WEST AFRICA RICE DEVELOPMENT ASSOCIATION

CONSORTIUM FOR INTERNATIONAL CROP PROTECTION

INTEGRATED PEST MANAGEMENT IN RICE IN WEST AFRICA

Concepts, Techniques, and Applications of Integrated Pest Management in Rice in West Africa

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INTEGRATED PEST MANAGEMENT IN RICE
IN WEST AFRICA

Proceedings of a Course

"Concepts, Techniques, and Application of
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7544

West Africa Rice Development Association
~~James T. Phillips, Jr. Regional Training Centre~~
Fendall, Liberia.

Report of a course held at the West Africa Rice Development Association's (WARDA) James T. Phillips Jr. Regional Training Centre, Fendall, Liberia, January 10 - 28, 1982, sponsored by WARDA and the Consortium for International Crop Protection (CICP) and the U.S. Agency for International Development (USAID) through Contract CICP/AID/DSAN-C-0252-Pest Management to CICP.

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Editors:- E.A. Akinsola
B. Cuayogode
I. Akintayo

PREFACE AND ACKNOWLEDGEMENTS

These proceedings are the lecture papers emanating from the short course, "Integrated Pest Management in Rice in West Africa" held at the West Africa Rice Development Association (WARDA) Training Centre Fendall, Liberia, January 10 - 28, 1982. The short course and this publication were sponsored jointly by WARDA, the Consortium for International Crop Protection (CICP), and the U.S. Agency for International Development (USAID).

At a seminar organized by WARDA in Bobo Dioulasso, Upper Volta in September 1979, pests were recognized as major constraints to rice production in West Africa and current control measures regarded as inadequate to cope with the problem posed by pests. Recommendations were made by the member countries that WARDA should initiate actions towards a regionally coordinated programme on Integrated Pest Management for rice in West Africa. The short course was a first step in this direction.

The overall objective of the course was to create awareness on the concepts, techniques and application of Integrated Pest Management in rice in West Africa. More specific objective were:

1. To introduce to extension and research officers and project supervisors working on projects related to rice pest control in WARDA region, the concepts, presently available and promising techniques, and application of integrated pest management in rice.
2. To review the pest problems affecting rice in West Africa and the present approaches to their control.
3. To establish mechanisms for effective dialogue and coordination among rice protection specialists in the WARDA region, and

4. To determine need for subsequent requirements in IPM training for personnel participating on Regional Programme on the Integrated Management of Pests of Rice in West Africa.

In addition to formal presentations, a field trip was conducted to the Central Agricultural Research Institute, Suakoko; a panel discussion looked into the aspect of post-harvest rice pest control; while participants, arranged in three agoecosystem teams prepared and presented status reports and recommendations concerning training needs, research requirements etc.

Twenty-eight trainees from 13 countries in West Africa namely: Benin, The Gambia, Ghana, Guinea, Guinea Bissau, Ivory Coast, Mali, Mauritania, Nigeria, Senegal, Sierra Leone, Togo and Upper Volta participated at the course. Lecturers were invited from national and international agricultural institutes and Universities in West Africa. Others came from the United States of America, Philippines and France. Some lecturers resided in the dormitory together with the trainees thereby having ample opportunities for informal discussions which in many occasions ran late into the night.

I wish to express sincere appreciation to CICP and the USAID for their role in the implementation of the course. Deep gratitude goes to the course coordinators, guest lecturers and trainees for their enthusiasm and dedication without which the course could not have achieved such a success.

Finally, I wish to express sincere thanks to those WARDA officials including translators and typists who have contributed to the preparation of this proceedings.

Sidi Coulibaly
Executive Secretary
W.A.R.D.A.

INTRODUCTION

There is a divergence of opinion as to whether the idea of integrated pest management is new to West Africa. Some workers believe that rice farmers, for instance, have practiced a form of integrated pest management. They claim to see nothing new and that recent hue and cry merely formalises and conceptualizes the idea.

The mangrove rice farmer who transplants old seedlings in order to escape crab damage, the highly laborious paddy systems of submerging weeds into puddled soils, transplanting seedlings old enough to compete successfully with later-germinating weeds and the system of planting rice on raised ridges to evade water-loving insect pests and soil problems - these may be cited as pestmanagement practices. But the application of these techniques were rather haphazard and unintegrated.

Integration connotes the idea of compatibility which can only be obtained through a conscious effort at understanding pest complexes and available control tactics. As stated by Professor T. Ajibola Taylor, "unless there is a basic understanding of the fact that integrated pest control is a conscious; carefully planned, and reasonably stable system in which all suitable methods of control and management are blended in such a way as to permanently reduce the significance of a pest as a source of economic damage or loss, there will be no conscious effort to develop the concept as a real strategy for pest control in many parts of Africa."

Herein lies the relevance of this short course. The meaning of, the approach to and the level of understanding of the concept of integrated pest management do vary and the course aimed at providing opportunities for crystalization of ideas and spread of the real concept of integrated pest management.

It is hoped that these proceedings would provide invaluable reference material not only to rice protectionists but also to all involved in crop protection in West Africa.

The editors acknowledge the excellent cooperation of the course lecturers and trainees who submitted written material incorporated into the Proceedings. We should note that one lecturer, Dr. Peter Kenmore, presented several formal lectures at the course (refer to agenda), but did not submit papers for incorporation.

E. A. Akinsola
B. Ouayogode
I. Akintayo

Dedicated to Baboucarr Cham of The Gambia, a trainee who lost his life shortly after the course.

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ORIGINS OF IPM

By

Dale G. Bottrell

University of California, Berkeley
Consortium for International Crop Protection
2288 Fulton Street, Suite 310
Berkeley, California 94704, USA

GENESIS OF PEST CONTROL

Long before the biology of pests was understood, human beings developed many biological, cultural, and physical methods for the protection of crops, animals, and self. Many of these practices subsequently proved scientifically valid, though originally derived from crude empirical methods (Ordish, 1976).

The earliest reference to the use of chemicals to control pests dates back to circa 2,500 B.C. when the Sumerians used sulfur compounds to control insects and mites. Thousands of miles east of Sumer, and some 1,000 years later, the Chinese developed plant-derived insecticides for protecting plant seeds and for fumigating plants infested with insect pests (Flint and van den Bosch, 1981). Chemicals were also used to control plant diseases at least 1,000 years before the Christian era; at the time of Homer, sulfur was used as a therapeutic agent (Walker, 1950).

Several centuries before Christ, the Chinese developed significant pest control techniques, learning 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, 1981).

The first methods of weed control involved human, livestock, and mechanical energy. From 6000 to 3000 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).

FOUNDATIONS OF IPM

The latter half of the 19th century and the first part of the 20th marked a significant era in pest control. As public agricultural experiment stations emerged in the late 1800s in the USA, for example, pest control experts began to discover the biological basis for earlier pest control methods developed largely by "trial and error" (Smith et al., 1976; Smith, 1978). Partially by intuition and partially because there were no effective alternatives, leading experts advocated habitat management practices that would maximize the benefits of natural biological and environmental control.

In the late 1800s, Stephen A. Forbes, entomologist at the University of Illinois in the USA, adopted the word "ecology" and stressed the broad application of ecological principles in controlling agricultural crop insects (Metcalf, 1930). Other pest control experts of this era 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; Watson et al., 1975; Newsom, 1975), and the modern approach to pest control known as "integrated pest management" (IPM) was born.

Plant pathologists also developed important disease management concepts and techniques during the late 1800s and early 1900s. For example, 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 (Apple, 1977; Walker, 1950).

The late 1800s and early 1900s also witnessed major developments in public health pest control. A mosquito management strategy that integrated ecological 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 1900s. Construction of the Panama Canal (completed in 1914) was made possible in part because the USA was able to manage the malaria and yellow fever mosquitoes which had prevented the French from succeeding earlier.

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 in various areas of the world. 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. The new chemical pesticides could be used by themselves and could achieve higher levels of pest control; they greatly simplified pest control, and the earlier integrated pest control schemes were viewed as obsolete.

Use of chemical insecticides in the USA dates from 1867, when Paris green (an arsenic compound) was used to control outbreaks of the Colorado potato beetle. Within a decade, Paris green and kerosene oil emulsion were being used against a variety of insect pests.

Common salt was apparently the first material used for chemical control of weeds in the USA. It was used extensively to control field bindweed in Kansas in the late 1800s. Copper sulfate was introduced toward the turn of the century for control of weeds in wheat (Timmons, 1970).

Around 1882 the use of Bordeaux mixture (quicklime and copper sulfate) as a fungicide (with some insecticidal properties) was accidentally discovered in France, adding further impetus to use of pesticides. This discovery was soon followed by fluorine-based insecticides and insecticidal compounds derived from plants (NAS, 1969). In the USA and certain other countries, there was optimism as early as the turn of the century that chemical pesticides would ultimately control both diseases and insects (Apple, 1977). The introduction of aircraft application in the early 1920s contributed further to the use of pesticides. The emergence of effective synthetic organic chemicals—such as the insecticide DDT and the herbicide 2,4-D—after World War II prompted further optimism and seemed to promise a pest-free environment.

The postwar pesticides initially produced spectacular results against agricultural pests, particularly insects and weeds, and public health pests, and the success of the materials led to widespread acceptance and reliance upon them in the developed countries.

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

RETURN TO ECOLOGICAL APPROACHES IN PEST CONTROL

In the USA and many other countries, the success of the chemical pesticides eventually created a dilemma. On the one hand, many of the necessities of life coevolved with pesticide technology to the extent that inhabitants of these countries become largely dependent upon the technology. Yet there were warnings against continuing to rely heavily on pesticide technology, and pest control experts begin to question whether this technology could guarantee serious pest ravages in the long term. Apart from the rising concern about the environmental and human health hazards of chemical pesticides, their continued use was challenged by the fact that significant groups of pests developed genetic resistance because of repeated exposure to (and thus "selection" by) the materials.

Moreover, in recent years, despite the economic gains realized from use of the materials, the price of synthetic organic pesticides has increased significantly parallel with the increasing costs of petroleum and other chemicals from which they are derived. These unsavory experiences have motivated government and institutional actions to support the development and implementation of pest control systems based on ecological principles. In the past 10 years, the USA, Canada, Europe, Australia, and many other countries have witnessed a major revival of the application of ecologically oriented pest control that was well-advanced by the early part of this century but cast aside as the postwar pesticides became available.

ORIGINS OF THE TERM IPM

The term integrated pest management evolved from "integrated pest control," originally proposed in the 1950s to describe the integration of biological and chemical controls into a cohesive insect pest management system (Bartlett, 1956; Stern et al., 1959). It was a conflict between entomologists who advocated the use of chemicals to control insect pests and entomologists who advocated the use of parasites and predators to control them that spawned the use of the term integrated pest control (Smith, 1978).

This first use of the term integrated pest control emphasized the integration of only chemical agents and biological control agents, and against insect pests only. In the USA, the first integrated pest control program, developed under that term per se, was for the spotted alfalfa aphid (*Therioaphis maculata*) by Vernon M. Stern, Ray F. Smith, Robert van den Bosch, and Kenneth S. Hagen (1959) of the University of California.

In 1965, the Food and Agriculture Organization of the United Nations (FAO) held an international conference in integrated pest control and in 1966 established the FAO Panel of Experts on Integrated Pest Control which still exists today under the chairmanship of Ray F. Smith (refer to training course paper by Dale G. Bottrell, Integrated Pest Management in a Global Perspective: Progress and Problems). The FAO Panel subsequently broadened the definition of integrated pest control to emphasize the use of control techniques other than chemicals and biological agents in integrated control programs against insects and also other pests (FAO, 1967).

The term pest management was introduced by Geier and Clark in 1961, and the term is still used widely today. Some consider the term to be synonymous with integrated pest management. But others believe that the terms imply two distinct approaches to pest control (Apple, 1977; Flint and van den Bosch, 1981).

Following FAO's initiative in the 1960s to promote integrated pest control and the subsequent initiative of the International Organization of Biological Control in Europe to do the same, the term integrated pest control has been popular world-wide among crop protection specialists. However, the term integrated pest management, introduced in 1972 by the U.S. Council on Environmental Quality (CEQ, 1972) is now preferred by many. Here, the term integrated pest control used by FAO (1967) is synonymous with integrated pest management introduced by CEQ (1972).

Integrated pest management was first articulated by insect control specialists and insect ecologists. It gained considerable attention and funding as an insect management approach before the concept came to include all classes of pests (Apple and Smith, 1976). The fact that IPM suggests integrated insect--pest management has alienated some weed scientists and plant pathologists although the integrated pest management concept is applicalbe to all classes of pests and all the pest control disciplines have shared in its development and implementation.

FOUNDATIONS OF IPM IN AFRICA

Though the term integrated pest management is not yet widely used in Africa, African farmers have practiced a form of IPM for centuries. Through trial and error, empirical methodology, and keen observation traditional African farmers developed cropping systems that "integrate" certain fundamental IPM components. For example, the highly laborious rice paddy system of submerging weeds into puddled soil, transplanting rice seedlings old enough to compete successfully with later-germinating weeds, and flooding probably evolved (first in Asia andthen in Africa) as a practical system to manage weeds. Traditional farmers in Africa developed and continue to use today a variety of innovations for protecting their crops and postharvest products against pests. Research has shown some of these control techniques to be quite effective for use in IPM schemes.

Literature Cited

Apple, J.L. 1977. The theory of disease management, p. 79-101. In J.G. Horsfall and E.B. Cowling (Eds.), Plant disease: an advanced treatise. Vol. I. How disease is managed. Academic, New York.

Apple, J.L., and R.F. Smith. 1976. Progress, problems, and prospects for integrated pest management, p. 179-196. In J.L. Apple and R.F. Smith (Eds.), Integrated pest management. Plenum, New York.

Bartlett, B.R. 1956. Natural predators. Can selective insecticides help to preserve biotic control? Agr. Chem 11(2): 42-44, 107-109.

Council on Environmental Quality. 1972. Integrated pest management. U.S. Govt. Printing Office. 41 p.

Flint, M.L., and R. van den Bosch. 1981. Introduction to integrated pest management. Plenum, New York. 240 p.

Food and Agriculture Organization. 1967. Report of the first session of the FAO Panel of Experts on Integrated Pest Control, Rome. 19 p.

Geier, P.W., and L. R. Clark. 1961. An ecological approach to pest control, p. 10-18. Proc. 8th Tech. Meeting of the Int. Union for Conserv. of Nature and Natural Resources, Warsaw.

Metcalf, C. L. 1930. Obituary, Stephen Alfred Forbes, May 29, 1844 - March 13, 1930. Entomol. News 41:175-178.

National Academy of Sciences. 1969. Principles of plant and animal pest control. Insect-pest management and control. Nat. Acad. Sci. Pub. 1695(3). 508 p.

Newsom, L.D. 1975. Pest management: concept to practice, p. 257-277. In D. Pimentel (Ed.), Insects, science, and society. Academic, New York.

Ordish, G. 1976. The constant pest. Peter Davies, London. 240 p.

Smith, R.F., J.L. Apple, and D. G. Bottrell. 1976. The origins of integrated pest management concepts for agricultural crops, p. 1-16. In J.L. Apple and R.F. Smith (Eds.), Integrated pest management. Plenum, New York.

Smith, R.F. 1978. History and complexity of integrated pest management, p. 41-53. In E. H. Smith and D. Pimentel (Eds.), Pest Control Strategies. Academic, New York.

Stern, V.M., R.F. Smith, R. van den Bosch, and K.S. Hagen. 1959. The integrated control concept. Hilgardia 29:81-101.

Timmons, F. L. 1970. A history of weed control in the United States and Canada. Weed Sci. 18:294-307.

Walker, J.C. 195[illegible]. Plant pathology. McGraw-Hill, New York. 699 p.

Watson, T.F., L. Moore, and G. Ware. 1975. Practical insect pest management — a self-instruction manual. Freeman, San Francisco. 196 p.

THE IMPORTANCE OF IPM IN RICE PRODUCTION IN WEST AFRICA

By

E.A. AKINSOLA
West Africa Rice Dev. Association
P.O. Box 1019
Monrovia, Liberia.

The Importance of Rice in West Africa

Rice as a food crop in West Africa has remarkably increased in importance in recent years. It is an important food item in most of the countries and a main staple food in many of them. Consumption ranges from 100 kg per year per person in the coastal countries on the western part of the region to 10 kg in some countries in the eastern part of West Africa.

The demand for rice in the region has been expanding at the rate of about 5% per annum over the last two decades, and the pace has accelerated further in the last two years (WARDA, 1980[a]). Such a high demand has been attributable to population growth, income growth, urbanization and substitution of other cereals and root crops. The effect of these factors on rice consumption in countries like Nigeria and Ivory Coast is tremendous (Sarfo, 1980).

Total paddy production is estimated at 2.8 million tons in 1980 and it is projected that rice demand in 1990 will surpass 4.2 million metric tons (WARDA, 1980[a]). The gap between production and demand has led to a rapid increase in imports, currently estimated at 1.7 million tons annually and valued at about $1,020 million.

High rice imports constitute major strain on the rather poor financial state of most of the countries. This is confounded by the universal high oil bills. With this background, several countries in West Africa have embarked on massive rice production programmes in order to minimize their heavy reliance on rice imports and save their foreign exchange.

Constraints to Rice Production

The full benefit of gigantic rice production activities cannot be realized without a conscious and determined effort to eliminate major constraints. Rice is cultivated under several ecosystems ranging from rainfed upland, irrigated, inland swamp, mangrove swamp, deepflooded to floating ecosystems. The constraints to production remain as varied as the ecosystems.

In general, both biotic and abiotic components of the environment are known to influence rice production. The problems of availability of water, temperature, solar radiation, nutrients and problem soils are largely predictable and with sound planning, are relatively easier to manage. The dynamic nature of living things confound problems associated with pests - weeds, plant pathogens, insects, rodents, birds, etc.

Pests as major constraints

The rice plant is attacked by several pests. Insects and other anthropods, plant pathogens, weeds, birds and rodents ravage the crop right from seeding through harvesting and storage.

Accurate information on the collective effects of the pests on grain yield in West Africa is not yet available. Recent data, however, show that protection of rice crops from insect damage alone could produce spectacular increase in yield. Crop protection on farmers' irrigated rice fields in Senegal gave yield increases of 3.25 and 5.67 t/ha (WARDA 1979). Grain yield increase of 34.8% was obtained on deepflooded rice in Mali, while increases ranging from 10 to 20% were reported for mangrove swamp rice in Sierra Leone (WARDA 1980[b]).

Cramer (1967) estimated that yield loss attributable to insects, diseases and weeds in Africa was 33.7% of potential production (Fig.1). This appears a rather realistic estimate. Considering the toll exerted by birds, rodents and anthropods such as crabs and mites, the ultimate yield loss must be staggering indeed. When Cramer's modest estimate is applied to 1980 rice production figure for West Africa the enormity of pest problems on rice is apparent. West Africa loses about 1 million tons of rice estimated at about $600 million.

Current control strategies

West African rice growers fall into one of two categories as regards crop protection activities. There are those that do very little as far as crop protection is concerned. They identify the most conspicuous and highly destructive pests in the locality, usually birds and perhaps weeds for special attention and ignore others that do not result in total crop failure. On those infrequent occurrences of sporadic and severely destructive pests like armyworms and locusts, they seek help from agricultural extension workers where available.

Otherwise they resort to whatever cultural practices that would minimize devastation. Other pest control measures adopted are labour-intensive i.e. hand weeding and use of human bird scarers. The farmer crops a small area (0.5 to 1.5 ha) and overwhelmed by the numerous constraints in rice production, he tolerates the endemic insect pests and diseases, and his yields are very low (1-1.5 ton/ha). The yield-depressing effect of pests are ignored. As rightly stated (Brady, 1979), a 20% reduction of a yield of 6 ton/ha is much more noticeable than a comparable reduction in a 2 ton/ha crop. Most of the farmers fall into this category.

The other group is made up of fairly large scale private or public farms which adopt some measure of middle level technology. Crop protection activity is a routine and pesticides, very often recommended by their manufacturers, are procured, stored and applied to the crop on calender regimes. Very often they are needlessly applied at times when low levels of damage do not justify their expenditure. Pesticide legislation is non-existent in many countries and a wide range of hazardous chemicals find their way into the ecosystem.

What is IPM?

I shall not attempt a definition of IPM in this presentation as this is the theme on which we shall deliberate in the next twenty days. Suffice it to say, however, that Integrated Pest Management has been described as a process for determining IF you need pest suppression treatments, WHEN you need treatment action (timing), WHERE you need treatment application (spot treatment), and WHAT strategy and mix of tactics to use (Anon, 1980).

The key factor in IPM is that all actions or non-actions must result in sound economic, ecological and sociological consequences.

Why IPM for Rice in West Africa

All indications point to the fact that rice production in West Africa requires an energetic boost. This is attainable by increasing production per unit area and by extension of planting area. Such intensification aggravates pest problems. The consequences of replacing traditional rice culture with new intensive culture has been aptly described for the Philippines (Glass, 1976). Brady (1979) gave three primary reasons for increased pest pressures associated with modern cultivars as limited host resistance, such cultural practices as heavy fertilization and increasing cropping intensities.

About 65% of rice growers in West Africa are poor peasant farmers, tending small holings and without any substantial amount of capital. The farmers as well as modern large-scale plantations need control strategies that are long-lasting, cheap, easy to adopt and free from environmental hazards. The concept of pest management, though not new in West Africa, has not been consciously implemented in rice production.

West Africa is endowed with a rich fauna of natural enemies of rice pests. Some workers believe that the seemingly low level of pest problems in certain areas is primarily due to the activities of the natural controlling agents.

What should one expect in an environment so stable as a result of diversity both in terms of its floristic and faunal composition. And yet it is this stability that will be affected by modern changes in rice culture. In spite of this, the balance between natural enemies and pests could be maintained by intelligent and rational approach to pest problems. Jung and Scheinpflug (1970) claimed that the increase in the importance of leaf- and plant-hoppers as pests of rice in Japan resulted from the destruction of their small spider and reduviid bug predators by insecticides for the control of the rice stemborers.

In order to minimize or eliminate such problems as outbreaks of potential secondary pests, it is absolutely essential to exercise utmost care against reduction or simplification of the biotic component of the agro-ecosystem. In this regard, there has been only a limited use of pesticides in rice production in West Africa and absolute reliance on pesticides should be discouraged. Apart from the drawbacks of pesticide usage - i.e. pesticide resistance, pest resurgence, secondary pest outbreak and residue problems (Smith and Reynold, 1966), experience the world over has shown that the application of a single control method is unlikely to overcome pest incidence successfully.

Integrated Pest Management has its own problems, it is not an easy task. Between planning and implementation of an IPM programme is a long and tortuous journey. There is training and general enlightenment on the principles and concepts of IPM at all levels; conduct of adaptive research to identify component tactics, and the demonstration of IPM package before full mass adoption.

One good thing about IPM is that it is not an "all or none" strategy and we do not need to wait till all problems are solved before initiating an IPM programme.

It has been said that successful IPM implementation might be achieved by relatively highly educated farmers. We believe that whatever strategy developed must be tailored to suit the generality of the farming population, be they educated or not. The farmers should be at the centre of the concept. The strategy of pest management may be different for both the developed and developing countries. The approach to IPM in the USA (Huffaker, 1980) and in China (Shin-Foo Chiu, 1979) are noteworthy examples.

Surveillance, monitoring and forecasting of pests form major component of pest management (Bottrell, 1979). It is often discussed whether this important aspect should be entrusted to government extension workers or to the farmers themselves. This is an issue to be determined at the appropriate time. However, although most of our farmers practise minimal crop protection now, they should have a scientific basis for "doing nothing." The situation might not remain the same for too long.

REFERENCES

Anon, 1980, What is IPM? The IPM Newsletter 2(5): 1980.

Barr, B.A., Koehler, C.S. and Smith, R.F. 1975. Crop losses, Rice Field losses to Insects, Diseases, Weeds and other Pests. USAID.

Brady, N.C. 1979. Overview of Rice Pest Problems, p.453-454. In Proc. IX Int. Congr. of Plant Prot. Washington D.C. Aug. 5-11, 1979.

Bottrell, D.G. 1979. Integrated Pest Mangement. Rpt. for Council Environ. Quality, U.S. Government Printing Office No.041-011-00049-1, Washington D.C.

Cramer, H.H. 1967. Plant Protection and World Crop Production. Pflanzenschutz - Nachrichten 20: 1-524.

Glass, E.H. 1976. Pest Management: Principles and Philosophy, p. 39-50. In J.L. Apple and R.F. Smith (Eds), Integrated pest management, Plenum Press, New York.

Huffaker, C.B. (ED.). 1980. New Technology of Pest Control. Wiley-Interscience, New York. 500p.

Jung, H.F. and H. Scheinpflug 1970. Rice growing in Japan with special emphasis on crop protection. Bayer Pflschutz-Nachr. 23: p. 235-263.

Sarfo, K. 1981. Personal Communication.

Shin-Foon Chiu 1979. Integrated Rice Insect Control in China, p. 466-470. In Proc. IX Int. Congr. of Plant Prot. Washington D.C. August 5-11, 1979.

Smith, R.F. and Reynolds, H.T. 1966: Principles, definitions and scope of integrated pest control. Proc. of the FAO Symp. on Integrated Pest Control I: 11-17. Rome.

WARDA 1979. Research Department Annual Report 1979. WARDA Monrovia.

WARDA 1980[a] Prospects of self-sufficiency in rice in West Africa. WARDA occasional Paper No.1, 1980.

WARDA 1980[b]. Research Department Annual Report 1980. WARDA, Monrovia.

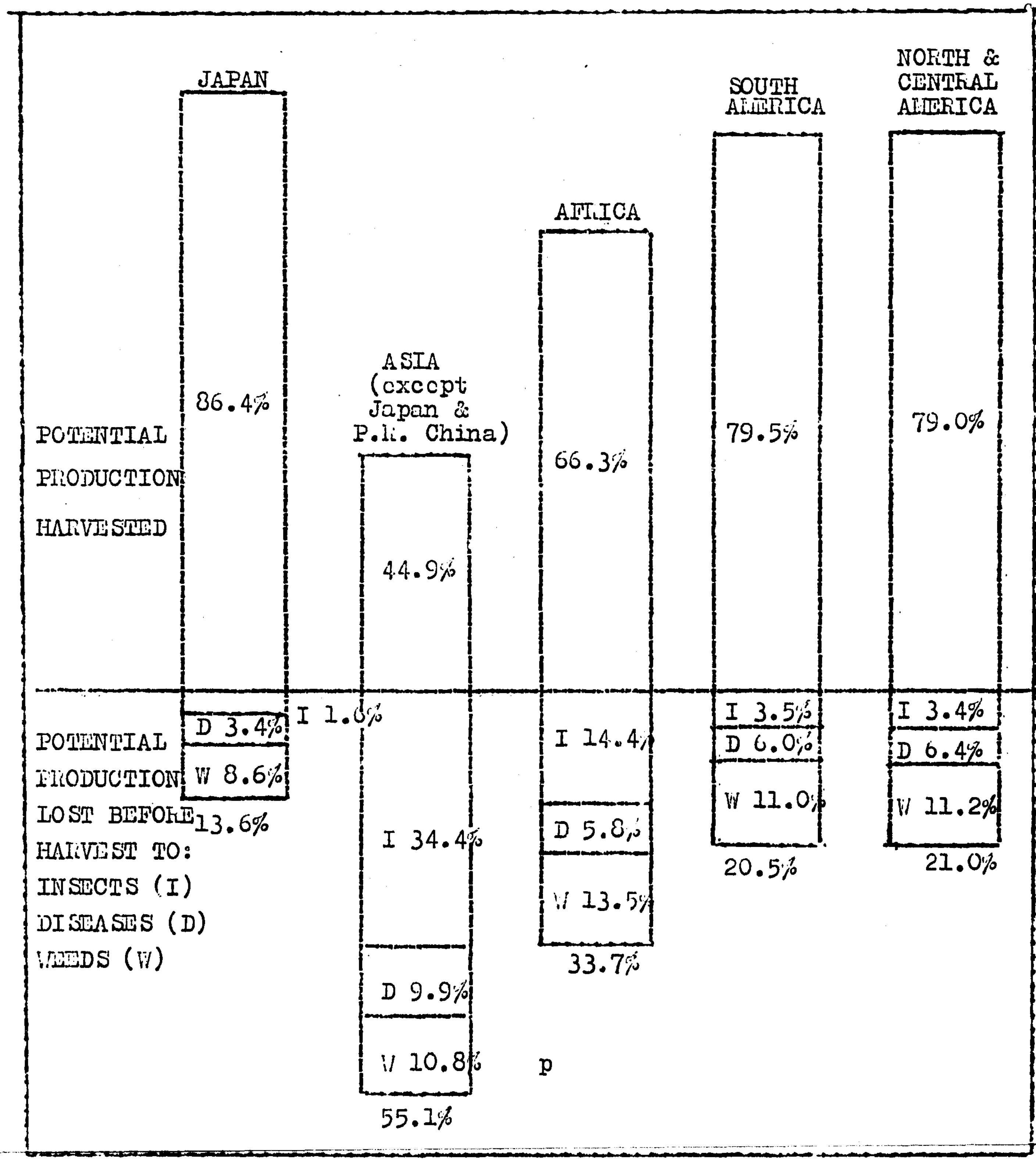


Fig. 1. Estimated percentage potential rice production actuallly harvested and percentage lost to insects, diseases and weeds in various areas (based on Cramer 1967 and reproduced from Barr *et al* 1975).

LEPIDOPTEROUS BORERS OF RICE IN WEST AFRICA BIOLOGY, DAMAGE AND CONTROL

By

J. Breniere
IRAT-GERDAT, Montpellier, France

Of all the insects attacking rice in the world, stemborers certainly constitute pest group which generally cause most damage.

Although leaf-feeding insects constitute red danger when in abundance at the early growth stage of the crop, however the borers start to develop at the **tillering** stage when they affect the production of many tillers and fruit-bearing stems. Some borers affect the heads and maturing grains by destroying the stems and panicles after the booting stage.

Generally crop losses are higher when irreversible damage caused to well developed crops is detected late. There are two types of rice stemborers namely the lepidoptera and the diptera. This lecture will discuss the lepidoptera borers in Africa and not diptera which are mainly diopside.

Lepidopterous borers of rice belong to two main groups namely Pyralidae and Noctuidae among which occur a few species found in all parts of the tropical regions. Species differ from one continent and one region to another but their behaviour, biology and the type of damage caused are similar. Lepidoptera borers of rice constitute a remarkable group of borers which are closely associated with borers of cultivated cereals.

In Africa the types of borers found are mainly Pyralidae such as Chilo, Scirpophaga and Maliarpha genera and the noctuids such as the Sesamia genus. We shall discuss successively these main genera and give an over view of control measures against the lepidoptera borers of rice in Africa.

CHILO SPP. Pyralidae: Crambinae

Two species are found on rice in West Africa namely, Chilo zacconius Blez., and Chilo diffusilineus. The former is mostly found in the Sahelo-Sudanese zone, and the latter seems to occur only in the humid equotorial Sudanese areas. Chilos species are polyphagous which does or does not attack cereals. Their biology is similar to that of C. suppressalis a borer which causes widespread damage in Asia. Agronomically speaking, it is difficult to identify species of Chilo whose caterpillars are difficult to defferentiate. Specialists are only able to identify them through the male genitalia. The following specifications mainly relate to C. zacconius.

Description (photographs)

Egg: oval, flat, creamy white with tiny particles lining the wall - The eggs are laid in two or three over lapping rows.

Caterpillar: ivory colour with 7 pink longitudinal stripes more or less distinct with the most ventral ones occurring above the spiracles. The head is more or less deep brown.

Adult: wings are pale yellow with irregular black spots.

Biology and damage: Oviposition take place on the upper or medium leaves.

After hatching, the young larva moves actively on the plant, feeds a little on the leaf and then enters the plant through the leaf sheath and the stem. The caterpillar consumes the tissues of the sheath and the stems and passes through 5 larval stages. Pupation takes place in the stem or in the sheaths when the culm is approaching maturity. Life cycle; egg - 4 days, larva 4 weeks, pupa 6-7 days. Average fecundity in the laboratory; 280 eggs laid in 3 or 4 batches.

There are two types of damages.

a). At the early tillering stage the larvae dig tunnels at the base of the young still flat stem consisting of a cluster of leaf sheaths which they perforate in different areas. The caterpillars thus lead a semi-endophytic life by mostly confirming themselves to the spaces between the leaves.

b). Caterpillars live in hollow stems of the internodes; however the youngest ones preferably develop in the upper parts of the stem specially the spike a few centimeters below the panicle. In the first case, they damage some stems which dry up after most of its parts have been severed. In the second case, either the tips of the stems dries up "deadhearts" or when they are older some panicle lose their chlorophyl and become whitish "whitehead". Finally, the based of the stem can be damaged and this slows down food supply to the upper parts. Generally, each damaged stem has many exit-holes. The same caterpillar can eventually move from one stem to another and many caterpillars can live together in the same stem. When they are still very young, 5 to 10 of them are often found together in the narrowest part of the stem below the panicle. Generally in such a case the entire stem is damaged.

Number of generations

There could be 5 to 7 generations in a year in the same farming area. In fact the number is limited by the length of the dry season when the food supply to dried-up plants is reduced. There could generally be a succession of two generations on a particular rice field. The first generation attacks the tillers and the second attacks the panicle stems and induce white heads.

During the dry season, the caterpillars mostly attack the shoots, some weeds such as Edrinochloa spp, Oryza barthii, Sorghum arundinaceum (Breniere, 1967, Descamps, 1956) or off-season rice fields. However they can live for several months without food (December to April in Casamance - Vercarnbre 1977).

SCIRPOPHAGA SPP -- Pyralidae: Scheoncbiinae:

The genus comprises 33 species (Hampson, 1895) which are scattered all over the world, and cause damage to rice and other crops. Their names and distribution pattern will be discussed. In Africa however, are found: Scirpophaga melanoclista Meyr: Ivory Coast, Mali, Nigeria, Angola, Cameroun, Senegal, Zaire, Madagascar (Lor sun Ly 1978). S. subumbrosa Meyr: Mali, Ghana......... These are probably the two widespread species.

Description Adult (photographs) the wings are whitish in colour and form a V shape at rest. Female: surface area 30-35mm, body slender and long, black thorax covered with tiny white scales, and white feet.

Egg - laying: The cluster is light brown and fluffy sticking either to the upper or lower part of the rice leaf about 10-18mm long, the overlapping of greyish eggs are two to three in a row. The larva is deep grey, and then becomes dull ochre covered with asiny layer of reddish brown pubescence. The pupa is elongated, pearly white and is quite transparent (Breniere 1976 a).

Biology, damage: Adults preferably lay eggs on the young rice plant at the tillering and booting stages. The fecundity is 100 to 180 eggs. The young caterpillar eats up the leaf sheaths followed by the heart of the stem a few centimeters below the neck.

When it is older it moves from one internode to another and can cause serious damage to the entire stems by cutting them in two areas in order to prepare an area about 4cm where it will live. Since it is protected by the stem, it floats and can move from one stem to another. It leads a semi-aquatique life which, in the case of floating or irrigated rice in deep water enables it to reach stem below the water level. The protecting stem is indispensable to old caterpillars.

Generally the pupa lives at the base of the stem in the median cavity constituted by the lower internodes.

Cycle: Egg: 8 days; larva: 28 to 44 days; pupa: 12 - 14 days; Adults: 8 days (Na Bouy Heng, 1978).

Importance of damage

Each caterpillar can destroy 1-4 stems of rice but it has been observed most plants are destroyed throughout their life cycle. The adult is very visible and active during the day. The egg is often attacked. Larva mortality is also very high undoubtedly because it must necessarily pass through the semi-aguatic stage. Therefore in Africa only very few cases of damage especially on floating rice (Mali, author's own observation) has been reported but these are not as serious as damaged caused in Asia by Tryporyza innotata, "the white stemborer" whose biology is similar to others.

Maliarpha separatella Ragonot (1888) - Pyralidae, Phycitinae. This is the African white rice borer.

This borer exists in Asia but it has never been considered as a rice borer in that continent. On the contrary it is considered as the main rice borer in Madagascar, and as a borer of the different types of rice in West Africa (from Senegal to Cameroun), in East and Central Africa. The name white borer refers to the yellowish white colour of the caterpillar.

Description (Photographs) Adult: wings yellowish with a reddish brown line along the edge of the fore wings. The body is covered with yellowish scales. At rest the wings are V shaped and stretched to cover the body.

Egg laying: overlapping eggs forming an elongated batch of eggs sticking to the upper part of the leaves by a strong substance which when dry causes the entire leaf to shrivel and envelop the eggs completely.

Larva: When hatched, it is transparently white then it becomes yellow. The pro-legs which are small and short only allow the larva to move inside the plant. The pupa is brown and elongated.

Biology : The eggs are laid on the leaves at the tillering stage. As soon as it hatches the caterpillar is very active in the morning, first moves from one plant to another then enters a leaf sheath and the stem, goes down the leaf sheath and then into the stem in the medium cavity. It completes its life cycle as a larva in only one stem by digging small circular cavities in the walls without piercing them and by moving from one internode to another by piercing the nodes.

The pupa which starts about 30 - 40 days after hatching takes place in the first big internode above the neck. The caterpillar had earlier prepared a silky conical channel which allow the young adult to move towards an area within the walls of the stem.

Life cycle: egg: 8 - 12 days, larva 40 - 72 days, pupa 32-65 days. It is rare to find more than one caterpillar or pupa in one stem

Damage: M. separatella is specific to genus Oryza. Therefore it is only found on cultivated and wild rice. O. barthii, O. longistaminata et O. punctata. The female does not lay its eggs on young seedlings except on the leaves of plants at the tillering stage (earliest 15 days following transplanting in irrigated rice). From the heading stage onwards, eggs are rarely laid and this mainly depends on the insects choice at this period.

The caterpillar's development is closely related to that of the plant. It is very active and it attacks tall plants (young plants from 50 - 60 days) Breniere, 1962). As a result, the plant will be affected indiscriminately since the laying of egg might have taken place more or less at an earlier stage.

The damage is difficult to estimate. Plants have never been destroyed by the "deadhearts". An early attack causes the formation of whiteheads. Such a formation is not caused by the modification of the panicles' spike but by the modification of the stem's base where the larva exists is the end of the growth stage during the rice booting stage. The whitehead" symptoms are quite sporadic and do not explain the cause of yield losses observed. However, when the panicle has a normal formation, the destructive action of the larva does not affect the constitution of the panicles, grain sterilisation, maturity and weight (Pollet, 1979 - Appert, 1970).

Yield losses observed when serious damage occur are attributed to the reduction in the average weight of the panicle. This can only happen when infestation occurs at an early stage to affect the strength of the plant at the booting and heading stages.

Annual cycle: There could be several generations of Maliarpha during the year but in pratice not more than two generations attack the same plant. Tr. development of the supple larva and the egg distribution cause a great variation in the rate of infestations which are greatly influenced by the seeding and transplanting rates in the same rice growing area. The 6th stage larva hibernates quietly at the base of dried stems. It becomes active once again when humidity sets in and quickly winds up its cycle. In the both wet areas the dormancy is very short because of the presence of cultivated rice (or wild rice) for most of the year.

Maliarpha mostly affects areas where rice is grown twice a year. It abounds more on irrigate rice than on upland rice fields.

Economic importance

The inter-relation mechanism between the insect and host plant explains the specific nature of the economic importance of this borer. Unlike the case of Chilo sp. and Sesamia sp the relationship between damage and yield loss is not a simple one. Generally there should be a heavy infestation before losses should be of economic importance. This is what happens in Madagascar where damages were estimated at 1 ton/ha with more than 90% of stems infested. In Africa, damage is generally lower i.e. 400 to 800 kg/ha when the infestation affects between 40 and 60% of the stems.

This constitutes an economic problem only in the permanent rice cultivation where rice is grown twice or three times a year and when there is a need to increase production.

The egg parasite is quite active others are very moderate in their action as they develop during the rainy season.

SESAMIA SPP. Noctridae - Ampipyrinae - pink borer.

Sesamia calamistis Hamps
S. nonagrioides botanephaga Tans and Bowden
S. cretica Led
S. poephaga Tans and Bowden

The polyphagous parasite similar to the *Sesamia* genera attacks most crops. *S. calamistic* seems to be the most common in East and West Africa, Madagascar and South Africa. *S. nonagrioides botanephaga* is less common and limited to wet tropical and equatorial areas of Africa.

Description: Adult - light beige colour, more or less with brown stripes, broad, whitish fringes partly greyish black. The hind wings are pearly white with broad fringes. Colour and types vary and does not make possible to identify easily the species or the geographic races.

Eggs: sub-spherical, flattened at the ends with a number of longitidunal stripes - They are yellowish.

Larvae: with few hairs, whitish yellow with pink patches.
Pupa: reddish brown: two dorsal spines and one with small ventral protuberance. (Breniere, 1976[a]).

Biology and damage

The adults which are nocturnal can cover long distances. Eggs are laid in the first night. The female lays its eggs in groups of varying densities under the sheaths of upper leaves. From 8 - 300 eggs are laid. The young caterpillars first feed on the laminae of the leaf and dig holes in the sheathes and stems. They dig a horizontal hole under the terminal bud and climb back along the internodes while taking cover under the sheaths of the stems. The life cycle of the larva lasts 4 - 5 weeks.

Pupation takes place at the vase of the stem in the folds of dried sheaths.

