphorus compounds
Azodrin (monocrotophos)
Dipterex (trichlorfon)
DDVP (dichlorvos)
malathion
Metasystox (oxydemetonmethyl)
Mocap (ethoprop)
naled
Orthene (acephate)
Tamaron (methamidophos)
Carbon cyclic derivaties of Phosphorus compounds
Abate
Folithion (fenitrothion)
Gardona (stirofos)
Lebaycid (fenthion)
parathion

Heterocyclic derivatives of Phosphorus compounds

Asuntol (coumaphos)
Diazinon (basudin)
Gusathion (azinphosmethyl)

Microbials

Dipel *Bacillus thuringiensis*
Biotrol " "

Synthetic Pyrethroids

Ambush (permethrin)
Belmark
Decis (decamethrin)

FUNGICIDES

Inorganics

Sulphur compounds e.g. Lime Sulphur
Copper compounds e.g. Perenox; Bordeaux mixture

Organics

Organo-mercury compounds
Ceresan
Dithio-carbamates
maneb (Manzate)
Zineb
Antracol (propineb)
Vapam
Dithane M 45 (mancozeb)

(Table 5 Continued)

Dicarboximides

captan (Orthocide)
folpet
Difolatan
Tersan (thiram)

Benzimidazoles

Benlate (benomyl)
Daconil (chlorthalonil)

Fumigants

Dowfume (methyl bromide)
chloropicrin
Bromofume (ethylene dibromide)

HERBICIDES

Phenoxy compounds

2,4-D
silvex

Substituted ureas

Karmex (diuron)
Bipyridyliums
paraquat
Triazines
Gesaprim (atrazine)
Gesagard (prometryne)
Gesapax (ametryn)

Miscellaneous herbicides

Hyvar
Amiben (chloramben)
dalapon
M S M A

RODENTICIDES

Anticoagulants

Ramik Green
Mondo Red
warfarin (Warf)
Racumin

19. U.S. VIRGIN ISLANDS

PESTS AND PESTICIDE MANAGEMENT

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INTRODUCTION

No specially prepared paper was contributed by the U.S. Virgin Islands for the Seminar, but instead a leaflet entitled Commercial Pesticide Applications Manual was submitted. This covers at least some of the information requested and is reproduced in full in the following pages. – Editor

COMMERCIAL PESTICIDES APPLICATOR MANUAL: RESEARCH AND DEMONSTRATION

This manual was adapted for Virgin Islands needs from materials furnished by the Training Branch, Operations Division, Office of Pesticide Programs, U.S. Environmental Protection Agency, Washington, D.C. It supplements the EPA/USDA publication: "APPLY PESTICIDES CORRECTLY – A GUIDE FOR COMMERCIAL APPLICATORS." That publication should be read first.

The information herein provides a base to use in preparing for the certification examination in the category of RESEARCH AND DEMONSTRATION PEST CONTROL.

Reference to commercial products or trade names is made with the understanding no discrimination is intended and no endorsement is implied by the College of the Virgin Islands Cooperative Extension Service.

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January, 1976

COOPERATIVE EXTENSION WORK IN AGRICULTURE AND HOME ECONOMICS
(Acts of May 8 and June 30, 1974)
Agricultural Extension Service, College of the Virgin Islands
and the United States Department of agriculture, cooperating
D.S. Padda, Actg. Director

The U.S. Environmental Protection Agency has set the following standards for individuals doing research and demonstrating the use of pesticides:

"Persons demonstrating the safe and effective use of pesticides to other applicators and the public will be expected to meet comprehensive standards reflecting a broad spectrum of pesticide use. Many different pest problem situations will be encountered in the course of activities associated with demonstration, and practical knowledge of problems, pests, and population levels occurring in each demonstration situation is required. Further they should demonstrate an understanding of pesticide-organism interactions and the importance of integrating pesticide use with other control methods. In general, it will be expected that applicators doing demonstration pest control work possess a practical knowledge of all the standards detailed in Section 171.4(b). In addition, they shall meet the specific standards required for categories (1) through (7) of this section as may be applicable to their particular activity.