The damage caused varies according to the age of the plant and the number of insects. It is mostly at the heading stage that the young caterpillars found in the upper parts of the stem can cause "whitehead" symptoms to appear. When they are young caterpillars first group themselves then they move in all directions and go down into the lower internodes even to the base which they can damage completely.

The life cycle is practically a continous one. Drought or cool weather setting in can cause delays but the caterpillar's development continues on off-season irrigated rice. The number of generations varies from 5 to 6 in wet intertropical Africa and there are only 3 generations in Sahelian areas.

Sesamia spp. mostly cause damage to upland rice and in areas close to corn fields, their prefered crops. Other pyralids and noctuids can feed at the expense of rice by boring sheaths and stems. Of all, E. saccharina is the greatest borer of sugar cane in Africa. It also attacks corn.

CONTROL OF LEPIDOPTERA BORERS OF RICE

Whereas the control of phytophagous pests can be done progressively following noticeable infestations, the control of borers is a necessarily a preventive one.

In reality, the larvae when very young are not easily visible when they enter the stem but their effect becomes noticeable when the damage is already caused.

Since losses caused by borers generally seem to vary from year to year it seems that it is possible to lay down a systematic control programme adapted to each agronomic and ecological condition.

Chemical Control

Only improved irrigated rice crops with high yielding varieties justifies the use of insecticides to control borers. Upland rice or less yielding varieties do not make it possible after treatment to anticipate any improvement of sufficient yield to cover the expenses made.

Every chemical control measure must take into account the entire entofauna (insect groups) and their dynamics must be examined at the level of the whole cultivated area and not one rice field level. In the same area, the succession of many cropping seasons, and the various growth stages of neighbouring rice fields cause an overlapping of generations of borers and a phenomenon which is essentially related to the phenology of a plant in each rice field.

It is important to draw a treatment schedule for each pest based upon the big seasonal variations, plant growth, varietal susceptibility and the degree of potential productivity. The spraying of insecticides on leaves is not very effective, necessitates a series of replications and can seriously affect entomophagous species.

On the contrary, insecticide application to the soil or water in the rice field allows the chemical to penetrate into the plant tissues. Contact insecticides such as Lindane, Diazinon can penetrate into the plant in the same manner as systemic chemicals. The granular formulation facilitates distribution and a slow dissemination by increasing persistence. There are many effective chemicals among which one Lindane, Diazinon at 1.5 kg a.i./ha or Carbofuran at 800 gr. a.i./ha (Danrote, 1967; Breniere 1976; Vercambre 1977; Soto, 1976).

In Senegal (Casamance) 2 replications of carbofuran: 10 days and 40 days after transplanting (800 gr x 2) appeared to be more effective (Vercambre, 1977). The persistence of Lindane mixed with granules in water in the ricefield lasts 3 weeks but that of Carbofuran can last over 1 month. In West Africa (Senegal, Ivory Coast) we can anticipate an increase only from 700 to 10000 kg of paddy when damage caused is serious (Anon, 1970 - Vercambre, 1977).

Formulations in which insecticides are mixed with fertilizers help minimise the treatment cost. In practice, insecticides are not much used on rice fields in Africa. They are only used on highly protected irrigated rice fields. There is no need to promote an extensive chemical control if its qualitative economic advantage and safety cannot be garanteed.

Agronomic Control Methods

These are cultural practices which breaks the borer's cycle. Theyjinclude: straw removal to eliminate diapausing caterpillars which remained at the base of the stems after harvest, interruption of cropping, attempts to limit the number of intermediary host plants whether cultivated or uncultivated and the flooding of rice fields after harvest. Generally these measures are not very realistic and effective in a disunified agricultural system beset with serious water problems and limited time for agricultural activities. These cultural practices and the use of manure for tillering and grain production cause increased infestations as well as better plant resistance. Generally they yield positive results.

Biological control

In principle, the use of entomophagous insects through the introduction of new useful species is a very good approach but it requires further studies on the present host-parasite relationship before envisaging the introduction of parasites which can live in available "ecological habitats". Research in this field in Africa is still at its early stage. The existing entomophagous species are being identified but up to now little efforts have been made to introduce parasites.

Varietal resistance

The resistance of certain rice varieties to borers is a fact which is easily observed on the living plants in agronomic stations. Breeders have realised that their inability to select insect resistant varieties especially the borer resistant ones, has led to the use of varieties which are more susceptible than local varieties.

Research is conducted in many countries (Ivory Coast, Mali, Senegal, Nigeria) to identify lines with strong resistant genes, (antibiosis). For instance in Senegal, Taitung varieties 16 and SC 302 are resistant whereas Rexoro and TN1 are susceptible and DJ 684 D and Ebandioulaye are very susceptible. In the Ivory Coast Moroberekan is more resistant than Iguape - Cateto; in Nigeria Ratna, H8, Maleg-kit, Sung Song and SML 81 B resist very strongly against *C. zacconius* whereas TK M6, W1263, Taitung 16 and SML 81B which are known to resist against *S. calamistis* are susceptible to *Chilo* and *Maliarpha* spp.

This aspect related to the control of borers is very promising and should be developed.

Statuus of Crop Protection in West Africa

By

Professor K. Kumar

University of Legon, Accra, Ghana

Introduction

The tropical climate of West Africa is highly conducive to the rapid multiplication of insects. A variety of insect pests affect man, his domesticated animals and crops. Because of the ravages of vector borne diseases to man, West Coast of Africa has been designated as "White man's grave". A variety of insect pests have from time immemorial devastated crops in West Africa and the farmers have been aware of the importance of insect pests. It is easy to imagine, for instance, that one of the advantages of shifting agriculture and mixed cropping practised in Africa is the avoidance of high losses from pests, disease and weeds. In Ghana, as early as 1908, Twi speaking farmers were aware of the destruction to cocoa trees caused by capsids and called these pests as Sankonuabe which literally means go back to your oil palm industry.

Losses due to crop pests in West Africa

Modern estimates of crop losses in West Africa, due to the activities of insect pests, are few and very scattered in the literature. Among the tree crops, we are aware of the ravages caused by cocoamirids to the cocoa tree, Theobroma cocoa cacao. Losses due to their activities in Ghana alone have been estimated at between 60,000 tons. Every year several West African governments spend large sums of money in trying to check the swollen shoot disease which is transmitted by mealy bugs. Closely related to cocoa is the kola tree which is the source of income to many farmers in the forest zone of West Africa, This crop in West Africa is attacked by at least 19 species of insect pests though reliable data on the losses due to them are still lacking. The coffee plant, a native of Africa is attacked by insect pests wherever coffee is grown. The coffee berry borer, indigenous to Africa, has now been exported to nearly all parts of the tropics. All over Africa and elsewhere large sums of money are spent in controlling this and other pests. The oil-palm industry in West Africa is seriously affected by the activities of a leaf-miner whose infestations may be so heavy that only the "spikes" of the trees remain green. Vast areas of farm land, forest and natural pasture in many West African countries have, from time to time, been devastated by locust/swarms. Over 500 genera and about 5000 species from Africa are included in the super-family Acridoidea, many of which are without doubt potentially serious pests.

One of the greatest limiting factors in attempts to increase the productivity of grain legumes in West Africa is the wide range insect pests with which they are associated. Okigbo (1978) states that "the potential of grain legumes will never be realised without understanding the pests and the pest control problems of legumes in the field, in transit, storage, processing and processed products and without developing scientific pest management systems for grain legumes",

Cereal crops in Africa are liable to attack by a variety of insect pests. Of these the stem borers have been considered as the most important. Losses due to their activities are difficult to assess.

Whitney (1977) has provided details of some losses caused by these pests. Soto and Sidoiqul (1978) in a discussion on insect pests and rice production in Africa state "little detailed research has been done on the various insect pests which affect African rice crops, primarily because there are so few workers in this field in Africa". The story does not end there. Whatever produce we are able to retrieve from the field must be stored and here insects come into the picture again. A large number of insects: including many species of beetles and moths, attack crops in farmers' bins mills, warehouses, retail stores and in home. The damage done in this way is estimated to run into millions of dollars annually. Cornes (1973) lists 219 species belonging to 56 genera of 11 orders of insects associated with stored products in Nigeria. Ditcher (1976) estimates that in sub-Saharan regions of Africa, losses of food grains during storage at farm or village level can amount 25-40% of the harvested crop. This wastage cannot be justified when so many people remain hungry.

In West Africa virtually every crop is attacked by insect pests and certain degree of protection against them is mostly necessary (see Whitney, 1977, Kumar, 1980 etc.) In some instances, for example cowpea and cotton, very little yield is obtained in monocultures unless the crops are protected by the use of insecticides, not only do insects cause great loss in quantity, but also seriously lower the quality of food.

Crop protection strategies in West Africa

In discussing the status of crop protection in West Africa, the particular features of agriculture in this part of the world must be borne in mind.

The size of farms in generally small. In West Africa live, 10-12 million small farmers, 8 million in Nigeria alone. The inadequate resources and poor education of the farmers also greatly influence crop protection practices. Further, government initiated extension services are virtually non-existent in most West African countries. The status of crop protection in West Africa may best be discussed in terms of different pest management strategies, currently being practised in various parts of the sub-region.

Chemical Control

According to Anonymous (1972), in 1968, the use of pesticides on cotton and cocoa in West African countries produced extra crops to the value of 139 million i.e. 5-10% of the exports of the region as a whole. While grave concern has been expressed over the side effects of the use of chemicals, 90% of insecticide usage throughout the would is effective and achieves the object (of its use) quickly and efficiently. Although the search for alternative methods of pest control continues at an accelerated pace, it is difficult to think of a time when it will not be necessary to make some use of insecticides for the control of crop pests.

In Francophone West Africa, well organized pest control campaigns have been undertaken to improve crop production. This has involved wide-spread improvement in the techniques of the use of better seeds, fertilizers and insecticides. Table 1 shows a comparison of average yields in the mid-1950s and in 1968.

Table 1: Comparison of the average yield of cotton (lint and fibre) in some Francophone countries) (FAO 1969).

Country	Kilograms per hectare		Per cent increase
	195 / 56	1968	
Upper Volta	100	400	300
Ivory Coast	100	650	550
Dahomey	60	520	767
Cameroun	340	630	85

The emergence of Ivory Coast as the world's number one producer of cocoa and coff e must, to a greater degree be attributed to well organised and executed pest control campaigns.

In the Anglophone West Africa, on the other hand, pest control services are poorly organised. Frequently, insecticides are not available when required for spraying.

The equipment used for treatment is generally obsolete and unsuitable, the extension services are lamentably inadequate and the state of chemical control has generally steadily deteriorated. In 1958, when cocoa production in Ghana had stabilized around 205/250,000 tons per annum, scientists at Tafo recommended the use of lindane against capsids to boost production. After treatment with lindane cocoa production rose to over 3000,000 tons and stabilized at around 400/450,000 tons in 1964/65. It should be noted that over 00,000 gallons of lindane were used every year before 1965. But from 1965, there was a dramatic drop in its sales with the volume sold declining to 70,000 gallons in 1965/66, then to 20,000 gallons in 1966/67, the quantity available depending on a foreign exchange made available by the government.

The chemical control of mirids in the most beneficial process for a cocoa tree. Even seriously affected trees whether young or old have a remarkable power of recovery as soon as they are properly treated. The canopy is soon restored, cocoa production commences and chemical treatments can be drasticelly reduced. The cost of treatment is equivalent to just a few dozen kilogrammes of dried cocoa per hectare. To provide a few million dollars worth of insecticides and machines to control capsidesto earn some $500 million or more annually is a very sensible investment but no government in Anglophone West Africa has considered fully meeting the pressing demands of the industry. Thus while properly organised and executed chemical pest control is capable of increasing crop production very considerably, the present state of crop protection by chemical against insect pests is in a very sad state.

The position with stored product pests is no better either. In Ghana, out of a total annual harvest of 250-300,009 tons of maize about 20% is lost to insect and rodent damage in storage (Prempeh, 1971). In Nigeria, up to 27.7% lossess have resucted from insect damage to maize stored in cribs for 4 months without pest control (Ogunlana, 1976). All these losses could be greatly reduced if the necessary preventive and other measures could be adopted.

Biological Control

As noted by Greathead (1971), none of the countries in West Africa have been consistently active in biological control. Actually, apart from unsuccessful effort to control the mealy bug vectors of swollen shoot disease of cocoa by biological agents, there are very few attemps at the use of biological control as a plant protection strategy in West Africa.

It was unfortunate that failure to control the mealy bugs (Planococoides njalensis) on cocoa disouraged further biological control work in West Africa. The difficulty in controlling these pests lies in the fact that many indigenous natural enemies already keeps the pest populations to low level. It is the ability of the very low numbers of the mealy bug pests to cause considerable damage which attempts in using natural enemies to control them (Kumar, 1979).

Mirid pests (Sahlbergella singularis and Distantiella theobroma) of cocoa are without effective local parasites but introductions against them have not progressed because of financial commitments from local governments. Recently the idea of manipulating the environment of a facultative predator so that it may press heavily on its pest prey has been developed by Leston (1970) and his associates. However, attempts at artificial spread of Oecophylla have not been successful (Collingwood and Marchart, 1970). Colonies of this ant tend to be stable and may occupy a nesting and foraging terriroty over several years without venturing into mirid infested trees. Moreover, this ant is absent from areas of broken cocoa canopy where the mirids thrive.

An undermined but highly lethal bacterial pathogen of S. singularis discovered in Nigeria has been found to be equally effective against D. theobroma and Helopeltis spp. Experiments by Boton (1973) in Ghana have shown that spraying with a suspension of bacterium resulted in a 32½ kill of capsid populations compared with untreated controls. Problems in maintaining and building up viable cultures of the pathogen have limited its use. It is difficult to see why such a promising approach has not been followed up further.

Commonwealth Institute of Biological Control (CIBC) set up a substation in 1969, at Kumasi, Ghana. The institute made special attempts at importation and release of parasites against lepidopterous stem borers at various localities in Ghana. 14 species of egg, larval and pupal parasites were imported from India and released against sugar cane stem borers at Asutsuare and Komenda between 1973 and 1978 (Scheibelreiter, 1980). In India these parasites are considered effective against stem borers of maize and sugar-cane. In Ghana these parasites bred well in the laboratory on Ghanaian borer species. But no recoveries were made in the yield.

Larvae of Ammalo insulate were imported and released against Eupatorium odoratum in Ghana as well as Nigeria. However, these larvae which proved highly successful in the control of the weed in South America and India, failed to survive in the West Africa ecosystem they are carried away by ants soon after release on the plants.

Actually, no significant control of pests was achieved by the CIBC substation and its activities in Ghana are almost negligible currently. However, CIBC has, with funding from IDRC, undertaken a three-year project exploring natural enemies of the cassava mealybug, Phenacoccus manihoti for release and assessment in Nigeria and other parts of Africa (Greathead, 1978).

Cultural practices

West Africa farmers practice a number of traditional methods of pest control by manipulating crops and land. In some West African countries, for example, Ghana, production of staple food crops such as maize would be impossible without such a method.

Here the practice of growing maize at the beginning of the first rainy season to avoid borer attack does not necessitate any control measures against the borer pests. However, to obtain a meaningful crop, during the second season, requires chemical control of borers, the use of fertilizers and irrigation of land.

In the Sudan savanna zone of Northern Nigeria, sorghum and millets are sown by farmers as early as possible in the Wet season. Yields are greater when an early onset of season is accompanied by early sowing. Further, cultivars used by farmers in this region have been selected over long periods to "start heading so as to set seed at the end of the normal rainy season" with the result that grains are not attacked by moulds and insects as they would be if heading was earlier (Kassam et al., 1976).

In Ghana and Nigeria, field observations have shown that if maize stalks remain in the field after harvesting, borer incidence increases considerably when maize is grown in both first and second seasons on the same land in consecutive years. The stalks contain larvae and pupae of the stem borers and adults emerge from the stalks and re-infest any young maize plants. The recommended practice of burning stalks completely after the grain has been harvested with a view to killing all the diapausing larvae, is seldom followed by the farmers who use stalks for a variety of purposes. The recent suggestion of Adesiun and Ajayi (1980) of partial burning of stalks which results in killing 95% of the larvae still needs to be adopted by the West African farmers.

In Ghana, Eldana saccharina is a major pest of sugarcane stands. Studies have shown that the larvae of E. saccharina remain in the stubble after harvest and reinfest new shoots. Thus the stubble serves as a reservoir for reinfestation by stemborers (Kumar and Sampson, 1982). The stubble larvae destroy the shoots in the ratooned field thereby reducing the tillers of the ratoons. The idea of discontinuing the practice of ratooning with a view to remove the stubble which serve as a reservoir for reinfestation still remains to be adopted by the sugarcane estates.

The above examples of cultural practices available to the West African farmers may be multiplied. There is the practice of "closed season" to control the pink bollworm on cotton in Nigeria and this has the backing of the law. There is the early planting of groundnut to obtain higher yield of the crop, by reducing losses from rosette virus disease transmitted by Aphis craccivora. Experiments in Nigeria has shown (IITA, 1973) that weeds in grain legume fields are positively correlated with insect damage to cowpea and soybean. Rotation of crops is known to be effective against insects having a restricted host range and those possessing limited migratory capabilities. Okigbo (1978) concludes that the traditional farmer practices intercropping because it gives higher total yields and greater returns than the same crops grown in pure culture. Similarly plant density is known to affect the pest incidence in cowpeas. It is surprising so little is currently being done to develop novel cultural practices from which the traditional farming already benefits so greatly in West Africa.

Plant Resistance

Plant resistance represents the inherent ability of a crop variety to restrict, retard or overcome pest infestations. Crop resistance, from the point of view of the farmer, is perhaps the easiest, most economical and effective way of controlling insect pests and diseases. It requires fewer technological inputs, creates no environmental hazards and is generally compatible with other methods of pest control. (Pathak and Saxena, 1976). In West Africa, resistant cultivars are being developed for cowpea at IITA. Singh (1978) reports a collection of over 10,000 cowpea accessions with the plant breeder adding several thousands segregating lines every year. This has enabled resistance to field pests such as leafhopper (*Empoasca dolichi*) and pod borer (*Maruca testulalis*) to be studied extensively. Bidaux (1978) has reviewed the screening for horizontal resistance to rice blast in Africa. It is thus clear that much more needs to be done to use the proven method of crop protection in West African Agriculture.

Other Methods of Crop Protection

Modern techniques utilising genetics, attractants, repellents, anti-feedants and hormones, in the management of crop pests, have hardly made a start in West Africa. Taking the subregion as a whole, it is only fair to say crop protection as a tool in increasing food production is not at all accorded a high status in most West African countries either in terms of research or extension. Ivory Coast perhaps stands out a single exception to this statement. Part of the problem is to educate administrators that, although costly, scientific research is a good investment and most productive when many scientists work simultaneously on the same problem.

Toye (1976) estimates that presently there are no more than 10 entomologists per 4.5 million people in Nigeria. The ratio elsewhere in West Africa is even more lamentably inadequate.

Literature Cited

Adesiyun, A.A. and Ajayi; O. 1980. Control of the Sorghum stem borer, *Busseola fusca*, by partial burning of stalks. Tropical Pest Management. 26(2): 113-117

Anonymous, 1972. Pesticides in the modern world. A symposium prepared by members of the Co-operative Programme of Agro-Allied Industries with FAO and other United Nations Organization 1972. Printed by Newgate Press Ltd., London. 59 pp.

Bidaux, J.M. 1978. Screening for horizontal resistance to rice blast (*Pyricularia oryzae*) in Africa. p. 159-174. *In* Rice in Africa. Ed. Buddenhagen, I.W. and Persley, G.J. Academic Press, London. 356 p.

Bolton, B. 1973. *In A Rep. Cocoa Res. Inst. Ghana*. 1970-71: 155-156.

Collingwood, C.A., and Marchart, H. 1970. *In: A. Rep. Cocoa Res. Inst. Ghana*. 1968-69: p.55.

Cornes, M.A. 1973. A checklist of the insects assosiated with stored products in Nigeria. *Rep. Niger stored Prod.* Res. Inst. 1971+73-98.

Dichter, 1976. The stealthy thief. *Ceres. FAO Rev.*9(4): 51-53,55.

FAO Production Year-book, 23, 1969. Food and Agriculture Organization, Rome.

Greathead, D.J. 1971. A review of biological control in the Ethiopian Region. Tech. Commun. Commonw. Inst. biol. control. No.5.162 pp.

Greathead, D.J. 1978. Biological control of mealybugs (Homoptera: Pseudococoidae) with special reference to cassava mealybug (Phenacoccus manihoti Mat. Ferr).p 70-73. In proceedings of the International Workshop on the cassava mealybug, Phenacoccus manihoti Mat. Ferr. (Pseudoccocidae) Ed. Nwanze, K.F. and Leuschner, K. IITA, Ibadan. 85 p.

IITA (International Institute of Tropical Agriculture). 1973. Report-Grain legume improvement program, Ibadan, Nigeria. 1972: 31-32.

Kassam, A.H., Dagg, M. Kowal, J.M., and Khadr, F.H. 1976. Improving food production in the Sudan Savanna zone of Northern Nigeria. SPAN 8 (6): 341-347.

kumar, R. 1979. Biological control of cocoa pests in West Africa. Proc. 5th Conf. West Africa Cocoa Entomologists 1976: 109-116.

Kumar, R. 1980. Research in Tropical Insect Science - a Ghanaian Perspective. An Inaugural Lecture delivered on 7th February, 1980. Ghana Universities Press. 18 p.

Kumar, R. and Sampson, M. 1982. A review of stem borer research in Ghana. Insect Sc. Application (in press).

Leston, D. 1970. Entomology of the cocoa farm. Ann. Rev. Ent. 15:273-294.

Ogunlano, M.C. 1976. Opening address at the 9th Annual Conference and 10th Anniversary celebration of the entomological society of Nigeria. Proc. 9th Ann.Conf. and 10th Anniv. Celeb. Ent. Soc. Nigeria, 18-23.

Okigbo, B.N. 1978. Cropping systems and related research in Africa. Association for the Advancement of Agricultural Sciences in Africa (AAASA). Occassional Publications Series OT-1.81 p.

Pathak, M.D., and Saxena, R.C. 1976. Insect resistance in crop plants. Current Adv. Sci. 27:1233-1252.

Prempho, H.R.B.A. 1971. Maize crop harvesting, processing and storage in Ghana. "Maize the wonder crop". Symposium at UST, Kumasi. 81-87.

Scheibelreiter, G.K. 1980. Sugarcane stem borers (Lep: Noctuidae and Pyralidae) in Ghana. Zeitschrift angewandte Entomologie. 89:87-99.

Singh, S.R. 1978. Resistance to pests of cowpea in Nigeria. p. 267-279. In Pests of grain legumes: ecology and control.

Ed. Singh, S.R. van Emden, H.F., and Taylor, T.A. Academic Press, London. 454 pp.

Soto, P.E. and Siddiqu, Z. 1978. Insect pests and rice production in Africa. p. 175-179. In Rice in Africa. ED. Buddenhagen, I.W. and Persley, G.J. Academic Press, London. 356p.

Toye, S.A. 1976. The role of entomology in the economic development of Nigeria. Proc. 9th Ann. Conf. and 10th Celeb. Ent. Soc, Nigeria. 3-10.

Whitney, W.K. 1977. Insect and mite pests and their control. p. 195-235. In Food crops of the lowland tropics. Ed. Leakey, C.L.A., and Wills, J.B. Oxford University Press, Oxford. 345 p.

CATEGORIES OF INSECT PESTS

Patricia C. Matteson
University of California, Berkeley
Consortium for International Crop Protection
2288 Fulton Street, Suite 310
Berkeley, California 94704, USA

When designing a system of integrated pest management, one must first ask: which ricefield organisms are considered pests? Why are they considered pests? And when do they become pests? These seemingly simple questions are, in fact, vital. Many pest control programs fail because (1) without valid reason, an organism is labeled a "pest" and decimated, and the surrounding ecosystem is thrown out of balance, releasing a whole new spectrum of new "pest" problems; of (2) the pest manager simply tries to kill the pest (a temporary solution) instead of discovering the reason why the organism has become a problem and changing that situation (a permanent solution) Flint and van den Bosch, 1981).

A pest is an organism regarded by people as harmful to their selves, their property, or their environment. In developing agriculture, we have created crop pests as we know them today. In the ricefield, these are consumers (rodents, birds, insect pests, diseases) and competitors (weeds) of resources which we want.

Modern conditions aggravate pest problems, in that we are increasingly less willing to give pests a share of the crop (Corbet, 1976). Land resources are diminishing, lost to urban development, desertification, or depletion and erosion due to mismanagement. The pressure of population rises, as more and more people must be fed while an increasing ~~proportion migrate to cities and no longer con tribute to the~~

agricultural production process. The remaining farmers are pressed to produce a surplus in exchange for cash, which they need to cope with new demands: the purchase of commodities that are not produced in the village, taxes, school fees (while school children are no longer available for labor).

With high-technology agriculture, the stakes are even higher: there is a bigger investment at risk (capital for land preparation, fertilizer, pesticides ...), and the share that pests may take is larger and more valuable. At the same time, the agricultural revolution of the twentieth century has further disrupted and complicated the stability of pest species in our agroecosystems. Through applcation of scientific genetic principles and technology, new high-yielding cultivars adaptable to mechanized culture, harvesting, and postharvest procedures have been selected and intensively planted over wide areas. Many new cultivars are genetically uniform and potentially more vulnerable to pest epidemics. The new cultivars must frequently be protected from pests, and so pesticides are extensively required to attain potential yields. Many cultural practices of modern agriculture also enhance susceptibility to disease, weeds, nematodes, or insects. These include: (1) irrigation, which favors many disease and insect pests as contrasted to the fluctuating soil moisture levels under natural rainfall conditions, (2) multiple cropping, which promotes rapid pest population increases, (3) dense crop plant populations, resulting in environmental changes favoring some pests, and (4) fertilization, which produces larger and more succulent plants, which are often more susceptible to pest attack than those grown in low-fertility levels (Smith, 1972).

Rice production in the Philippine Islands offers an excellent example of what happens when production is intensified quickly without adequate safeguards against pest epidemics.

Traditional rice culture in that country produced each year a modest but rather constant yield. The varieties were rank tall types that survived on low fertility and competed successfully against weeds. They were not immune to insects, diseases and rodents, but all pests were reasonably tolerated. Rice was cultivated once a year during the wet monsoons and was followed by a 5- or 6-month fallow through the dry season. Pest survival during the dry period, when hardly a green blade of rice or their grass can be found except along stream banks, was low, and only insignificant populations survived to attack the next crop (Glass, 1976).

Compare this situation to the new intensive rice culture in the same country. First, there is irrigation as one crop follows another throughout the entire year. The new varieties are short and stiff and require weed control to realize full yield potentials. The earliest high-yielding varieties were not selected for pest resistance. Inevitably pest problems increased significantly and in 1971 severe losses from leafhopper attack and the leafhopper-transmitted virus disease "tungro" were experienced over thousands of hectares in the "rice bowl" of Luzon. More recently another leafhopper-transmitted virus, grassy stunt, struck the area (Glass, 1976).

Population densities of an insect species stay fairly stable over a long period of time and can be said to fluctuate around a mean level which entomologists call the equilibrium position. The maintenance of this equilibrium position (or characteristic abundance) is due primarily to constraints set by the environment (density-independant factors) together with feedback mechanisms operating on both intra- and inter-species levels.

These mechanisms - such as predation, parasitism, intraspecific competition for food or available nesting sites, and territoriality - characteristically exert much heavier pressures when populations are high and have diminished influence when populations are low; they are thus called density-dependent factors (Fig. 1) (Flint and van den Bosch, 1981). Most insects are never common enough to be considered pests. When a species population rises above the level that causes economic losses, however, the species becomes a pest (Fig. 2).

Nonpests are those organisms in the ecosystem that have no potential for becoming injurious because of their place on the food chain relative to the resource. The effects of these organisms are often beneficial. For example, they may play an important role as natural enemies of pests, by recycling nutrients, by pollinating fruit or seed crops, or by providing alternative nutrition and shelter to beneficial organisms (Flint and van den Bosch, 1981).

Careful work must go into the decision that a certain insect is a pest, and when. The field situation may not be as it superficially seems. Insects must be properly identified and then studied: their biology, seasonal distribution and abundance, weather effects, natural enemies, the effect of crop growth stages on their activities, crop loss caused under various circumstances. In West African rice, for instance, one must be able to distinguish beneficial coccinellid predators from Epilachna similis, the phytophagous pest of the same family (Brenière, 1976). Pests do not necessarily do the most damage when they are numerous. For example, cowpea "flower thrips", Megalurothrips sjostedti, is most destructive when comparatively low populations attack flower buds early in the season. In addition, damage must not be confused with crop loss.

Leaf-feeding rice insects such as the pyralid *Nymphula stagnalis* may cause spectacular defoliation, but important crop losses result only from attacks occurring up to the middle stage of tillering (Brenière, 1976). The stage of crop attacked can also influence the pest status of a species. Stemborer dead heart infestations of up to 10 percent can be compensated for in rice plants up to 7 weeks after transplanting (Pathak and Dyck, 1972). Finally, pest damage may even increase yield. Sublethal infestations of rice hispa have a subsequent stimulating effect on plant growth (Lippold, 1972).

Migrant pests, such as locusts, *Locusta migratoria migratoroides* and *Schistocerca gregaria*, and some armyworms, *Spodoptera* spp., are highly mobile and will infest the West African rice crop periodically for short periods of time, often inflicting severe damage.

Potential pests comprise the vast majority of resource consumers and competitors. These organisms never cause enough damage to inflict significant loss of yield under prevailing management practices. However, they have the potential to become pests if management practices are changed (Flint and van den Bosch, 1981). In the Philippines, the introduction of high-yielding rice varieties led to rapid increases of the planthoppers *Nilaparvata lugens* and *Nephotettix* spp., the rice gall midge, *Orseolia oryzae*, the the rice whorl maggot, *Hydrellia philippina*, the rice leaffolder, *Cnaphalocrocis medinalis*, and the leafhopper-vectored grassy stunt and tungro viruses (Kiritani, 1979). The leafhopper outbreaks have recently been traced to pesticide-induced mortality of their natural enemies (P. Kenmore, pers. comm.).

Occasional pests are organisms whose populations flare up to cause significant damage once in a while but generally do not cause intolerable loss (Fig. 2). Their flare-ups are often due to disruptions in natural control, climatic irregularities, or mismanagement by people (Flint and van den Bosch, 1981). Larvae and adults of rice hispid Beetles, Hispa sp., are a West African example. They can do extensive foliar damage by gnawing the surface of leaves, but large infestations occur seldom (Brenière, 1976).

Organisms that cause a significant reduction in yield every season unless some pest management action is taken are known as key pests. These are the pests around which management systems are built. (Flint and van den Bosch, 1981). It should be kept in mind that a certain crop in a given location may have no key pests. Stemborers are suspected key pest insects of West African rice, but definitive crop loss assessment studies generally remain to be done.

Through changing cropping practices, use of resistant cultivars, and preservation and augmentation of natural enemies, populations reach a new equilibrium level that is not economically damaging (Fig. 3). Pesticides can then be used selectively, when needed, to deal with occasional and migratory pests or with key pests for which no other control measure is yet available.

REFERENCES

Brenière, J. 1976. The principal insect pests of rice in West Africa and their control. West Africa Rice Development Association, Monrovia, Liberia. 52 p.

Corbet, P.S. 1976. Pest management in ecological perspective, p. 51-57. In J.L. Apple and R.F. Smith (Eds.), Integrated pest management. Plenum Press, New York. 200 p.

Flint, M.L. and R. van den Bosch. 1981. Introduction to integrated pest management. Plenum Press, New York. 240 p.

Glass, E.H. 1976. Pest management: principles and philosophy, p. 39-50. In J.L. Apple and R.F. Smith (Eds.), Integrated pest management. Plenum Press, New York. 200 p.

Kiritani, K. 1979. Pest management in rice. Ann. Rev. Entomol. 24: 279-312.

Lippold, P.C. Principles of integrated control of rice pests. International Rice Commission. Fourteenth Session of the Working Party on Rice Production and Protection. Bangkok, Thailand, 6-10 November 1972. A Working Paper. 32 p.

Pathak, M.D. and V.A. Dyck, 1972. Rice insect control studies at IRRI. Workshop on Integrated Rice Pest Control in Southeast Asia. 9-12 May 1972. IRRI, Los Banos, Philippines. 16 p.

Smith, R.F. 1972. Management of the environment and insect pest control. In 1972 Food and Agriculture Organization Conference on Ecology in Relation to Plant Pest Control. FAO, Rome.

van den Bosch, R. and P.S. Messenger. 1973. Biological Control. Intext. New York. 180 p.

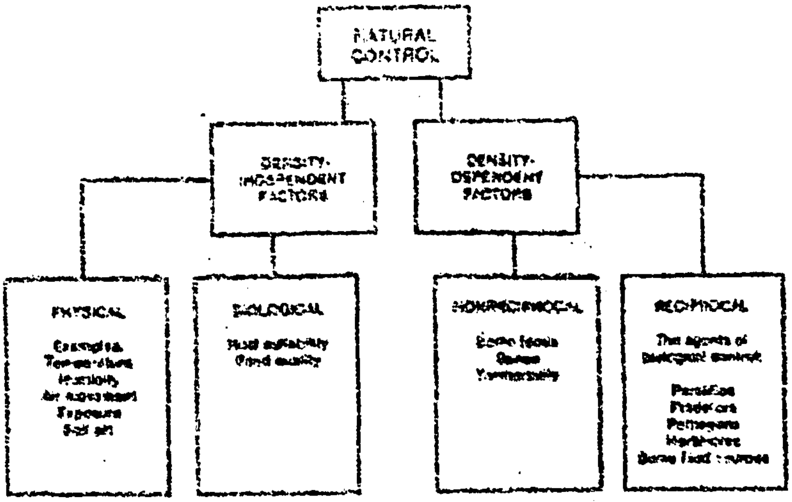


FIGURE 1. The components of natural control. Reciprocal density-dependent factors are those in which feedback mechanisms play a role in determining the supply of the factor as well as the population density of the organism in question. The quantity of nonreciprocal density-dependent factors is not affected by pest population levels (from van den Bosch and Messenger, 1973).

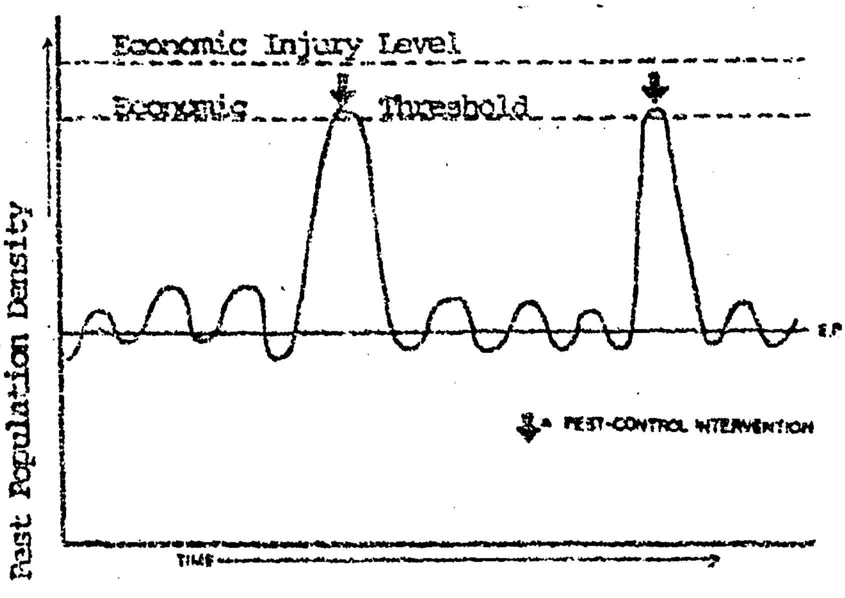


FIGURE 2. Equilibrium level is well below economic injury level, but for various reasons the population density sometimes reaches the economic injury level. This is an occasional pest; occasional control action is needed (from Flint and van den Bosch, 1981).

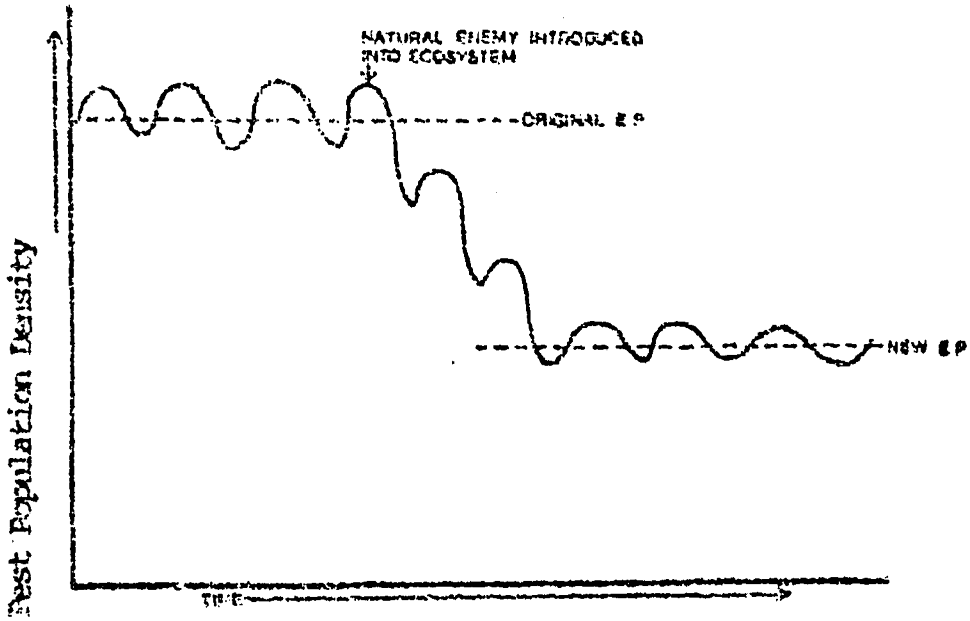


FIGURE 3. Lowering of the equilibrium position by the introduction of a new natural enemy. The same effect can be obtained by changing the physical environment so that fewer individuals can survive (from Flint and van den Bosch, 1981).

THE KEY PEST CONCEPT

By

Dale G. Bottrell
University of California, Berkeley
Consortium for International Crop Protection
2288 Fulton Street, Suite 310
Berkeley, California 94704, USA

PESTS AS A CONSTRAINT TO RICE

Rice may be attacked by a wide range of unwanted organisms such as insects, diseases, weeds, birds, rodents, and other— collectively "pests." Because of the widely diverse conditions under which rice is grown from temperate to tropical areas and from sea level to altitudes of 3,000 meters, pest problems vary from one area to another. As shown in Table 1, the composition and severity of rice insect pests and diseases even differ considerably between the Humid Tropical and Guinean Savanna climatic zones of West Africa.

Insects are common pests of rice. Over 800 species attack the field crop or the harvested grain (Grist and Lever, 1969). A large number of fungi, bacteria, viruses, mycoplasma-like organisms, and nematodes also commonly infect the crop (Ou, 1972; Barr et al., 1975). Weeds create problems every place that rice is grown and may be one of the most important factors limiting rice production (Kasasian, 1971; Barr et al., 1975). Rodents, particularly rats, may be the most important pests attacking field rice in some areas and cause especially severe damage to the harvested rice (Fall, 1977; Barr et al., 1975).

Table 1: Comparison in insect pests and diseases affecting rice in the Humid Tropical and Guinean Savanna zones of West Africa

Scientific Name	Common Name	Humid Tropical	Guinean Savanna
INSECTS			
Orseolia oryzae	Rice gall midge	-	xx
Chilo zacconius	Stemborer	x	xx
Chilo diffusilineus	"	xx	xx
Maliarpha separatella	"	xx	xx
Sesamia calamistis	"	x	x
Sesamia botanephaga	"	xx	x
Diopsis spp.	"	xx	xx
Trialeurodes oryzae	White fly	-	xx
Aleurocybotus sp. indicus	"	-	xx
Amblyseius sp.	Mite	-	xx
Olygonychus sp.	Mite	-	xx
Locusta migratoria	Locust	-	xx
Isoptera	Termites	xx	x
Spodoptera exempta	Armyworm	x	x
Stenocoris southwoodi	Rice bug	x	xx
Riptortus tenuicornis	"	x	xx
Mirperus jaculus	"	x	xx
Aspavia armigera	"	x	xx
DISEASES			
Helminthosporium oryzae	Brown spot	xx	x
Rhyncosporium oryzae	Leaf scald	xx	xx
Ustilaginoideae virens	False smut	xx	x
Xanthomonas oryzae	Bacterial blight	-	-
X. transluscens f. sp. oryzicola	Bacterial leaf streak	-	-
Rhizoctonia solani	Sheath blight	x	x
Virus	Pale yellow mottle	x	-
Pyricularia oryzae	Seedling blast	xx	xx
Pyricularia oryzae	Leaf blast	xx	xx
Pyricularia oryzae	Neck blast	xx	xx

- absent
x not common
xx common

Source: West Africa Rice Development Association, Monrovia, Liberia.

Miscellaneous pests include crabs, snails, deer, monkeys, wild pigs, birds, and elephants (Barr et al., 1975). Though generally localized in nature, the damage by the latter pests can result in devastating losses in some areas.

Accurate data on worldwide losses from rice pests are not available. Current methods for assessing losses incurred from pest infestations rely almost exclusively on "experts' opinions" and not on hard data.

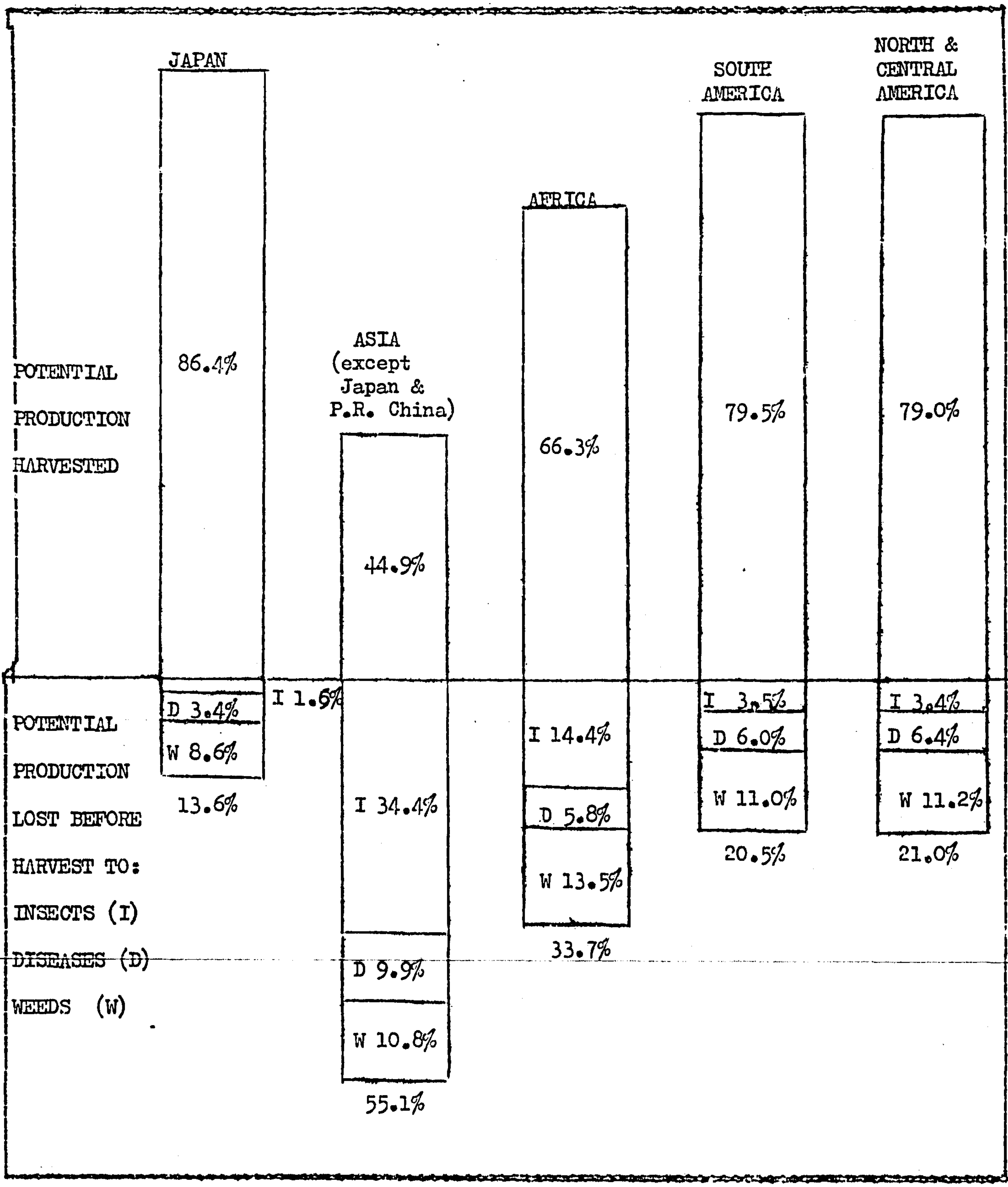
The field losses to rice pests have been reviewed by Cramer (1967) and Barr et al. (1975). Though the degree of accuracy of the loss estimates is questionable, the estimates of rice losses caused by various rice pests are alarming (Figure 1). For Asia (excluding Japan and the People's Republic of China), Cramer estimated that more rice is lost to insect pests, diseases, and weeds than is harvested. He estimated that rice production would more than double if these losses were entirely eliminated.

The enormity of rice losses attributed to pests in the developing countries is shown in Table 2.

PEST HIERARCHIES

As discussed by Patricia C. Matteson at this training course (Categories of Insect Pests), correctly identifying the pests and differentiating them according to their damage potential are essential in integrated pest management (IPM). Information on the Pests' taxonomy, seasonal abundance and distribution, and epidemiology (in the case of rice diseases), and the effect of weather, natural enemies, and rice growth on them are important. Without this information, the IPM program may in fact focus on the wrong pests and yield disappointing results.

Figure 1: Estimated percent potential rice production and percent lost to various pests



Source: From Cramer (1967) as modified by Barr et al. (1975).

Table 2: Rice production in various regions in 1972 and potential estimated losses by pests

Region or Country	Production (1,000 metric tons)	Estimated losses by insect pests, diseases, and weeds (1,000 metric tons)
Asia (excluding Japan and P. R. of China)	149,200	183,100
Africa	7,420	3,770
South America	10,200	2,630
Japan	15,480	2,440
North and Central America	5,250	1,400

Source: from Barr et al. (1975) after Cramer (1967) and FAO (1972).

A given rice field may be infested with dozens of potentially harmful pest species at any one time. For each situation, however, there are rarely more than a few pest species in sufficient density to cause significant damage. These often recur at regular (and often fairly predicatable) intervals.

Pests that generally recur regularly and cause economic losses if not controlled are the focal point for integrated pest management programs; they are known as "key" pests (Smith and van den Bosch, 1967). Most key arthropod pest species lack effective natural enemies.

The key pests contrast to "occasional" pest or secondary pests which attain injurious levels only irregularly when conditions of the natural environment (e.g., optimal weather, low incidence of natural biological control) are particularly favorable for their increase. Another category of pests, "potential" pests, includes potentially harmful species that reside at subeconomic levels unless aggravated by human manipulations of the agroecosystem (e.g., introduction of a new crop variety, use of an insecticide that disrupts biological control) which favor their increase. A final category of pests, "migratory" pests, is exemplified by migratory species (e.g. migratory armyworms or locusts) that do not reside in a given agroecosystem but occasionally enter it, sometimes causing severe damage.

The key pests are not always the most abundant species in the crop, but they are the potentially most serious. In West African rice, a leaf-feeding rice insect such as *Nymphula* stagnalis, for example, may be far more abundant than one of the lepidopterous stem borers (e.g., *Chilo zacconius*, *Maliarpha separatella*, or *Sesamia* sp.)

Yet its potential for causing significant yield losses may be much less (Brenière, 1976).

The classification of a species as a key pest depends on the synchronization of its damaging stage with the vulnerable stage of rice growth, the type of damage resulting, the crop plants' tolerance to the damage, the value of the crop, the pest's natural enemies, and sometimes other variables.

Understanding the relationship of pest infestation and crop phenology is especially important. The crop may be highly susceptible to damage during one stage of growth but only barely, or not at all, susceptible during other stages. For example, low population densities of a weed, 1 - 2 per meter of row, may cause serious yield reductions when the weeds infest a young rice crop. But very high population densities of the same species may have no appreciable effect when inhabiting a more mature rice crop.

APPLYING THE KEY PEST CONCEPT

When developing an integrated pest management strategy, it is particularly important that actions taken to manage the focal pests, the key pests, do not aggravate the potential pests. The improper use of insecticides directed at key arthropod pests frequently has resulted in the outbreak of potential pest species. The total fauna of key and potential arthropod pests in a given agroecosystem may be likened to an iceberg in a body of water. The real pests (the key pests), those which usually lack effective natural enemies, are readily recognized above the surface; the potential pests, which may represent 80-90 percent of all the pest species present, are not readily recognized and will remain innocuous if their natural enemies are not destroyed.

A ship navigator views the visible portion of an iceberg as a danger signal to a potntially more serious problem and, therefore, approaches it cautiously. The IPM specialist similarly should approach the management of the key pests cautiously in order to avoid the creation of potentially more serious problems.

As discussed in the training course paper, Establishing and Using Economic Thresholds (Dale G. Bottrell), integrated pest management efforts aim to manipulate the environment so to reduce a key pest's equilibrium position (i.e., mean population density) permanently to a level lower than the economic threshold. This is achieved by introducing natural enemies, pest-resistant or pest-tolerant varieties of crop plants, or habitat modifications such as crop rotation, crop harvest residue destruction, and soil tillage.

Pest management practices can also raise the equilibrium position of a pest. For example, repeated applications of insecticides may destroy natural enemies, thus creating a higher equilibrium position than when an insect pest was regulated by its enemies. A basic feature of IPM programs is to devise ways to lower the equilibrium positions of key pests while avoiding practices that create environments favorable to pests of secondary importance.

THE KEY PESTS OF WEST AFRICAN RICE

Of the 18 insect pests and eight diseases listed in Table 1, only 2 or 3 of the insect species and 1 or 2 of the disease organisms may recur each year in a given area of West Africa and cause significant damage if left uncontrolled. The stemboring insects and rice blast are probably the most serious, perennially occurring rice pests, i.e., key pests, of the region.

Rats and grain-eating birds are other key pests affecting rice in some of West Africa.

Weeds are undoubtedly major pests of rice in West Africa. However, weed scientists may argue that the key pest concept has little validity in the management of weeds, particularly in tropical agricultural areas where the weed flora is quite rich in composition with a complex of major noxious species. If one of these weed species is removed from a crop by herbicides or other means, it may be replaced by another species that is just as severe or even more severe—a phenomenon known as "weed species displacement."

Literature Cited

Barr, B.A., C.S. Koehler, and R.F. Smith. 1975. Crop losses— Rice: field losses to insects, diseases, weeds, and other pests. UC/AID Pest Manage. and Related Environmental Protection Proj. Univ. of California, Berkeley.

Brenière, J. 1976. The principal insect pests of rice in West Africa and their control. West Africa Rice Assoc., Monrovia. 52 p.

Cramer, H.H. 1967. Plant protection and world crop production. PF/Schutz-Nachr. Bayer. 20: 1-524.

Fall, M. W. 1977. Rodents in tropical rice. Tech. Bull. No. 36. Rodent Res. Center, Univ. Philippines at Los Banos, Laguna. 39 p.

Food and Agriculture Organization of the United Nations. 1972. Production Yearbook. 1972. Vol. 26, 496 p.

Grist, D.H., and R.J.A.W. Lever. 1969. Pests of rice. Longmans, Green and Col., Ltd., London and Harlow. 520 p.

Kasasian, L. 1971. Weed control in the tropics. The Chemical Rubber Co., Cleveland, Ohio. 307 p.

Ou, S.H. 1972. Rice diseases. Commonwealth Mycological Inst., Kew, Surrey, England. 3?3 p.

Smith, R.F. and R. van den Bosch. 1967. Integrated control, p. 295-340. In W.W. Kilgore and R.L. Doutt (Eds.), Pest control—biological, physical, and selected chemical methods. Academic, New York.

Wood, B. J. 1971. Investigations of rats in rice fields demonstrating an effective control method giving sbustantial yield increase. PANS 17:180-193.

CATEGORIES OF PLANT DISEASES, NATURE AND CAUSES

By

Professor Oladele F. Esuruoso
Univeristy of Ibadan
Ibadan, Nigeria

Introduction

Plant disease is a physiological disorder or structural abnormality that is caused by continuous irritation to the plant, that is harmful or deleterious to the plant or any of its parts or products, or that reduces their economic value. In practical terms in agriculture, plants are regarded as diseased if their normal growth is impaired in any way; or the quantity, quality or market value of their products is reduced. Hence, for example, any form of physiological disorder that kills, reduces the growth, or reduces the yield of the rice plant in the field, or reduces the quality or market value or causes the deterioration of its product either during the growth of the plant or during the transportation, storage or use, of these products is a disease of rice. Thus concepts regarding diseases of crops are not only biological, but also economic.

Various factors in the environment in which the plant grows interact with one another and with the plant itself before disease can develop. The main components in this interaction are the plant itself, whether or not it is susceptible or capable of becoming diseased; the environment, whether or not it is favourable for disease to develop; and in the case of disease caused by microorganisms, whether or not the microorganism or pathogen is virulent.

Disease development in plants therefore is a positive result of the interactions among the plant, the environment, and the causal organism of diseases or pathogen.

Symptoms of Disease

Generally, symptoms are produced in diseased plants. Symptoms are evidences of disease which the plants themselves present either individually or in groups. But a symptom should not be confused with the disease in reaction to which the plant has produced the symptom.

For example, the spotting of the leaves, the rotting of the basal parts, the stunting of the growth or the death of seedlings of the rice plant and the discoloration of its seed are all symptoms of one disease or another. Similarly, the rotting of the pod in cowpea or cocoa, the rotting of the fruit in banana and orange, the decay of the tuber in yam or potato, the mottling and yellowing of leaves in mosaic diseases, the swelling of the stem or shoot in certain diseases of cocoa, or the knotting of roots of tomato, okra, cowpea or kenaf, are all symptoms of diseases. Most symptoms like those referred to above, are of the visible type. Sometimes, however, symptoms of disease in plants may not be perceived through the eye, but are detected through taste, smell or touch, as in the rotting of citrus fruits or mango, or in the deterioration of rice seed.

Classification of Disease

It is useful to put plant diseases into various categories, or to classify them, in order to have a full understanding of their nature, cause, and ultimately, their control.

The approaches to the classification of plant diseases have varied over the centuries with the opinions of plant pathologists. The ultimate purpose of the classifiers have always determined the basis for classification. Thus plants diseases have been classified on various bases such as symptoms or groups of symptoms, the causal agents, the affected plant parts, and the pathological or physiological processes disturbed or affected. Classification has even been based on the site or location where symptoms have been observed, i.e. whether it is above or below soil level. Each of these bases has its own merit and demerit.

Classification based on symptoms

The earliest attempts at classification of plant diseases were based on symptoms or groups of symptoms. But even now, centuries after the formulation of the mircrobial theory of disease in plants, classification in which symptoms form the central theme is still very valid, useful and of very practical importance, particularly in developing countries.

Many people can distinguish between a living plant and a dead one, but only a few have ever taken the time to note the numerous changes that first indicate disease in plants. The recognition of such changes and familiarity with the terminology applied locally, nationally and internationally to describe them, form the basis for the description and diagnosis of diseases.

Diagnosis enables one to discriminate between the disease of the plant and to distinguish such diseases by characteristic symptoms.

The rapid and accurate diagnosis of plant diseases on the basis of symptoms is very important in plant disease surveys in plant diseases eradication campaigns and in extension work. It is also important in the field recognition of diseases which are caused by biotic and abiotic factors. Diagnosis is an art which should be highly and constantly and consistently cultivated and applied.

Nature of Symptoms

Every disease of plants is expressed through a number of symptoms; these symptoms are generally commonly combined to form definite symptom pictures or syndromes. Take for example the blast disease of rice.

The most conspicuous symptoms of the blast disease of rice are those that appear on the leaves and neck of rice plants. On the leaves, there are diseased lesions or spots which are spindle-shaped, pointed at both ends, and often showing a brownish margin with a greyish centre. The size, colour and shape of the spots may vary with environmental and cultural conditions and varietal resistance. Greyish-brown lesions are formed in the neck, and the neck later becomes girdled causing the head of panicle to fall over. If the disease occurs before the milk stage, the grains are not filled, they become empty. If it appears later, the grains may be partially or partly filled, but the kernels appear chalky and brittle or green in colour.

All these are various symptoms of the syndrome of the rice blast disease. The disease reduces the yield or even causes the death of the plant.

Another disease which can be referred to is the wilt of tomato. The disease may appear at any time that conditions for its development are favourable. Yellowing of the lower leaves appears first, usually affecting the leaflets unilaterally. The peticles drop, the affected leaves die. After the plant has been diseased for a few weeks, browning of the vascular system may be seen in cross sections of the lower stem. The plant as a whole is stunted; the leaves wilt and die whilst still clinging to the upright woody stem.

Signs of Causal Microorganisms

In many cases particularly in the very early stages of the development of diseases caused by microorganisms, signs of the causal agents, the microorganisms, are associated with the symptoms. Such signs may be in the form of mycelium, hyphal fragments or spores of fungi, cells or cell ooze of bacteria, eggs or larvae of nematodes. Insect vectors of viruses may also be found on diseased plants.

But such signs are not to be confused with the symptom or the disease itself. When symptoms are observed in the early stages of disease development, signs of the causal organism may constitute a reliable means of indicating the actual type of disease-causing agent. For example, the causal organisms for the diseases referred to above are *Pyricularia oryzae* Cav. for the blast disease of rice and *Fusarium oxysporum* f. sp. *Pycopersici* (Sacc.) Snyder and Hansen for the wilt of tomato. This latter example is particularly important in that many types of microorganism for example fungi, bacteria and nematodes or even abiotic factors may cause wilting in tomato, and the correct identity of the causal agent is of a great value in formulating control measures.

If the diseases have been on for some time before the symptom is observed, the signs associated with the symptoms may not be those of the causal organisms. For example, if the sympton is recognized early in the black pod disease of cocoa, the associated signs are the mycelia and sporangia of the causal organism.

Phytophthora palmivora (Butler; if however, the disease has been very advanced before the symptoms are observed, the associated signs may be the spores of Botryodiplodia theobromae Pat. a secondary invader of the rotten tissue, and not those of the main causal organism.

Types of Symptoms

There are well over fifty different types of symptoms of plant diseases, but all of them can be put into three broad categories, namely (i) necrosis or necrotic symptoms, those that are expressed in the form of degeneration, disintegration or death of plant tissues, (ii) hypoplasia or hypoplastic symptoms, those that are expressed in the form of reduction, or stoppage of growth of plant tissues, and (iii) hyperplasia or hyperplastic symptoms, those that are expressed in the form of excessive multiplication, overgrowth or overdevelopment of plant tissues.

Some examples of necrosis are yellowing, as in leaf yellowing of rice caused by a virus; wilting, as in the fusarium wilt of tomato, cotton and other malvaceous and solanaceous plants, caused by Fusarium spp.; streak, as in bacterial leaf streak of rice caused by Xanthomonas translucens f. sp oryzae.

Pordesimo, or as in maize streak caused by a virus; leaf spot, as in brown leaf spot of rice caused by Helminthosporium oryzae Breda de Haan (syn. Cochliobolus miyabeanus (Ito and Kuribayashi) Drechsler ex Dastur); blight as in seedling blight of rice caused by Sclerotium rolfsii Sacc. or bacterial leaf blight of rice caused by Xanthomonas oryzae (Uyeda and Ishiyama) Dowson; damping-off, as in the damping-off of seedlings of vegetables and forest trees caused by Rhizoctonia solani Kühn, Sclerotium rolfsii Sacc. and various species of Phytophthoria; blast as in the blast disease of rice caused by P. oryzae; rot, as in stem rot of rice caused by Leptosphaeria salvinii Catt. (syn. Sclerotium oryzae Catt. = Helminthosporium sigmoideum Car.) or foot rot of rice caused by S. rolfsii; die-back, as in the die-back of cocoa caused by Calonectria rigidiuscula and scald, as in the leaf scald of rice caused by Rhynchosporium oryzae Hashioka and Yokogi.

Examples of hypoplasia are rosetting, as in ground-nut rosette; dwarfing, as in the "tungro" disease of rice; and chlorosis, as in the chlorosis of leaves of tomato, cocoa, and pepper. All these examples are of diseases caused by different viruses. Examples of hyperplasia are knotting of roots as in root-knot of okra, tomato, cowpea, etc. caused by the Meloidogyne spp, of nematodes; swelling of shoot as in the swollen shoot disease of cocoa caused by a virus; crown gall of rosaceous plants or of tobacco caused by Agrobacterium tumefaciens (E.F. Smith and Townsend) Conn., and tumour, as in stem tumour of cassava caused by Agrobacterium manihotis.

Classification based on causal agents

The positive proof by De Bary and Berkeley during the latter half of the nineteenth century that the late blight of potato is caused by the fungus *Phytophthora infestana* (Mont.) De Bary was the beginning of the golden age of mycology and its influence on plant pathology. Subsequent investigators were able to demonstrate that various other species of fungi cause diseases in plants. Thus mycology dominated the scene in plant pathology.

Later, other workers were able to prove that microorganisms other than fungi, for example, bacteria, viruses and nematodes cause diseases in plants. As a result of these series of investigations, diseases came to be equated with microorganisms and were classified on the basis of causal organisms. This was the aetiological approach.

Prior to the advent and acceptance of the microbial theory of plant disease development, diseases were usually attributed to the effects of various unfavourable climatic conditions; microorganisms associated with diseases were regarded as excrescence from diseased tissue. But even after the microbial classification had dominated the scene, researches continued into the harmful effects of adverse environmental factors as causes of plant diseases.

Diseases have been classified into five broad categories on the basis of the causal agents. These are (i) those caused by fungi or fungal diseases, (ii) those caused by bacteria or bacterial diseases, (iii) those caused by viruses or virus diseases, (iv) those caused by nematodes or nematode diseases, and (v) those caused by non-parasitic or inanimate agents. There are numerous variants of this system of classification.

The main merit in this type of classification is that the true cause of disease is identified, and such a knowledge helps in formulating control measures. The draw-back is that the same mircoorganism may cause diseases with different types of symptoms in different crops, and diseases with the same type of symptoms may be caused by different mircroorganisms even in the same plant. Thus wilting or tomato, for example, may be caused by fungi, bacteria and nematodes alike.

Diseases caused by fungi

About 80% or more, of allplant diseases known in West Africa are caused by fungi. The fungal body is made up generally of a network of hyphae known as mycelium, and fruiting bodies which produce the spores or conidia. Such spores or conidia may or may not be enclosed in or borne in or on structures such as sporangia, asci, basidia pycnidia, and acervuli. The spores or conidia are in most cases the propagules which cause the infections that lead to plant disease development. Some groups of fungi do not produce spores; with them the infecting propagules are either the ordinary hyphae or specialised ones known as sclerotia. Fungi belong to four main classes, namely, the Phycomycetes, Ascomycetes, Basidiomycetes and Fungi Imperfecti. Each of these classes can be subdivided into orders, families, genera and species. Some disease classifications have even been based on these subdivisions of fungi.

It will take a great deal of time and space to give example of diseases caused by various groups or subgroups of fungi. In any case, some examples have already been given in the section on symptomatology.

There is generally no uniformity in the pattern of symptoms of diseases caused, or in the range of host plants in which diseases are caused, by member of a group or subgroup of fungi; symptoms of diseases caused by member of a group of fungi can be as varied as possible. However, there are certain instances in which some groups of fungi cause diseases of somewhat similar symptoms. Examples of such diseases are the downy mildews caused by the Peronosporales, the powdery mildews caused by the Erysiphales, the smuts caused by the Ustilaginales, and the rusts caused by the Uredianales. In such cases, the same names have been applied to both the diseases and the fungi which cause them.

Some examples, other than those already given in the section on symptomatology, of rice diseases caused by fungi are irregular stem rot, caused by *Helminthosporium sigmoideum* var. *irregulare* with symptoms similar to those of stem rot, but in which the damage caused is less severe; sheath blight, caused by *Corticium* spp.; foot rot, caused by *Gibberella fujikuroi* (Saw) Wollenw.; narrow brown leaf-spot, caused by *Cercospora oryzae* Miyake; leaf smut, caused by *Entyloma oryzae*; false smut or green smut, caused by *Ustilaginoidea* virens (Cke.) Tak; smut, caused by *Tilletia barclayana* (syn. = T. horrida); rhizoctonia sheath spot, caused by *Rhizoctonia solani* Kuhn, and dirty panicle disease, caused by *Curvularia lunata* other species of *Curvularia*, *H. oryzae* and *Nigrospora* spp.

Diseases caused by bacteria

Bacteria are the causal agents of about 10-12% of diseases of plants. Bacteria are generally microscopic one - celled organisms.

Like the fungi, bacteria can be classified into several groups depending on the shape and size of individual bacterial cells, whether or not flagella are present on the cells, the number and shape of the flagella, and the reaction of the bacterial cell to gram staining.

Symptoms of diseased caused by bacteria can be nectrotic, as in the angular leaf spot or black arm of cotton, caused by Xanthomonas malvacearum (E.E. Smith) Dows; wild fire of tobacco, caused by Pseudomonas tabaci (Wolf and Foster) Stevens; bacterial blight of cowpea, caused by Xanthomonas vignicola; soft rot of vegetables caused by Erwinia carotovora (R.L. Jones) Holland; stem canller of tomato, caused by Corynebacterium michiganens. (E.F. Smith Jensen; and bacterial wilt of many vegetables, caused by Pseudomonas solanacearum E.F. Smith.

They can also be hyperplastic, as in the crown gall disease of tobacco and rosaceous plants, caused by Agrobacterium tumefaciens (E.F. Smith and Towns) Conn.; and the stem tumour of cassava caused by Agrobacterium manihotis.

Bacterial diseases with hypoplastic symptoms are mainly in the form of chlorosis, as in the halo blight of french beans caused by Pseudomonas phaseolicola; and haloed leaf blight of cassava, caused by Xanthomonas campestris pathovar cassavae.

Examples of rice diseases caused by bacteria are bacterial leaf blight caused by Xanthomonas oryzae (Uyeda and Ishiyama) Dowson; and bacteria leaf streak caused by Xanthomonas translucens f. sp. oryzae Pordesimo (syn. X. oryzicola Fang et al.) Rice diseases caused by bacteri have not yet been recorded in some countries of West Africa e.g. Nigeria.

Diseases caused by viruses

Viruses are the causal agents of about 5% of plant diseases, but the economic importance of diseases caused by viruses is very great. A virus is biochemically and biophysically a nucleic acid strand associated with a coat of protein. Biologically a virus particle is, unlike fungi and bacteria, incapable of independent metabolism; its propagation depends on the nucleic acid and protein synthesising enzyme systems of the plant which the virus infects.

Viruses are the cause of certain plant diseases of great economic importance. The swollen shoot of cocoa is an example of a disease with hyperplastic symptom; the example of one with hypoplastic symptom is the rosettee of ground-nuts. The mosaics which cause mottling and chlorosis of leaves of many plants, for example potato, tobacco, tomato, beans, cowpea, okra, eggplant, pepper and cocoa, and the yellows, in which the symptoms are mainly yellowing and curling of leaves, or excessive branching of the shoots of plants are important virus diseases.

Rice diseases caused by viruses include yellow dwarf, grassy stunt, yellow leaf orange, tungro, hoja blanca, and orange leaf.

Disease caused by nematodes

Knowledge of the association of nematodes with rice diseases and diseases of other plants came much later than that relating to the part played by fungi, bacteria and viruses in plant diseases. Nematodes are roundworms which live in soil or water. Many nematodes are free-living; others cause diseases in plants or animals.

Symptoms of diseases caused by nematodes could be necrosis as in the root lesions of plants caused by *Pratylenchus* spp. e.g. *Pratylenchus brachyrusus*. in maize, or hyperplasia as in the root-knot or root galls of many plants caused by *Meloidogyne* spp. or hypoplasia as in the stunting of plant parts caused by many nematode species such as *Meloidogyne* spp. *Heterodera* spp. *Trichodorus* spp.

Diseases caused by nematodes in rice include the white tip, caused by *Aphelenchoides besseyi* Christie, which reduces the number of grains and increases the proportion of sterile spikelets per panicle, the ufra stem disease, caused by *Ditylenchus angustus* Filipjev, the symptoms of which are stunting of plants, often with withered leaves and with brown areas near the nodes; root knot caused by *Meloidogyne* spp. stunting caused by *Heterodera oryzae* and *Tylenchorhynchus* spp.

Non-living or abiotic causes of plant diseases.

It is not only microorganisms that cause diseases in plants. Certain plant diseases are caused by the effects of various adverse climatic and environmental factors. Such causes are variously referred to as abiotic inanimate, non-parasitic, nutritional or physiological. The last is clearly a misnomer in that all plant diseases are physiological in nature, whatever their causes; but it is a term which has been used by various workers and occurs very frequently in the literature on plant diseases. For this reason, it has more or less come to stay in several publications.

The main causes of this category of diseases are nutritional disorders, soil-moisture disturbances, atmospheric impurities, and light and temperature effects.

Some workers have included injuries due to, for example, lightning and other phenomena among the causes of such diseases; but injuries should not be equated with diseases. Horsfall and Dimond (1959) have clearly made a distinction between the two processes: injury implies that the action which causes the impairment comes and goes suddenly; injury results from sudden or transient irritation, whereas disease results from continuous irritation. Injury, however, may pave the way for the entry into a plant of a pathogen which may later cause disease in the plant.

Nutritional disorders may result from deficiencies or excesses of major (essential) or minor (trace) elements in the nutrition of the plant.

Diseases caused by nutrient deficiences

Effect of the deficiency of essential elements are generally manifest in the leaves of the rice plant. The plant as a whole becomes stunted in growth, and tillering is reduced. Deficiency of nitrogen and sulphur in the soil leads to yellowing of the leaves, that of phosphorus causes the leaves to be dark green, erect and narrow; while that of potassium causes the leaves to be very dark green and droopy, the tip of the lower leaves becoming yellow.

With iron deficiency the entire leaves become chlorotic and whitish; zinc deficiency causes the young leaves to become chlorotic; calcium deficiency caused the tips of the upper leaves to become white, leading to the death of the growing point in extreme cases; root elongation is retarded and tips of roots become brown.

Inter-veinal chlorosis of lower leaves occurs with magnesium deficiency; with manganese deficiency, there is at first interveinal chlorosis of the youngest leaves, the older leaves remaining relatively yellowish green. Later brown chlorotic lesions or spots appear on the leaves, and newly emerging leaves become short and narrow with severe chlorosis. Boron deficiency leads to a stunted growth of the plant, with emerging leaves developing white tips and, in severe cases, dying. In cases of copper deficiency, the leaves first appear bluish green; later they become chlorotic from the tips down-wards along both sides of the midrib, with dark-brown necrosis of the tips. The new emerging leaves fail to unroll, but maintain a needle-like appearance.

<u>Diseases caused by excess of certain nutrients</u>

Excess of certain elements in the soil may cause toxicity or hazard, and may result in diseases in the growing plant.

Toxicity due to an excess of iron and some other elements, leads to bronzing, characterised by the appearance of tiny brown spots in the lower leaves, starting from the tips and spreading towards the basal parts of the leaves. In severe cases, entire leaves turn purplish brown, while the affected plants develop scanty root systems which are dark brown and coarse. The plant becomes stunted and produce less tillers. Excess of some elements may induce the deficiency of some others; for example, iron toxicity may induce deficiency of phosphorus and potassium.

Nutritional disorders are generally related to soil conditions. In the application of fertilizer and herbicide, due regard should always be made to the local conditions of the soil.

Classification on the basis of diseased plant parts

Some plant diseases are grouped and designated on the basis of the affected plant parts, such as the root, as in root rot, of kenaf caused by *Phytophthora* spp; the stem as in stem rot of cowpea caused by *Rhizoctonia* solani Kuhn the leaf as in leaf blight, of maize caused by *Helminthosporium maydis*; the unfloresoence as in the infloresoence blight of castor-oil plant caused by Botrytis ricini, fruit and pad, as in the fruit rot and pod rot of many crops. Such a classification is largely one of convenience. Many examples of diseases which can come under this type of classification have been given in the earlier sections of this lecture.

Classification based on the site or location of diseases in plants

This is very similar to the one that has just been considered except that instead of naming the part of plant on which the symptoms are observed, the site, whether it is above ground level or below ground level, whether it is on the root system or the shoot of system the plant is named.

Diseases below ground level will be those observed on the roots or underground stems of plants. Examples will be root lesions and root-knots caused by nematodes; root rots caused by various groups of fungi; dry or wet rot of tubers of yam and potato. Diseases above ground level are those that occur on the aerial parts of the plant, such as the stem leaf, flowers in-florescence, pods, fruits, etc.

The structure and physiology of the various parts of the plant and the nature of the causal organisms will determine to some extent where and when disease can develop.

<u>Classification based on the physiological and pathological processes or disturbed</u>

This is the latest and so far perhaps the most correct approach to plant disease classification. It is based not on the causal organism or the symptoms expressed, not on the part of the plant in which symptoms have been observed, but on the actual disease processes the physiological and pathological processes - that generate the symptoms.

It was the English plant pathologist H. Marshall Ward in 1901 who first gave the hint about this type of classification. He observed that all disease is physiological in so far as it consists in the disturbance of normal physiological function of the plant, and he cautioned against confounding the causal agent with the disease itself or of confusing the symptom with the malady. An American plant pathologist, Stevens, in 1977, stressed that in the consideration of plant diseases, it is the diseases themselves, and not the causal agents, which need classification.

Horsfall and Dimmond in 1959 used this approach to classification of plant diseases and recognized six disturbed physiological processes in diseased plants, namely, tissue is disintegrated examplified by various symptoms of necrosis; growth is affected as in many cases of dwarfing or galling reproduction is affected as in ergots and smuts; host is starved; water is deficient; and respiration is altered.

Many of the examples which have already been cited of disease in plants will fit into one or the other of these categories.

This system of classification is very good for the science of plant pathology; for the understanding of the fine details of the nature of the disturbed processes in plant diseases, but it is rather impracticable to use for the rapid diagnosis of plant diseases in disease surveys and in disease eradication campaigns.

Conclusion

No single system of disease classification is absolutely adequate. Each of the approaches has its own merits and demerits. It may be useful to consider all the available systems of classification in order to fully understand the nature and causes of plant diseases, and to develop adequate and appropriate measures for their control and management. Furthermore, a consideration and understanding of the various bases of classification of plant diseases is pertinent for the formulation and development of effective integrated pest management programmes for plant diseases.

Influence of environment on the distribution and dissemination of plant pathogens

By

Oladele F. Esuruoso
Professor of Plant Pathology
Department of Agricultural Biology
University of Ibadan, Ibadan, Nigeria.

INTRODUCTION

In the previous lecture on "Categories of plant diseases: nature and causes", it was mentioned that disease in plants is the resultant of the interacting factors of the host plant, the environment, and the pathogen. In this lecture we shall examine in greater detail the effect of environmental factors on the distribution and dissemination of plant pathogens.

Plant Pathogens

Microorganisms such as fungi, bacteria, viruses and nematodes which cause disease in plants are called plant Pathogens.

The body of the fungus is made up of a network of fine threadlike strands known individually as hyphae and collectively as mycelium. There are those hyphae whose function is mainly to provide support and absorb nourishment for the fungus from the medium or substratum on which the fungus grows. Such hyphae constitute the soma. There are also those hyphae whose function it is to ensure the continuous existence of the fungus from one generation to another.

These hyphae form the fruiting bodies or sporocarps in spore-forming species and give rise to spores and conidia; in non-spore-forming species as well as in some spore-forming species, they give rise to sclerotia. Such hyphae constitute the sporangia, sporangiophores and sporangiospores of the Phycomycetes; the asci, the ascospores and associated structures and fruiting bodies of the Ascomycetes; the basidia, basidiospores and associated structures and fruiting bodies in the Basidiomycetes; and the pynicidia, acervulia, conidiophores, conidia, and sclerotia of the Mycelia sterilia.

It is the spores, conidia, and sclerotia from structures such as those already described above, as well as the growing mycelium, dormant mycelium in seeds or other parts of plant, mycelial strands or rhizomorphs that constitute the infective propagules or bodies that enable fungi to cause infection in plants. It is these infective progagules that are distributed and disseminated.

The corresponding infective propagules for bacteria are the individual bacterial cells while those for nematodes are the eggs and the cysts. Viruses are incapable of independent metabolism; their infective propagules are the viroid particles, the propagation of which depends on the nucleic acid and protein-synthesizing systems of the host plants.

<u>Environment</u>

For plants, and therefore for plant pathogens, the environment is generally conceived of in terms of the soil and the atmosphere. An additional aspect of the environment for plant pathogens will be the host plants themselves.

The components of the soil environment are the soil type, soil moisture, soil pH, soil temperature, other living organisms in the soil and the remains of dead organisms; those of the atmospheric environment are weather conditions such as temperature, relative humidity, dew, gaseous composition of the air, wind velocity, rainfall, etc., and the type and number of other living organisms, particularly insects and rodents. The host plant environment consists of the roots and the rhizosphere, the stems, the leaves and the floral structures, culminating in the seed. These plant parts harbour a lot of micro-organisms other than the pathogens such other organisms do interact positively or negatively with the pathogens and affect their distribution and dissemination.

Some factors of the environment, e.g. moisture and air, are common to both the soil and the atmosphere.

All these components of the environment exert a great influence on the distribution and dissemination of plant pathogens.

Dissemination by water

Water in the form of rainfall, free water, dew and relative humidity exerts a great influence on the local distribution and dissemination of plant pathogens.

In some cases, rain is an important factor in the distribution within or between farms, of infective propagules of many bacterial and fungal pathogens which remain viable in the decaying debris of plant parts. For example *Xanthomonas malvacearum* which causes angular leaf spot or black arm of cotton, and the infective propagules of many nematode species are spread largely by rain water, surface water or irrigation water.

Phytophthora palmivora which causes the black pod of cocoa is spread by splattering and splashing during rainfall. For example pods on lower parts of trees get infested first. Spores of fungi, particularly those that are extruded in gelationous masses that may harden when dry, are seprated from one another and washed down trees and other kinds of plants during rains or heavy dews.

The swelling through the imbibition of water, of gelatinous substances aids the liberation of spores in many fungi. This is the case with spores formed in the sporangia of many Mucoralea, in the perithecia of many Ascomycetes and in the pynicidia of the Sphaeropsidales. In these examples, the spores are released by extrusion resulting from the swelling of the gelatinous substance, which then pushes out through the ostiole. The spores thus extruded germinate.

Most pathogenic Phycomycetes, particularly the Pythiaceae such as species of *Phytophthora* and *Pythium* produce motile zoospores within their sporangia. On liberation, these zoospores which are ciliated or flagellated swim for a short time, then come to rest and germinate. When soil containing sporangia of these fungi is wetted to saturation, or sporangia from soil are placed in water, large numbers of motile zoospores are released. When free water is no longer available, the zoospores encyst repidly.

Most plant - pathogenic bacteria for example, *Pseudomonas solanacearum*, *P. phaseolicola* and *Erwinia amylovora* are motile by means of flagella. It is known that motility increases the infection potential of these pathogens by making it possible for them to reach favourable sites of entry.

Cells of *E. amylovora* inside host tissues are not motile, but become so when placed in contact with free water, provided the temperature is optimal for synthesis of flagella.

Dissemination by wind

Perhaps the most efficient means of extensive dispersal and dissemination of spores of fungi which cause diseases in aerial parts of plants is the wind. Various studies with volumetric spore traps have shown that spores of fungi such as *Pyricularia oryzae*, *Drechslera* (*Helminthosporium*) *oryzae*, species of *Curvularia*, *Alternari*, *Diplodia*, *Fusarium*, and a host of others are readily released into the air and are subsequently disseminated by wind.

Many fungal pathogens are very remarkably adapted to dissemination by wind. Various mechanisms operate for the release of spores from the sporescarps. Some involve changes in moisture stress or relative humidity of the air. Others involve forcible and violent release - into the air. They produce and liberate into the air by these various mechanisms countless number of small and light spores which are carried over short or long distances by the wind. Dissemination by wind has been the cause of the spread of fungi e.g. rusts, country to country, or over as spent expanse within continents.

Interaction between wind and moisture in dissemination

There is generally a close relationship between moisture, either in the form of rain, dew or atmospheric relative humidity and wind dispersal, especially with spores in which the spore wall is relatively thin. The spores of most of such fungi are generally released when the relative humidity is at or nearly 100%. Thus in the climatic conditions in West Africa, there is a diurnal periodicity in the release of fungal spores.

Most of the spores are released in the early hours of the morning or in the late hours of the evening when the relative humidity is high and the drying effect of sunshine has not set in, or has disappeared.

Under continuously wet conditions provided by dew deposits or by rain-fall, the spores of many fungi are released from spore-bearing bodies such as pynicidia, perithecia, etc., into the air. In many cases, wind-blown rain and rain - splashes proved to be very effective means by which conidia are dispersed; the distance of dispersal and the numbers caught at various distances are generally highly correlated with the mean wind velocity during the rainy periods. With Venturia inaequalis, the causal organism of apple scab, wind - blown rain was found to be an effective mechanism for dissemination. A similar observation has been made in respect of Calonectria crotolariae and Calonectria rigidiuscula, the latter being the causal organism of the die back disease of cocoa, in which spore dispersal is mainly by wind - blown rain splashes.

Studies on the release and dispersal of sporangia of Phytophthora palmivora have emphasized the combined effects of rain and wind in the dissemination of the pathogen. Sporangia could not be recovered on Hirst spore trap slides placed in infected papaya (pawpaw) fields even though infected fruits surrounding the trap or in wind tunnels were subjected to a wide range of meteorological conditions that were known to be suitable for the release of dry sporangia of Phytophthora infestans from infected potato leaves.

However, wind - blown rain collected from severely diseased orchards contained sporangia. Rain-splash experiments showed that the sporangia of this pathogen were readily released in splash droplets formed when rain drops impact on diseased lesions. Detached sporangia held at relative humidity values lower than 100% dehydrated in 2 - 4 minutes, and failed to germinate when subsequently placed in water. Thus wind - blown rain appears to be a very ideal mechanism for the release and dispersal of the sporangia and spores of this species of fungus.