Persons conducting field research or method improvement work with restricted use pesticides should be expected to know the general standards detailed in 171.4(b). In addition, they shall be expected to know the specific standards required for categories (1) through (9) of this section, applicable to their particular activity, or alternatively, to meet the more inclusive requirements listed under 'Demonstration'."

The above standards do not apply to (1) persons conducting laboratory type research involving restricted use pesticides and (2) Doctors of Medicine or Veterinary Medicine applying pesticides as drugs or medication during the course of their normal practice.

As can be seen this is an important category as individuals certified herein not only provide and disseminate information on pest control but through their attitudes and actions serve as an example for other applicators. Therefore, in addition to specific category expertise they should be knowlegable in the following areas:

PESTICIDE-ORGANISM INTERACTIONS

Both the beneficial and harmful effects of pesticides are determined by pesticide-organism interactions or how pesticides and organisms react to each other. To do its job, a pesticide must usually penetrate the organism, move or be transported to the site of action and there disrupt or alter a vital function. The manner in which the pesticide affects the vital function is called its mode of action. Penetration, transport, and mode or action involve pesticide-organism interactions, as well as the metabolism, accumulation, and elimination of pesticides and biodegradation and biological magnification.

Selectivity (the ability of a pesticide to kill or otherwise alter one organism and not another) and the development of pesticide resistance are often caused by differences in pesticide-organism interactions.

Penetration

The speed and extent of penetration depends on the permeability of the organism to the specific pesticide. This differs significantly among organisms and even among different tissues or the same organism. Among animals, tissues of the respiratory and digestive system are usually more permeable than the skin. With plants, hardened growth and bark generally provide a more effective barrier than new and succulent growth. The ability of a pesticide to penetrate an organism depends on its chemical nature and the formulation. Penetration is usually increased tremendously by organic solvents.

Transport

The movement of the pesticide from the place where it entered the organism to the site of action involves the motility of the pesticide molecule and the efficiency of the transporting mechanism of the organism and the effect of each on the other.

Mode of Action

The pesticide performs its main function only after it reaches the site of action within the organism. This is usually the protoplasm of a living cell and often a particular kind of a cell. For example, the site of action for organophosphate insecticides is the nerve cell.

Pesticides kill or otherwise alter an organism by disrupting or interfering with some vital physiological function. This is called the pesticide's mode of action. As an example, the mode of action of organophosphate insecticides is the inhibition of cholinesterase, an enzyme that is essential in regulating the

nervous system. When cholinesterase is inhibited, muscles and glands become extremely overactive because of excessive stimulation by the nerve cells.

Metabolism

Metabolism is the process by which a pesticide, or another chemical, is changed into one or more different chemicals within a living organism. The metabolic product, or metabolite, may be either more toxic or less toxic than the original pesticide chemical. Some pesticides are effective only after they have been metabolized to a lethal compound by the organism. Given enough time, most organisms can metabolize most pesticides to non-toxic metabolites. Survival of the organism may depend on whether or not the organism can metabolize the pesticide into non-toxic metabolites before the toxic activity is complete or irreversible.

Accumulation and Elimination

Pesticide chemicals and their metabolites may be stored or accumulated within the organism or be eliminated as waste. If the level of exposure to most accumulative pesticides remains constant, an equilibrium between storage, metabolism, and elimination will be reached and the concentration of the pesticide and its metabolites will remain constant within the organism. If the level of exposure is changed, then the concentration within the organisms will correspondingly increase or decrease.

Biodegradation

Pesticides in the environment can be destroyed by ultra-violet light and chemical reactions but pesticide-organism interactions are involved when they are biodegraded. Biodegradation is simply metabolism but generally it refers to the decomposition of a pesticide residue by bacteria and other microorganisms.

Biological Magnification

This is the tendency for certain pesticides to become progressively more concentrated in each type of organism when moving from the bottom to the top organism within a food chain.

DDT in Lake Michigan is probably one of the best examples of biological magnification. The bottom sediments were found to contain an average of .0085 ppm. Small invertebrates averaged 0.41 ppm while predacious fish such as coho salmon and lake trout contained 3 to 8 ppm. Herring gulls, at the top of the food chain, contained as much as 3177 ppm of DDT. In this case, the overall magnification from the bottom sediment was about 370,000 fold.

Biological magnification has resulted in deaths and reproductive failures among predatory animals, especially hawk-like birds and brown pelicans. Perhaps the most familiar example of reproductive effects is the association of thin egg shells with certain organochlorine insecticides.

CLASSIFICATION OF PESTICIDES

Man's desire to control his environment has created many useful chemicals. Among the first were arsenite insecticides in first century China and sulfur fumigation by ancient Romans. Some of the natural plant products such as pyrethroids, nicotine, strychnine, and rotenone were used as toxicants by primitive peoples around the world. The middle of the last century, starting with carbon bisulfide fumigation, saw the advent of fumigants, inorganic toxicants, and petroleum products for pest control. Synthetic organic insecticides first appearing for public use were the dinitro compounds and thiocyanates in 1925. The most significant discovery that led to present day proliferation of new synthetic pesticides was the discovery of DDT's insecticidal properties by Muller in 1939. This opened the way for a number of chlorinated hydrocarbon insecticides. The second massive introduction of new insecticides was initiated by Gerhard Schrader with his work on the organophosphorus compounds. Carbamates are the newest group of synthetic insecticides to be made available.

Following is a discussion of some of the more important groups of insecticides in use today:

Chlorinated Hydrocarbons

This first major group of synthetic insecticides includes such chemicals as DDT, BHC, chlordane, dieldrin and aldrin. All the compounds belonging to this group are characterized by the presence of carbon, chlorine, hydrogen, and sometimes oxygen atoms, attraction to fatty tissue, and (most unfortunately for modern environmental concerns) very stable compounds.

Organophosphates

The organophosphorus (OP) compounds account for approximately 30% of the registered synthetic insecticides today and the number is increasing. Examples of these

include: TEPP, parathion, fenthion, coumaphos, diazinon, etc. The chemicals in this category possess the common characteristic of being excellent inhibitors of cholinesterases. Members of the group can be generally toxic (parathion) or selectively toxic (malathion). They are used as stomach and contact poisons, fumigants, and systemics.

Carbamates

This new arrival is also a cholinesterase inhibitor. Most of them are synthetic derivatives of physostigime (eserine) which is the principle alkaloid of the calabar bean plant. A widely used carbamate in the Islands today is carbaryl or sevin.

Thiocyanates

These were important insecticides before the advent of DDT. They produce a rapid knockdown and paralysis of insects. As such they are widely used as fly space sprays. They are a mild general poison with a good warning effect.

Dinitrophenols

These early insecticides still have some usefulness today as dormant sprays and herbicides. They are quite toxic to cells of all types, including plant cells.

Fluoracetate Derivatives

Fluoroacetate derivatives are characterized by their structural requirement that only the compounds which can give fluoroacetic acid on activation in animal or plant tissues are active. Since these compounds have the same biochemical processes in insects and mammals, it has been difficult to develop selective chemicals.

Acaricidal Chemicals

Today there is a group of acaricidal compounds that normally contain two chlorinated benzene rings linked with a sulfur atom — the sulfones, sulfonates and sulfides. As mentioned above the ancient Romans had already discovered the acaricidal properties of elemental sulfur.

Fumigants

These are all very volatile compounds whose usefulness is mainly applied to situations where they can be confined, such as, in the fumigation of warehouses for stored grain insects and rodents. These can be very flammable to the point of explosive. As they are general toxicants, proper protective equipment must be used.