Dissemination by insects

Insects are in a special category as agents of dissemination of plant pathogens, particularly viruses and certain bacteria. There are only a few viruses that are not known to have special insect vectors. All the diseases caused in rice by viruses are transmitted by insects generally by species of leaf hoppers and plant hoppers. The tungro, yellow - orange leaf, leaf - yellowing, yellow dwarf, and transitory yellowing diseases are transmitted by the green leaf-hopper Nephotettix impicticeps or by N. apicalis. Grassy stunt is transmitted by the rice brown plant-hooper, Nilaparvata lugens.

Transmission of plant viruses by insects is made after certain conditions are completed. Such conditions include acquisition of the virus by the insect vector during feeding, virus incubation period in insect vectors, during which time the virus multiplies and becomes infective, retention of the infective virus in the insect vector, inoculation feeding on new host plants by insect vector, during which time the infective virus is introduced into fresh host plants, and finally incubation of the inoculated virus in the host plant.

The duration of each aspect of the transmission cycle varies with viruses and with the vectors.

Although aphids and leaf - hoppers are perhaps the two most important groups of plant virus vectors, other insect groups such as the white flies and the mealy bugs transmit plant viruses. For example, the cowpea mosaic virus as well as the potato leaf roll virus are transmitted by theaphid Myzus persicae, the bean mosaic virus is transmitted by Aphis fabae, while the cassava mosaic virus is transmitted by the white - fly, Bemesia sp.; cocoa swollen shoot virus is transmitted by mealy bugs. The virus-host plant relationship may be persistent and propagative or non-persistent. However, a given vector may transmit one virus in a persistent manner, and another virus in a non-persistent manner. Long distance spread of virus by insects may be aided by thewind. Most insect vectors have sucking mouth parts, others such as flea beetles and grass hoppers have biting mouth parts.

Certain bacterial pathogens of plants are transmitted by insects. For example Erwinia tracheiphila, the causal organism of cucrbit wilt is transmitted by cucumber beetles, Acalymma vittata and Diabrotica undecimpunctata; Erwinia carotovora, the causal organism of blackleg of potato is transmitted by the seed-corn maggots Hylemya cilicrura and H. trichodactyta. Erwinia amylovora, which causes fire blight of apples, pears, and certain other members of the family Rosaceae, is disseminated by bees and wasps, while Xanthomonas stewartii which causes wilt of maize and X. vasculorum, the causal organism of sugar-cane gummosis are disseminated by flea beetles.

A few fungal pathogens are also initiated by insects. For example, rusts, species of *Fusarium*, *Collectotrichum* and a number of other fungal plant pathogens such as *Phytophthora*, *Helminthosporium*, *Colleistrishum*, *Septoria* and *Botrytis* are also transmitted and disseminated by insects, particularly wasps, bees, beetles and ants. In a way similar to what obtains with viruses, control of these insect vectors may reduce substantially the amount of diseases caused by those fungi.

Dissemination by nematodes and other animals

Some viruses are soil-borne and may be disseminated by ectoparasitic nematodes. Examples are the tobacco ringspot virus transmitted by *Xiphinema americana*, tomato blackering virus transmitted by *Longidorus elongatus* and tobacco rattle virus transmitted by *Trichodorus christici*. Active spread of viruses by nematodes may be accompanied by passive spread through rain splashes of the infested soil.

Birds do spread spores of fungi e.g. rusts, from plants to plant and from field to field. Birds also carry large number of spores in their feathers and deposit them on susceptible plants. When birds feed on vector insects, they also help in the dissemination of plant pathogens.

Man also through activities like grafting, slashing of plants, etc., help in the dissemination of viruses.

Dissemination through the soil

The vertical distribution of nematodes in cultivated soil is usually irregular but is generally closely related to the distribution of plant roots particularly in the rhizosphere. Soil type, soil moisture, soil temperature, aeration, and pH interact to influence the survival of nematodes in the soil.

Nematodes cannot move more than a few centimetres per growing season on their onw. Factors such as water, either as rain, irrigation water, rain splash, etc., contaminated farm equipment, and infested plants or plant parts used as planting materials, help in the dissemination of nematodes.

Some soil fungi also transmit viruses. For example, the tobacco necrosis virus is transmitted by zoospores of Olpidium brassicea which carry the virus on their surface, while the lettuce big vein virus is present inside these zoospores.

Dissemination through seed and other planting materials

Seeds and other planting materials such as tubers, corms, bulbs and rhizomes, constitute a very important medium for the dissemination of plant pathogens. In this jet age when distant countries can be reached very quickly through air travels, dissemination of plant pathogens through seeds and other planting materials is fast and has assumed tremendous importance.

Infective propagules of the various pathogens - fungi, bacteria, nematodes and viruses are generally carried in or on the seed, where they remain viable and quiescent or dormant until the seed is sown. These infective propagules then become active, develop, and form sources of inoculum for causing diseases in plants.

There are three main ways in which pathogens are distributed with plant seeds. They can be found in the form of fungal hyphal fragments, dormant mycelium, or bacterial cells, virus particles or nematode cysts within the tissues of seed, i.e. in the embryo, in the cotyledons, within the pericarp or under the seed coat.

Examples of pathogens which are seed-borne in this way are various species of the fungal genera Cercospora, Collectotrichum, Fusarium, Phoma, Septoria, Sclerospora, and the smut fungi. Bacteria such as Xanthomonas malvacearum, and viruses such as the common bean mosaic virus, the tobacco ring-spot virus and the tomato spotted wilt virus, are also borne within seed tissues.

Pathogens can also be carried superficially on the surface of the seed, in the form of adhering propagules such as spores, sclerotia, pieces of mycelium, hyphal fragments and bacterial cells. Examples of pathogens commonly borne on the seed surface include species of the fungal genera Alternaria, Stemphylium, Fusarium, Helminthosporium, Pyricularia and Cercospora, the bacterium Xanthomonas visicatoria on tomato and the virus tobacco mosaic virus. The rice white tip nematode, Aphelenchoides besseyi is also seedborne.

The third type of pathogen distribution with seed is in the form of concominant contaminant, i.e. in the form of infected plant debris, sclerotia, hyphal and mycelial fragments, nematode cysts and infected soil particles, mixed with the seed.

Suitable methods have been developed and standardised for detecting seed-borne pathogens. The association of plant pathogens with seeds in the ways already described ensure very effective and efficient distribution and dissemination of these pathogens. Seed trade between and within countries have developed tremendously over the years. In the efforts to improve the yields of various crops, lots of seeds for planting are purchased and introduced into a country from other countries. Unless effective quarantine methods are developed, seed-borne pathogens which may cause diseases of great economic importance, are introduced along with the imported seed lots.

Pathogens can also be disseminated and distributed in the same way with other planting or propagative materials such as seed potato, seed yam, seed cassava, or even with soil, particularly soil with mycorrhizal fungi which is sometimes imported into a country in order to improve the establishment potential of certain seedlings, particularly forest tree seedlings.

Conclusion

Generally the various effects of the environment are not exerted in isolation for the distribution and dissemination of plant pathogens. These environmental factors like those we have already discussed interact with one another to ensure effective dissemination of plant pathogens. The practical test of effective dissemination is the level of the development of disease resulting from the dissemination. The fact that disease in plants develop from season to season without the introduction of fresh pathogens provides abundant evidence that inits totality, the influence of the environment on the distribution and dissemination of plant pathogens is really tremendous.

METHODS OF PLANT DISEASE CONTROL

By

Dr. Melville D. Thomas
UNV/Assistant Professor of Plant Pathology,
Department of Agronomy, College of Agriculture
and Forestry, Univeristy of Liberia.

INTRODUCTION

Crop losses due to plant diseases have been recorded since 1800 BC, and man probably provided favourable ecological changes some 9000 years ago for disease-causing organisms when he started to cultivate plants as crops (11). In present day almost all food crops grown by man are attacked singly or in combination by fungi, bacteria, mycoplasma-like forms, nematodes, protozoa, and by virus and viroid particles. It has been estimated that plant diseases alone are responsible for losses of 135 million tons (MT) of cereals, 31 MT of vegetables, and 35 MT of fruits on a global scale (1). From 1978 prices, the total value of losses caused by plant diseases in the world was 70 billion dollars (1). The value of losses caused by diseases, insects, and weeds for all produce in Africa in terms of percentage is 42 (1). These figures show that there is a need for plant disease control measures at all levels in national agricultural programs.

In planning control strategies to reduce the incidence of diseases in food crops the total environment should be considered so that control methods which could be harmful to the components of the ecosystem would be avoided. In addition to considering the environment, several control methods could be employed for either a specific disease or for the major diseases of a crop in order to achieve the best possible results within given economic constraints.

It is within this framework that the importance of integrated control in plant disease management is being stressed. Integration implies a multi-factor approach in applying control methods as opposed to a single-factor approach. Management implies the consideration of the effect of control methods on both the biotic and abiotic components of the environment within the immediate ago-ecosystem, and beyond into the broader ecosystem.

The first part of this lecture will consider the general methods of plant disease control. A full discussion of these methods is outside the scope of this lecture. In the second part of the lecture some approaches to integrated control will be discussed.

METHODS OF PLANT DISEASE CONTROL

General: In controlling diseases plants are for the most part treated as populations, not as individuals. Most often control methods are preventive rather than curative. Exceptions to these two general approaches occur in the control of tree crops where in some cases the tree is treated as an individual and therapeutic methods are applied following infection and establishment of the causal agent. Disease control methods could be classified as, regulatory, cultural, cultivar resistance, biological, physical, and chemical. The first three are usually preventive measures, whereas the three latter methods could be both preventive and curative.

Regulatory Methods: To ensure that plant materials having disease-causing agents are not transported across country, state, and county borders, laws are enforced which regulate the movement of infected plant materials. This form of disease control is extremely important in situations where a particular disease is not known to occur in a country or in a given area within a country. Inspection through plant quarantine is carried out at strategic points, especially at airports and border posts. Seeds and other propagative materials are inspected by trained personnel who will declare them disease free. Quarantine laws could state the conditions under which some crops may be grown in any area. Inspection and regulation of the movement of plant materials could be government controlled, or voluntary through farmers' co-operatives for small local areas. The idea is to keep the host plant and the source of infection apart. Regulatory control may be referred to as exclusion. The major variable is the distance between the host and the source of inoculum.

Cultural Methods: Cultural control methods involve the manipulation of agronomic practices to minimize disease incidence and severity. One approach to this method is the eradication of host plants haboring the pathogen by physical removal and/or burning. The host plant may be the primary crop, a secondary host of no economic importance such as weeds, and an economically less important alternate host in which the pathogen completes its life cycle. The population of plant pathogens in soil may either be reduced to economically low numbers or be eliminated by crop rotation. Species or families of plants not attacked by a given pathogen could be grown for four to five years depending on the longevity or half-life of the pathogen in soil.

Crop rotation is most effective for pathogens which need either the living or dead host tissue for survival, and for those which cannot compete successfully as saprophytes with other soil microbes for food.

Proper disposal of infected plant parts, thorough washing and disinfection of farm tools, good drainage, proper use of fertilizers, and good plant spacing all directly or indirectly contribute to the control of some diseases.

Resistant Cultivars: One of the best methods for controlling plant diseases is the use of resistant cultivars. Though it may take several years to produce a resistant cultivar, its complement of genes, which confers resistance to it, could last for many years without being overcome by new strains of pathogens. Thus a crop resistant to the economically important diseases in an area can be planted with very little or no need to implement other control measures. This will depend on the degree of resistance shown by the crop. Constant monitoring of the population of the important pathogens in an area is necessary so as to identify new strains or biotypes of the pathogens that might be able to overcome the resistance shown by the crop.

Biological Methods: Certain microoganisms and viruses are parasites of some plant pathogenic organisms. For example, bacteriophages, mycoparasite, and nematophageous fungi have been shown under experimental conditions to attack bacteria, fungi, and nematodes, respectively which are pathogenic to plants. However, biological methods of plant disease control are not widely used under field conditions and have met with limited success (1). Biological methods have the potential of becoming very cheap and effective means of plant disease control, with little or no adverse effects on the environment.

Physical Methods: Heat treatment is used to sterilize soils in nurseries and greenhouses. The soil is heated by steam or hot water. Seeds and other propagative materials may be treated with hot water to kill any pathogens infecting them. Heat treatment of storage organs and of plants, postharvest refrigeration of fleshy plant products, and use of different types of radiation are also employed.

Chemical Methods: Various chemical compounds are toxic to fungus, bacterium, and nematode pathogens of plants. Most of these chemicals are sprayed on to the foliage as a preventive measure. Others have systemic action and are taken up by the plant after application to soil and to seeds. Systemic chemicals have therapeutic action on plant pathogens.

SUGGESTED APPROACHES TO INTEGRATED PLANT DISEASE CONTROL

Rationale for Integrated Control: The idea of integrated control is not new in plant pathology. Pathologists have always, at least in theory, advocated the combination of several methods to control plant diseases. In practice however, this has not always been the case. Chemicals have been used exclusively and widely to control some diseases. Over the years, the single-factor approach to insect control by the sole use of insecticides in North America, Europe, and some parts of Asia has shown that resistant insect pests develop in the insect population, beneficial species are destroyed, outbreaks of secondary pests occur, chemical residues are left in foods, feeds, and the environment, and general hazards to humans and the environment are created (4).

Integrated control programs should therefore consider the consolidation of all available techniques into a unified program to manage pest populations, without the overuse of chemicals, so that economic damage is avoided and adverse side effects on the environment are minimized (4). This approach to plant disease control, where all available pertient information regarding a crop, its pathogens, the environmental conditions expected to prevail, locality, availability of materials, and costs are taken into account is the most successful and economical (1).

Horizontal Resistance in Integrated Control: Two main types of genetic resistance to diseases occur in plants. Vertical resistance is controlled by either a single gene or a few genes. Horizontal resistance (HR) is controlled by several genes. In comparing both forms of resistance, HR manifests itself for longer periods in a crop. It is more difficult for pathogens to develop new strains or biotypes which could overcome the many resistant genes in crops with HR. In addition, HR is usually effective against several known strains of a pathogen. For these reasons and for the fact that in general growing resistant cultivars is the cheapest, easiest, safest, and most effective means of control (1), crops with HR to the economically important diseases in a given area should be the core of an integrated control program. HR implies, in some cases, the presence of a residual amount of disease in the crop below the economic threshold. Changing weather conditions and other ecological factors could, from time to time, favor a pathogen population to the extent that the disease approaches epiphytotic levels in a crop with HR. Also HR may not be effective against a secondary or minor pathogen which has the potential of reaching epiphytotic levels. To avoid such occurrences other measures could be taken to reduce sources of pathogen inoculum. These other measures will form the peripheral control measures in addition to the existing HR at the core (Figure 1).

Peripheral control methods which could be integrated into a HR program in order of priority are, cultural, biological where feasible, and chemical. For example, LAC 23 is an improved rice cultivar developed in Liberia and is resistant to blast, the most serious disease of rice. It is also resistant to brown spot, another serious disease of rice. However, LAC 23 is susceptible to leaf scald disease of rice. Leaf scald is prevalent in Sierra Leone and Liberia (9, 10). Preliminary research data have shown that nitrogen fertilizer as urea and narrow plant spacing favor leaf scald development (M.D. Thomas, unpublished). In addition, the leaf scald fungus *Rhynchosporium oryzae* Hashioka & Yokogi is seed transmitted (6), and short distance spread within a rice field could occur through rain splash (9). Thus, proper fertilization and good plant spacing together with seed treatment could help produce a healthy crop of LAC 23 with low levels of leaf scald. Some of these cultural manipulations might not be readily applicable to small scale farming, where farmers broadcast rice by hand at random and do not use fertilizers. Under such circumstances an effective extension service may help farmers who grow LAC 23 and who can afford the cost involved to spray their rice crop with a suitable and safe chemical at timely intervals and at moderate concentrations. Four sprays of the systemic fungicide benomyl (methyl (1-butyl-carbamoyl)-2-benzimidazole carbamate) under conditions in Sierra Leone, at 0.3 kg a.i./ha, significantly suppressed leaf scald disease in the rice cultivar ROK 16. Similar results were obtained for LAC 23 in Liberia (M.D. Thomas, unpublished). Benomyl is one of the safest agricultural chemicals. It has a low toxicity level (LD_{50} oral is 9590 mg/kg) and has no known adverse effects on the environment (3).

Susceptible Crops in Integrated Control: In situations where resistant cultivars to the prevailing diseases are not available, the core of an integrated control program could be suitable cultural methods. Peripheral measures for integration into the central core when necessary, inorder of priority, could be regulatory, physical, biological where feasible, and chemical (Figure 2). However, in areas with effective quarantine and inspection services regulatory methods of control could form the central core of the management program. In such a program cultural methods would take precedence over biological, physical, and chemical methods at the periphery of the program (Figure 3). Except there is an effective government extension service or a properly administered farmer co-operative to supervise the production, inspection, and distribution of disease-free seeds and vegetative planting materials, regulaotry methods will not be of any use in an integrated control program. This will also be true where quarantine laws governing the movement of plant materials across state and county borders are not enforced or are non-existent.

The Importance of Weather in Integrated Control: In the presence of a susceptible host and a pathogen disease manifestation in plants becomes apparent only if a suitable external environment exists which is conducive to disease development. In this respect, two weather parameters affect disease development the most. These are moisture (rainfall) and temperature. Many plant pathogens are favored by relatively high humidity and low temperatures. Fluctuations in rainfall and temperature during the growing season might affect the degree of severity a disease.

Leaf scald of rice is favored by prolonged moist conditions in Brazil (2). Relatively cool temperature and high and prolonged rainfall in Sierra Leone increase the infection rate of leaf scald disease in rice (M.D. Thomas, unpublished). Under tropical conditions rice blast causes severe damage to rice plants where there is frequent and long periods of rain (5). Meteorological data should therefore form an integral part of disease management systems. Daily and protracted forecasting systems are extremely useful in predicting certain epiphytotics. Prior knowledge of weather conditions could enable suitable measures to be taken in advance, if it is known that such impending weather may favor an epiphytotic.

Other Considerations in Integrated Control: A high level of control of a disease may be achieved if weaknesses in the life cycle of the pathogen, under specific ecological conditions, are known. These weak points can be exploited in a control program. How do pathogens survive during the dry season? Do they have a secondary host? Do they form resistant structures? To what extent is the pathogen saprophytic? Are there any natural enemies of the prevalent pathogens in a given locality? We need to know the primary source(s) of inoculum and means of long and short distance spread of the pathogens. How do local cultivars grown by farmers respond to the prevalent diseases as compared to improved cultivars? How rich a source are these local farmers' cultivars for resistant genes? What are some of the stress factors which might trigger an epiphytotic in a seemingly unimportant or "dormant" host-pathogen relationship? In terms of the latter, both *Fusarium moniliforme* Sheldon

and *F. moniliforme* var. *subglutinans* Wr. and Reink.

have been isolated from healthy looking maize kernels and seedlings in Nigeria and Sierra Leone (7, 8), and in Liberia (M.D. Thomas, unpublished). These fungi are known to cause stalk and cob rots in maize in many parts of the world. What factors in the West African ecology might induce this commensal-like relationship between the Fusaria and maize to change it into a diseased situation? Possibly the maize cultivars sampled have good sources of resistant genes and therefore can be used in an integrated control program for stalk and cob rots of maize.

LITERATURE CITED

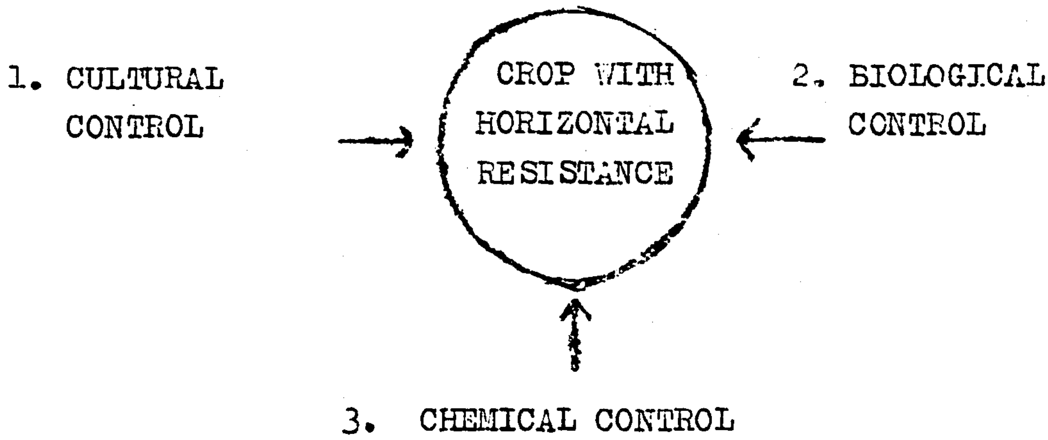
1. AGRIOS, GEORGE N. 1978. Plant Pathology. Academic Press, New York. 703pp.
2. FARIA, J.C., and A.S. PRABHU. 1980. A sreening technique to evaluate resistance of rice to Rhynchosporium oryzae. Plant Dis. 64: 845-846.
3. GREEN, M.B., G.S. HARTLEY, and T.F. WEST. 1977. Chemicals for Crop Protection and Pest Control. Pergamon Press, Oxford. 266pp.
4. METCALF, ROBERT L., and WILLIAM H. LUCKMAN. 1975. The pest management concept. In Introduction to Insect Pest Management, eds. Robert L. Metcalf and William H. Luckman. John Wiley & Sons, New York. 587pp.
5. OU, S.H. 1972. Rice Diseases. Comm. Mycol. Inst., Kew, England. 368pp.
6. SINGH, AMU S., and SEN GUPTA. 1981. Transmission of *Rhynchosporium oryzae* Hashioka & Yokogi by seed. Interln. Rice Res. Newsl. 6(2): 11.
7. THOMAS, M,D, and I.W. BUDDENHAGEN. 1980. Incidence and persistence of *Fusarium moniliforme* in symptomless maize kernels and seedlings in Nigeria. Mycologia 72: 882-887.

8. THOMAS, MELVILLE D. 1981. Occurrence of two *Fusarium* species in two maize cultivars in West Africa. Mycologia 73: 1004-1007.

9. THOMAS, MELVILLE D. 1981. Preliminary studies on isolation and means of spread of the rice leaf scald fungus in Sierra Leone. Interln. Rice Res. Newsl. (In Press).

10. VIRMANI, S.S., and F.J. SUMO. 1978. Incidence of leaf scald disease on dryland rainfed rice in Liberia. Interln. Rice Res. Newsl. 3(4): 5-6.

11. WHITNEY, P.J. 1977. Microbial Plant Pathology. Pica Press, New York. 160pp.



<u>FIGURE 1</u>: An integrated disease control program having a crop with horizontal resistance as the core of the program. Cultural, biological (where feasible), and chemical control methods are at the periphery and are incorporated into the core of the program, in that order of priority, if the need arises.

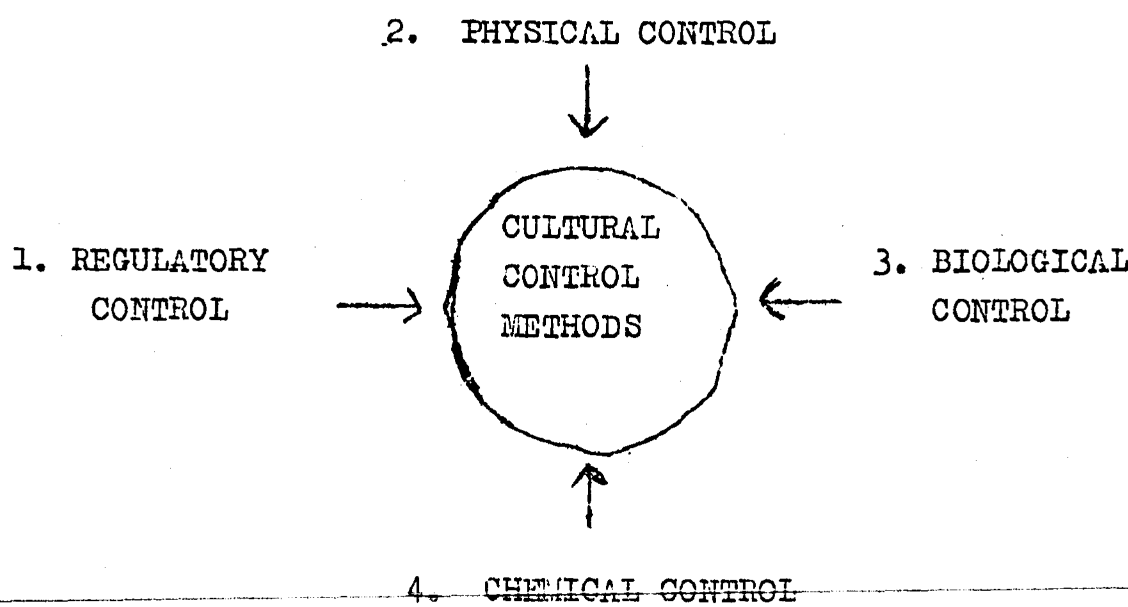


FIGURE 2. An integrated disease control program having cultural methods as the core of the program. Regulatory, physical, biological (where feasible), and chemical control methods are at the periphery and are incorporated into the core of the program, in that order of priority, if the need arises.

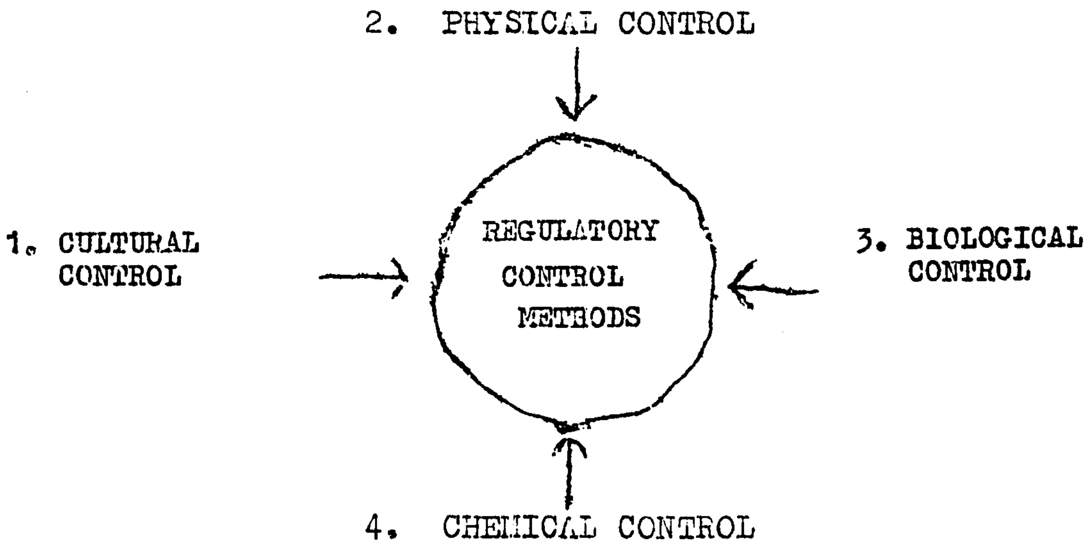


FIGURE 3: An integrated disease control program having regulatory control methods as the core of the program. Cultural, physical, biological (where feasible), and chemical control methods are at the periphery and are incorporated into the core of the program, in that order of priority, if the need arises.

INSECT PESTS CONTROL

By

MBAYE NDOYE
National Agronomic Research Centre
Bambey, Senegal

It can rightly be said nowadays that man consumes what has been left by insects. The rapid increase of human population has inevitably led to the development of extensive monocultures i.e. large areas sown to single crops which have become an ideal feeding ground for insects which cause extensive damage and are refered to in English as "pests."

The Food and Agriculture Organisation (FAO) has estimated that only 80% of food produced in the world is consumed by man, the remaining 20% is by insects. The food crisis in the world would have partially been solved if this 20% were consumed by man.

From time immemorial man has been devising ways to minimise damage caused by insect pests without much success. This is why a large number of pesticides has been developed by the chemical industry following various attempts to kill these pests. Man is still today devising new methods of control to improved on the previous ones.

However it should be understood that more agro-chemicals are currently being used than ever before. In the not too distant past in developed and sometimes in developing countries, pests were being controlled through preventive methods. Besides giving rise to more resistant pests thereby requiring additional treatments, the food chains were being contaminated through the use of these insecticide and this constituted a serious threat to the ecosystem.

We have reached a turning point in pest control. Definitely chemical control is being considered in many respects as the only available method but it is being argued that other methods such as biological, autocidal integrated pest control, pest management or target pest control methods should also be taken into account for the great benefit of mankind.

I. CHEMICAL CONTROL METHODS

Insecticides which have been for many years the only chemicals used by farmers to control insect pests are being considered today as harmful whose use should be limited in order to ensure its effectiveness.

For this reason, insecticides should be used in the following manner.

1. They should be used at a very convenient period on the basis of the pest's biology. Treatments should therefore not be given in an irregular manner.

b. Use the insecticide most effective for killing a specific insect pest.

c. Use the most appropriate spraying method.

An insecticide is a strong poison and for this reason it is necessary to lay down its method of application and absolutely respect insecticide legislation. An insecticide is not only harmful through its active ingredients but also through its soluents and catalysts. It is harmful to the following:

- Plants

The most common harm done is the phytotoxicity which results from the fragile nature of the plant and this is characterised by small or big dark brown spots being symptoms of necrosis.

Such diseases which cannot be very noticeable are similar to symptoms of respiratory or seed germination diseases.

Other symptoms detected in the plant are of trophobiosis defined by CHABOUSSOU (1966) as the "exhaustion of the living organism's ritality resulting from a beneficial alteration of its food pattern". In this case this refers to the food obtained from the host.

Insecticides used on plants have yielded opposite results since they have rather given rise to outbreaks of pests.

- Man and domestic animals

Man and domestic animals have been directly or indirectly contaminated by insecticides and this constitutes the most immediate danger. Practically, all insecticides are harmful. Some which are of plant origin are less harmful but the systemic ones are the most dangerous. Those who use insecticides are likely to suffer from direct poisoning. Domestic animals and insects are often entirely destroyed. The persistance of the insecticides which determines its stability over a certain period constitutes a danger for the users. The persistence factor is very essential since it shows a distinction between farmers who wish to possess very persistent insecticides and other users who wish that such products should be as less posistent as possible in other to be able to keep their food in a healthy state.

In any case, nowadays, legislation on pesticides is based on the persistence factor because of the serious dangers facing the ecosystems and other users.

Ecosystems

Very often, residue of insecticides remain in the environment and cause irreversible condition. The danger is universal and generally, the long term effect of the product used is unforseen.

The most common case is that of DDT. Since 1945, millions of tons of DDT were imported and the chemical considered less harmful. DDT provided a great service to mankind but today heavy concentrations of this product are found in the lipids of all animals. The food chains have been contaminated. In 1970, the use of DDT was banned in the US and in Sweden although it is still being used in many African countries. This is a fact one should know of before using a chemical for control measure. There are many types of insecticides and their production (for use in farms) is the most important aspect of the chemical industries.

Overview of the main insecticides used in agriculture

There are 5 main types:

1.1.1. Insecticides of mineral origin

These insecticides were mostly used in the past because they were cheaper and effective but nowadays they are not frequently used except for poisoning baits. A typical example is the lead arsenate which was mostly used in Europe to control doriphores.

1.1.2. Insecticides of plant origin

These are nicotines, pyrethrins, and notenones which are generally known for killing insects instantly and causing no harm to man.

Initially these insecticides were mostly used in homes. Synthetic pyrethroids which were developed quite recently have made this type of insecticides to be known however they are more stable and their effect is not much known.

1.1.3. Chlorinated hydrocarbons: synthetic organic insecticides

These are one of the most popular types of insecticides given the number of its synthetic components and the quantity produced. They were mostly used between 1950 and 1970 and today they are still very popular among pest control products. For over a decade many countries have adopted a more retional approach with respect to the use of this products because of their persistence and side effects which are now well known.

The following insecticides are among the most popular and the most important types.

- Dichloro, diphenot.e, trichloro-octane the famous and controversial DDT.
- Hexachloro - cydo - hexane (H.C.H) which is quite popular and well known for killing migratory or local locusts especially in the Sahelian areas.

There are other popular insecticides such as dieldrin, endosulfan or thiodan, heptaponder of taxaphine etc., which are often used.

1.1.4. Phosphoric esters (Organo-phosphates)

There are two types namely:

- Exotherapic esters: examples of which are ethyl azinphos, choronvinfos drazinon which is still used to kill insect pests of rice, dichloruos or Vapona, fenithrothion, malathion, parathion and trichlorifon which are all widely used although they are very toxic to man and domestic animals.

- Endotnerapic esters or systemic insecticides which penetrates the plant and is carried to all parts by the vascular system. Examples of these are Dimetroate, endothion, phosdrine, vamidothion.

Generally these are insecticides used for various purposes but their use is limited because of their toxicity.

1.1.5 Carbamates

Carbamates are synthetic organic insecticides made from carbanic acid and whose effect is similar to that of the systemic insecticides. Carbary, the most popular, is used against the caterpillars of Lepidopterous pests. Mention must also be made of the arbocarb and the famous Baygon which are widely used in Africa.

In conclusion, this overview only gives a partial indication of the number of chemical products used in agriculture. It further shows that there is a need to have qualified people capable of selecting appropriate insecticides against a particular species. The wide range of insecticides used at present is to some extent an indication of man's failure to control effectively the populations of insect pests destroying his crops.

Therefore it has become necessary to seek other control methods and to define a new philosophy in order to secure a greater quantity of the food produced.

II. Biological Control

In a very broad sense, biological control consist of all methods which minimise pest damage and this exclude chemical and other control methods which destroy pests directly. Traditionally, the biological control method is a method used to kill pests by using their natural enemies either in the form of plants or animals. (BALACHOWSKY 1951).

To those who use this term, Biological control implies the use of entomophagous organisms which generally include the following:

- Insects whose larval development entirely or partially depends on one and the same host.

- Predators which consume a number of hosts or preys at every instar. Given the remarkable progress made by microbiological control methods and its importance it is necessary to understand the biological control concept propounded by BALACHOWSKY.

In reality in 1874 when Louis Pasteur was at the final stage of his research on silk worm diseases and while phylloxera was causing great damage to vires in France, he suggested that some diseases could be used to control insect pests in agriculture. This suggestion was also made earlier in the United States (CONTE, 1872). Research was later conducted about the same time in many countries METCHNIKOV in Russia, PAILLOT in France etc.,. Different results were obtained during these initial research works and although people were enthusiastic from the onset they later became skeptical about the effectiveness of the biological control method.

With respect to the entomophagous, insects, Rodolia (Novius) Cardinalis MUL was very effective against the Australian citrus bugcottony cushion scale - (Icerya purchasi MASK) and its effectiveness was promptly ascertained through the acclimatisation of specific parasites such as Cryptognatha nodiceps MHLT, a bug from Trinidad which attacked.

Aspidiotus destructor SIGN, a pest which was destroying palm trees in the Fiji Islands; Croptolaemus montroerieri MULS which a predator of Psendococcines or again Prospatella beclesei How., a specific Psendolacaspis pentagona TAG; however these parasites have revealed to a certain degree the limitations of the biological control method.

The intensive use of synthetic organic insecticides after the second World War which were persistent and consequently resulted in adverse effects led to renewal of interest in the widely concept of biological control methods. And particularly, the works of STEIN HAUS (1946 and 1949) and Californian researchers based on the experimental results in agricultural practice (80,000 ha treated from 1939-1952 by departments of the Ministry of Agriculture) with the bacteria Baccilus popilliae DUTKY, in the North East of the United States against the Japanese Hanneton rekindled the interest in the biological control method.

Following this awareness there was a general need to maintain the natural equilibria, and consequently research on biological control took a new turn.

It can also be said with BILIOTTI (1966) that documentation available today are scattered and are not equally far-fetched although there are data on some areas where the biological control method has been used for a number of years. Reviews dealing with such information are those of CLAUSEN (1956) for the U.S.A., WILSON (1960) for Australia and New Guinea, MCLEOD (1962) for Canada, and BENASSY (1971) for France. There are other bulletins which contain important information (DE BACH, 1964, HURPIN, 1971).

Whatever the biological agent used in biological control, the following basic principles should be applied.

- Knowledge of the biology of the target pest and its environment should be as accurate as possible.
- Knowledge of the economic value of damage caused by this pest in relation to its population dynamics.
- Thorough knowledge of the populationdynamics of pest in order to measure the effectiveness of biological agent introduced compared with other control methods for crop protection.

The use of entomophagous species (insects) requires detailed knowledge of the following:

a) biology of natural enemies and their practical importance;
b) method of production of entomophagous insects in order to always have biological material necessary for experiments.
c) reactions of entomophagous insects used in the new environment where they are released and where various factors can negate their action, such as indigenous natural enemies and the phytosanitary treatments applied through the year against other pests.

Researchers have laid down principles regarding the use of entomopathogenous microorganisms in biological control and these include:

a) Principles based on microbiology:

These principles lay emphasis on the identification and the desrption of pathogens' characteristics. About 1200 species were identified as follows: bacteria, reckettsia, viruses, protozoa and fungi. Their main characteristics are their ability to be virulent, persistent to attack a specific area, protect themselves and multiply on a large scale.

b). Principles based on pathology:

The use of pathogenic microorganisms is based on the determination of disease development from the enzootic to the epizootic stage before or after man's action. These factors are related to the aggressiveness of the germ, the receptiveness of the host as well as the environmental influence.

c). Principles based on ecology:

The objective, already well known, is to introduce in an ecosystem an agent to maintain constantly the level of pest population below the economic injury threshold with regard to a specific crop. This preventive measure implies that we should not only take the insect and the pathogen into consideration but also the environment in which the pathogen shall multiply. In this case the Unit area to be subjected to treatment is very important. The pathogen's hideouts are the first to be treated since the maintenance of an endemic disease is always related to persistance of a minimum population. A parasite which is introduce can compete with other biotic agents and a general treatment based on the use of a micro-organism can pollute the environment.

d). Principles based on agronomy:

The opinions of the microbiologist, the pathologist and the ecologist are not always in agreement with those of the agronomist. Thus the use of microbilogy most often tends to include biological preparation in an intregrated pest control programme; the long term epizootic effect is sometimes incompatible with crop protection either quantitatively on the basis of the pest's minimum rate survival and the tolerance threshold of the crop or qualitatively on the basis of marketing practices. The type of crop determines the control methods to be used.

The nature of the action taken on a rice field is different from that of groundnut plantation.

It is very important to appreciate the economic value of the method to be used in order to know, from the onset, what will be the weaknesses of the method in agriculture. Because of its specific and complex nature, the biological control method is most often initiated by the government and this gives it a national character. All agricultural officers and agents are involved in the programme and as such the use of the biological control method requires the participation of specialists in various fields.

Today the biological control method has proved many times a success (more than 200 cases in 60 countries according to DEBACH, 1964). Undoubtedly, this figure is relatively low compared with the great number of pests to be killed. However the biological control method is a lasting success and cannot cause unforseen side effects. Furthermore it should be noted that research conducted to develop this method made it possible to determine in certain cases the best preventive measures to be taken.

The real weaknesses of this method are based on the number and imagination of experts in this field and the means available to them. But the general tendency of these experts to promote integrated pest control does not reflect their failures or weaknesses, far from that, undoubtedly, this tendency is a sine qua non for the continuation of their work and the result of their general attitude to use the concepts of general ecology and population dynamics.

III. Genetic or autocidal control method:

III - 1. Introduction

The disadvantages of the use of chemical pesticides already mentioned against insect pests have led to research on new control methods.

- The use of entomophagous, species as already discussed, has led to the massive introduction of parasites and predators from their native areas and the development of mass breeding techniques in mass release programmes.

- The microbiological control method where pathogens capable of causing epizootics in pests are used.

- Plant resistance through varietal improvement. The autocidal control method as a new concept developed in 1938 by KNIPLING in the United States was a remarkable success.

III-2. Principles

The natural population of a species can be considerably reduced sometimes to a point that it becomes extinct when a reduction factor is applied equally and constantly even at a relatively low degree. This principle can definitely apply to the chemical control method as it was proved by KNIPLING. However, if this theory is unduly applied, it may lead to unfavourable results.

The insect pest itself can be used to reduce its own population. Knipling (1962) showed that this could be achieved through the following:

- The release of sterilised male species through irradiation.
- The use of chemical products to sterilise natural populations.

- The release of diseased adults, the aim which is to destory the off springs through direct infection or through environmental contamination.
- The development and release of insect species with defective genetic characteristics.

The elegance and efficacy of these methods were highly appreciated after they succeeded in eliminating the livestock fly, Codilionyia hominivorax COQUEREL in the Southern United States and in the Curasao Island - since 1954.

The releases of BUSHLAND and HOPKINS (1953) BAUMHOUER et al. (1955) and KNIPLING (1960) were based on theoretical calculations worked out by KNIPLING himself. (see table 1).

Table 1: Theoretical reduction of population when sterile male insects are added with a constant number to a natural population:

Natural population of virgin females	Sterile males released	Ratio of sterile males/ fertile females	Percentage of females mated with sterile	Population of fertile females obtained
1,000,000	2,000,000	2/1	66,7	333,333
333,333	2,000,000	6/1	85.7	47,619
47,619	2,000,000	42/1	97,7	1,107
1,107	2,000,000	1807/1	99.95	less than 1

The use of such a method requires certain preconditions as noted by FERON (1963):

- Rearing of the insects should be an easy procedure with a possibility of doing it on a large scale and at a reduced cost.
- Sterilisation should allow males to maintain their normal mating potential and accepted by females.

- If the males cannot be easily separated from the females, both sexes must be sterilised.

- The unique (singular) mating of the female is a good thing but not indispensable.

- The natural insect population's density should be low.