Inorganic Compounds

Relatively non-specific compounds, these need large quantities to achieve control in the field. Arsenicals and fluorides are the most common inorganic chemical groups used today.

Botanical Compounds

Botanical alkaloids have been used for many years. These are derived from natural plant species, but today many synthetic analogues are being prepared. They vary from very toxic materials, such as nicotine and strychnine to selective ones, such as pyrethrum and rotenone.

INTEGRATED PEST MANAGEMENT

Properly planned and executed, integrated pest management practices can maintain pest populations at a level low enough to satisfy human needs with minimal adverse effects on non-target organisms and on environmental quality. Integrated pest management can be more effectively accomplished if the agricultural crop or other site of a pest problem is considered in its entirety and not merely an arena in which to fight a pest. Past, present, and future conditions or practices tremendously affect the level of pest populations, the choice of pest control methods, and the degree of pest control achieved.

It should be recognized that any pest control practice, including the application of pesticides, will have effects other than the intended one. Such side effects may be good or bad, gross or slight, short-lived or long-lived, local or distant, obvious or nebulous. One should be ever observant for these side effects and consider them in reporting, demonstrating, and recommending pest control practices. The essence of integrated pest management is to select those pest control measures that will maximize beneficial effects and minimize harmful ones. Individual elements, or control measures, within the integrated pest management program should be selected, used in the proper sequence and timed to be compatible with each other, with other cultural or maintenance practices and use of the item that is being protected from pests.

Neither pesticides nor any other individual control measure should be overused to the extent that it loses its effectiveness, interferes with the effectiveness of other control measures, or adversely affects man, other non-target organisms, or the environment.

Resurgence of target pest populations or population explosions among secondary pests

or non-target pests may follow pesticide applications because of the destruction of natural enemies. For instance, aphids and mites frequently thrive after aphislions, lady beetles, syrphid fly larvae or other natural enemies are destroyed by a pesticide application. This occurs not only after applying pesticides that are not effective against aphids or mites but in some instances when the pesticide is applied precisely for aphid or mite control.

Parasite and predator populations may survive a pesticide application but be decimated by starvation when the pests and other hosts are killed off.

In certain instances, an organism is not an important pest simply because of competition from another organism. Such an organism becomes a pest when its competition is removed. If broad-leaved weeds are selectively killed by a herbicide, grassy weeds will usually thrive. Some pests that occur on crops late in the season are pests because the crop has been protected from competitors.

In some instances, a pest may be supporting another organism that becomes a pest when its host is controlled. Weeds may harbor insects such as plant bugs and certain caterpillars that move to cultivated crops when the weeds are destroyed. Fleas may move from dead rats to human or pets.

The certified applicator in demonstration and research pest control must be ever mindful of the extreme complexity of the usual environment in which pest control is practiced. Biological phenomena, climate, topography, various physical and chemical characteristics, maintenance or cultural practices, and use patterns are so interrelated that it is extremely difficult to adequately assay the effects that a pesticide may have on the ecosystem. One must be constantly alert and thoughtful in developing, recommending and demonstrating pest control practices.

TOXICOLOGY TERMINOLOGY

The layman has a fear of "lethal" chemicals. But as Paracelsus pointed out in 1530 ". . . only the dose determines whether the compound is poisonous." So any chemical can be lethal if taken in excessive amounts. Even common salt can kill if one consumes too much of it. Thus what is really important is the degree of toxicity of a chemical.

Toxicologists rate the degree of toxicity in a universal shorthand which gives the relative toxicity of a particular dose of given compound to an individual species. Take for example, the cryptic "LD_{50} 100 mg/kg for Norway rats". Roughly this tells us that 100 milligrams of a particular chemical is sufficient to kill about four average-size Norway rats, but there is much more information in that simple line.

The lethal dose (LD) was based on a test run with captive animals. There may have been 2 or 100 individuals in the test but that particular dosage killed half of the animals or 50% (LD_{50}). This percentage of kill can be expressed in any ratio from LD_0 (none of the animals in the test were killed at that particular dosage) to LD_{100} (all of the test animals were killed). However, LD_{50} is a practical level as under field conditions where individual doses cannot be metered exactly, a majority of the target animals will receive overdoses sufficient to kill most of individuals resistant to the median dose.

The "100 mg/kg" is the ratio of the amount of compound to the live body weight of the target animal, expressed in the metric system of milligrams/kilograms. Thus 100 mg of the chemical would be sufficient to kill four average-sized Norway rats weighing about 250 grams each. If dogs had been the target species and their average weight was 10 kilograms (22 pounds) the above ratio would tell us that it would require 1000 milligrams of the chemical to kill one individual dog — 1000mg/10kg or 100mg/kg.

Sometimes the exact dose initially given cannot be determined, such as fish in a tank of water or rats in a fumigation chamber. In these cases, the toxicity is expressed as LC_{50}. This means that the lethal concentration (LC) of a compound dissolved in water or in gaseous state at a particular level will kill 50% of the test population.

Other frequently used abbreviations are "ppm" and "ppb". These stand respectively for "parts per million" and "parts per billion". PPM is the same as the mg/kg ratio (1 milligram/1000 x 1,000 = 1,000,000).

Persons certified for the (10) Research and Demonstration category must also be qualified in any of the previous categories in which they are expected to function. For the Virgin Islands, the following categories have been established:

(1-i) Agriculture: Plant

(1-ii) Agriculture: Animal

(3) Ornamental and Turf

(7) Industrial, Institutional, Structural and Health Related

(8) Public Health

(9) Regulatory

APPENDIX

TOXICITY OF PESTICIDES IN USE IN THE CARIBBEAN

The following has been taken from Alleyne, E.H. Safety Guide for Pesticide Users, Bulletin No. 2 of the Ministry of Agriculture, Food and Consumer Affairs, Barbados, 1979, as a concise guide to readers who may wish to make a quick check on the toxicity of any particular pesticide they are likely to encounter in the Caribbean region.

Toxicity of pesticides

Undoubtedly the most damaging factor associated with the use of pesticides is their "poisonousness" or toxicity. This toxicity is often non selective and as a result both intended and unintended targets may be affected. Pesticides enter the body by three routes. These are by the mouth (oral), through the lungs (inhalation), or through the skin (dermal). If the pesticide is taken in a single large dose then poisoning is said to be "acute". When repeated small dosages are taken then "chronic" poisoning results. Chronic poisoning is most difficult to detect and should be of particular interest to farmers who spray regularly, as the small dosages absorbed over an extended period could affect them chronically. The "poisonousness" of a pesticide is usually quoted as acute oral or acute dermal toxicity in milligrams of active ingredient per kilogram body weight (i.e. parts per million (p.p.m)). This is primarily because it is much more difficult to measure the chronic toxicity value, although toxicologists generally hold the view that the value for chronic toxicity can be obtained with a high degree of probability, in tests over a 2-year period. The test animals used in toxicity trials are usually rats or mice although occasionally human volunteer. Toxicity values are usually assessed from the dosage of pesticide required to kill 50% of the test animals. These values are known as LD_{50}'s (LD = lethal dose), and are given in mg/kg body weight.

Such values have enabled pesticides to be grouped according to hazard (Table 1). It must however, be borne in mind that the LD_{50} values obtained for any pesticide are dependent on a number of different factors including sex and species of test animal, its age, method employed to determine the value, the purity of the chemical and whether the animal was fasted or unfasted. Hence under different conditions a different value would be obtained. Again the hazard is also dependent on the way the chemical is used. If the acute oral is high and acute dermal is low then the danger is greatly minimised in areas when skin contact is the major means of exposure. The type of formulation also affects the hazard of the particular pesticide. In general, liquid and dust formulations, because of wind drift and spillage, present a far greater hazard than granules. Some extremely toxic pesticides are available only in granular formulations.