- The dispersion of sterile insects should be easy.

- Areas where integrated control methods will be used should be protected so that reinfestation cannot occur easily.

111-3. Applications and Conclusions

In addition to gamma ionising radiations produced by Cabalt 60, many chemical substances such as the acylating agents, antimetabolites, or mitotic poisons were used to obtain the sterilisation of males of various fruit flies, mosquitoes, ticks, Dynactidae as well as the livestock fly.

Considering its importance, it is a method worth using but which is very expensive and requires advanced studies in ecophysiology and biology.

The most obvious weakness of this method however is that it can make a species to cause thelyotokous parthenogenesis (producing only females). This method has raised hope in many people and shows that atomic energy can be applied to enthomology.

INTEGRATED PEST CONTROL

This control method was defined by SMITH and REYNOLDS (1965) as "a system designed to regulate populations of pests which, given the specific environment and the population dynamics of the pests, always use suitable techniques to maintain pests populations below the economic injury level.

The realistic and sound philosophy was propounded as a result of the serious consequences encountered in the excessive use of chemical products in Europe and in the United States where they were considered as the only means to eliminate insects and because of the weaknesses of other control methods used thus far.

Undoubtedly the introduction of Integrated pest control, pest management or target pest control (MATHYS and BAGGIOLINI 1967) concept has resulted in the net evolution of crop protection. It is not necessary to argue about its semantics since we are all agreed today on definition given by FAO.

However this development should occur in a world where there is an acute shortage of food resources and where the role of agriculture is being questioned especially in the countries which initiated this evolution. The real problems can only be overcome by finding in each case the solution best suited to local conditions while taking all aspects of the problem into consideration.

The basic knowledge is still not yet fully acquired but the integrated pest control concept shows how the means available can best be utilised. It is necessary at this stage to be acquainted with the outlines of this method.

IV-1. <u>Ecological basis of Integrated Pest Management</u>

It is necessary to have a thorough understanding of the agro-ecosystem whichyou have to deal with. The agro-ecosystem is an entity made up of a large number of organisms relased to crops in a given area which can be mofified through man's agricultural industrial or social activities. Thus the number of pests and their competition, predators and parasites are the important elements to consider.

The agricultural ecosystems are very complex and varied, and their sizes also vary. This complexity is not static but dynamic; changes. Moreover the physical boundaries of an agro-ecosystem are seldom clear but generally in integrated pest control measure, only physical boundaries are defined e.g. a rice field, an orchard etc. Thus it can be said that the various biotic factors exercise some influence within this area.

Generally, there are a few, two or three main pests, very often with many secondary pests and finally potential pests which do not cause damage under prevalent environmental conditions.

Each factor should be considered on the basis of its importance.

IV-2. <u>Economic injury threshold</u>

As far as this notion is concerned, a population should not be eliminated because an experiment which was conducted did not yield the expected results. The primary objective to be achieved for the success of any integrated pest control programme is to identify the level of economic damage corresponding to the yield acceptable to the farmer before a control programme is started. Beyond this threshold, the most suitable method will be used to minimise damage caused by specific pest. It has to be noted that this species lives in the agro-system and this fact must be taken into consideration.

For this reason it is necessary to ascertain the ~~degree of damage caused by the various pests and reckon~~ the injury done by each pest in order not to be mistaken about the identity of the pest actually causing the particular damage at the time of selecting the control method.

IV-3. Classical methods of pest control

The use of chemical pesticides should now take the form of a rationalised treatment in order to minimise damage whilst avoiding the disadvantages of control measure for this pest. Henceforth, chemical products should be used as tactical measure whilst other measures shall be used as long-term strategic methods in an effort to maintain the natural stability necessary for crop protection.

The whole system to be implemented should attach great importance to biological agents which exercise some influence within the ecosystem against pests. For this reason the complex nature of the method, the agro-ecosystem and pest-parasite relationship should be considered on the basis of its importance.

It is not easy to reckon the biological factors which regulate the stability of the agro-ecosystem and consequently use the knowledge acquired in pest control. In reality a detailed knowledge of the ecology, systematics, pest behaviour, physiology and of other disciplines is necessary. Therefore integrated pest control is a method which requires the participation of specialists of various disciplines as well as important human and financial resources but it is not a panacea capable of solving all the problems related to crop protection.

V. Conclusion

We have just had a sweeping overview of the main pest control methods currently being used to control insect pests. This presentation has made it possible to ascertain the trends of efforts made by man in this area.

It has dealt with the general aspects of pest control in order to give you an insight into this problem. The other presentations to be made in this month of January will enable you to have a detailed knowledge of the method which has been developed to protect rice and the most important features of rice insect pests.

R E F E R E N C E

BALACHOWSKY (A.S.), 1951 - La Lutte contre les Insectes: principes méthodes, application. Fayot Edit., PARIS, 380 p.

BAUMHOVER (A.M.) at al., 1955. Screw. Worm control through release of sterilized flies. J. Econ. Ent., 48, 562-566.

BENASSY (C), 1971 - La lutte biologique et son application pratique en arboriculture fruitiere. La pomologie Francaise T. XIII No. 1: 9-23.

BUSHLAND (R.C.) and HOPKINS (D.E.), 1953 - Sterilization of Screw-Worm flies with X-rays and gamma-rays. J. Econ. Entom., 46: 648-656.

BILLIOTTI (B), 1966 - Les limites des méthodes traditionnelles de lutte biologique - Proceedings FAO Symp. integr. pest control, 1: 63-73.

CHABOUSSOU (F.), 1966 - Nouveaux aspects de la phytiatrie et de la phytopharmacie. Le phénomène de la trophobiose. Proceedings FAO symp. on integr. pest control, 1: 33-61.

CLAUSEN (C.P.), 1956 - Biological control of Insect pests in the continental United States. U.S.A. Tech. Bull. No. 1139 : 151 pp.

DE BACH (P.), 1964 - Biological control of insect Pests and Weeds. Chapman and Hall, London, 844 pp.

FERON (M), 1963 - La lutte contre les insectes par les méthodes autocides - Revue Zool. Agric. appl., 63: 37-48.

HUPPIN (B.), 1971 - Principes de la lutte microbiologique en agriculture. Ann. Parasit. Hum. Comp. 46 No.3 bis: 243-276.

KNIPLING (E.F.), 1960 - Use of insects for their own destruction. J. Econ. Entom. 53: 415-420.

1962 - Potentialities and progress in the development of chemosterilants for insect control. J. Econ. Entomol. 55 : 782-786.

MC LEOD (J.H.), 1962 - Biological control of pests of crops, Fruit Tree, Ornementals and Weed in Canada up to 1959. Common. Inst. Biol. Control. Techn. Comm. No.2 1-33.

PAILLOT (A.), 1933 - L'infection chez les insects. G. Pastissies, Trevoux, 535 p.

PASTEUR (L.), 1974 - Sur l'utilisation des champignons pour combattre la Phylloxora. C.R. Acad. Sci. PARIS, 79: 1233-1234.

SMITH (R.F.) & REYNOLDS (S.T.), 1966 - Principles, definitions and Scope of integrated pest control., 1: 11-17.

STEINHAUSS (E.A.), 1946 - Insect microbiology - Comstock Pul., Co., Ithaca N-Y. 763 p.

- 1949 - Principles of insect pathology, Mac GRAW Hill Books Co., New York, 757p.

WILSON (F.), 1960 - A review of the biological control of insects and weeds in Australia and Australian New Guines - Comm. Inst. Biol. Control - Tech. Com. No. 1: 102 p.

ASSESSMENT OF RODENT DAMAGE IN FIELD RICE AND RODENT CONTROL PROCEDURES

By

OLUWADARE FUNMILAYO

DEPARTMENT OF AGRICULTURAL BIOLOGY
UNIVERSITY OF IBADAN, IBADAN, NIGERIA

INTRODUCTION

Rodents are responsible for a tremendous reduction in the quantity, and also the quality of rice available for utilization by man in most parts of the world. Rodents attack the stems of rice in the field causing mechanical damage which suppresses fruit yield. Rodents also cause yield losses by consuming planted, ripening and mature grains. Poor storage conditions may also cause harvested grains to be contaminated and consumed by commensal rats at the pre-processing and processing phases, and at warehouse, commercial stores and domestic pantries levels of storage.

Clowes (1950) estimated that rodents destroy about 12 million tons of rice annually throughout the world. It is necessary to drastically curtail rodent damage if the time and material inputs into rice production for utilization are to result in commensurate increased crop yield and food availability to the human consumers.

This paper will examine the species composition of the rodent pests of rice. Methods for assessing yield losses caused by rodents and for protecting rice crops from ravages of rodents in the field are also enumerated and discussed.

SPECIES COMPOSITION OF RODENT PESTS

Even though more than 10 species of rodents may be associated with rice crops in a given locality Table (1) only a few of these are usually sufficiently troublesome to need control. The composition of the species that cause much losses in fields vary locally and regionally. Correct identification of each rodent pest species is a pre-requisite to efficient and effective control. A rodent species could be identified initially in its local name (which is of immense value in communication with local farmers) and later in its common English/French and scientific names. The methods of determining the identity of problem species include direct visual observations of diurnal species while they are feeding on rice crop. Such diurnal species include Arvicanthis nilotious Desmarest, Lemniscomys striatus Linnaeus, Xerus erythropus Geoffrey. Types of run ways, foot prints, patterns of damage and faecal pellets could be used as indirect ways of identifying the rodents visiting a rice crop (e.g. T. swinderianus, A. niloticus). Rodent pest species can also be identified by capturing (by trapping or snaring) and stomach content analysis for nocturnal species (e.g. Rattus rattus Linnaeus, M. natalensis, Dasymys incomtus Sundevall, Tatera kenpi Wronghton, Mus sp. Temminck).

Some rodents pests of sown seeds can be identified by dying the seeds before sowing. This method was used by Funmilayo and Akande (1974). Rice seeds were dyed green and planted. Vertebrates were later captured in the fields planted with the dressed seeds and their stomaches were examined.

Any vertebrate with green stomach lining or with remants of green rice seeds in its stomach was incriminated to be a pest of sown rice seeds. The status of each pest species was, however, determined from its population density and the vulnerability of the rice crop to its attacks.

The species of rodents commonly associated with rice crops and the types of damage caused by each species are shown in Table 1. Nuisance and pestiferous rodents fall into three categories: The seed removers - these seek, remove and consume planted seeds. They include the pigmy mouse (M. musculoides) Fox's brush-furred rat, (Uranomys foxi Thomas), the ship or roof rat (R. rattus) and the multimammate rat (M. natalensis). The most important rodent in seed removal depends on the locality but M.natalensis owes its important pest status to its usual occurrence in plague populations which is due to its high reproductive rate, and its ability to reproduce outside and within buildings. Seedling and young stem cutters - these fell, chop to pieces and chew seedling and young stems. Damage could be very severe when stems (Primary tillers) are cut at pre-tillering stages and a whole plant is therefore totally killed or retarded. After the stems have tillered fully this types of damage becomes relatively unimportant as only one or two outer tillers of each plant are affected. The rodents responsible for cutting seedlings and young stems are A. niloticus, T. kempi, X. erythropus and D. incomtus. may be very important in irrigated fields because of its ability to swim.

Flowering and fruiting stem cutters - these fell, chop to pieces and chew stems from about the flowering stage to when the fruits are about ready for harvest and thereby prevent fruit production or maturation.

Only the inner tissues of the stems are consumed, the outer sheath and leaves being discarded. The main rodent pest of tillered, flowering and fruiting stems is the cane rat, *T. swinderianus*, which has been known to cause extensive damage in many rice farms.

ASSESSMENT OF RODENT DAMAGE TO FIELD RICE

Rodent damage to field rice can be measured at three stages; (1) At planting when freshly planted seeds are removed and consumed by small rodents, (2) At seedling stage when young plants are cut down by rodents, and (3) At flowering to fruiting stages when rice stems are "grazed" by cane rats.

Losses at each stage can be measured by counting the number or proportion of seeds, seedlings and stems killed. The crop yield losses from the numbers of seeds/seedlings/ stems killed are then estimated by comparing with the figures of the average crop yield per plant/tiller obtained from the same field, or in the case of total damage, from other rice farms established under similar soils and ecological situations in the same locality. Cash losses are estimated on the basis of current price of paddy rice per kg.

PREVENTION OF DAMAGE AND CONTROL OF RODENT PESTS

Prevention of Damage

Rodent damage to rice crop can be prevented or considerably reduced, without killing the nuisance rodents, by good crop husbandry measures and by preventing physical contract between rodents and rice crops. These can be achieved by:

1. Early planting which reduces seed removal and seedling damage because of the low population density of the rodent pests at this stage which is just before the production of the first annual crop of offspring by most species.

2. Synchronized planting of rice over wide areas reduces the period during which the crop is available to rodents and therefore the annual damage for that locality is reduced.

3. Clearance of weeds, bush and accumulated debris in and around crop reduces harbourage for pestiferous rodents and therefore lowers the numbers of rodents that could cause damage.

4. Maintaining the water level in irrigated fields reduces damage during germination and at other times because most rodent pests cannot swim.

5. Prompt harvesting to prevents grains from dropping to the ground and being available to rodents. Grains should be harvested as soon as they are mature and not left on the field until they are dry.

6. Rodents can be excluded from rice crops by various forms of fencing. Fencing is however expensive and advisable only with highly valuable seeds. Normal fencing is of no consequence against climbing and burrowing rodents (e.g. M. natalensis, R. rattus) since it cannot prevent their incursions.

7. Electrical fence has been used in the Philippines. The current is supplied from a 6/12 volt battery transformed to 125/250 volts and fed into a wire fence so that rodents climbing the fence are electrocuted. To reduce the danger to man and other non-target animals the current is switched on only at night and is therefore not effective against diurnal and crepuscular rodent pests. Fencing is very useful against grazing of rice farms by wild pigs and cows.

Control of Field Rodents

Small plots of rice are inadvisable since they are easily liquidated by pests and therefore rice farms should be sufficiently large. Rice plots should be examined regularly for signs of rodent infestation and damage because early detection of these would lead to prompt control which will prevent massive losses. Methods of killing rodents include trapping, snaring, shooting and poisoning. Various forms of snares (Everarad 1968, Funmilayo and Akande, 1976) are used in each locality against the different species of rodents. There are also several types of traps which kill by two main methods - by breaking the head of back (break-back or snap trap) or by holding the leg while the rodent dies of starvation and exhaustion from the struggle to free itself. Live rodent traps could also be used in the case of small infestations.

Cane rats and the ground squirrel are big enough to be controlled by shooting, using a No. 8,7,6,5, or 4 cartridge fed into a 12 bore short gun. They are also killed with wire snares and various forms of leg-holding traps. Exclusion of cane rats from plots with low (1m. high) chicken wire is a common practice.

Small field rats and mice can be controlled efficiently with snap traps baited with oil palm fruit, maize-on-cob or other suitable baits. For quick effect, the number of traps employed has to match the size of the infestation i.e. the number of traps has to be in excess of the number of rodents suspected to be present or the number of discrete feeding points and runways.

Rodenticides are poisons made specifically to kill rodents. There are two types of rodenticides: An acute rodenticide is supposed to kill a rodent after the ingestion of a single adequate dose while a chronic rodenticides is supposed to kill a rodent after the ingestion over a number of days of many adequate small doses. A rodenticide is applied in the field in bait boxes of the size 25 x 12 x 10 cm., with two openings each 10 - 12cm in diameter. These bait boxes could be made of metal, wooden, plastic opaque or transparent materials. Suitable large bamboo stem internodes could also be managed as bait boxes. Bait boxes prevent poisoned bait from getting wet and from being blown about by the wind. They also make the poison to be fairly target specific since animals exceeding the size of small rodents are unable to enter the bait boxes.

Acute rodenticides include Antu, Arsenic oxide, Phosphorus, Raticate, Red Squill, Zinc phosphide, Sodium Fluoroacetate, Strychnine, Castric etc. Acute rodenticides are not recommended because of their high toxicity and because antidotes for some of them are not definitely known. They are generally used mixed with a cereal bait (which can be either milled, broken or whole grains) in the proportions recommended by the manufacturers. If the cereal bait is whole or broken grains then an adhesive (e.g. oil, milk) is necessary to cause the poison to adhere to the bait. Pre-baiting is essential i.e. the unpoisoned bait has to be laid in baiting stations for 4-8 days before being replaced with poisoned bait. It must be realized that one of the greatest problems in the eradication of rodents with any type of poison is to induce the rodents to consume lethal quantities of poison. Refusal of rodents to consume poisoned bait is often experienced, either because the poison is wet or mouldy or is unpalatable as a result of the proportion of active ingredient in the poisoned bait being too high.

It is not advisable to apply acute rodenticide more than twice annually in the given location because poison-shy survivors could make more frequent poisoning ineffectives.

Fumigants or poisonous gasses are another type of acute poisons which could be used against rodents in compact soils or within stores.

The fumigant, Hydrogen cyanide powder or aluminium phosphide tablets that have come into contact with moisture. Rodents that live in burrows in compact soils could be controlled with hydrogen cyanide gas. The powder or tablets is applied into the exit of burrows in damp soil and the exits blocked firmly with earth. Reopened burrows are treated again and blocked and the process is repeated until the burrows ceased to be re-opened.

Chronic rodenticides are anticoagulants which prevent blood from clotting so that the affected rodent dies of massive haemorrhege. The chronic rodenticides are relatively safer to handle than the acute rodenticides because the antidote for the ingestion of an anticoagulant is an intravenous injection of vitamin K. Chronic rodenticides are sold in four forms: as tracking powder for application into areas where rodents are active or frequent, as ready-to-use poisoned-bait, as a concentrated poison (master-mix) to be mixed with cereal bait and in a water soluble form for rodents to drink.

The anticoagulant rodenticides commonly used all over the world include Chlorophacinone, Diphacinone, Fumarin, Pival, PMP, Talon, Warfarin. Talon is an anticoagulant which is reputed to be capable of killing "Super Rats" which are the rats that are genetically-resistant to anticoagulant poisons.

There is no need for pre-baiting with an anticoagulant rodenticides. The anticoagulant poisons are usually applied at dosage levels of 0.005 to 0.05%, achieved by mixing the poison concentrate and milled maized or rice or wheat grains in the ratio of, say for instance, 19:1 (i.e. 5% poison to 95% bait), recommended by the manufacturers. Bait boxes containing 100-200g. of anticoagulant poisoned bait should be placed about 15m apart and also near to rodent holes, runways or where rodents will usually find and consume them before reaching the items at risk. Dead rodents should be found in about 5 days from the beginning of poisoning. If re-infestation is not occuring the consumption of poisoned bait should drop in about one week and finally stop in 3-4 weeks by which time all the rodents must have been eliminated. Surplus poisoned bait and dead rats must be buried deep in the soil or preferably burnt.

REFERENCES

CLOWES, H.G. (1950). Rice Production and Utilisation Nature, 166: 168-170.

EVERARD, C.O.R. (1968). Some Snares used in Western Nigeria. Nigerian Field, XXXIII (3): 117-142.

FEAKIN, S.D. (1970). Pest Control in Rice. PANS Mannual No. 3, pp. 193-217 and 235-236. Centre for Overseas Pest Research London.

FEFFREY, S. (1973). Rats and mice of the dry high forest of Ghana. Nigerian Field, XXXVIII (3): 126-137.

FUNMILAYO, O. (1973). A general survey of the incidences and control methods of vertebrate pests of crop plant in the Western State of Nigeria. Research Bulletin No.1., Institute of Agricultural Research and Training, University of Ife, Ibadan. 40 pp.

FUNMILAYO, O. and AKANDE, M. (1974). The ecology, economic impact and control of vertebrate pests of upland rice in the Western State of Nigeria. Research Bulletin No.5, Institute of Agricultural Research and Training, University of Ife, Ibadan. 41 pp.

FUNMILAYO, O. and AKANDE, M. (1976). Estimated cost of control of vertebrate pests on a rice farm. The Nigerian Agricultural Journal, 13 (1): 15-18.

FUNMILAYO, O. and AKANDE, M. (1977). Vertebrate pests of rice in south-western Nigeria. Oans, 23 (1): 38-48.

FUNMILAYO, O. and AKANDE, M. (1979). Habitat selection and economic importance of rodents in Moor Plantation, Ibadan,. Wildlife Management in Savannah Woodland: 127-135. Taylor and Francis Ltd., London, (Editors: S.S. Ajayi and L.B. Halstead).

FUNMILAYO, O. and AKANDE, M. (1979). Body weight, diet and reproduction of rats and mice in the forest zones of south-western Nigeria. Wildlife Management in Savannah Woodland: 136-141. Taylor and Francis Ltd., London. ~~(Editors: S. S. Ajayi and L.B. Halstead).~~

ROSEVEAR, D.R. (1969). The rodents of West Africa. British Museum (Nat. History), London.

ASSESSMENT OF BIRD DAMAGE IN FIELD RICE AND BIRD CONTROL PROCEDURES

By

OLUWADARE FUNMILAYO
University of Ibadan, Ibadan-
Nigeria.

INTRODUCTION

Rice represents one of the most important staple food of the human populations in West Africa. The development and sustenance of high productivity of rice crop agriculture is important not only to guarantee a regular supply of staple food to the human populations but also because increased production and availability of food is prerequisite to political stability and industrial development.

It is generally acknowledged that grain-eating birds are the principal pests of rice crop and that they quite often totally destroy both small peasant rice crops and large modern rice plantations. Such total liquidation of rice crops by birds pest have been reported from many institutional and Government farms all over the West Africa sub-region.

Peasant farmers grow only small rice crops which they can protect physically from bird pests. The non-availability of efficient bird destruction devices to local farmers has limited the size of traditional rice crops to small holdings. West Africa can no longer rely on small rice farms if she is to be self-sufficient in rice production for local utilization. Rather, rice has to be produced in large scale agricultural schemes using advanced agricultural techniques.

These latter categories of agricultural rice production schemes cannot be protected effectively against birds by traditional measures but with modern bird pest destruction devices. These devices incorporate the use of appropriate pesticides and equipments to destroy large number of birds pests at a time.

The need for bird destruction in rice farms occurs in two stages: (1) at planting when bush fowls, doves and pigeons remove and consume planted seeds and young seedlings necessitating supplying and replanting which normally results in unequal growth of rice crop and poor yield. (2) at fruiting when different species of weaverbirds consume milky, maturing and matured grains which often leads to total crop loss.

This paper identifies the most important avain pests of rice in West Africa and discusses the various methods by which bird pests can be controlled to guarantee increase rice crop yield.

Species Composition of Avian Pests of Rice

The main avain pest species and the types of damage they cause to rice crop in West Africa are shown in Table 1.

The main avain pests of planted seeds and seedlings are waterfowls and medium-large grain-eaters. The waterfowls are made up of Palaertic migrants like the ruff (*Philomachus pagnax*), black-tailed godwit (*Limosa limosa*) and the garganey (*Anas querquedula*) and resident water-fowls like the spur-winged goose (*Plectropterus gambiensis*), Egyptian goose (*Alopoohen aegyptiacus*) knob-billed goose (*Sarkidiornis melanotos*), white-faced tree duck (*Dendrocygna fulva*).

Waterfowls consume seeds from the time of planting until all the stored food in the seed has been used by the growing plant. They also trample seedlings and make irrigation water dirty and unhealthy for good growth performance of rice. This type of damage is severe only in a few localities.

The planted rice grains of rain-fed rice are picked and consumed by wild fowls, doves and pigeons (Table 1). Total loss of all planted seeds necessitating replanting has been caused by bush fowls (*Francolinus* sp.) and doves (Stretopelia sp.) in many peasant farms.

The most important avian pests are the small weaverbirds (Ploceidae) which consume rice from the flowering stage until the fruit is harvested. The genera involved are *Quelea*, *Phoceus*, *Euplectes*, *Passer* and *Lonchura*. The most numerous species with the widest geographical distribution range is the red-billed quelea, *Quelea quelea*. Equally important in the wetter parts of West Africa is the village weaverbird (*Ploceus cucullatus*). Many species belonging to the genera of weaverbirds mentioned above are capable of causing severe local damage. The smallest weaverbirds puncture the husk of the maturing grains and suck the milk while the queleas both suck milk of maturing grains and also consume dehusked mature grains and the bigger species, like *Ploceus*, consume only the dehusked matured grains.

Assessment of Bird Damage to Field rice

Bird damage to field rice can be measured at three stages:

~~1). At planting when planted seeds are removed and consumed~~

2). At seedling stages when young seedlings (of both upland and irrigated rice) are killed and (3) At fruiting when milky, maturing and matured grains are consumed by weaverbirds.

Losses at stages (1) and (2) above can be measured by counting the number or proportion of seeds removed or the number or proportion of seedlings killed. Losses at stage (3) above can be measured by determining the total area or proportion of the rice crop consumed by weaverbirds. The yield losses in each case can then be converted to cash losses by using the current market price of 1 kg of paddy rice.

Control of Avian Pests of Rice

Various scare crows can be used to prevent the use of rice fields as roosts by waterfowls and thus prevent wild fowl trampling of young rice plants and the visit of pestiferous birds to freshly planted rice fields. Areas which are boradcast seeded may have severe seed and seedling damage and may therefore need a lot of reseeding.

Poisoned grains (e.g. maize grains soaked in insecticides like Dieldrin, Endrin, Telodrin have been used to kill bush fowls, doves and pigeons which consume planted cereal grains) but this method is potentially dangerous and should not be encouraged.

The most serious damage in rice is caused by the grainvorous weaverbirds of which the most notorious is *Quelea quelea*. *Quelea quelea* lives in large colonies consisting of thousands of individuals. The troublesome colonies are located during the day and the assessible ones are destroyed at night with explosives, petrol bombs, flame throwers or organophosphorus poisons. It must be added that most of these pesticides and the equipments for dispensing them are not sold commonly in any of the West African countries.

Millions of queleas are destroyed anually and a measure of crop protection is achieved in many localities but there is need for improvements in the specificity of the chemicals used and of the methods of application to reduce risk to non-target species and man.

Human scaring is the most widely used method in West Africa to prevent weaverbird damage to rice from ripening to harvesting. Scaring is only effective in small plantations and when the birds have an alternative source of natural food (like wild grass fruits) to feed on. In many West African villages farmers use "juju" or locally-made repellents to prevent pestiferous birds from visiting their farms. The effectiveness of "juju" still needs to be confirmed.

A non-lethal chemical repellent, Methiocarb (3,5-dimethyl-4) (methylthio) phenol methylcarbamate) has been used to reduce bird damage to both freshly planted rice (Bruggers and Ruelle 1977) and ripening rice grains (Bruggers 1977) in Senegal. This replellent is yet to be used on commercial scale.

Table 1: Species composition, types of damage and control methods of avian pests of rice in West Africa

Name of bird: Common	Name of bird: Scientific	Type of Damage	Severity of Damage	Control Methods
Ruff	Philomachus Pugnax	Consumption of freshly planted seeds and seedlings of irrigated rice.	Usually small but could be locally severe.	Scaring, Chemical repellents and shooting.
Black-tailed godwit	Limosa Limosa	Fouling of irrigation water.		"
Garganey	Anas querquedula	"	"	"
Spur-winged goose	Plaectropterus gambiensis	"	"	"
Egyptian goose	Alopochen aegyptiacus	"	"	"
Knob-billed goose	Sarkidiornis melanota	"	"	"
White faced tree duck	Dendrocygna fulva	"	"	"
Bush fowl	Francolinus bicalcaratus	Consumption of freshly planted and germinating seeds of upland rice.	Moderate but could be locally severe	Scaring, Poisoning, Chemical repellents & shooting.
Crake	Crecopsis egregia			
Red-eyed turtle dove	Stretopelia semitorquata	"	"	"
Red-billed dove	Turfur afer	"	"	"
Laughing dove	Stigmatopelia senegalensis	"	"	"

Name of bird		Types of Damage	Severity of Damage	Control Methods
Common	Scientific			
Red-billed quelea	*Quelea quelea*	Consumption of maturing and ripe grains of both irrigated and upland rice.	Usually severe	Scaring "juju" Extermination of birds in roosts and nesting colonies Chemical repellent
Red-quelea	*Quelea erythrops*		"	
Village weaver-bird	*Ploceus cucullatus*		"	
Chestnut-and Oblack weaver bird	*Ploceus nigerrimus*		"	"
Bronze manninkin	*Lonchura cucullatus*	"	"	"
Blue-billed manninki	*Lonchura bicolor*	"	"	"
Golden Sparrow	*Passer luteus*			
Glossy starling	*Lamprotornis* spp.			

MORPHOLOGY AND GROWTH STAGES OF RICE

By

A. O. Abifarin
Senior Rice Breeder - IITA/
WARDA Liaison Scientist

A. MORPHOLOGY

INTRODUCTION

Morphology of rice is the form and structure of rice. Rice morphology describes the way in which the plant is seen under its environment, the plant's parts and how they are carried or bound together. Thus the plant morphology could be looked upon as the plant architecture. Plant-type is an associated term that also describes how the plant carries itself or the plant architecture.

Morphological characters of the plants that are covered in this lecture (illustrated with slides) are as follows:

1. Height

Tallness is generally referred to as an undersirable character for most type of rice. Tallness on the negative side is associated with lodging, low responsiveness to fertilizer, low tillering etc. On the other hand under some ecologies intermediate height (100 - 150 cm) to real tall plants (150 - 300cm) are advantageous e.g. under floating rice ecology.

2. Leaf

In the consideration of rice morphology leaves are the most prominent, most seen and most influential for physiological, physical and pathological activities. Leaf may be defined from morphological point of view as a lateral organ borne by the stem on axis of most plants.

Other morphological terms associated with leaf are briefly defined below:

(a) Flag leaf:-

This is the topmost leaf below the panicle.

(b) Leaf blade:-

In rice it is the thin, flattened conspicuous portion of the leaf joined to the leaf sheath. It is the major part of the plant responsible for photosynthesis. It is green for most part of the plant life-cyle. Leaf blade may be short or long, narrow or broad.

(c) Leaf sheath:

The lower part of the leaf which invest or wraps around the stem. A good basal wrapping of the leaf sheath is an important feature for lodging resistance.

(d) Leaf angle:

In rice it refers to the distance of the leaf blade from the stem. It determines the openess or closseness of the leaf. The general descriptive terms often used are erect (angle of 0-30°) intermediate(31-60°) horizontal (61-90°) descending or droppy (over 91°). Erect flag leaf discourages bird attack as the grains on the panicles are less showy therefore more difficult to reach.

3. Culm

This is the stem of the rice plant. The leaves have to be removed to see the culm except when leaf sheath wapping is incomplete. Culm is round and smooth with nodes and internodes. In rice it is the upright axis of the shoot. Morphological importance is the relative ability to carry the leaves and the panicle. Usually thick culms are lodging resistant though height, disease, insect pests, soil fertility, stem anatomy etc., are other factors that influence lodging.

4. Panicle

This is the harvest portion containing the rice grains. Panicles may be long, short, may be lax or open or tight and compact.

Other terms of morphological importance associated with panicles are:

a). Panicle axis:- the main axis of the panicle. It is often distinctively grooved, extending from the base to the apex.

b). Panicle base:- the nearly solid node between the uppermost internode of the culm in rice and the main axis of the panicle. The first primary panicle branches originate from this node.

c). Panicle exsertion:- this is the exposure of the uppermost internode below the panicle base above the flag leaf. A well exserted panicle is one in which panicle base is clearly above the flag leaf sheath; partly exserted panicle is one in which the panicle base appears at the same level as the top of the flag leaf sheath.

5. Others

There are other minor morphological aspects of the rice plants. Some of these are associated with the grain e.g. grain length, shape, size and awns. There are other physiological morphological aspects such as vigor and tillering. These were illustrated with slides during the lecture.

B. GROWTH STAGES

Growth stages may be defined as distinct periods in the life cycle of a rice plant. There are 9-10 major g wth stages of rice. Most of these were illustrated with slides.

1. Germination to emergence

Germination is the initial growth of the embryo from the seed. The radicle first protrudes from the seed followed by the shoot. Emergence is the act of a germinated seed coming into view above the ground surface after sowing.

2. Seedling or transplanting

This is when the seedlings have reached at least 3-4 leaf stage or 3-4 weeks after sowing.

3. Tillering

Tillering stages is usually between the period of 10-60 days after transplanting.

4. Stem elongation

This is the stage when the 4-6 elongated internodes start to elongate. This often coincides with the tillering stage although the 1st and 2nd (topmost) internodes may continue to elongate past the maximum tillering stage.

5. Booting

Booting is the characteristic swelling or enlargement prior to flowering. It is preceeded by panicle initiation. In 130 - day maturing rice varieties it occurs 75 days after seeding and about 55 days prior to maturity. It is 20-25 days before flowering. The panicle is 1 millimeter in size at this stage.

6. Heading

This is the stage when the panicle emerges out of the flag sheath.

7. Flowering

This is the stage when the spikelets are opened. Flowering occurs about 35 days after the panicle initiation and about 25-35 days before harvesting.

8. Milk stage

This is the reproductive phase when the grains are just being filled with carbohydrates. The grains are very soft and on pressure a milk like fluid extrude from the grains. The milk stage is about 8-13 days after fertilization.

9. Dough Stage

The stage when the rice grains are filled but still soft to pressure and the lemma and palea are still green. It is about 14 - 21 days after anthesis or fertilization.

10. Mature grain

This is the stage when the grain is ripe. It takes about 30 days after fertilization. The palea and lemma changes from green to straw color. The grain moisture content varies from 18 - 22% at maturity during dry season.

Suggested reading materials

1. Benito S. Vergara 1979. A farmer's primer on growing rice. International Rice Research Institute, Box 933, Manila, Philippines - pp. 221.

2. International Rice Testing Program 1980. Standard evaluation system for rice. 2nd edition. The International Rice Research Institute, Box 933, Manila, Philippines -- Vii pp. 44.

WEEDS AND THEIR CONTROL IN WEST AFRICAN RICE ECOSYSTEMS

By

I. Okezie Akobundu
Weed Scientist
International Institute of Tropical Agriculture
P.M.B. 5320, Ibadan, Nigeria.

INTRODUCTION

Rice is grown in West Africa in a wide range of ecological situations, ranging from dryland (upland) through hydromorphic to shallow swamps and flood plains. Consequently, weed infestation is by many different species adapted to the specific ecology in which rice is grown. Weeds have for long been accepted in West Africa, as the natural consequence of land clearing and crop production. Since weeds do not appear to damage crops physically as many insects and diseases do, weed control measures (if used at all) have largely remained the old method of hand pulling at the farmer's convenience. Limited research information available on weed interference in rice production in West Africa show that yield loss caused by uncontrolled weed growth is high.

This paper reviews weeds of West African rice lands, their biology and methods of control that are applicable to farmers that may not have access to herbicides.

WEED BIOLOGY

Definition

A weed is a plant growing where it is not wanted, a plant out of place. Maize seedlings in a rice field are weeds, and vice versa.

Plants are also considered weeds when they interfere with the utilizations of land and water resources or otherwise intrude upon man's welfare. Some other plants are weeds because they are poisonous to man and/or livestock, or are obnoxious at all times.

Characteristics of weeds

Weeds have certain characteristics that make them undesirable and unsightly.

1. A tendency to grow in an undesired location.
2. Competitive and aggressive habits.
3. Wild and rank growth. Some weeds have rapid growth habit and tend to use the habitat more efficiently than rice and other crops e.g. Rottboellia exaltata, Euphorbia heterophylla and Eupatorium odoratum.
4. Persistent and resistant to control. Weeds that show these characteristics have diverse forms of propagules and strutural protection from control practices e.g. Cyperus esculentus, Cyperus rotundus and Commelina spp.
5. High reproductive capacity and consisting of large population. Many weeds that show these characteristics are annuals. They are often adapted to overcrowding. Examples are Tridax procumbens and Ageratum conyzoides.

Classification of weeds

In addition to the taxonomical classifications, rice weeds can be further classified based on life form, life span and habitat.

Classification based on life form

(a) Grass weeds: Members of this group are annuals and perennials and the leaves have parallel veins. At early vegetative stages they are characterized by a growing point that is protected by layers of leaf sheath. They are difficult to control at the early stages because many members look like rice seedlings. Common examples are *Digitaria horizontalis* Willd, *Setaria longiseta* P, *Echinochloa colona* L and *Rottboellia exaltata* L.

(b) Broadleaf weeds: These are dicotyledonous plants with leaves that are net-veined. Members of this group that are pests of rice include *Acanthospermum hispidum* DC, *Ageratum conyzoides*, *Sphenoclea zeylanica* Gaertn., *Eichhornia natans* and *Azolla* spp.

(c) Sedges: Weeds in this group resemble grasses but can be distinguished by the following characteristics: cross section of the stem is triangular and the leaves occur in three ranks. Underground stems of some members are modified storage rhizomes or tubers. Common examples are *Cyperus rotundus* L., *Cyperus difformis* L, *Kyllinga bulbosa* P. and *Mariscus* spp.

(d) Algae: These are aquatic and semi aquatic group of simple photosynthetic plants. They can be troublesome in paddy fields where the water is stagnant.

2. Classification based on life span

Weeds of West African rice lands can be classified into two groups on the basis of life span. These are annuals and perennials.

(a) Annuals: These are weeds that complete their life cycle in one growing season. They may be grasses, broadleaves or sedges. Annual weeds produce large quantities of seeds and have efficient methods of seed dispersal. Common examples include *Echinochloa colona*, *Brachiaria deflexa* and *Tridax procumbens*.

(b) Perennials: These weeds either require more than one growing season to complete their life cycle or tend to grow indefinitely. They are particularly adapted to fallow systems and generally have perennating structures e.g. tubers, rhizomes or stolons. Examples are *Cyperus rotundus*, *Oryza longistaminata* and *Cynodon dactylon*.

3. Classification based on habitat

Weeds are classified as aquatic or non-quatic depending on what moisture regime they have adapted themselves to. All aquatic weeds have in common, a preference for aquatic habitat. Aquatic weeds are further classified as:-

(a) Floating hydrophytes: Weeds that are in contact with water and air only e.g. water lettuce (*Pistia stratiotes* L.), and *Azolla* spp.

(b) Emergent (Emersed) hydrophytes: Aquatic weeds that are in contact with substrate, water and air e.g. white water lily (*Nymphaea ampla*), water spinach or aquatic morning-glory (*Ipomoea aquatica* and *Leersia hexandra*).

(c) Submerged (submersed) hydrophytes: These weeds root in the substrate or hydrosoil but do not emerge above the water e.g. Elodea (*Lagarosiphon spp.*)

4. Taxonomical classification

This is the classical binomial classification that groups angiosperms into monocotyledonous and dicotyledonous plants. Within each group the weeds are further separated into families, then into genera and species e.g. Family: Compositae, Genus: *Emilia*, Species: *sonchifolia*.

WEEDS OF MAJOR RICE ECOSYSTEMS IN WEST AFRICA

Weeds of upland rice

Weeds of upland rice are similar to those of other upland crops. Upland rice is grown in ecological zones from forest through savanna to mid-altitudes, the weed flora in these zones vary mainly in response to changes in rainfall and microclimatic conditions. The intensity of weed infestation and species richness are also modified by local soil conditions, land use system and cropping pattern and frequency. Thus, while Rottboellia exaltata may be the major weed limiting rice production in one area, Echinochloa colona may predominate in another region. Some weeds such as Rottboellia exaltata and Euphorbia spp. are problems because they germinate at approximately the same time as the rice crop and competes with the crop for nutrients, moisture or light. Other weeds are ephemeral annuals that are found in stands by maturing rice plants, as they germinate after the last hand-weeding. Such late weed infestation has little effect on crop yield but it interferes with crop harvesting and often harbours rodents. A list of common weeds of upland rice is given in Table 1. The major weeds of the humid regimn include Panicum maximum and Eupatorium odoratum.

Perenial weeds of drier cleared forest and derived savanna zones include Cyperus spp. and Imperata cylindrica. The perennating tubers and rhizomes of these weeds make them more difficult to control than the annual weeds.

Weeds of hydromorphic soils

Weed competition is more severe in hydromorphic soils (Fadamas, bolilands) than in upland rice conditions. In addition to the weeds discussed above, weeds adapted to water-logged conditions like Fimbrystylis spp., Echinochloa spp., Alternanthera spp.

and wild rice (Oryza spp.) are common problems of hydromorphic soils. At least three timely hand-weeding are necessary to minimize yield losses caused by weed competition. Mechanical method of interrow weeding is not applicable in these conditions because of high soil moisture conditions.

Weeds of lowland and deep water rice

Aquatic weeds predominate in this habitat. These weeds include sedges, grasses and broadleaves. A list of common aquatic weeds of lowland rice are given in Table 2. Aquatic weeds with wide distributions are Oryza longistaminata, Cyperus spp., Pycreus spp, Fimbristylis spp., Eleocharis spp., Scirpus spp., Echinochloa spp., Sphenoclea spp. and Leptochloa. They are difficult to control by cultural methods.

LOSSES CAUSED BY WEEDS IN RICE

One of the most labour requiring operation in rice production is weed control. Hand weeding in many rice areas in West Africa has been estimated to be 250 to 780 man-hours per hectare, depending on the ecosystem, frequency of weeding and environmental conditions during cropping. Poor land preparation at planting time is a major factor affecting the severity of weed infestation. In paddy rice, water management is another factor in weed control. Typical yield losses in rice are given in Table 3. In upland rice a heavy infestation of Rottboellia exaltata has been known to cause total crop loss. A yield reduction of up to 80% has been reported for weed flora in upland conditions. In direct-seeded lowland rice uncontrolled weed growth can cause yield loss of up to 70%. In transplanted lowland rice weed competition can be serious where there is intermittent supply of water.

Weeds also cause crop loss by serving as alternate hosts for several insects, nematodes and fungal diseases of rice plants. They also provide shelter for birds and rodents.

METHODS OF WEED CONTROL

Increased yields from use of improved varieties cannot generally be realized by farmers until weed control practices are improved. There are several methods for reducing weed related yield losses. The choice of method will in part depend on farm size, labour availability and the economics of operation. An integrated method of weed management is in most situations better than use of any one method of weed control.

1. Land preparation

There are two main objectives in land preparation. The first is to provide good physical conditions for the germination and subsequent growth of the rice. The second objective is to provide weed-free conditions at rice planting. In most rice growing conditions, several tillage operations are usually required to achieve a weed-free seedbed. Although a fine tilth favours seed germination, a rough seedbed is often needed in West Africa this reduces greatly the possibility of soil structural breakdown under highly erosive rains.

For lowland rice, proper land **levelling** is necessary to ensure a uniform water depth.

2. Hand-weeding (Hand pulling)

This is a practical and efficient method of eliminating weeds within the rows and hills of crops in which weeds will be difficult to reach with the hoe or other interrow weeders.

It is the best method of control for annuals and simple perennials. This weed control method usually requires that the farmer wait until the weeds are large enough so that they can be firmly held and pulled out. A disadvantage of this method is that the weed may have caused damage to the crop through competition by the time it gets to this stage.

In upland rice, two hoe weedings at 30 and 70 days after rice seeding are necessary to minimize yield reduction caused by weeds. This weeding frequency applies to most rice growing conditions except widely spaced hydromorphic rice where a third weeding is generally necessary. Another disadvantage of hand-weeding is that it is applicable to small farm sizes (less than one hectare). At early crop establishment some seedling weeds e.g. Echinochloa spp. and wild rice resemble seedling rice and could be mistaken for the seedlings of cultivated rice.

3. Hoe weeding

This is the most widely used method of weed control in West Africa. It is a faster operation than hand pulling of weeds. Like hand-pulling, it is most economical in small plots and in areas where labour is cheap and available when needed. There is also a risk of accidental crop damage. The effectiveness of hoe-weeding is reduced and frequency of weeding increased in high rainfall conditions or in hydromorphic soils because the weed is invariably removed with a ball-of-earth and may end up first transplanted from one location to another. Hoe weeding requires that rice be sown in lines and at interrow spacing (45 cm is popular with many West African farmers) that will permit easy maneuvering in the plots. It is a difficult method to use where broadcast seeding is practised.

4. Mechanical Interrrow weeding

This is a weed control method adapted to medium and large scale rice production. It is effective where weed infestation ranges from light to medium; and in locations where rainfall is moderate, soils are light and not water-logged. Interrow weeding does not control weeds within the row. These have to be removed by some other methods. Like hoe weeding, interrow cultivation is practicable only where the rice is sown in rows.

5. Water management

Many weeds cannot germinate in flooded paddies, therefore, flooding is used for weed control in lowland rice. Failure can occur where paddies are not level and land is exposed, or where water level is allowed to fall so that weed seeds germinate or regrowth occurs. Water depth of at least 10 cm when rice is at the seedling stage helps to control many annual weeds. In transplanted rice, maintaining water level throughout the crop season helps to control weeds.

6. Preventive weed control

This weed control method comprises all measures taken to prevent the introduction and spread of weeds. It is often the most practical method of weed control. Preventive weed control involves (a) making sure that weeds are not carried into an area along with contaminated seed, machinery and water; (b) preventing weeds in an area from going to seed, (c) preventing the spread of perennial weeds which reproduce vegetatively and (d) ensuring that weed-free rice seeds are used for planting.

7. Crop rotation

Each crop has its own characteristic weeds and by growing the same crop on the same piece of land every year, these weeds tend to increase in population. The possibility of a build up of a certain weed species is greatly reduced by rotating crops. The rotation should be planned such that no group of weed species has a chance for undisturbed development. In addition, the correct sequence of crops may result in an increased vigour of the different crops in the cycle. It is known that phosphate or nitrogen fertilizer applied either preplant or at the early stages of rice growth stimulates growth of grassy weeds. The same phosphate applied to the crop preceding the rice in a rotation benefits the rice and not the weeds.

Rotation of lowland rice with an upland crop (in the dry season) hs been shown to reduce the infestations of water tolerant weeds in the lowland rice crop and dryland weeds in the upland rice.

8. Chemical weed control

Herbicides are now widely used for weed control in rice. They are often the most practical, effective and economical means of reducing crop losses and production costs. In areas where rice is broadcast, chemical weed control is the only alternative, to hand or hoe weeding. Use of the right herbicide, applied at the right rate and time, with properly calibrated spray equipment and with the correct nozzle is essential for optimum control of weeds. Herbicides that have been reported to be effective in parts of West Africa are fluorodifen, thiobencarb, MCPA and oxadiazon when each of these is applied as a mixed formulation with propanil 10-21 days after seeding or transplanting. In lowland rice, chemical weed control is enhanced by good water management.

Among the limitations of chemical weed control are lack of knowledge of proper use of herbicides, lack of consumer useable packages (1-5 litre packages) and deep-seated and often wrong ideas about herbicide safety and cost. Increasing cost of labour and labour scarcity has made chemical weed control cheaper than other methods of weed control in many West African countries. The foreign exchange to import herbicides may be a disadvantage to chemical weed control in some West African countries.

9. Integrated weed management

No weed control method is ideal for solving weed problems in rice or any other crop. Integrated weed management involves the use of two or more methods of weed control at lower input levels than when one method is used alone. The use of a low herbicide rate in combination with good water control in lowland rice is an example of an integrated weed management system. In hydromorphic rice weeding frequency can be reduced by reducing interrow spacing from 45cm to 15cm. Rice yield in OS 6 and ITA 116 cultivars was similar in plots with 15cm interrow space where one weeding was done at 30 d.a.s. compared to plots weeded three times or maintained weed-free at the same interrow spacing. In 45cm row plots, at least three weedings were necessary to minimize rice yield loss.

CONCLUSION

One of the constraints to higher yield of West Africa rice is excessive weed growth. Both annual and perennial weeds are common. Although the farmer may attempt to control weeds, his timing is often wrong, mainly because of other labour demands during the appropriate weeding time.

It is necessary to improve the weed control practices of West African rice farmers in order for them to benefit from the use of other production inputs such as improved varieties, use of fertilizer, and improved land preparation techniques.

REFERENCES

Akobundu, I.O. and S. O. Fagade. 1980. Weed problems of African rice lands. In: Rice in Africa (Eds. Buddenhagen, I.W. & Persley, G. J.). pp. 181 - 192. Academic Press, London.

Akobundu, I. O. (Ed.) 1980. Weeds and their control in the Humid and Subhumid Tropics. IITA Proceeding Series No.3. IITA, Ibadan. 421 p.

De Datta, S.K. 1978. Weed control and soil crop management in rainfed rice at IRRI and other locations in tropical Asia. In: Rice in Africa (Eds. Buddenhagen, I.W. & Persley, G. J.) pp. 201 - 211. Academic Press, London.

Smith, R.J., Jnr. and Shaw, W.C. 1966. Weeds and their control in rice production. U.S. Dept., of Agr. Handbook No.292.

Williams, A. 1970. Progress in weed control projects in rice. Proc. Ann. Weed Sci. Soc., Nigeria 5: 89 - 112.

Table 1: Common weeds of African dryland rice ecosystems

AMARANTHACEAE	Alternanthera sessilis (L.) R. Br. ex Roth
	Amaranghus hybridus L
	A. spinosus L.
	A. viridis L.
	Celosia spp.
COMMELINACEAE	Commelina benghalensis L.
	C. erecta L.
	C. diffusa Burm. f.
COMPOSITAE	Acanthospermum hispidum DC
	Ageratum conyzoides L.
	Aspilia spp.
	Bidens pilosa L.
	Chrysenthellum americanum (L.) Vatke.
	Emilia spp.
	Synedrella nodiflora Gaert.
	Tridax procumbens L.
CONVOLVULACEAE	Ipomoea spp.
CYPERACEAE	Cyperus esculentus L.
	C. rotundus L.
	C. sphacelatus Rottb.
	C. tuberosus Rottb.
	Mariscus spp.
	Fimbrystylis spp.
EUPHORBIACEAE	Acalypha ciliata Forsk.
	Croton lobatus L.
	Euphorbia heterophylla L.
	Phyllantus amarus Schum. & Thonn
GRAMINEAE	Brachiaria spp.
	Chloris pilosa (L.) Schum.
	Eleusine indica (L.) Gaert.
	Digitaria spp.
	Dactyloctenium aegyptium (L.) Beav.
	Imperata cylindrica (L.) Beav. var. africana (Anderss.) C.E. Hubbard
	Panicum maximum Jacq.
	Paspalum orbiculare Forst.
	Rottboellia exaltata L.
	Setaria spp.
	Pennisetum spp.
	Cynodon dactylon (L.) Pegs.

Table 1 (cont'd.)

LOGANIACEAE	Spigelia anthelmia L.
MALVACEAE	Hibiscus spp.
	Sida spp.
NYCTAGINACEAE	Boerhavia diffusa L.
PAPILIONACEAE	Desmodium spp.
	Indigofera spp.
PORTULACACEAE	Portulaca oleracea L.
	P. quadrifida L.
	Talinum spp.
RUBIACEAE	Borreria spp.
	Oldenlandia spp.
SOLANACEAE	Physalis spp.
	Solanum nigrum L.
TILIACEAE	Corchorus spp.
	Triumfetta cordifolia A. Rich.
VERBENACEAE	Stachytarpheta spp.
URTICACEAE	Fleurya spp.

Table 2. Common weed of African lowland rice ecosystems

AMARANTHACEAE	Alternanthera spp.
COMMELINACEAE	Commelina spp.
CYPERACEAE	Cyperus difformis L.
	C. distans L.f.
	C. haspan L.
	C. sphacelatus Rottb.
	Fimbrystylis spp.
3	Kyllinga spp.
	Mariscus spp.
	Pycreus spp.
GRAMINEAE	Brachiaria spp.
	Cynodon dactylon (L.) Pegs.
	Echinochloa colonum (L.) Link
	E. crus-pavonis Schult.
	E. pyramidalis (Lam.) Hitch & Chase
	Ischaemum rugosum Salisb.
	Leptochloa caerulescens Steud.
	Oryza breviligulata A. Chev. & Roehr
	O. longistaminata A. Chev. & Roehr
	O. punctata Kotschy ex Steud.
	Paspalum spp.
	Sacciolepsis spp.
ONAGRACEAE	Ludwigia spp.
PONTEDERIACEAE	Heteranthera callifolia Rchb. ex Kunth
POLYGONACEAE	Polygonum spp.
RUBIACEAE	Pentodon pentandrus (Schum. & Thonn) Vatke
SALVINIACEAE	Salvinia spp.
SPHENOCLEACEAE	Spenoclea zeylanica Gaert.

INTEGRATED WEED MANAGEMENT IN RICE IN WEST AFRICA

By
WILFRIED GODDERIS
WARDA, Monrovia -

Integrated weed management combines cultural, biological and chemical weed control methods to keep the weed populations at an acceptable economic level i.e. at a level where the cost of weed control is lower than the value of the crop yield increase this increase being the result of the weed control. No single weed control method gives continuous and effective weed control, so farmers use several methods simultaneously.

In the absence of efficient weed control other inputs such as high-yielding disease and insect resistant varieties, fertilizers, water control, etc. will be useless (Dadey,1973). An economic study has shown that in the case of upland rice in Ivory Coast more than 50% of the yield variation can be explained by the labour input for weeding (Lang,1979).

1. WEEDS AS PESTS

1. A weed is a plant growing where it is not desired.

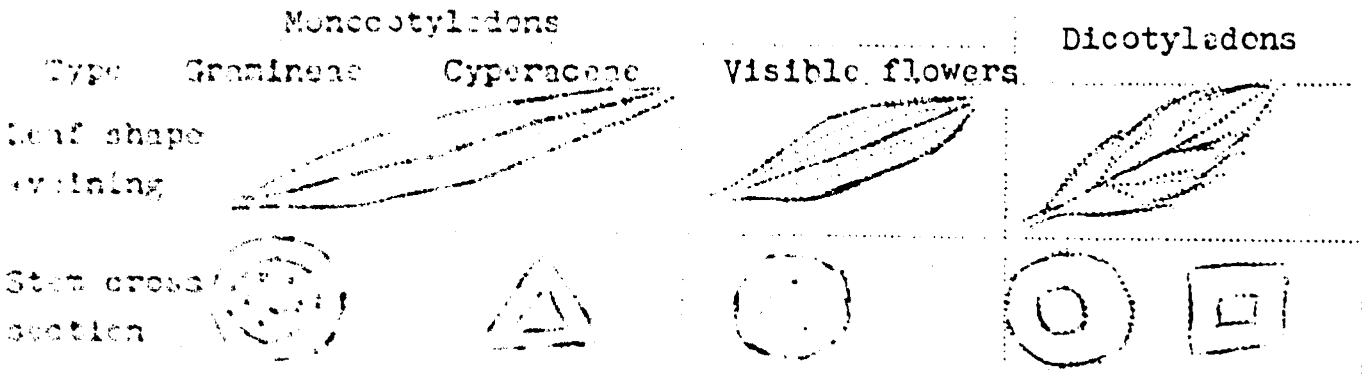
For non-weed scientists a weed is merely any uncultivated plant. However, most wild plants are not weeds because they do not occur with crops but serve various functions in nature. Fewer than 1,000 plants are said to behave as weeds in agriculture and only 250 of these are important for world agriculture (Holm et al.,1979). In my opinion only about 50 weeds are serious for rice cultivation in West Africa.

2. Characteristics of the main weed groups in West Africa.

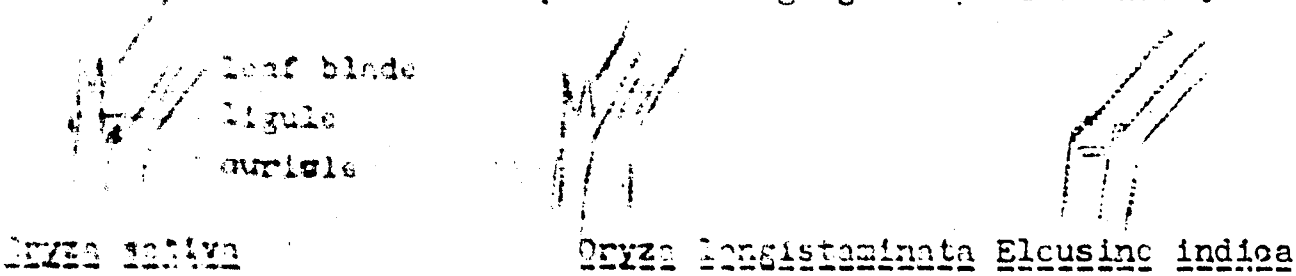
For non-botanists the following books can be recommended :

- Ivens, G.W., Moody, K. & Egunjobi, J.K., 1978. West African Weeds, Oxford University Press, Ibadan, Nigeria.
- Berhaut, J., 1967. Flore du Sénégal, Editions Clairafrique, Sénégal.

a. Differences between dicotyledons and monocotyledons, between Cyperaceae and Gramineae.



b. Differences between *Oryza sativa*, *Oryza longistaminata* and another species belonging to the Gramineae.



3. The most serious weeds in West African rice fields.

The following weeds have been selected out of 316 different weed species found in West African rice fields (Geddaris, W., 19[illegible])

a. Annuals

In upland rice: Dicotyledons: Ageratum conyzoides, Synedrella nodiflora, Phyllanthus amarus, Portulaca oleracea, Borreria verticillata, Oldenlandia corymbosa, Corchorus olitorius.

Monocotyledons: (with visible flowers:) Commelina benghalensis, Commelina erecta; (Gramineae) Dactyloctenium aegyptium, Digitaria horizontalis, Echinochloa pyramidalis, Eleusine indica, Pennisetum subangustum, Rottboelia exaltata; (Cyperaceae:) Mariscus alternifolius.

In lowland rice: Dicotyledons: Alternanthera sessilis, Eclipta prostrata, Jussiaea linifolia, Sphenoclea zeylanica, Commelina diffusa;

Monocotyledons: (Gramineae); Echinochloa colona, Eragrostis gangetica, Ischaemum rugosum, Oryza barthii, Panicum laxum; (Cyperaceae:) Cyperus difformis.

b. Perennials:

In upland rice: Dicotyledons: Sida acuta, Sida rhombifolia, Crotalaria hyssopifolia, Talinum triangulare, Striga hermontheca; Monocotyledons: (Gramineae:) Chloris pilosa, Cynodon dactylon, Imperata cylindrica, Paspalum orbiculare, Sporobolus pyramidalis; (Cyperaceae:) Cyperus esculentus, Cyperus rotundus.

In lowland rice: Dicotyledones: Ipomoea aquatica; Monocotyledones: (Gramineae:) Oryza longistaminata, Panicum repens, Paspalum conjugatum, Paspalum vaginatum. (Cyperaceae:) Cyperus distans, Cyperus sphacelatus, Cyperus tuberosus Eleocharis acutangularis, Fimbrystilis dichotoma, Fymbrystilis littoralis, Kyllinga pumila.

4. Means of multiplication

a. Annuals and biennals are generally propagated by seed. They grow rapidly after the first rains and should be destroyed in their early growth stages. Once the top of the flower is killed, the weed dies without any means of propagation.

e.g. - 1 Amaranthus may produce about 100,000 seeds
- Cyperus iria and Cyperus difformis flower in about a month.
- Some Commelinaceae produce new shoots from the nodes and are therefore difficult to control.

b. Perennials, having a life cycle of more than 2 years, are difficult to control. They may possess:- rhizomes (underground stems):- e.g. Paspalum vaginatum, Oryza longistaminata, Cyperus rotundus and other perennials produce buds on their rhizomes and thus new plants. The rhizomes should therefore be removed by e.g. spring tines and offset disc harrows and not be cut by e.g. plows. If the rhizomes are cut, the buds produce new plants.

- dormant seeds: e.g. Echinochloa crus-galli may produce about 7,000 seeds, which can remain dormant for 40 to 70 years in the soil. Herbicides are mostly ineffective against dormant seeds. Pre-irrigations, cultural practices and favourable conditions may break the dormancy of the seeds of e.g. Oryza longistaminata.

- bulbs (swollen underground buds acting as food storage): e.g. Cyperus bulbosus has bulbs. So the top growth has to be repeatedly destroyed to deplete the bulb.

- Tubers (swollen underground stems or roots acting as food storage): e.g. Cyperus esculentus and Cyperus rotundus possess tubers.

- Culmnodes that produce roots and axillary buds: e.g. Oryza longistaminata.

5. Rice yield reduction.

a. Crop-weed competition.

Weeds may compete with rice for water, sunlight, nutrients and space.

- In upland rice cultivation weeds with numerous and deep roots may extract water from the same soil layer as the rice plant. C_4 plants having a crassulacean acid metabolism, such as Echinochloa, Imperata cylindrica, Panicum repens, Cyperus rotundus require less water and utilize it better than C_3 plants such as rice and are therefore very competitive.

- Tall weeds such as Echinochloa pyramidalis, Pennisetum subangustum and Rottboelia exaltata may overshadow short and intermediate statured cultivars. Cyperus difformis grows so rapidly that it may overshadow lowland rice seedlings in 3 to 4 weeks time after sowing or transplanting rice.

- The higher the soil fertility, the higher the weed infestation will be if no particular weed control method is applied.

b. Weeds as hosts for insects and diseases.

The following common insects and diseases in rice cultivation in West Africa are found in West African weeds (Moody, 1973) Chilo in Echinochloa stagnina, Oryza barthii and Pennisetum purpureum; Sesamia in Pennisetum purpureum; Maliarpha separatella in Oryza barthii; Pachydiplosis in Oryza barthii. Blast, stemrot and tungro in Eleusine indica; hoja blanca in Eleusine indica and Echinochloa colona. Nematodes in Portulaca oleracea, Paspalum orbiculare and Mariscus alternifolius.

c. Allelopathy.

Setaria and Rottboelia exalata may exude growth inhibitors from their roots that suppress the growth of rice.

d. Increased costs

Weeds increase the costs in rice cultivation in many ways; e.g. for land clearing, the different weed control treatments, cleaning of the irrigations systems, cleaning of the rice grains, hampering the harvest efficiency and most of all by reducing the potential crop yield.

II. CULTURAL WEED CONTROL METHODS

First, it is essential to weed for the first time not later and not much earlier than 3 weeks after sowing or transplanting, because; 1. the potential rice yield decreases most during the early growth stages of rice when weeds, reaching the 3 leaf stage, start competing seriously (Moody 1973); and 2. time requirements increase rapidly if weeding is delayed (DeDatta, 1979). The shorter rice varieties can tolerate weeds for 3 weeks, the taller, leafier varieties for 4 weeks (Moody, 1979). In Sierra Leone, in 1971, there was an almost total yield loss on a 25 ha upland rice farm due to a 3-week delay in weeding (Moody, 1974).

Secondly, it is equally important that on small-sized farms rice is sown or transplanted in rows and that sharp, long-handled hoes are used for weeding. Three persons working 8 hours a day can hoe-weed 1 hectare in about 7 days (FAO, 1976).

If the time requirements are compared:

a. for planting + handweeding:
 -- broadcasting: 5 + 1150 = 1155 manhours/ha
 -- seeding in pre-marked rows: 80 + 321 = 401 man-h/ha
 -- dibbling : 77 + 380 = 457 man-h/ha
 -- transplanting : 140 + 340 man-h/ha.

b. 1 hoe-weeding: 160 man-h/ha; 2 hoe-weedings (3 + 6 weeks after planting) = 252 man-h/ha.
 1 handweeding: 330 man-h/ha; 2 handweedings (,,): 471 man-h/ha it becomes clear that extension officers should convince the farmers of row-sowing and proper and timely hoe-weeding.

The yield of upland rice cultivation, which accounts for 62.5% of the total rice cultivated area in West Africa (WARDA 1980b) could be increased by 60% by seed dibbling, timely weeding, and top dressing of 40 kg N/ha (WARDA, 1981a). By timely weeding is meant: the 1st weeding 3 weeks after dibbling and the second weeding 1 month later.

Indirect Methods

1. Land preparation:

Zero tillage requires a non-residual pre-plant herbicide such as glyphosate at 1.4 to 4 kg a.i./ha to dessicate the fallow vegetation. The crop is planted with a minimum disturbance of the soil. Subsequently a pre-emergence herbicide such as Stam F-34 can be used to destroy weeds. However, after some years perennial weeds become such a problem that conventional tillage has to be used again (Akobundu, 1979).

Start land preparation soon after the harvest of the first crop to reduce the period when the weeds grow undisturbed. The rice fields should only be plowed on a very dry soil in upland rice to have the rhizomes of perennials dry out in the sun, and only after pre-irrigation in lowland rice to break the dormancy of weed seeds. Only plowing by tractors of at least 60 hp can turn up the upper soil layer to a depth of 25 to 30 cm to expose the rhizomes of wild rice (FAO, 1976). Destroy germinated weeds in upland rice by harrowing, which should take place shortly before sowing, and in lowland rice by puddling, passes of an offset disc harrow or of a tractor with cage wheels. In lowland rice cultivation levelling of the field should be the last land preparation operation.

2. Preventive weed control

Preventive measures include the use of uncontaminated seed (particularly to avoid the spreading of red rice), the eradication of weeds around the rice fields during the off-season (fire is not very effective because only a small part of the weed seeds are killed. It further encourages growth of certain weeds e.g. Imperata cylindrica), proper composting of manure (i.e. well made compost produces sufficient heat to kill weed seeds).

3. Crop competition

Provide favourable conditions for rice and unfavourable conditions for weeds.

a. Planting:

- Straight row planting makes weeding faster and more efficient.
- Dibbling in upland rice facilitates weeding
- Transplanting in lowland rice is the best planting method because it gives rice a headstart, a competitive advantage at transplanting time over

weeds in a "weed free" seed bed. Since transplanting requires about 45 mandays/ha and thus limits the size of the field to less than a hectare for a small family, direct row seeding of pregerminated rice has to be done in larger fields (FAO, 1976).

b. Cultivars: 120 to 130 cm tall, droopy-leaf, moderate to heavy tillering cultivars such as LAC 23 in Liberia provide better weed competition than semi-dwarf, low tillering varieties under upland farm conditions. On the other hand, in lowland rice cultivation tall cultivars lodge more and yield less than semi-dwarfs. Early maturing cultivars require an earlier second weeding (i.e. before the grains begin to fill) than later maturing. Some early maturing cultivars may be harvested before red rice produces viable seeds.

c. Plant density: Spacing closer than 20 x 20 cm may mean higher crop competition and thus fewer weeds but it may also mean higher insect and disease infestation. If spacing exceeds 30 x 30 cm weeds will infest the rice fields. If, however, in the case of proper spacing rice seeds do not germinate sufficiently, tillers can be taken from well established rice plants to replace the missing rice plants (Dobelman, 1976).

d. Fertilizer applications: Fertilizer applications should be made after weeding so that they are most beneficial to the crop and the least to the weeds. If not, fertilizers such as nitrogen and phosphorus stimulate weed growth as well as rice growth. On small holder upland rice farms it can be more profitable to apply mulch from Leucaena glauca than nitrogen from urea or sulphate of ammonium (WARDA 1981). On lowland farms incorporation of Azolla pinnata may increase yield by about 20% (Lumpkin 1980).

4. Water Management

a. Upland rice cultivation: Plowing mulch into the soil may help to conserve moisture, which stimulates both rice and weed seed germination. If moist compost or mulch is timely applied in rows to the dry ricefield, the rice seeds sown in these rows will germinate, whereas the weed seeds in the unfavourable zones will fail to germinate. Live mulch, according to a study at IITA (Akobundu, 1980), also minimizes weeding and fertilizer applications.

b. Lowland rice: Submerging rice fields to 2.5 cm will reduce Gramineae, whereas submerging them to 15 cm from 4 days after transplanting to the late dough stage will suppress Gramineae (such as red rice) and Cyperaceae (De Datta, 1979).

5. Cropping system

a. Crop rotation: Each crop has its characteristic weeds. So by rotating crops, the building-up of certain weeds is reduced. In upland rice cultivation effective smother crops such as sweet potatoes, sorghum, maize may be grown during the dry off-season. Nodulated legumes used in crop rotation may add nitrogen to the soil: Peanuts (72 to 124 kg nitrogen/ha), soybean (1-168 kg N/ha), Stylosanthes (34-220 kg N/ha), cowpeas (73 - 354 kg N/ha), Centrosema (126 - 395 kg N/ha), Leucaena (74 to 584 kg N/ha) (Nutman, 1976). In lowland rice cultivation rotation with an upland crop may result in reduced infestations of water tolerant weeds (e.g. red rice).

b. Mixed cropping, when broadcast, makes weeding very difficult and inefficient.

c. Intercropping: Attempts to control weeds by interrow cultivation have failed both in Ivory Coast and Nigeria, because the penetration of light after the harvest of the first crop stimulates weed growth (Moody, 1974).

Direct methods

1. Hand and hoe-weeding:

Both methods are very effective, if carried out properly and on time (i.e. 3 weeks after sowing or transplanting and a second weeding 1 month later) for farms up to 1 ha.

If farmers wait until the weeds have reached a certain height i.e. the 4 or more leaf-stage because it is easier to pull these weeds out, the rice plants will never recover from this initial setback. Manual weeding is very effective on all young weeds, even young perennials, but ineffective against annual wild rice and older perennials.

Two hand-or hoe-weedings are very time consuming: 471 man-h/ha and 252 man-h/ha respectively (FAO, 1976). Any delay further increases time requirements (De Datta, 1979).

One weeding may suffice in lowland rice cultivation with good water management, 2 are necessary in upland rice and even a third one is required in hydromorphic rice.

a. Handweeding: In upland rice the weeds should be uprooted and dried out in the sun or made into compost. In lowland rice the weeds may be either trampled into the soil, where they add organic matter, or uprooted, removed from the field and made into compost, which is more effective.

b. Hoe-weeding: Hoe-weeding is one of the cheapest and most effective means of weeding and twice as fast as handweeding (FAO, 1976). Therefore more research is needed on the most efficient types of handhoe in West Africa.

2. Mechanical weeding:

Mechanical weeding is necesary in the case of 1 to 4 ha per family or in medium to big-sized farms. It always requires straight planting.

In upland rice cultivation powered rotary weeding with a hand tractor is the most effective of all mechanical methods, according to a study carried out in Nigeria Curfs, 1974). It is fast, about 35 hr/ha over 1 crop for 3 weedings (FAO, 1976). In the Gambia pedestrian tractors are used for weeding with modest success but maintenance of these machines often poses problems (Terry, 1981). In Ghana 1 man needs 15 to 20 days to weed 1 hectare with a handhoe, whereas he can do the weeding with donkey drawn cultivator in 2 days and needs a few more days for the complementary hoeweeding between the rows (Korem, 1978). However, animal traction is not possible in many parts of West Africa, particularly in the wet regions, because of diseases and undernourishment.

In lowland rice cultivation special care has to be taken to have well adaptedmachines e.g. with cage wheels so as not to clog the soil. A lot of research is still needed. According to one study (FAO, 1976) both animal traction and the Japanese type of rotary weeder did not seem promising in Senegal. Moreover, mechanical weeding operations must be repeated a number of times to control wild rice. Land preparation and weed control under mangrove conditions have successfully been carried out by a single axle power tiller in Rokupr, Sierra Leone.

IIII. BIOLOGICAL WEED CONTROL

This method uses living organisms to control pests.

1. Tall, droopy-leaf, moderate to heavy-tillering cultivars compete well with weeds under upland conditions.

2. Some other crops such as peanuts, soybeans, Stylosanthes, etc., compete well with weeds during the off-season and add nitrogen to the soil (Nutman 1976). They can be used as organic manure after the harvest.

3. Bush fallowing in the forest zones suppresses perenial grasses but is becoming an expensive control measure (Akobundu, 1980).

4. Catch and trap crops against Striga hermontheca (Del.) Benth. (Korem, 1978).

Striga is a parasitic weed of rice in some parts of West Africa. Catch crops such as Guinea corn, maize, millet stimulate the germination of Striga seeds. Before the Striga weed can produce seed i.e. 90 to 120 days after planting the crop, the farmer cuts the catch crop to feed the cattle and plows only the stubble with the Striga plants down.

Trap crops such as soybean, sunflower, castorbean, cotton, wild sorghum and cowpeas, which are not parasitized by Striga, stimulate its germination but not its maturing and flowering. Therefore it is not necessary to plow trap crops down.

5. Animals

After the harvest of the rice crop sheep, goats and wild life should be encouraged to feed on weeds such as red rice. During the off-season fish can be introduced into the irrigation canals to control algae and other aquatic weeds.

6. Insects

Attempts to control _Eupatorium odoratum_ by means of the insect _Emalo insulta_ have failed in Nigeria (Kumar, 1982).

IV. CHEMICAL WEED CONTROL

Because of the many constraints, rapid adoption of herbicides by small farm holders in West Africa is not likely. Properly trained extension officers, low volume sprayers and small herbicide packages are needed.

In applying herbicides, one must take into account:

1. The herbicide action:

- Contact herbicides kill on or near the point of application, whereas systemic herbicides kill plant tissues some distance from the point of application.

- Selective herbicides damage certain plants without causing damage to others, whereas non-selective herbicides destroy all vegetation.
- Persistent herbicides still cause damage to plants long after their application, whereas non-persistent herbicides do not remain toxic for a long time.

2. Timing of application:

Some herbicides are applied before planting, a second group before emergence of the crop and/or weeds, and a third group after emergence of the crop and/or weeds.

3. Factors influencing the herbicide action:
- Weeds should not have passed the 3 leaf stage.
- The best time to spray is early in the morning (because the dew reduces losses of spray) of a sunny day (because fair weather opens the stomata of the weed leaves),

when there is no strong wind (so that the herbicides do not drift) and no rains are expected (because they would wash foliar contact herbicides off the leaves). The soil should be left undisturbed in the case of systemic soil herbicides, because their effect would be reduced.

4. The weed **specificities:**

a. Selective herbicides against annual weeds:

- Young Dicotyledons: Propanil)Stam F-34, Rogue, Chem. Rice, Surcopur), Fluorodifen (Preforan), 2, 4 - D (Weedone, Hedonal), MCPA, 2 4, 5 TP (against woody plants) Herbazol (Agerzol 1000), Oxadiazon (Ronstar), Butralin.

- Young Gramineae: Propanil, Fluorodifen, Butachlor (Machete), Nitrogen (Tok), Avirosan, Benthiocarb (Saturn), Molinate (Ordram, against Echinochloa), Tribunial, SB 3153.

- Young Cyperaceae: Bentazone, 2,4D, MCPA, Nitrogen, Avirosan.

b. Non-selective herbicides against serious perennials:

Paraquat (Gramaxone, against weeds up to 15cm), Dalapon (against wild rice too), Glyphosate (against wild rice and many Cyperaceae), Molinate (Ordram, Goal, Anitrole, Diuron.

c. Herbicide mixtures:

- Propanil (foliar contact, selective, non-persistent graminicide, post-emergence application)+ MCPA = Stam Super A; + Benthiocarb (persistent, pre-emergence) = Tamariz; + Molinate (pre-emergence); + Butachlor (pre-emergence, against Dicotyledons); + Tribunil.

[illegible], selective, post-emergence [illegible] effective against [illegible] and [illegible] + [illegible] ([illegible]) = [illegible] PL 2; + [illegible]) = [illegible]; + [illegible] ([illegible]) = [illegible]; + 3,4,5 TP = [illegible] + [illegible] = [illegible].

[illegible] in the [illegible] region [illegible].

[illegible], [illegible] season 1980:

[illegible] generally superior but [illegible], at [illegible] F 34 and [illegible] 3 EC [illegible] at [illegible] (The Gambia), [illegible], [illegible] (Ivory Coast), [illegible], [illegible] and [illegible] (Togo).

[illegible], [illegible] season 1980:

[illegible] of [illegible] as well as weed [illegible]. [illegible] F34 at [illegible] [illegible], [illegible] Super A at Richard [illegible] super) at [illegible], [illegible] Bissau) and [illegible], [illegible] at [illegible] (Liberia) [illegible].

[illegible] ([illegible]): [illegible] A.

7. [illegible] WEED CONTROL

[illegible] in the [illegible] in West Africa, [illegible] findings in Asia is [illegible].

1. In upland rice cultivation.

In short, intermediate and tall-statured rice cultivars 2 rotovations following 1 plowing decrease weed weight most. Two handweedings and 30 kg N/ha increase rice yield by 100% over no N. One herbicide weeding followed by 1 handweeding equals 2 handweedings and is far superior to 1 single herbicide weeding.

2. In lowland rice cultivation.

IR 36 with its spreading canopy competes more effectively with weeds at 2.5 and 5 cm water depth than IR 3 with erect leaves at the same water depths. When pre-plant herbicide treatment is followed by a tillage operation, weed control is satisfactory. Herbicide treatment followed by 1 handweeding equals 2 handweedings. When fertilizers and weed control are applied together, significantly higher rice yields are obtained than when they are applied singly.

VI. ECONOMICS OF WEED CONTROL

1. A case study of weed control trials carried out at Marovoay (Madagascar) in 1971 and 1972 (Dobelman, 1976) gave the following results:

	Chemical weed control	Manual weed control
	8 liters Stam + 2 liters 2,4 D and complementary handweeding	Two handweedings
Yield	3, 762 kg/ha	4,330 kg/ha
Time requirements	133 h/ha	286 h/ha
Production costs	9 090 F MG	8, 580 F MG

Manual weed control yields more and is cheaper, but takes twice as much time as chemical weed control.

2. Overall situation in the WARDA region:

Based on the 1981 Rice Statistic Yearbook of WARDA (1981b) and assuming a modest loss of 15% (Parker et al, 1975) in paddy weight of the 1979 production of 2,668, 100 metric tons in the WARDA region, losses due to weed infestation would account for 400,215 metric tons of paddy, valued at US$114,061,275 (The weighted average 1979 price received by farmers being 28.5 cents per kilogram of paddy). This wastage is a little under 20% of the costs of the 1979 rice imports of the WARDA region (paddy equivalent 1,326,300 = 2,000,545 x 0.285 = US$572,720,454 and average milling ratio = 0.66). This loss is also equivalent to 9% of the 1979 rice consumption of the WARDA region (the paddy equivalent 2,948,500 = 4,467,424 metric tons of paddy). This loss also represents the consumption of about 13 million persons, assuming the WARDA per capita consumption of 20.3 kg in 1979. (400,215,000 kg of paddy converted to rice: 400,215,000 x 0.66 = 264,141,900.

$$\frac{264,141,900}{20.3} = 13,011,916 \text{ persons})$$

SELECTED REFERENCES

1. Akobundu, I.O., 1979. Weed Control in Nigeria, p. 287-289. In: Tropical Pest Mangement 25(3), Centre for Overses Pest Research, London W 85 SJ, England.

2. Akobundu, I.O., 1980. Live mulch: a new approach to weed control and crop protection in the tropics. In: Proceedings of the British Crop Protection Conference - Weeds.

3. Curfs, H.P.F., 1974. Soil preparation and weed control for upland and irrigated rice growing, pp. 79-86. In: Expert Consultation on the Mechanization of Rice Products, IITA, Ibadan, Nigeria.

4. Dadey, C.A. 1973. Plant Protection for the Rice Crop. In: Plant Protection for the Rice Crop, Seminar, WARDA, Monrovia, Liberia.

5. De Datta, S.K. 1979. Weed problems and methods of control in tropical rice, p. 9-44. In: Weed Control in Tropical Crops, Ed. Moody, K., W.S.S.P., Phillipines.

6. Dobelman, J.P., 1976.. Riziculture pratique - riz irrigué, Presse Universitaire de France, Paris, France.

7. F.A.O., 1976. Mechanization of Rice Production, India - Nigeria - Senegal, University of Wageningen, The Netherlands and F.A.O., Rome, Italy.

8. Godderis, W. 1981. List of Weeds in West African Rice Fields, WARDA, Monrovia, Liberia.

9. Holm, LeR., Pancho, J.V., Herberger, J.P. & Plucknett, D.L., 1979 A Geographical Atlas of World Weeds, Wiley Interscience, New York, U.S.A.

10. Korem, P., 1978. Weeds and Their Preventive Mechanical, Cultural and Biological Control. In: Weed Control in Northern Ghana Ghanaian-German Agricultural Development Project, Tamale, Ghana.

11. Kumah, R. 1982. Status of Crop Protection in West Africa. In: Course on Concepts, Techniques and Application of Integrated Pest Management in Rice in West Africa, WARDA, Monrovia, Liberia.

12. Lang, H., 1979. The Economics of Rainfed Rice Cultivation in West Africa. In: Socio-Economic Studies on Rural Development, Ed., Prof. Kuhnen, F., Saarbrucken, Germany.

13. Lumpkin, T.A. & Plucknett, D.L., 1980. Economic Botany, 34 (2), Azolla: Botany, Physiology and use as Green Manure, New York Botanical Garden, Bronx, New York, USA.

14. Moody, K., 1973. Weed Control in Rice , IITA, Ibadan, Nigeria.

15. Moody, K., 1974. Weed Control System for Upland Rice Production, pp. 71-77. In: Report on the Expert Consultation on the Mechanization of Rice Production, 10-14 June, 1974, IITA, Ibadan, Nigeria.

16. Nutman, T.S., 1976. IBP Field Experiments on Nitrogen Fixation by Nodulated Legumes. pp. 211-237. In: Symbiotic Nitrogen Fixation in Plants, Ed. Nutman, T.S., Cambridge University Press, Cambridge, England.

17. Parker, C. & Fryer, J.D. 1975. Weed Control Problems Causing Major Reduction in World Food Supplies. In: FAO Plant Protection Bulletin, Vol. 23, No. 3/4, Rome, Italy.

18. Terry, P.J. 1981. Weeds and Their Control in the Gambia, pp. 44 - 52. In: Tropical Pest Management 27(1), Centre for Overseas Pest Research, London, England.

19. WARDA, 1980a. Coordinated Weed Control Trials - Main Season 1980. In Annual Research Report 1981, WARDA, Monrovia, Liberia.

20. WARDA, 1980b. Prospects of Self-sufficiency in Rice in West Africa, WARDA, Monrovia, Liberia.

21. WARDA, 1981a. Final Report of Workshop on WARDA Upland Rice Research Policy, May 13 - 15, 1981, WARDA, Monrovia, Liberia.

22. WARDA, 1981b. Rice Statistics Yearbook, Abstracts, WARDA, Monrovia, Liberia.

PRINCIPLES OF INTEGRATED PEST MANAGEMENT

By

Dale G. Bottrell
University of California, Berkeley
Consortium for International Crop Protection
2288 Fulton Street, Suite 310
Berkeley, California 94704, USA

WHAT IS IPM?

Experience with many crops in many parts of the world has shown that yield increases and yield stability are more likely if the burden of crop pest protection is systematically spread over a combination of biological, genetic, physical, and chemical control techniques rather than a single technique. The term integrated pest management—or IPM—has been used to describe this approach. Discussions of the origins of IPM and its status in various parts of the world are covered in other papers of this training course (refer to Origins of Integrated Pest Management, and Integrated Pest Management in a Global Perspective: Progress and Problems, by Dale G. Bottrell).