The smaller the LD_{50} value the more toxic and hence hazardous the pesticide. Table 1 gives the values of comparative hazards, while in Tables 2-7 most of the pesticides available locally and some others, are grouped according to the level of hazard. Although this is a useful method of grouping pesticides, it is by no means the only one employed by toxicologists. As in other classifications which are based on only one characteristic there are deficiencies, but for most purposes it provides an excellent guide.

Table 1. Classification of Comparative Hazard of Pesticides

Level of Hazard	Oral LD_{50} in rats in mg/kg body weight
Extremely hazardous	less than 10
Very hazardous	11 - 50
Moderately hazardous	51 - 100
Fairly hazardous	101 - 500
Relatively safe	501 - 5000
Safe	More than 5000

The values in Tables 2-7 are the lowest values recorded for the particular chemical. In "route" column, 0 = oral and D = dermal.

Table 2 Extremely hazardous (LD_{50} 0-10 mg/kg)

Common Name	Some Trade Names	LD50 mg/kg	Route
aldicarb	Temik	0.93	O
carbofuran	Furadan	8	O
chlorfenvinphos	Sapecron, Birlane	10	O
chlormephos		7	O
chlorthiophos		9.1	O
cyanthoate	Tartan	3.2	O
demephion	Cymetox, Atlaselox	0.046 ml/kg	O
demeton-S	Systox	2.3	O
dieldrin	Octalox	10	D
dimefox	Terra Sytam, Pestox 14	1	O
disulfoton	Di-syston, Disyston	2.6	O
fensulfothion	Dasanit, Terracur P	3.5	D
fonofos	Dufonate	7.9	O
mephosfolan	Cytrolane	8.9	O
methamidophos	Monitor, Tamaron	10	O
mevinphos	Phosdrin	3	O
monocrotophos	Azodrin, Nuvacron	8	O
oxamyl	Vydate	5.4	O
parathion	Alkron, Folidol, Fosferno	3.6	O
phorate	Thimet	2	O
phosfolan	Cyolane, Cyolan, Cyalane, Cylan	9	O
prothoate	Fac	9	O
schradan	Pestax 3, Sytam	9	O
sodium fluoride		0.22	O
sulfotepp	Bladafum	5	O
terbufos	Counter	2	O

Table 3 Very hazardous (LD_{50} 11-50 mg/kg).

Common Name	Some Trade Names	LD_{50} mg/kg	Route
aminocarb	Metacil	21	O
azinphos-ethyl	Gusathion A	12.5	O
azinphos-methyl	Gustathion M, Guthion	16.4	O
bendiocarb	Ficam W	35	O
calcium arsenate		35	O
carbophenothion	Trithion, Garrathion	32.2	O
coumaphos	Asuntol, Muscatox, Resitox, Co-Ral	15.5	O
cyanofenphos	Surecide	43.7	O
dicrotophos	Bidrin, Carbicron, Ektafos	16.5	O
dimetilan	Snip	47	O
dioxathion	Delnav	23	O
DNOC	Antinonnin, Sinox	25	O
endothion	Endocide	30	O
ethoprophos	Prophos, Mocap	26	D
isothioate	Hosdon	50	O
leptophos	Phosval, Abar	50	O
mecarbam	Murfotox, Pestan	36	O
methidathion	Supracide	25	O
methiocarb	Mesurol, Draza	40	O
methomyl	Nudrin, Lannate	17	O

(Table 3 continued)

Common Name	Some Trade Names	LD_{50} mg/kg	Route
methyl sulfone		37.5	O
nicotine		50	OD
omethoate	Folimat	50	O
parathion-methyl	Dalf, Folidol-M, Bladan M, Metacide, Ridan, Nitrox 80	14	O
phosphamidon	Seosil, Dimecron, Imidan	20	O
pindone	Pival, Pivalyn	50	O
thionazin	Nemafos, Zinophos, Cynem	11	D
trichloronate	Agrisil, Agritox, Phytosol	16	O