Integrated pest management (also known as "integrated pest control") utilizes all suitable techniques either to reduce pest populations and maintain them at levels below those causing economic injury or to so manipulate the populations that they are prevented from causing such injury (Smith and van den Bosch, 1967). The techniques are harmonized in an organized way after the ecology of the pests are known and the cost effectiveness and environmental suitability of the control measure have been determined.

Use of crop varieties possessing 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, but they are employed only as required to reduce and maintain pests at tolerable levels based on economic and ecological criteria developed to show when and where control is truly justified.

The objective of IPM is to control pests in an economically efficient and ecologically sound manner. By using pesticides selectively and judiciously, IPM strives to prevent needless insult to the environment and human health. For both traditional and modern rice farmers, IPM promises to reduce pest losses to their crops on a continuing basis and at the lowest cost.

GENERAL PRINCIPLES

There is considerable disagreement about what constitutes integrated pest management. It has become a convenient term sometimes used erroneously to describe any combination of measures for control of pest— even the isolated use of two different pesticides without an analysis of need or consideration of alternative measures. But the meaning of IPM is distinctly different.

Various authors have attempted to delineate IPM from other approaches, for example, Huffaker (1972), van den Bosch and Messenger (1973), Bottrell (1979), Barfield and Stimac (1980), Smith (1980), and Flint and van den Bosch (1981). From these efforts, five general principles can be recognized and are used here to characterize the IPM strategy:

1. <u>The potentially harmful species will continue to exist at tolerable levels</u>

In integrated pest management, it is assumed that every pest species in a cropping ecosystem—insects, diseases, weeds, rodents, and other pests—has a population level below which there is no economic injury. Though each of the species is potentially harmful, and remedial actions may be required to maintain the pests at noninjurious levels, IPM does not advocate eradication of the pests. Integrated pest management rejects the notion that the mere presence of the pest species necessarily justifies action for control.

Integrated pest management assumes, in fact, that low-level infestations of some pests in the cropping systems may be desirable. It is well-known that non-injurious levels of some agricultural insects and mites, for example, may provide important sources of food or reproductive hosts for natural enemies—predators, parasites, and pest diseases. Complete annihilation of these pest organisms may starve the beneficial species or force them to leave the cropping system and, therefore, produce harmful side effects.

A requisite to any IPM program is to discern the "real" pests in the cropping system from those that may be perceived as real pests but actually are not. The population level that determines whether a reputedly harmful species has attained real pest status is the "economic threshold" (refer to the training course papers of Patricia C. Matteson, Crop Loss Assessment, Economic Injury Levels, and Economic Thresholds, and Dale G. Bottrell, Establishing and Using Economic Thresholds).

The economic threshold is the level of a pest population below which the cost of applying control measures exceeds the losses caused by the pest (Stern, 1973).

2. The agroecosystem is the management unit

Any manipulation of the agroecosystem—i.e., the cropping system—may aggravate pest populations on the one hand or effectively manage pest populations on the other. Even manipulations that appear subtle to use may affect the pests. The change to a new crop variety, rotation to another crop, change in fertilizer, modified row spacing or irrigation schemes, change in pesticide use patterns, shift from a crop monoculture (single crop) to a polyculture (crop mixtures)—these and other manipulations may cause a rather drastic shift in the status of pest species in a crop or group of crops in a given agroeco-system.

If they are not carefully studied and introduced, changes in cropping practices over a large area may lead to severe pest outbreaks and result in the establishment of permanent, often devastating pest hierarchies. For example, changes in the rice ecosystem is tropical Asia in the past 15 years have seriously aggravated the brown planthopper (*Nilaparvata lugens*), elevating it to status of "key" insect pest of high yielding rice in the region (refer to the training course paper by Dale G. Bottrell, The Key Pest Concept, for a discussion of key pests). ~~Kenmore (1979) listed four major changes in the~~ rice ecosystem that are thought to have accentuated the brown planthopper problem:

(1) Widespread planting of modern, high yielding rice varieties.

The modern varieties apparently provided a more favourable habitat for the brown planthopper than the traditional varieties did, and they lacked genetic characteristics of the traditional varieties that had resisted the pest.

(2) Increased use of nitrogen fertilizers

The increased use of fertilizers with nitrogen is thought to have increased the nutritional value of the rice plants to the brown planthopper and therefore speeded up the insect pest's growth and reproduction.

(3) Increased use of chemical insecticides

Use of insecticides on the modern rice varities is known to: (a) directly kill some natural enemies important in keeping the brown planthopper in check in untreated fields; (b) disrupt food chains of important natural enemies, forcing emigration of them; (c) kill off susceptible brown planthoppers, thus selecting for insecticidal resistant strains; (d) stimulate reproduction and feeding rate of the brown planthopper when applied at sublethal dosages; and (e) accumulate in the resistant populations of brown planthoppers, and thus harm the susceptible natural enemies that eat the insect pests.

(4) Expansion of irrigation schemes

The expansion in irrigation in tropical Asia extended the length of therice growing season (from 1 to 2 or more crops per year), created a moist micro-climate favorable for brown planthopper buildup, and resulted in an increase in the amount of ratoon (second growth) and volunteer rice in a given area.

Integrated pest management strives to manipulate agroecosystems as to hold pests such as the brown planthopper to tolerable levels while avoiding disruptions that aggravate notarget pests. Other papers of the training course discuss the procedures of manipulation known to be important in managing the brown planthopper in tropical Asia (Peter E. Kenmore, The Green Revolutionin Rice: Promise and Problems, and , ibid., Management of Natural Enemies in IPM Programs). As these papers discuss, knowledge of the actions, reactions, and interactions of the agroecosystem's components that significantly affect the target pest species is requisite to an effective IPM program. Without this knowledge, the IPM specialist cannot be expected to design an optimal pest management strategy.

3. Use of natural control agents is maximized

Integrated pest management emphasizes existing factors in the crop ecosystem which check the pests' numerical growth: limited resources (food, space, shelter), periodically inclement weather or other hazards (heat, cold, wind, drought, rain), competition within the species or with other plants and animals, and natural enemies. Natural enemies may be insignificant in the control of some pest species; however, they are highly effective against others, particularly insects and mite pests. Although resources rarely seem to be in short supply, weather can be constantly favourable, and competitors scarce or absent, natural enemies of many insect and mite species are almost universally present, often significantly so (van den Bosch and Messenger, 1973).

Because the combined actions of various natural suppressive forces are potentially significant against all pest species, an important goal of IPM is to alter pest environments so to enhance the action of all natural forces determined to be important. The procedures may entail conservation and augmentation of resident natural enemies, introduction of new natural enemies, use of pest-resisting crop varieties, and other environmental manipulations which are discussed in various papers of the training course.

4. Any control procedure may produce objectionable effects.

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. Many of these practices subsequently proved scientifically valid, though originally derived from crude empirical methods.

The list of pest control procedures is almost endless. Table 1 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. In addition, chemical pesticides have considerable value in IPM programs.

Use of chemical pesticides has dramatized that any single control procedure can have unexpected and undesirable consequences (refer to papers of this training course by Patricia C. Matteson, The Limitations and Benefits of Pesticides, and Impact of Pesticides on the Environment).

But the use of any of the alternatives may also produce undesirable consequences. No alternative is a panacea any more than DDT was to all insect problems. Genetic strains of insect pests may evolve that resist plant varieties, insect growth regulators, or other alternative control techniques that were once effective. Pests are continuously changing, evolving new strains, and adapting to new habitats and control techniques. A basic assumption of integrated pest management, therefore, is that no single control will be permanently successful because of the remarkable adaptive powers of the pest organisms. The most lasting form of pest protection is achieved when the burden of pest control is systematically spread over a combination of techniques.

5. <u>An interdisciplinary systems approach is essential</u>

During the past 10 years a burgeoning literature has been developing on the application of systems science in pest management. Though the terms "modeling" and "systems analysis" have only recently found their way into pest management literature, the underlying concepts have always been a part of pest control. Traditionally, pest management specialists have attempted to abstract and collate information from literature and from field observations to build a model, whether physical or mental, of the whole system surrounding the pests in question. Though not equipped with computers being used by their modern colleagues, some pest management specialists working during the pre-synthetic pesticide era employed a systems approach and were very successful in developing conceptual models of various pests' life systems and the interacting variables affecting their abundance.

By studying and conceptualizing the actions, reactions, and interactions of the pests' life system, they could make maximum use of the natural suppressive forces that were regulating the densities of the pests. System analysis, as defined by Watt (1966), is merely a body of techniques and theories for analyzing complex problems, viewed as systems of interlocking cause-effect pathways. These are the kinds of pathways that some of the early pest management specialists sought in their fight against various pests.

However, the emergence of effective synthetic organic pesticides in the late 1940s and the 1950s largely eliminated the need for a continuation of the systems approach. The simplistic approach of pesticidal control led to less sophistication, less complexity, and less emphasis on studying life systems.

The recent trend toward integrated pest management has created a need for more sophisticated analytical and synthesis techniques, and computer models are being developed to unify and guide the research and to give a clearer understanding of the various interactions in the pests' life systems and the crop ecosystems. The apparent utility of the models is that they could be used, for example, to determine how to manipulate a crop (use of a **particularly** combination of variety, fertilizer, planting schedule, crop rotation, etc.) to achieve optimal pest management. Efforts to develop these models require the cooperation of a range of biological, physical, and social disciplines.

Table 1 Examples of alternatives to chemical pesticides

Insects, mites and other invertebrates

Biological control
- Parasites
- Predators
- Pathogens

Plant and animal resistance

Environmental manipulations
- Plant spacing
- Species diversity
- Timing
- Crop rotation
- Plant hormones
- Water management
- Fertilizers
- Soil preparation
- Sanitation

Induced sexual sterility

Physical and mechanical control
- Window screens
- Light traps
- Fly swatters
- Protective packaging
- Sifting devices
- Barriers
- Flaming and burning

Attraction and repellency
- Attractants
- Repellents

Genetic manipulation of pest populations
- Lethal genes
- Male-producing genes

Plant diseases

Disease resistance

Reduction and losses by manipulations of plants and pathogens

Control of plant pathogens by natural enemies

Disease- and nematode-free seed and propogating material

Crop rotation and soil management

Destruction of inoculum sources

Vector control

Nematode attractants and repellents

Weeds

Insects and other herbivores

Diseases

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

Natural stimulants and inhibitors

Plant competition

Revegetation of weed- and brush-infested grazing lands

Breeding highly competitive forage species

Birds, mammals, and other vertebrate pests

Noise and physical repellents

Chemosterilants

Chemical repellents

Trapping and shooting

Behavior

Environmental manipulation

Exclusion

Source: Anon. (1965)

The development of computer models is not a requirement for integrated pest management, and, in fact, some of the most effective IPM schemes in use today evolved without the aid of computer models. However, an interdisciplinary systems approach is essential in order to successfully integrate the efforts of pest control specialists, agronomists, economists, sociologists, and others into developing IPM schemes that are compatible with the agronomic and socio-economic structure for the farming operation for which developed as well as the surrounding community. Successful integration requires interdisciplinary cooperation in all phases: research, development, and implementation.

A range of disciplines is usually required to collect the information, formulate the IPM strategy, execute the strategy on the farmers' fields, and evaluate the results. To be effective, the interdisciplinary team must cooperate in a mode true to the systems approach. That is, they must anticipate integration of their activities completely from the elemental research phase through the implementation and evaluation phases. Otherwise, they may complete their work only to find that the fragmented results obtained from the various components cannot be fitted together as a meaningful "whole." This horrendous outcome may be avoided by adopting a systems approach that utilizes the talents of systems scientists versed in ecological principles and application to IPM development. Peter E. Kenmore's paper at this training course, The Role of Modeling and Forecasting: Simple Examples, discusses the role of model development as part of this approach. Kiritani (1979) reviewed developments in rice pest management that relate to the systems approach.

DISCUSSION

Many obstacles—technical, economic, social, and attitudinal—slow the development of integrated pest management. One of the major obstacles is widespread lack of understanding among pest control specialists, extension officers, and administrators of the principles of IPM and how this approach differs from alternate approaches to pest control. Even where the strategy is developed, it may be difficult to translate its advantages and necessity to these individuals, especially those who are still locked into their faith and favourable experiences with effective chemical pesticides. The development and implementation of IPM are thus heavily dependent upon the philosophical education as to what IPM is. The trainees of this course can serve usefully in bringing about this education in West Africa.

Anon. 1965. Restoring the quality of our environment. Rep. of the environmental pollution panel. President's Sci. Advisory Comm. The White House. U.S. Government Print. Office., Washington, D.C. 317 p.

Barfield, C.S., and J.L. Stimac. 1980. Pest Management: an entomological perspective. BioScience 30:683-689.

Bottrell, D. G. 1979. Integrated pest management. Council on Environmental Quality. U.S. Govt. Printing Office. Washington, D.C. 120 p.

Flint, M.L. and R. van den Bosch. 1981. Introduction to integrated pest management. Plenum, New York. 240 p.

Huffaker, C.B. 1972. Ecological management of pest systems, p. 313-342. In J.A. Behnke (Ed.), Challenging biological problems—directions toward their solution. Oxford Univ., New York.

Kenmore, P. E. 1979. Limits of the brown planthopper problem: implications for integrated pest management. Paper presented at a Saturday Seminar, June 30, 1979. Int. Rice Res. Inst., Laguna, Philippines. 79 p.

Kiritani, K. 1979. Pest management in rice. Ann. Rev. Entomol. 24: 279-312.

Smith, R.F. and R. van den Bosch. 1967. Integrated control, p. 295-340. In W. W. Kilgore and R. L. Doutt (Eds.), Pest control—biological, physical, and selected chemical methods. Academic, New York.

Smith, R. F. 1980. The integrated pest management approach. Proc. Seminar and Workshop on Pest and Pesticide Manage. in the Caribbean, Nov. 3-7, 1980. Vol. II, Invited Papers, p. 105-109. Caribbean Graphics, Bridgetown, Barbados.

Stern, V. M. 1973. Economic thresholds. Annu. Rev. Entomol. 18: 259-280.

van den Bosch, R. and P. S. Messenger. 1973. Biological control Intext, New York. 180 p.

Watt, K. E. F. 1966. The nature of systems analysis, p. 1-14. In K. E. F. Watt (Ed.), Systems Analysis in Ecology. Academic, New York.

CROP LOSS ASSESSMENT, ECONOMIC INJURY LEVELS, AND ECONOMIC THRESHOLDS*

By

Patricia C. Matteson
University of California, Berkeley
Consortium for International Crop Protection
2288 Fulton Street, Suite 310
Berkeley, California 94704, USA

Many national crop protection services in West Africa have undergone rapid growth in the recent past, partly due to foreign agricultural aid programs. New training programs and increased staff and equipment have led to a substantial expansion of pesticide use. Often government pesticide intervention teams bring in pesticides and sprayers to treat farmers' fields free of charge when an infestation is reported. Farmers, and thus government officials, are pleased and enthusiastic. A favourable uncritical attitude toward pesticide use is quickly developing, similar to that in the U. S. before the limitations and hazards of pesticide use became clear. Unfortunately, all this is happening in the absence of data on West African pests that indicate when crop protection measures are actually justified.

To determine whether an insect has reached pest status in a given season, and when control measures are justified, one must know the economic injury level (EIL) and the economic threshold (ET) for that pest on the crop in question. The EIL is defined as the pest population level below which specific intervention is needed to prevent a pest outbreak and significant crop injury. It is the criterion for treating key, occasional and migratory pests: without an estimate of the pest density that can be tolerated without significant crop loss, there can be no reasonable safeguard against either overtreatment or unacceptable crop damage.

The ET is the pest density at which control measures should be taken to prevent an increasing pest population from reaching the EIL (Headley, 1975).

At present, EILs and ETs have been established for relatively few of the most important pests of world agriculture. Most of these are for species of insects, mites and composite weeds; few have been established for plant pathogens or nematodes (Glass, 1975).

Three factors are considered in determining when to undertake pest control measures. First, the crop income-pest intensity relationship is the route through which quality and quantity losses become inputs in the decision to take protective action. Secondly, control cost becomes another input through the control costpest intensity relationship. Finally, the producer's attitude toward pest damage risks will affect control decisions (Carlson, 1971).

Crop loss assessment. The crop income-pest intensity relationship is determined through crop loss assessment experiments. The main reasons for making such damage evaluations in pest management are (1) to define the economic status of a given pest species in order to plan research priorities and allocation of resources, (2) to establish economic thresholds and economic injury levels, (3) to estimate the effectiveness of control measures, and (4) to evaluate resistant varieties and lines of crop plants (Ruesink and Kogan, 1975).

Crop loss assessment experimentation is complex and difficult. Losses will vary from place to place (with varying weather and soil conditions), ~~and from year to year.~~ They are also affected by season, type of agroecosystem, crop variety, stage of crop attacked, cultural practices and plant condition.

Experiments should be conducted for at least three years at each of a number of locations, and such information needs to be up-dated, perhaps every five years. This will be even more true in the future because of rapidly changing cultural practices, the introduction of new plant varieties and agricultural chemicals (Le Clerg, 1971).

It is not surprising that most developing countries have not had the capability to conduct comprehensive surveys designed to assess losses due to various types of pests on any reliable and consistent basis, let alone on a detailed annual basis. Even in developed countries, crops loss figures sometimes lack precision. Information on crop losses in developing countries, when available at all, is usually incomplete and varied, consisting of estimates of lossess occurring in especially bad years or in especially affected districts, estimates of losses caused by a particular pest, very general estimates of losses due to all or several pests, results of experiments comparing yields of rice protected from pests to yields of rice not so protected, and so on. The literature abounds with phrases such as "most destructive pest," "serious pests," "heavy crop losses," and "major losses annually" rather than precise figures. Even when figures are available, often a distinction is not made as to whether the losses given pertain to a particularly bad year or to a more normal year, and often estimates appear to apply only to the area badly affected by the pest with no accompanying information as to the extent of the affected area (Barr et al., 1975).

The primary objective of most crop loss experiments is a comparison of protected and unprotected plots (paired-treatment experiments) which involve an estimate of pest intensity and yield on a number of experimental sites.

The results from paired-treatment experiments give a measure only of the estimated loss caused by a particular pest in a particular season and location, as reflected by the intensity of a single pest on crop yield. Such experiments do not indicate (a) the increment of loss per unit increment of pest intensity, nor (b) the competitive or interaction effects of more than one pest on yield loss. Data of these kinds permit a more reliable description of crop losses. However, to obtain this information, more sophisticated or complex field experiments are required including (a) an appropriate experimental design, (b) the establishment of various intensity levels for each of the pests under study, (c) the availability of objective methods for the measurement of pest intensities, (d) the determination of crop yield at each level of pest intensity, and (e) the statistical evaluation of the crop-loss data obtained (Le Clerg, 1971.

To determine the relationship between crop yield and crop income reduction and pest population levels, one compares crop losses from sets of plants subjected to attacks from various known populations of an insect pest to losses from a set which is kept free from attack. Several methods can be used to establish different levels of pest intensity. (a) Experiments can be duplicated in crop areas known to differ in intensity of pest attack. (b) Artificial infestation levels can be maintained by mechanical means, such as hand-picking. (c) Plants can be caged with various population levels of the pest. In this case, uninfested controls are needed to indicate the effect of the cages on the pl ants. Also, cages may drastically change the microclimate around the plants and produce results that may not apply to open-field conditions. (d) Selective insecticides can be used to produce uneven population levels. However, pesticides or their solvents or carriers may have a direct effect on yield in addition to their effect on the pest, so for accurate results one must set up a check to confirm there is no bias caused by the chemicals used.

In addition, insecticide drift and the contiguity of many sprayed plots can reduce natural enemy populations in control plots, artificially depressing the control yields. (c) Another approach consists of using plants grown under natural field conditions. Estimation of losses is made by regression analysis using yields of plants displaying different levels of injury (Le Clerg, 1971); Ruesink and Kogan, 1975).

Reliable sampling methods and procedures must be used to quantify the insect populations in question, and yield loss. Direct or indirect sampling methods can be used for insect pests. 1). Actual counts of insects per unit area; for example, total numbers of insects per square meter, individual plot, or meter of row. 2) Relative counts based on number of insects per minute of collection or observation, or per sweep, trap light, or number per sticky board. 3) Indirect counts where the insects themselves are not counted, but the effects and products of their activity are noted. These include indices such as white heads, dead hearts, "onion shoots," hopperburn, defoliation, or the presence of products such as grass or exuviae (FAO, 1979).

Many sampling methods and devices are used depending upon the insect pest, crop and the location to be sampled. Specific examples of sampling procedures are described by Nishida and Torii (1970) for rice stemborers and for other rice pests by Gomez (1972). Sampling can be extensive, covering a large area, or intensive, involving sampling of a single population in a limited area. Sample survey methods have been summarized by Church (1971). A particularly comprehensive account of sampling methods and techniques relevant to ecological projects is given by Southwood (1968). Quantifying yield loss is relatively simple for direct pests, which attack produce (i.e., the marketable fruit or grain) directly.

Indirect pests attack plant parts that may be physiologically related to yield but do not produce by themselves, damage usually resulting only by intensive or extended infestation (Turnbull and Chant, 1961). In the latter case experiments must clearly link various levels of pest population with both damage and the resulting yield loss.

Single-pest attacks rarely occur in nature, where interactions between major groups of harmful organisms must be expected. Their joint effect on yield may be additive, synergistic, or antagonistic. For instance, a leaf-eating insect pest and a fungus disease may each take 10% of the crop if they occur separately, for an additive crop loss of 20%. If they occur simultaneously, and mechanical damage from insect feeding facilitates infection of the crop by the fungus, losses to the fungus may rise above 10%, for a synergistic total effect on crop loss which will be greater than 20%. Conversely, if differnet pests attack the same plant part, their damage may be antagonistic: the combined infestation may cause a lower total crop loss than would be expected from combined isolated attacks by each pest. For instance, if two species of rice bugs are present, each numerous enough to spoil 40% of the grains, total crop loss will be less than 80% because much grain will sustain attacks from both species. The study of the joint effect of two or more pests requires factorial experiments using selective control measures. Appropriate methodology has not been well-research (Le Clerg, 1971).

Most crop loss experiments consider only the measurable effects on current yield but there are other loss aspects to consider. These include effects on future yields, limitations on cropping operations and sequences, and delay and complications in harvesting (Chiarappa, et al., 1971). Reduction in quality of the crop is an important consideration.

Losses in quantity and quality must then be converted to losses in crop income. This will depend on the current market price of the crop. Changing price levels must be monitored, and recurring patterns and the effects of changing government policy should be anticipated.

Control costs vs. pest intensity: Control costs for dealing with various intensities of pest infestation must be carefully calculated. These can include 1) decreased revenues from lower-yielding resistant varieties; 2) unprofitable crop rotations; 3) labor costs, which will vary with season and skill level and may be for cultural controls, application of chemicals, or harvesting a bigger yield; and 4) input costs such as clean seed, insecticides and fungicides, and sprayers. Longer-term costs such as damage to the environment and dealing with pest resistance to pesticides and pest-resistant crop varieties, or with pesticide-provoked attacks by secondary pests, are often ignored (Carlson, 1971). The cost picture is distorted when government subsidy provides insecticides or spray services to farmers free of charge.

Farmer risk: Risk varies among producers. It will be highest for farmers who have limited off-farm employment opportunities, little crop diversity and large crop investments at stake (Carlson, 1971).

The aforementioned cost and crop income relationships, when adjusted for the producer's particular attitude toward risk, will determine the economic threshold (Fig. 1). This is the pest density for which there is the biggest difference between crop income and control costs - i.e., the biggest return to the farmer. At population levels greater than the economic threshold, the farmer would not get more from the additional crop revenue than the amount of money invested for its protection (Carlson, 1971).

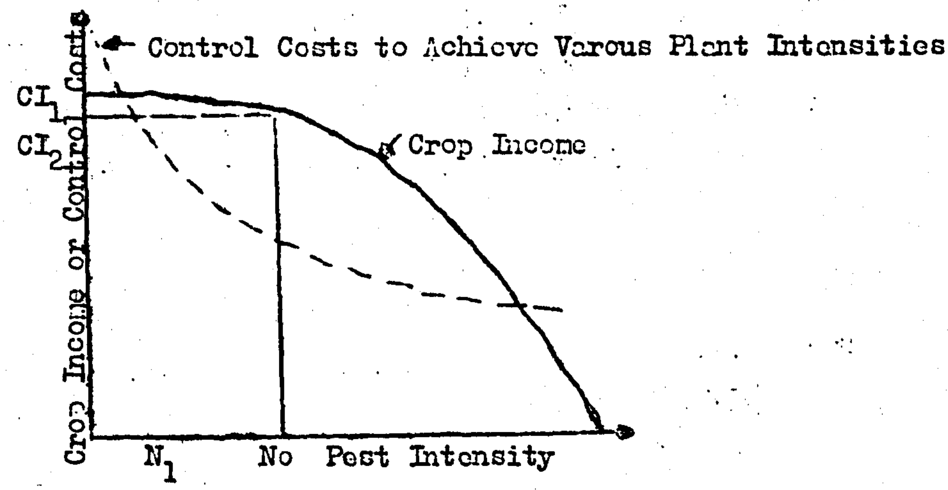


FIGURE 1. Crop income- and control cost-pest intensity relationships. N* is the economic threshold (from Carlson, 1971).

Before treating a crop, levels of natural enemy activity should be observed. If the high pest population is heavily parasitized, or if predators are abundant, artificial control measures may be unnecessary. In West Africa, caterpillars of the skipper butterfly Parnara sp. occasionally become abundant, defoliating rice. However, these high populations have been observed to be heavily parasitized by a wasp, Brachymeria sp. (Breniere, 1976).

The economic threshold will shift with changes in risk and the cost or crop income curves, and its adjustment must be a continuing process. It will deffer with crop development stage, crop variety and region, and must be revised to account for new pests, new varieties, new management practices, new marketing standards and variations in commodity prices and control costs.

The complexities involved in establishing economic thresholds are so great that many researchers are tempted to give up indespair. Others believe that until economic thresholds and economic injury levels are established with the most rigorous accuracy and in the most minute detail, they cannot be used effectively in integrated pest management. However, empirical evidence from previous experience and replicated observations can be very useful in the establishment of provisional thresholds. Successful pest management programs can be developed around such crude first approximations. The thresholds can then be refined as additional information becomes available (Glass, 1975).

REFERENCES

Barr, B.A.C.S. Koehler, and R.F. Smith. 1975. Crop losses-Rice: Field losses to insects, diseases, weeds and other pests. UC/AID Pest Management and Related Environmental Protection Project. University of California, Berkeley.

Brenière, J. 1976. The principal insect pests of rice in West Africa and their control. West Africa Rice Development Association, Monrovia, Liberia. 52 p.

Carlson, G.A. 1971. Economic aspects of crop loss control at the farm level, p. 2.3/1-2.3/6. In L. Chiarappa (Ed.), Crop loss assessment methods. FAO manual on the evaluation and prevention of losses by pests, disease and weeds. Commonwealth Agricultural Bureaux, London.

Chiarappa, L.,F.J. Moore and A.H. Strickland. 1971. Introduction, p. 1/1-1/2. In L. Chiarappa (Ed.), Crop loss assessment methods. FAO manual on the evaluation and prevention of losses by pests, disease and weeds. Commonwealth Agric. Bureaux,London.

Church, B. M. 1971. The place of sample survey in crop loss estimation, p. 2.1/1-2.2/8. In L. Chiarappa (Ed.), Crop loss assessment methods. FAO manual on the evaluation and prevention of losses by pests, disease and weeds. Commonwealth Agricultural Bureaux, London.

FAO. 1979. Guidelines for integrated control of rice insect pests. FAO plant Production and Protection Paper 14. 115 p.

Glass, E.H. 1975. Integrated pest management: rationale, potential, needs and improvement. Entomological Society of America Special Publication 75-2. 141 p.

Gomez, K.A. 1972. Techniques for field experiments with rice. Layout/sampling/sources of error. IRRI, Los Banos, Philippines. 46 p.

Headley, J. C. 1975. The economics of pest management, p. 75-99. In R. L. Metcalf and W. H. Luckman (Eds.), Introduction to insect pest management. John Wiley and Sons, New York. 587 p.

Le Clerg, E.L. 1971. Field experiments for assessment of crop losses, p. 2/1/1-2.1/11. In L. Chiarappa (Ed.), Crop loss assessment methods. FAO manual on the evaluation and prevention of losses by pests, disease and weeds. Commonwealth Agricultural Bureaux, London.

Nishida, T. and T. Torii. 1970. A handbook of field methods for research on rice stemborers and their natural enemies. International Biological Programme Handbook No. 14. F. A. Davis, London. 132 p.

Ruesink, W. G. and M. Kogan. 1975. The Quantatative Basis of Pest Management: Sampling and Measuring, p. 309-351. In R. L. Metcalf and W. H. Luckmann (Eds.), Introduction to insect pest management. John Wiley and Sons, New York. 587 p.

Southwood, T.R.E. 1968. Ecological methods. Methuen, London.

Turnbull, A. L. and D. A. Chant. 1961. The practice and theory biological control of insects in Canada. Can. J. Zool. 39:697-753.

PESTICIDE USE IN INTEGRATED PEST MANAGEMENT PROGRAMMES

By

C. Michael Smith
Louisiana State University
Baton Rouge, LA 70803, U.S.A.

Control of insect pests of rice, as in most other major agricultural crops, relies largely on the use of chemical pesticides. Indeed pesticides are among the most powerful of all tactics currently available for use in integrated pest management (IPM) systems. It is often said and remains largely true that pesticides are the "backbone" of an effective IPM program. In addition to lowering the population levels of a pest insect however, insecticides cause changes within both the organism under scrutiny, the coinhabitants of its environment and the host plant. By examining some of those problems resulting from improper pesticide use in the past also with some of the ways we are presently avoding these problems, perhaps we can define ways to better establish the pesticide use patterns of the future.

Insecticide Resistance: Insecticide resistance occurs in insect populations when, after repeated exposure to above average doses and/or number of applications of pesticides, the survivors of the original populations are unaffected by the normally toxic pesticide. Currently, over 400 insect and mite species are known to be resistant to one or more pesticides (Reynolds 1978). Among these are all of the major rice insect pests in Japan (Asakawa 1975), one major pest in the Philippines, (IRRI, 1971) and one in the United States ~~(Everett et al 1964) (Table 1)~~.

Table 1: Insecticide resistance in rice insect pests

Pest Species	Pesticide.	Year of Occurrence
Rice leaf miner, *Agromyza oryzae*	BHC, DDT	1964
Rice stemborer, *Chilo suppressalis*	BHC	1965
Smaller brown planthopper, *Laodelphax striatellus*	malathion	1965
	fenitrothion	1965
	diazinon	1965
Rice water weevil, *Lissorhoptrus oryzophilus*	aldrin	1964 1/
Green rice leaf hopper *Nephotettix cincticeps*	malathion	1964
	diazinon	1964
Brown planthopper *Nilaparvata lugens*	BHC, malathion	1967
	lindane	1974
	MIPC, MTMC	1979
	diazinon	1970 2/
Rice leaf beetle, *Oulema oryzae*	BHC	1964

1/ United States
2/ Philippines (All others occur in Japan).

The development of resistance depends not only on the selection pressure placed on the insect population in terms of insecticide use, but also on pest insect biological factors such as generation time, dispersal behavior, net rate of reproduction and degree of reproductive isolation (refrugia) of various segments of the total pest population. Short generation time, and relative lack of reproductive isolation favor the development of insecticde resistance in insect pests of rice, and for this reason attempts should be made to minimize the use of insecticides and avoid the occurrence of resistance.

How is this possible? To avoid insecticide resistance it is necessary to treat only certain geographic segments of the pest population at such at time when populations warrant treatment, in order to keep the pest's genes for insecticide resistance at a low frequency. The ability to pinpoint the proper time and location of application hinges on an intensive field scouting program supplemented by trapping insects with black light, pheromone, sticky or pitfall traps. For pest insects such as rice borers, timing of application is especially critical, since the period of maximum exposure is a small "window" of time, just after the peak larval hatch and just prior to dispersal and entrance into the plant stem.

In the early 1960's an aldrin rice seed treatment was adopted as standard practice in the United States for control of the rice water weevil, Lissorhoptrus oryzophilus Kuschel. Within 6 years all L. oryzophilus populations in the southern Unites States were aldrin-resistant and different chemicals had to be developed for L. oryzophilus control (Bowling 1968, Rolston et al 1965) (Table 2). This is an example of the kind of heavy selection pressure which is exerted on an insect population when persistent insecticides are applied simultaneously over a large geographic area.

Table 2. Occurrence of aldrin resistance in populations of Lissorhoptrus oryzophilus in the southern United States.

State	Reference and Year
Louisiana	Everett et al 1964
Arkansas	Rolston et al 1965
Texas	Bowling 1968

Selective use will also extend the useful life of the insecticide and reduce its impact on non-target beneficial insect predators and parasites.

Newsom et al (1980) give a striking example of the detrimental effects of an improperly timed insecticide application on soybean yield and beneficial predators of the soybean pod feeder, Heliothis zea (Table 3).

Table 3. Effect of timing insecticide applications on control of H. zea and yield in large scale field trials. North Carolina, 1976.[1/]

Time of Application	Yield (bu/Ac)
Immediately prior to H. zea field infestation	6
When H. zea populations reached economic injury levels	30
Control	18

1/ from Newsom et al 1980.

Applications of insecticide to fields just prior to H. zea infestation eliminated predators, which allowed H. zea populations to reach very high levels and inflict heavy crop damage. Application of insecticide when H. zea infestations reached an economically damaging level however, combined the effects of the predator population and the insecticide, resulting in significantly higher soybean yields.

Once a selective insecticide use pattern has been adopted in an IPM program, a monitoring system will also be necessary to keep records of the level of susceptibility in various geographic segments of the pest population and document the occurrence of chemical control failures. Specific segments of the population can then be tested to determine if in fact insecticide resistance has developed. Our research program at Louisiana State University includes a system of such bioassays to detect carbofuran resistance in rice water weevil populations. A typical set of monitoring data is shown in Table 4.

Table 4: Carbofuran resistance monitoring in 5 adult *L. oryzophilus* populations. 1978.

	LD_{50} (ng/weevil)		
	Month of collection		Location
Location	June	August	X
Stuttgart, AK	5(3-7)a/	4(1-5)	5
Benoit, MS	12(8-28)	5(4-6)	7
Jones, LA	11(8-33)	5(3-6)	7
Crowley, LA	6(4-8)	5(3-6)	7
Kaplan, LA	6(5-7)	9(8-10)	7
Seasonal X	8	6	

a/ 95% confidence limit.

Pest Insect Resurgence: Pest resurgence occurs when post-treatment pest insect population levels exceed pretreatment population levels, due to treatment with either a non-selective insecticide and/or an abnormally high dose rate of insecticide. While these practices effectively eliminate the pest population temporarily, they also cause population levels to increase dramatically thereafter, due to the elimination of beneficial insects. Data for soybean looper populations in soybeans (Figure 1) depict such a typical resurgence reaction, in this case due to application of methomyl and methyl parathion (Shepard et al 1977). In rice, resurgence of the brown planthopper, *Nilaparvata lugens* (Stal) has been induced with applications of methyl parathion, diazinon and decameth in (Chelliah & Heinrichs 1980). In this instance however, hoppers were attracted to treated plants due to increased plant growth. Population increases though were actually due to stimulation of hopper reproduction by feeding on insecticide treated plants.

Lack of Insecticide Selectivity: The lack of insecticide selectivity is a major problem with insecticide use in IPM programs, since non-target organisms such as beneficial insects as well as pollinators, wildlife, man and domestic livestock are all subject to the effects of non-specific insecticides. This problem is of added importance in IPC on lowland flooded rice since harvest of aquatic invertebrates and fish is an important food producing mechanism. Reynolds (1978) divides insecticides selectivity into physiological and ecological categories. Physiological selectivity is related to specific insecticides which are effective in controlling only specific insects or groups of insects. While this type of development would seem the ultimate in safe insecticide usage, the occurrence of such compounds is rare, due primarily to the high cost of development to chemical companies. Notable exceptions are several acaricides and the biological insecticide Bacillus thuringiensis (Table 5).

Table 5: Selective insecticides currently in use in IPM programs

Insecticide	Class	Crop	Pest Species Affected
Bacillus thuringiensis	Bacteria	Soybean	Velvetbean caterpillar Green Cloverworm Soybean Looper
		Rice	Rice Leafroller Rice Stemborer Rice Skippers
cyhexatin (Plictran[R])	Organotin	Apples	European Red Mite
propargite (Omite[R])	Sulphate		
formetanate (Carzol[R])	Carbamate		

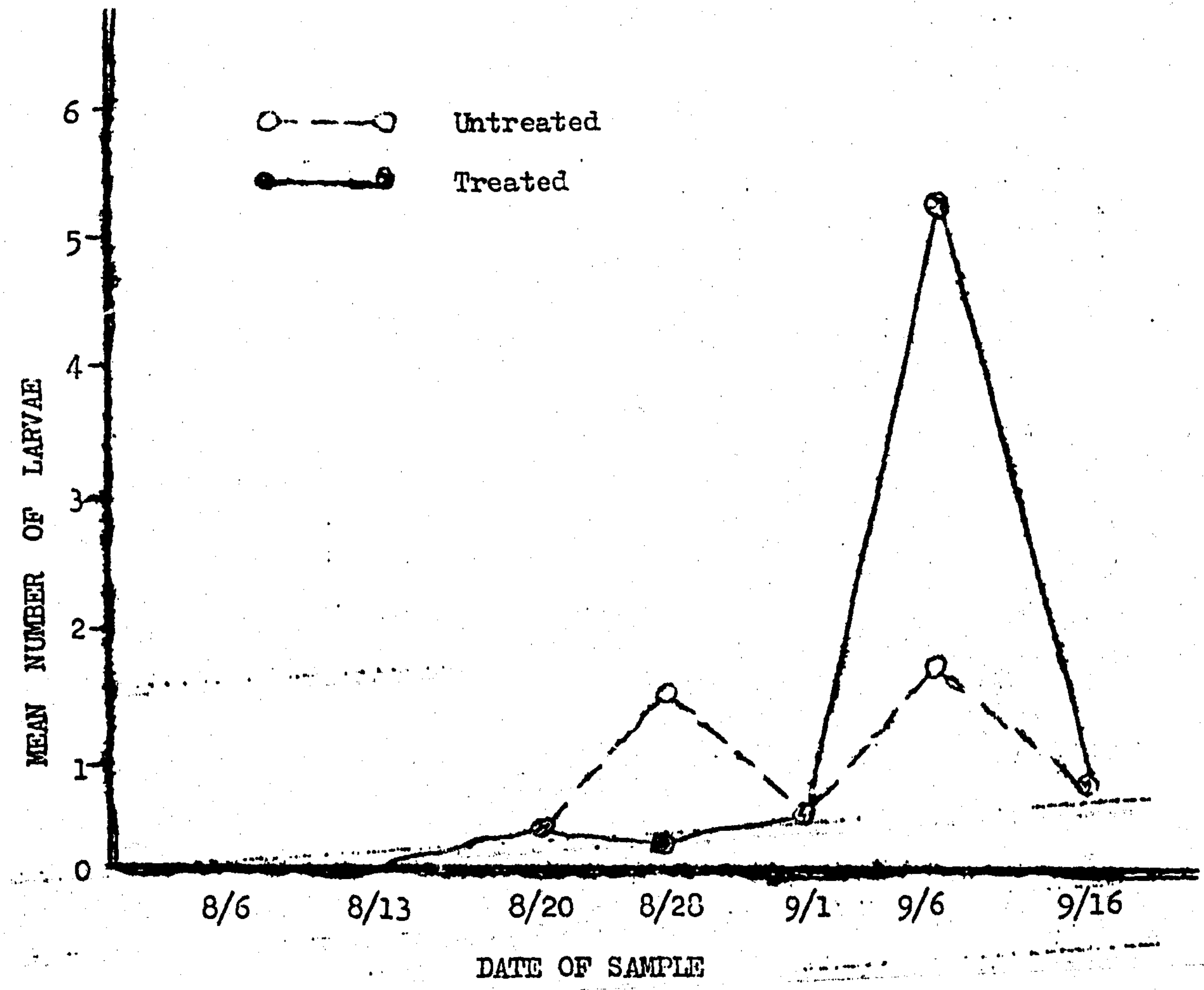


Fig. 1. Resurgence of Pseudoplusia includens populations in soybeans after application of methomyl + methyl parathion. From Shepard et al 1977.

Ecologically selective techniques however, can be developed with existing insecticides but rely on a thorough knowledge of the relationship between the pest insect biology and host plant phenology. Reduction of pesticide dosage rates is one method of ecological selectivity which has recieved considerable investigation in recent years. Simply stated, this method defines the minimum necessary dose rate of a pesticide needed to give effective control of an insect pest. Due to this type of research, extensive revision has occurred in the minimum dose rates for soybean insect pests in the United States (Turnipseed et al 1974)(Table 6).

Table 6. Changes in the minimum effective dose rate for control of soybean insect pests. 1973-1977. 1/

Insecticide	Pest Species	Recommended Rate lbs. A.I./Acre 1973	1977
Carbaryl	Bean Leaf Beetle	1.50	0.50
	Velvetbean Caterpillar	1.50	0.50
	Corn Earworm	2.00	0.50-1.00
Methyl parathion	Southern Green Stinkbug	0.50	0.25-0.50
	Bean Leaf Beetle	0.50	0.25

1/ from Newsom et al 1980.