Table 4 Moderately hazardous (LD_{50} 51-100 mg/kg)

Common Name	Some Trade Names	LD50 mg/kg	Route
aldrin	Octalene	67	O
bromophos-ethyl	Nexagan	71	O
bufencard	Bux	87	O
2-(2-butoxyethyl) ethyl thiocyanate	Lethane 384	90	O
camphechlor	Toxaphane	80	O
chlordecone	Kepone	65	O
crotoxyphos	Ciodrin	90	O
demeton-S-methyl	Metasystox i	57	O
dichlorvos	Dedevap, Nogos, Vapona, Nuvan	56	O
dioxacard	Famid, Elocron	60	O
endosulfan	Malix, Thiodan, Thionex, Cyclodan	76	O
ESP	Metasystox S, Estox, Thiometan	100	O
gamma BHC gamma HCH	Gammexane, Gammalin, Lindane, Gammatox	88	O
heptachlor		100	O
heptenophos	Hostaquick	96	O
isoxathion	Karphos	98.4	O
oxydemeton-methyl	Metasystox R	65	O
promecarb	Carbamult	74	O
propoxur	Baygon, Blattanex, Unden	90	O
quinalphos	Ekalux	62	O
sodium fluoride		75	O
triazophos	Hostathion	82	O

Table 5. Fairly hazardous (LD_{50} 101-500 mg/kg).

Common Name	Some Trade Names	LD_{50} mg/kg	Route
acephate	Orthene	215	O
allethrin	Pynamin	480	O
bioallethrin	D-trans, Pynamin	480	O
BPMC	Osbac	410	O
bronopol	Bronocot	180	O
cartap	Pandan	225	O
chlordane	Octachlor	457	O
chlordimeform	Galecron, Fundal	340	O
chlorpyrifos	Dursban, Lorsban	135	O
cryolite	Feldan	200	O
cuprous oxide	Perenox, Yellow cuprocide, Copper Sardez	470	O
cypermethrin	Ripcord	242	O
DDT	Gesarol, Guesarol, Neocid, Arkotine	113	O
2,4-D		375	O
dialifos	Torak	145	D
diazinon	Nucidol, Basudin, Neocidol Diazol	300	O
dibromochloro-propane	Nemagon, Fumazone, Nemafume	170	O
dichlofenthion		270	O
2-4-dichloro-6 (o-chloranilino) -s-triazine	Dyrene	460	O
di-(2-Chloroethyl ether)	Chlorex	105	O
dichloroprop	Cornox RK	400	O
dimethoate	Fostion MM, Cygon, Dimetate, Rogor, Roxion, (Cela), Perfekthion (BAST)	320	O
ethiofencarb	Croneton	411	O
ethion	Nialate	208	O
ethoate-methyl	Fitics	340	O
fenitrothion	Folithion, Sumithion, Cytel, Accothion, Cyfen	250	O
fenthion	Baycid, Baytex, Entex, Lebaycid, Mercaptophos, Queleton, Tiguvon	190	O
fenvalerate	Belmark	427	O
formothion	Anthio, Aflix	375	O
linuron	Afalon Lorox	500	O
mirex		235	O
morphothion	Ekatin M, Morphotex	190	O
MPMC	Meobal	380	O
m-tolyl-methyl-carbamate	Tsumacide, Metacrate	268	O
naled	Dibrom	430	O
paradichloro-benzene		500	O
phenthoate	Cidial, Elsan	300	O
phosalone	Zolone	120	O
propachlor	Ramrod	380	D
pyrazophos	Afugan, Curamil	286	O
pyrethrins		484	O
rotenone		132	O
thiometon	Ekatin	120	O
2-4-5TP (fenoprop)	Kuron	500	O
XMC	Macbal	374	O

Table 6. Relatively safe (LD_{50} 501-5000 mg/kg)

Common Name	Some Trade Names	LD_{50} mg/kg	Route
alachlor	Lasso	1200	O
ametryne	Gesapax, Evik	935	O
amino-triazole	Weedazol	1100	O
ammonium salt of chloramben	Amiben, Amoben	1360	D
bromophos	Nexion	720	O
butopyronoxyl	Indalone	3400	O
chlorpyrifos-methyl	Reldan	941	O
crufomate	Ruelene	660	O
cyanaphos	Cyanox	610	O
deet	Metadelphene	2000	O
decamethrin	Decis	537	O
dichlorophen	Supermoss Killer & Lawn fungicide	1250	O
dicofol	Kelthane	668	O
dinocap	Karathane, Arathane, Crotothane	980	O
dimethyl phthalate		4800	D
dimethyl tetra-chlorotere-phthalate	Dacthal	3000	O
diphenamid	Dymid, Enide	600	O
DSMA	Ansar	1800	O
diuron	Karmex	3400	O
ethohexadiol		2000	O
ethylhexanediol		2000	D
fenchlorphos	Nankor, Trolene, Korlan	1740	O
iodofenphos	Nuvanol N	2000	D
isobornyl-thiocyanoacetate	Thanite	1603	O
malathion	Cythion, Malathon, Malathiozol, Malathiozoo	2800	O
metaldehyde	Meta	600	O
methoxyethyl-mercury chloride	Agallol, Aretan 6	570	O
metobromuron	Patoran	2500	O
MSMA	Ansar, Daconate, Bueno	900	O
naphthalene		2200	O
pentachlorophenol	Dowicide 7, Santobrite, Dowicide G, Santophen 20	210	O
permethrin	Marlate, Ambush, Kafil	1000	O
phoxim	Baythion, Volaton	1000	D
pirimiphos-methyl	Actellic	575	O
propineb	Antracol	1000	D
prometone	Primatol, Pramitol	2200	D
pyrazon	Pyramin	3300	O
pyrethrum		584	O
resmethrin		2000	O
ryania		650	O
sabadilla		4000	O
temephos	Abate, Abathion, Abat, Swebate, Nimitex, Biothion	1930	D
tetrachlorvinphos	Gardona	2500	O
trichlorfon	Dipterex, Neguvon, Tugon, Dylox	560	O
thiophanate-methyl	Cercobin M, Topsin M, Mildothane	3000	O

(Table 6 Continued)

Common Name	Some Trade Names	LD_{50} mg/kg	Route
tridemorph (H-tridieyl-2, 6-dimethyl-4-tridecylmorpholine)	Calixin	750 mm3/kg	O
trifluralin	Treflan	5000	O
(fenchlorphos)	Nankor, Trolene, Korlan, Ronnel	1740	

Table 7. Safe (LD_{50} 5000 mg/kg)

Common Name	Some Trade Names	LD_{50} mg/kg	Route
anthraquinone	Morkit	5000	O
benomyl	Benlate	10000	O
bioresmethrin		9000	O
captan	Orthocide 406	9000	O
dibutyl phthalate		2000	O
dibutyl succinate	Tabutrex, Tabatrex	8000	O
dipropyl isocinchomeronate		5230	O
dipropyl pyridine		5230	O
folpet	Phaltan	10000	O
2-hydroxyethyl octyl sulphide		8530	O
mancozeb	Dithane M-45	8000	O
maneb	Dithane M-22, Manzate	6750	O
methoxychlor	Marlate	6000	O
phenotrhin		5000	O
piperonyl butoxide		7500	
quintozene	Brassicol, Tritisan, Folosan, Terrachlor	12000	O
simazine	Gesatop, Primatol	5000	O
tetrachloroisophthalonitrile	Daconil 2787, Termil, Exotherm Termil	10000	O
tetramethrin	Neo-pyamin	5200	O
zineb	Parzate Zineb, Dithane Z-78	5200	O