Another method of reducing insecticide dosage is by means of ultra low volume (ULV) application of pesticides, which uses rates of from 1 to 10 l diluent/ha, compared to low volume sprays of 10-100 l diluent/ha or high volume sprays of 100-1000 l diluent/ha. ULV sprayers are now manufactured for use by the small famer and advantages of this method include reduced amounts of water, which saves time and labor, and reduced pesticide run-off, compared to high volume spraying, which saves money spent on pesticide. Considerable susscess has been achieved using the ULV technique in controlling the rice stink bug, *Oebalus pugnax* (F.) (Table 7), rice leafrollers and armyworms (Shin-Foon 1980).

Table 7: ULV insecticide application for *O. pugnax* control in rice. 1/

Insecticide	Kg Ai/ ha	1 spray/ ha	Post treatment control (%) 1 day	3 days	7 days
Malathion	0.116	0.74	89	85	79
Sumithion	0.116	0.74	89	80	99
Methyl parathion	0.045	18.2	96	95	46

1/ from Oliver et al 1971.

It should also be pointed out that pesticides can be adversely affected by the pH of the water used for mixing and application. Pure water has a pH of 7 but depending on geographic location, most water is either acidic (pH 0-7) or alkaline (pH 7-14). Carbamate and organophosphate pesticides undergo alkaline hydrolysis, a process which breaks apart the pesticide molecule and inactivates it. In general, the rate of decomposition depends on the degree of alkalinity of the water. Many of the currently used pesticides work best when mixed in slightly acidic water. Table 8 lists some of the adverse affects pH changes can have on pesticides.

Table 8: Alkaline hydrolysis of some common insecticides. 1/

Pesticide	Water pH	Time (hr) for 50% hydrolysis
Dylox	7	6.4
	8	1.0
Guthion	7	240.0
	9	12.0
Imidan	7	12.0
	8.3	4.0

1/ from Laemmlen 1981.

Selective use of pesticides can also be due to discrete placement of chemicals on specific plant parts. Examples of this technique include the use of systemic insecticides in the root-zone treatment of rice for gall midge control (Shin-Foon 1980) and the root-coat treatment of rice seedlings for control of whorl maggot and green leafhopper (Seiber 1977). In both cases the need for foliar spraying was removed and few adverse effects were observed on natural enemies of the pest insects.

Conclusions: These remarks give but a brief overview of past and present insecticide use, but I am hopeful that they will illustrate some ideas on how we can better use insecticide in future rice IPM programs. Unfortunately, as a pest control tactic insecticides have been overrelied upon and as a result, overused. However, this in no way diminishes their effectiveness nor their need in IPM when they are properly used. Ultimately insecticides in African rice IPM will serve a useful purpose only if pest management specialists at all levels help the farmer understand their benefits and limitation.

REFERENCES CITED

Askawa, M. 1975. Insecticide resistance in agricultural pests in Japan. Japan Pesticide Information. No. 23 pp. 5-8.

Bowling, C. C. 1968. Rice water weevil resistance to aldrin in Texas. J. Econ. Entomol. 61:1027-30.

Chelliah, S. and E.A. Heinrichs. 1980. Factors affecting insecticide-induced resurgence of the brown planthopper, Nilaparvata lugens on rice. Environ. Entomol. 9:773-77.

Everett, T. R., R. D. Hendrick and W.B. Showers. 1964. Rice water weevil resistance to aldrin insecticide. 56th Ann. Prog. Rtp. Rice Exp. Sta. Crowley, La. pp. 240-43.

Laemmlen, F. F. 1981. Pesticides and water pH. Imperial Agricultural Briefs. (April, 1981).

IRRI, 1971. Annual Report for 1971. Los Banos, Philippines, 238 pp.

Newsom, L.D., M. Kogan, F.D. Miner, R.L. Rabb, S.G. Turnipseed and W. H. Whitcomb. 1980. General Accomplishments Toward Better Pest Control in Soybean. pp. 51-98. In C.B. Huffaker (Ed.) New Technology of Pest Control. Wiley-Interscience, New York, 500 pp.

Oliver, B.F., J. R. Gifford, and G. B. Trahan. 1971. Ultra-low-volume insecticides to control the rice stink bug in southwest Louisiana. J. Econ. Entomol. 65: 981-83.

Reynolds, H.T. 1978. Insecticides as a Component of Integrated Pest Control Programmes In Proc. Regional Training Seminar on Integrated Pest Control for Irrigated Rice in South and Southeast Asia. October 16-November 18, Maligaya and Los Banos, Philippines.

Rolston, L. H., R. Mayes and Y. H. Bang. 1965. Aldrin resistance in the rice water weevil. Ark. Farm. Res. Nov.-Dec.,1965.

Seiber, J.N. 1977. Seedling root-coat treatment with carbofuran. IRRI Newsltr. 2:7-8.

Shepard, M., G. R. Carner and S. G. Turnipseed. 1977. Colonization and resurgence of insect pests of soybean in response to insecticides and field isolation. Environ. Entomol. _:501-506.

Shin-Foon, C. 1980. Integrated Control of Rice Insect Pests in China. pp. 239-250. In Rice Improvement in China and Other Asian Countries. International Rice Research Institute. 307 pp.

Turnipseed, S.G., J.W. Todd, G.L. Greene and M. H. Bass, 1974. Minimum rates of insecticides on soybeans: Mexican bean beetle, green cloverworm, corn earworm and velvetbean caterpillar. J. Econ. Entomol. 67:287-91.

IMPACT OF PESTICIDES ON HUMAN HEALTH AND THE ENVIRONMENT

By

Patricia C. Matteson
University of California, Berkeley
Consortium for International Crop Protection
2288 Fulton Street, Suite 310
Berkeley, California 94704, USA

The increasing use of chemical pesticides in world agriculture and public health has conferred many benefits but is beset by many problems. The dimensions of the hazard to human health and the environment are still largely speculative, but enough data and experience has accumulated to show that pesticides have been, and are being, dangerously misused, and that great care must be taken to apply less dangerous chemicals safely and judiciously. Such caution is especially necessary in developing countries, where the populace generally remains ignorant of the dangers involved, extension services tend to be weak, environmental monitoring is usually nonexistent, and facilities for recognizing and treating human pesticide poisoning are inadequate. This paper discusses pesticide hazards to human health and the environment. "The limitations and benefits of pesticides" in agriculture is the subject of another article in this volume.

The properties of individual pesticies determine their acute and long-term effects on plants and animals (including people) and their persistence in the environment. These properties include their water-solubility (soluble chemicals are more readily broken down through hydrolysis), their tendency to adsorb onto soil particles (inversely correlated with solubility), their volatility (how easily they evaporate), and how readily they are degraded by microorganisms or through chemical processes such as hydrolysis, oxidation and photodecomposition (Antazo, 1978).

Most herbicides and organophosphate, carbamate, and synthetic pyrethroid insecticides are relatively non-persistent. They are rapidly degraded chemically and by microorganisms in the environment, and higher animals metabolize them and excrete the breakdown products with bodily wastes (McEwen and Stephenson, 1979).

Breakdown by microorganisms was well-illustrated by a study of diazinon degradation in Philippine rice paddies. The chemical was degraded in two months in a previously untreated paddy, as opposed to six-month persistence in unflooded soil. Even less persistence - two weeks - was observed in paddies that had been sprayed with diazinon before, and this faster degradation was associated with local buildups in the population of microorganisms that can use the pesticide as their sole carbon source. Workers isolated one of these species, a Flavobacterium (Sethunathan, 1972).

Mercury, arsenic, and organochlorine pesticides such as DDT, HCH, aldrin, dieldrin, lindane and heptachlor persist in organisms and the environment for long periods. Most of the environmental problems associated with pesticides have centered around these compounds. They are water-insoluble and tend to adhere to soil particles and accumulate in the top few inches of soil, where they are resistant to breakdown by chemical processes or microorganisms. The organochlorines are highly fat-soluble, and when they are consumed or absorbed by living things, they are not excreted quickly but collect instead in fatty tissues (McEwen and Stephenson, 1979).

The term "biological magnification" refers to the progressive accumulation of residues of persistent pesticides in the food chain. Low residue levels may be found in soil or water, but the pesticides are further concentrated in micro flora and-fauna, and even more so in the larger organisms at higher trophic levels, depending on the amount of pesticides in their diet and pesticide metabolism and excretion patterns specific to each organism. **Table 1 shows typical residues in various segments of the environment. In aquatic habitats, predatory fish and filter feeders such as crabs and shellfish contain relatively high levels of pesticide residues.**

Table 1: DDT residues in various segments of the environment, averaged from many studies (from Kenaga, 1972).

Trophic Level	Environmental sector	Residue(ppm)
-	Fresh water	0.00001
1	Plankton	0.0003
2	Aquatic invertebrates	0.001
3	Freshwater fish	2.0
4	Predatory birds	10.0

People, being omnivorous, feed at trophic levels two to four. As might be expected, the average U.S. citizen has 6 ppm DDT in her tissues. This level has decreased from 11 ppm since 1972, when DDT was banned in the U.S. Other persistent compounds such as dieldrin and heptachlor epoxide are also commonly found in people in many regions of the globe and are secreted in mother's milk at levels much higher than we would wish (McEwen and Stephenson, 1979).

Except when persistent insecticides such as dieldrin are applied at high rates, pesticides do not seem to have a lasting adverse effect on soil flora and fauna. However, most studies have been short-term, the results are variable, and it is difficult to obtain and interpret good data in this subject area (Fryer, 1977; Graham-Bryce, 1977).

Pesticides must be used with extreme care in aquatic environments, especially where crabs, fish and shellfish are eaten out of the affected paddies and streams, and when people drink, bathe, and wash household goods there. Herbicide residues in water are high initially, but sink rapidly and are not detectable after a few days or weeks. Residue levels in aquatic organisms act similarly. Most herbicides do not accumulate and persist in fish and shellfish, but are instead rapidly excreted in body wastes. Herbicide levels required for weed control are usually too low to cause acute toxicity to fish. Mortality depends on water quality, water temperature, length of exposure and formulation of the herbicide (Frank, 1972).

Insecticides can be extremely toxic to aquatic animals. DDT, endrin, endosulfan and other chlorinated hydrocarbons are especially poisonous to fish. Most organophosphates have lower toxicity. Table 2 compares the acute toxicity of selected pesticides to some fresh water fish, and Table lists the relative persistence of some pesticides in natural waters.

Pesticides can affect aquatic organisms in many ways. Direct poisoning, and death after eating pesticide-killed and contaminated food, are short-term effects. Some species are more sensitive to poisoning than others, so the effects are selective.

The disappearance of certain species will mean that others later starve from lack of food, leading to changes in competition for food (Ferguson, 1969). Herbicides affect the aquatic habitat and food supply by altering vegetation patterns, and oxygen depletion caused by rotting herbicide-killed plants can be lethal to aquatic animals (Robson and Barrett, 1977).

Sublethal effects can also be very poerful. Experiments have shown that sublethal poisoning by pesticides causes abnormal behavior (affecting competitive ability, and thus species composition), and pathological conditions that affect growth and reproduction. Fish fry have been observed to be killed at the yolk sac absorbtion stage because of the high DDT content of the eggs. Some aquatic organisms become resistant to often-used pesticides in certain areas, leading to isolation and changes in populations, and to mortality of predators which consume the high levels of pesticides tolerated in the tissues of their prey.

TABLE 2. Acute toxicity of selected pesticides to some fresh water fish. LC_{50} in ppb. values are for 48 hours unless indicated otherwise[a] (from McEwen and Stephenson, 1979).

Pesticide	Striped Bass[b]	Fathead Minnow	Rainbow Trout	Bluegill	Goldfish	Channel Catfish	Carp
Aldrin	7.2	28	3.0	13†	28†		
Chlordane	11.8		10*	77†	81†		
DDT	0.53	19†	7†	8†	21†	16†	10†
Dieldrin	19.7		19†	3.4	31†		
Endosulfan	0.1		1.2		8*		
Endrin	0.094	1.8†	1.8*	0.35*		140	
Heptachlor	3.0		9.0	19	230		
Methoxychlor	3.3	25*	7.2	30	56†		
Toxaphene	4.4			6.8†			
Temephos	1000.0						
Azinphosmethyl		235†	130†	22†	4200†	3250†	695†
Chlorpyrifos	0.58		20				
Diazinon			380*	52*			
Dimethoate			19000*	9600			
Ethion				230			
Fenitrothion							8600
Malathion	14.0	8650†	170†	103†	10700†	8910†	6540†
Ethyl Parathion	17.8	2050†	2000	47			
Methyl Parathion		8900†	2750	5720†	9000†	5710†	7130†
Phosphamidon			8000				
Carbaryl	1000.0	13000†	4380†	6760†	13200†	15800†	5280†
Carbofuran			280	240		210	
Propoxur		250					
Allethrin		19					
Rotenone			22				
Amitrole				>50000			
Atrazine			12600				
Dalapon		440000*	>500000	115000			
Dicambe			35000	130000			
Dichlorbenil			20000	20000			
Diquat		140000†	20000	145000	35000†		
Endothal		480000		280000	175000		175000
MCPA				10000†			
Monuron						75900*	
Paraquat				400000*			
Picloram		64000*	34000*	26500*	32500		
Prometone							
Simazine			56000	118000			
Trifluralin			152	210	100		
2,4-D				960	1300		
2,4,5-T (acid)			1300	500			
Copper Sulfate				150	>500	>400	>330
Dichlone			48	340*			140*
Nabam						21100	
Benomyl			400				
TFM-2B[c]			3850				

[a] Data from numerous reports with extensive use of that collected by Pimentel (1971). Water temperatures not constant.
[b] Juvenile fish in saline 96 hours. LC_{50}. Korn and Earnest, 1974.
[c] Rye and King, 1976.
* 24 hour exposure.
† 96 hour exposure.

TABLE 3. Relative persistence of some pesticides in natural waters (from McEwen and Stephenson, 1979).

Non Persistent[a]	Slightly Persistent[b]	Moderately Persistent[c]	Persistent[d]
azinphosmethyl	aldrin	aldicarb	benomyl
captan	amitrole	atrazine	dieldrin
carbaryl	CDAA	ametryne	endrin
chlorpyrifos	CDEC	bromacil	hexachlorobenzene
demeton	chloramben	carbofuran	heptachlor
dichlorvos	chlorpropham	carboxin	isodrin
dicrotophos	CIPC	chlordane	monocrotophos
diquat	dalapon	chlorfenvinphos	
DNOC	diazinon	chloroxuron	
endosulfan	dicamba	dichlorbenil	
endothal	disulfoton	dimethoate	
fenitrothion	DNBP	diphenamid	
IPC	EPTC	diuron	
malathion	fenuron	ethion	
methiocarb	MCPA	fensulfothion	
methoprene	methoxychlor	fonofos	
methyl parathion	monuron	lindane	
mevinphos	phorate	linuron	
parathion	propham	prometone	
naled	Swep	propazine	
phosphamidon	TCA	quintozene	
propoxur.	thionazin	simazine	
pyrethrum	vernolate	TBA	
rotenone		terbacil	
temephos		toxaphene	
TFM		trifluralin	
2,4-D			

[a]Half-life less than 2 weeks.
[b]Half-life 2 weeks to 6 weeks.
[c]Half-life 6 weeks to 6 months.
[d]Half-life more than 6 months.

All these impacts on aquatic organisms act as a significant evolutionary force in the natural ecosystem. Long-term changes in species composition and distribution must be expected in rivers, lakes, and paddies where pesticides are used. (Ferguson, 1969). It is impossible to predict whether these changes will be desirable for the well-being of the humans who depend on those resources.

Pesticides also pose a hazard to birds and mammals. Much wildlife is directly killed by pesticide applications. Sublethal doses of organophosphates and carbamates are metabolized and excreted, but organochlorines persist and can accumulate to toxic levels in the bodies of animals, as well as causing behavioral and physiological changes due to chronic exposure (McEwen and Stephenson, 1979).

Reproductive failures in small mammals and high bioaccumulation rates in bats have been documented, but harmful sublethal effects of pesticides have been most thoroughly studied in birds. In fact, the chronic poisoning of bird populations in the U. S. and Europe first made us aware of the long-term effects of persistent pesticides. Many species high on the food chain, especially fish-eating predators, accumulated high levels of pesticide residues (principally DDT and its metabolites) in their bodies and this led to reproductive failures and the complete disappearance of some large populations. Eggs had thin eggshells and a high breakage rate, clutch sizes were reduced, embryo and chick mortality were high, and late and unusual nesting behavior was observed. The cause-and-effect relationship has been determined through correlation studies, and the physiological mechanisms involved are unknown. Conflicting evidence from laboratory feeding tests indicates that some bird species are more vulnerable than other (McEwen and Stephenson, 1979).

Effects on human beings are of two sorts. Pesticide use can involve adverse social effects, as well as health hazards. An example is the growing tendency toward herbicide use in developing countries. Unless there are jobs available for them in other sectors of the economy, agricultural laborers who are thrown out of work by such modern technology will remain unemployed, so that the quality of life is lowered nationwide and the government must deal with an additional burden and source of unrest.

Acute poisoning of human beings by pesticides is a serious problem throughout the world, but it is especially severe in developing countries because farmers are not familiar with the dangers of pesticides or the safety precautions that should be taken. Pesticides, many of them banned in the First World but still exported to the Third World, are often sold through illegal channels without labels or instructions, and where extension services are not adequate to in struct farmers in their correct use. Ironically, some of the environmentally undesirable persistent pesticides such as DDT have a lower acute toxicity to applicators than the compounds that are replacing them. Most acute poisonings occur with organophosphates, but illness after overexposure to endrin, heptachlor, and other organochlorine insecticides has been reported in applying, mixing and formulating these products. Recovery from poisoning with carbamates and organophosphates is relatively rapid. Organochlorine poisoning is more difficult to diagnose, and recovery is slow (McEwen and Stephenson, 1979).

The long-term effect on humans of sublethal doses of pesticides is speculative. Only a limited number of studies involving effects of pesticides have been conducted directly on people. Residue hazards to humans have generally been evaluated by 1) studies in experimental animals, 2) human epidemiologic studies of the incidence of illness in exposed populations, and 3) exposure studies, so that human and animal effects can be correlated (Durham, 1979). Unfortunately, animal studies may not be a very good indicator of human toxicity because of species differences in metabolic processes, and thus far, epidemiologic studies have produced conflicting data.

Other mammals show extensive sublethal effects, including modifications in enzyme production, growth rate, reproduction and activity levels, as well as tumor production and the deformation of offspring. There is no evidence that any of the widely used pesticides are carcinogenic, teratogenic or mutagenic in man. Some have been proved as such in some laboratory animals, especially when administered in large dosages and/or by routes (such as injection) not characteristic of human exposure. Responses differ in different laboratory mammals, and to date there is no way to assess the significance of these findings in terms of human risk factors (McEwen and Stephenson, 1979).

Recent discoveries concerning chronic effects of mercury on those consuming it and on their offspring, the role of diethylstilbestrol (DES) in predisposing female progeny to some types of vaginal cancer, and the teratogenic effects of thalidomide and some dioxins give reason for concern. These examples of the potential toxicity of new chemicals, plus observed harmful effects on wildlife from pesticide concentrations also encountered by people, dictate that all new products be screened carefully and that exposure to new chemicals be accepted only where it can be shown clearly that these contribute to peoples' welfare (McEwen and Stephenson, 1979).

Although pesticide use in West Africa has been minimal compared to that in some other areas of the world, it is a mistake to think that Africans do not encounter significant hazards. Acute pesticide poisoning is common, but pesticide residue surveys reveal additional evidence of widespread misuse of pesticides and indicate that Africans in many countries are already being routinely exposed to unacceptable levels of residues in marketed foodstuffs. GTZ, the German foreign aid organization, has been sampling pesticide residue levels in a wide range of products sold in local markets. This was done in Niger in 1978, and 51% of all samples were found to be contaminated and unfit for sale by German standards. This included 13 of 13 cereal samples, three of which were rice. Locally-produced rice and rice imported from China and Nigeria all contained HCH and lindane residues at 5-25X permissible levels.

56% of fresh vegetables tested were contaminated, not only with HCH and lindane: various samples showed excessive residues of aldrin, dieldrin, heptachlor epoxide, heptachlor, chlordane, endrin, and DDT as well (Ulsperger, 1979). The sampling was repeated in 1981. As of this writing, only the results for fresh vegetables have been computed, but these indicate that the problem is growing. 72% of the samples were contaminated with excessive residues of one or more pesticides (Ulsperger, 1981).

Such an example illustrates the urgency for establishing better pesticide regulations, management, and extension services. The hazards and frequent misuse of pesticides are a powerful argument for the creation of integrated pest management systems which will minimize dependence on pesticides and favor safer, more ecologically desirable methods.

REFERENCES

Antazo, T.A. 1978. Chemodynamics of pesticides, IPC/SP/36. In Proceedings of the regional training seminar on integrated pest control for irrigated rice in South and Southeast Asia, Oct. 16 - Nov. 18, 1978. IRRI, Los Banos, the Philippines.

Durham, W.F. 1979. Pesticides and human health, p. 83-93. In T. J. Sheets and D. Pimentel (Eds.), Pesticides: Contemporary roles in agriculture, health, and environment. Humana Press, Clifton, New Jersey. 186 p.

Ferguson, D.E. The effects of pesticides on fish: changing patterns of speciation and distribution, p. 83-86. In J.W. Gillett (ED.), The Biological impact of pesticides in the environment. Proceedings of the Symposium held August 18, 19 and 20, 1969 at Oregon State University, Corvallis, Oregon. 210 p.

Frank, P. A. 1972. Herbicidal residues in aquatic environments, p. 135-148. In Fate of organic pesticides in the aquatic environment, a symposium sponsored by the Division of Pesticide Chemistry at the 161st Meeting of the American Chemical Society, Los Angeles, Calif., March 29-31, 1971. Avances in Chemistry Series III. American Chemical Society, Washington, D. C.

Fryer, J. D. 1977. Recent developments in the agricultural use of herbicides in relation to ecological effects, p. 27-46. In F. H. Perring and K. Mellanby (Eds.), Ecological effects of pesticides. Academic Press, London. 193 p.

Graham-Bryce, I. J. 1977. Recent developments in the chemical control of agricultural pests and diseases in relation to ecological effects, p. 47-60. In F. H. Perring and K. Mellanby (Eds.), Ecological effects of pesticides. Academic Press, London. 193 p.

Kenaga, E.E. 1972. Guidelines for environmental study of pesticides: Determination of bioconcentration potential. Res. Rev. 44: 73-113.

McEwen, F.L. and G.R. Stephenson. 1979. The use and significance of pesticides in the environment. John Wiley and Sons, New York. 538 p.

Robson, T.O. and P.R.F. Barrett. 1977. Review of effects of aquatic herbicides, p. 111-118. In F.H. Perring and K. Mellanby (Eds.), Ecological effects of pesticides. Academic Press, London. 193p.

Sethunathan, N. 1972. Diazinon degradation in submerged soil and rice-paddy water, p. 244-255. In Fate of organic pesticides in the aquatic environment, a symposium sponsored by the Division of Pesticide Chemistry at the 161st Meeting of the American Chemical Society, Los Angeles, Calif., March 29-31, 1971. Advances in Chemistry Series III. American Chemical Society, Washington, D.C.

Ulsperger, W. 1979. Résultats des analyses d'échantillons provenant du Niger. PN 73.2028.6, mimeographed. Projet d'analyse des résidus de pesticides (GTZ), Darmstadt. 25 p.

Ulsperger, W. 1981. Ergebnisse Proben Niger. Mimeographed. Pesticide-Residue Project, Darmstadt. 13 p.

CULTURAL METHODS AVAILABLE FOR CONTROLLING RICE INSECT PESTS AND DISEASES

By

C. Michael Smith
Lousiana State University
Baton Rouge, LA 70803
USA

The development of short-stature, nitrogen-responsive, high yielding varieties (HYV's) of rice has been a mixed blessing to rice farmers all over the world. These varieties do increase productivity, (in many cases making the difference between survival and starvation) but their use has also led to an increased incidence of pest insects and diseases. Thus, the farmer is left in a quandary as to whether or not he or she should continue to use traditional varieties, or use HYV's and adopt the use of a group of integrated pest management (IPM) tactics. Cultural techniques, which manipulate water and fertilizer use or planting and harvest dates and procedures, are one of the least expensive and most effective groups of all IPM practices.

Cultural techniques were used by the Chinese several centuries before Christ, when planting dates were adjusted to avoid pest insect outbreaks and crop stubble was burned to destroy pest habitat (Flint and van den Bosch 1981). Today in much of the rice production area of China, cultural controls are the foundation of insect and disease control. Using cultural techniques requires a complete knowledge of the relation between rice phenology and pest biology, especially the most vulnerable period of the pest's life cycle.

For this reason, timing of treatment is the key to success of cultural control tactics. To better define how cultural controls are used in an IPM system, pertinent examples in several categories will be described.

Planting: As with many crops, synchronized, early planted rice will generally be more free of large accumulations of insects and diseases than mid and late season plantings. This trend holds true for the brown planthopper, *Nilaparvata lugens* (Stal), the rice gall midge, *Orseolia oryzae* and rice thrips, *Chloethrips oryzae*. Delaying planting until after emergence of the first generation of rice borers however, allows the crop to "miss" this peak infestation and avoid yield loss. In order to succeed, this tactic requires uniform monitoring of early season borer populations to predict their emergence. In Pakistan, farmers are prohibited by law from planting until after the emergence of first generation moths (FAO 1979). Ling (1980) has described several planting practices which reduce the incidence of rice disease occurrence. These include the use of pathogen free seed and selection of weed and debris free seed bed sites. Increasing plant to plant spacing in transplant nurseries also has been shown to decrease the incidence of rice blast disease, *Pyricularia oryzae*, and sheath blight, *Thanatephorus cucumeris* (Rush 1980).

Water Management: Since the majority of rice insect pests feed above the paddy water level, flooding of infested fields will often reduce pest population (Table 1).

Table 1: Rice pests adversely affected by flooding of infested fields

brown planthopper	Nilaparvata lugens Stal.
rice swarming caterpillar	Spodoptera mauritia Hubn.
fall armyworm	Spodoptera frugiperda J.E. Smith
rice leafroller	Susumia exigua (Butler)
rice stemborer	Chilo suppressalis (Walker)
yellow stemborer	Tryporyza innotata (Walker)
stem rot	Sclerotium oryzae Catt.
rice blast	Pyricularia oryzae Ca.

In China, early Spring flooding is more effective for control of over-wintering borer larvae, due to higher metabolic activity of larvae at that time of year and greater penetration of stubble by flood water. Conversely, larval populations of the root feeding rice water weevil can be reduced by draining paddy water off fields (Isely and Schwordt 1954). This practice is expensive though, due to the expense and labor of reflooding fields, fertilizer loss and ineffectiveness of killing larvae when the rice is reflooded too soon.

Some important rice diseases are also controlled by judicious water management, since this practice affects retention of fertilizer in the soil, survival of soil pathogens and movement of soil innoculum. Stem rot, caused by Magnaporthe salvinii (Sclerotium oryzae) can often be controlled by changing the water level during the vegetative stage of rice growth. When lesions on the outer sheathes are covered with water, the rot and fungus does not penetrate into the inner sheaths. By dropping the water level afterwards, many of the lower leaf sheaths are exposed so that they dry up and fall away from the culm, preventing penetration by S. oryzae. Similar measures can also be used to control rice blast (Rush 1980).

Fertilizer Management: The incidence of the major rice insect and disease pests usually increase as the rate of fertilization increases (Table 2). As mentioned previously this is one of the major problems which has developed since the inception and use of HYV's. Although fertilizers do have merit in terms of increased yields, the extent of their use should be tempered by the degree of crop loss incurred due to insect and disease losses.

Table 2. Pests favored by the use of increased amounts of chemical fertilizer in cultivated rice.

Pest	Fertilizer	Reference
rice gall midge, *Orseolia oryzae*	potash	Reddy 1967
brown planthopper, *Nilaparvata lugens*	nitrogen	Mochida & Dyck 1977
rice stem borer, *Chilo suppressalis*	nitrogen	Ishii & Hirano 1958
rice water weevil, *Lissorhoptrus oryzophilus*	nitrogen	Bowling 1963
rice blast, *Pyricularia oryzae*	nitrogen	Atkins 1956
stem rot, *Sclerotium oryzae*	nitrogen	Atkins 1975

Weed Control: Weed control is one of the truly applicable cultural practices available for use in rice IPM systems, since wild grasses and weeds provide habitat for many pest insects and diseases and reduce rice yields. Removal of wild grasses, which provide habitat for many rice insect pests (Table 3), has been shown to reduce pest incidence.

Table 3: Rice insect pests utilizing wild grasses and sedges as alternate hosts.

Insect	Host	Reference
rice gall midge, *Pachydiplosis oryzae*	*Panicum* & *Cynadon* spp.	Reddy 1967
rice stink bug *Oebalus pugnax*	*Echinochloa*, *Panicum* & *Paspalum* spp.	Odglen and Warren 1962
leafhoppers, *Nephotettix* spp.	Various grasses and sedges	Grist and Lever 1969
rice bugs, *Leptocorisa acuta* *L. oratorius*	Various grasses and sedges	Grist and Lever 1969

Harvesting, burning or rouging alternate weeds in the field and transplant nursery also reduces the incidence of rice diseases. Similarly, there is a direct relation between rice yield and the degree of in-field weed control.

Harvest Practices: The method by which the rice crop is harvested also affects the frequency of pest populations. Studies in Malaysia, Bangladesh and Indonesia with rice stem borer (Table 4) indicate that cutting stalks near ground level gives significantly better borer control than harvest at 100 cm above ground. In tropical climates, the greatest number of larvae

Table 4. Position of white rice borer, *Tryporyza innotata*, larvae in rice stems at harvest. 1/

Height (cm) from ground level	Number of larvae	Mortality (%) expected from cuting
0	10	100
0–10	65	98
11–20	82	81
21–30	37	61
31–40	125	52
41–50	44	21
51–60	30	10
61–70	7	3
71–8–	2	1
81–90	–	1
91–100	2	1
101–110	–	0

were found in rice stems between 10 to 60 cm above ground level, and in semi-tropical and temperate growing areas they were concentrated even closer to ground level. Though a greater amount of labor may be required to remove a larger portion of the stalk, low sickle cutting or burning of rice stalk residue will eliminate borer reinfestation and disease incidence in ratoon and other following crops.

Crop Rotation: Crop rotation is a cultural practice which helps prevent the continuous breeding of pest insects and diseases in areas where multiple rice crops are grown each year. No where is this more clear than in areas where HYV's have been introduced. In China, the adoptation of double and triple rice production systems has led to outbreaks of *N. lugens*, *O oryzae* and the yellow stem borer, *Tryporyza incertulas* (Shin Foon 1980). To reduce the problem, farmers allow a short fallow period between crops to eliminate borer habitat. Double and triple crop fields are also separated geographically to prevent gall midge outbreaks since they occur only over short distances.

In areas of rice production where multiple cropping causes significant pest problems, it may be beneficial to grow alternate season crops such as vegetables.

Conclusions: The examples discussed here indicate that cultural control techniques are effective IPM practices. Many of these practices involve actual farming methods which, with minor modification, can become some of the lease expensive and most effective. Cultural control techniques should receive a high priority in the development of African rice IPM systems.

REFERENCES CITED

Atkins, J.G. 1956. An outbreak of Piricularia on rice in 1955. Plant Dis. Reporter. 40:372-73.

Atkins, J.G. 1975. Controlling Diseases of Rice. pp. 58-68. In Six Decades of Rice Research in Texas. Texas Agric. Exp. Stn. Res. Monograph 4. 137 pp.

Bowling, C. C. 1963. Effect of nitrogen levels on rice water weevil populations. J. Econ. Entomol. 56:826-27.

FAO. 1979. Guidelines for Integrated Control of Rice of Rice Insect Pests. FAO Plant Production and Protection Paper 14. 115 pp. FAO, Rome.

Flint, M. L. and R. van den Bosch. 1981. Introduction to Integrated Pest Management. Plenum Press, New York, 240 pp.

Grist, D.H. and R.J.A.W. Lever. 1969. Pests of rice. Longmons, Green and Co., London. 52 pp.

Isely, D. and H. H. Schwardt. 1934. The rice water weevil Ark. Agric. Exp. Stn. Bull. 299.

Ishii, S. and C. Hirano. 1958. Effect of fertilizers on the growth of the larva of the rice stemborer, Chilo suppressalis Walker. I. Growth response of the larvae to the rice plant cultured in different nitrogen level soils. Jap. J. Appl. Entomol. Zool. 2:198-202.

Ling, K. C. 1980. Studies on Rice Diseases. pp. 135-147. In Rice Improvement in China and Other Asian Countries. International Rice Research Institute, Los Banos, Philippines. 307 pp.

Mochida, O. and V.A. Dyck. 1977. Bionomics of the brown planthopper, Nilaparvata lugens. In The Rice Brown Planthopper (Proc. Int. Seminar, Tokyo, Oct. 1976) ASPAC, Tapei. pp. 192-198.

Odglen, G.E. and L.O. Warren. 1962. The rice stink bug, Oebalus pugnax F., in Arkansas. Univ. Arkansas Agric. Exp. Stn. Report Series 107. 23 pp.

Reddy, D. B. 1967. The rice gall midge, Pachydiplosis oryzae (Wood, Mason). pp. 457-491. In IRRI. The Major Insect Pests of the Rice Plant. John Hopkins Press, Baltimore. 729 pp.

Rush, M. C., J. M. Bandong and J. P. Crill. 1979. Integrated Pest Management and Control of Rice Diseases. IRRI Thursday Seminar. Nov. 15, 1979. Dept. of Plant Pathology. 25 pp.

Shin-Foon, C. 1980. Integrated Control of Rice Insect Pests in China. pp. 239-250. In Rice Improvement in China and Other Asian Countries. International Rice Research Institute, Los Banos, Philippines. 307 pp.

PROMISING ALTERNATIVE APPROACHES TO PEST CONTROL

By

C. Michael Smith
Louisiana State University
Baton Rouge, LA 70803 USA

In addition to the chemical, biological and cultural control tactics which have been available for use in IPM systems for several years, several new alternative approaches to pest control have been or are being developed. All of the approaches are based on affecting the pest insect selectively, at a vulnerable point in its life cycle. In some cases the approach has not yet reached the point of total field utility, but within each approach, definite progress has been made toward controlling insect pests. For purposes of discussion these new tactics can be broadly classed as behavior modifying chemicals, microbial insecticides, insect growth regulators and autocidal control.

Behavior Modifying Chemicals: Behavior modifying chemicals have been used both presently and in the past in traps to either detect the occurrence of introduced pest species (methyl eugenol to trap the Japanese beetle *Papillica japonica*) or as toxic baits (molasses mixed with insecticides for grasshopper control). With the development of synthetic pheromones however, entomologists now have much more powerful behavior modifying chemicals, since the pest insect in question depends on these compounds for location of a suitable mate for survival of that species.

Pheromones are olfactory stimulants used by insects in chemical communication and occur as either sex pheromones (released by one sex and causing premature mating behavior by the other sex) or aggregation pheromones (released by either sex and causing the approach of both sexes of a given species).

With the exception of the male produced aggregation pheromone of the cotton boll weevil, *Anthomonous grandis grandis* Boheman, most all pheromone research has been conducted on female sex pheromones produced prior to mating. As a result, two main strategies have developed for the use of sex pheromones in IPM programs. The first involves the use of pheromone baited traps for population reduction (control). The second involves permeating the field atmosphere with male sex pheromones to confuse or disrupt the male during its normal mating behavior (Shorey 1977).

Until recently the only practical use of pheromones in IPM was in pheromone baited traps to monitor the spread of the pink bollworm, *Pectinophora gossypiella* (Saunders), on cotton in the southwestern United States. Correlations between male *P. gossypiella* trap catches and ensuing larval populations were used to increase the efficiency of insecticides applied for *P. gossypiella* control (Table 1) (Toscano et al. 1974). More recently however, Heneberry et al. (1981) demonstrated that the *P. gossypiella* pheromone gossyplure, impregnated on 0.05 cm^2 three layer plastic "flakes" and applied aerially, reduced larval infestations more than in plots treated with conventional insecticides only (Figure 1). These results confirm the use of the pheromone disruption technique in IPM of *P. gossypiella* on a small area (195 ha) of a commercial cotton acreage.

Almost simultaneously on the other side of the world similar tests were being conducted on mating disruption of the rice stalk borer, Chilo suppressalis (Walker) in Japan (Kanno et al. 1980). In these tests, the C. suppressalis mating disruptant Z-5-hexadecene was incorporated onto plastic strips and suspended on poles above the rice plants in 0.2m^2 plots. Results of these tests (Table 2) indicated that disruptant treated fields have significantly less plant injury than untreated control fields. Though they

Table 1. Comparisons of pink bollworm infested cotton bolls obtained from 2 different insecticide treatment programs in the Imperial Valley of California 1971-1973. 1/

Treatment	X No. of Treatments	X No. of Infested Bolls (%)
Scheduled	10.9	9.5
Based on moth catches	6.7	8.9

1/ From Toscano et al 1974.

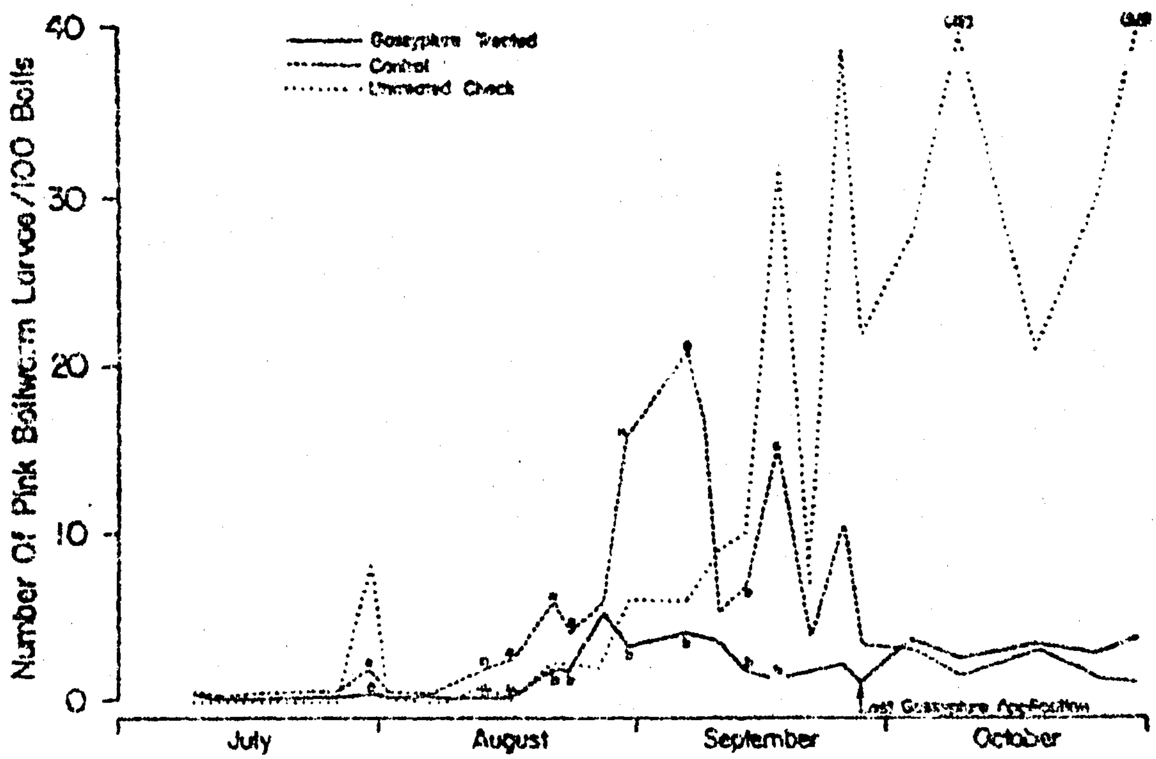


Figure 1. Mean number of pink bollworm larvae per 100 bolls in gossyplure-treated, control and untreated check plots. Arizona, 1979. (From Heneberry et al. 1981).

Table 2. Effect of the mating disruptant Z-5-hexadecene on injury of rice plants by larvae of *Chilo suppressalis*. 1/

Treatment	$\bar{X}$ 2/ % Injured Stubble
Z-5-hexadecene	13.2
Untreated	28.8

1/ From Kanno et al. (1980).
2/ X of 500 Stubbles

have not been evaluated in field mating disruption tests, the pheromones of the pink rice borer, *Sesamia inferens*, (Nesbitt et al 1976) and rice green caterpillar, *Naranga aenescens* (Ando et al. 1977) have been identified. Another pest of rice, the gall midge *Orseolia oryzae*, also appears to possess a sex pheromone (Coffman et al. 1977).

Microbial Insecticides: These insecticides use insect disease-causing microorganisms or their by products to cause toxicity in insects. For this reason they are not truly synthetic chemical insecticides. The greatest advantages to the use of these organisms is their highly specific toxicity to insects and safety to nontarget organisms. Thus far no adverse effects to humans or other vertebrates have been reported from the use of these biological insecticides.

The microbial insecticides include the bacteria, viruses and fungi normally found in insect populations which can be cultured in the laboratory or manipulated in nature to lower the population level.

Of all developed to date, the bacteria Bacillus thuringiensis (B.t.) and a similar bacteria Bacillus popillae (Milky spore disease) which is toxic to the Japanese beetle, Papillica japonica, are the most widely used. In the United States B. t. has been registered for use to control Lepidopterous larvae on numerous crops and is marketed commercially (Table 3). B. t. has

Table 3. Pest insects included for control under the commercial registration label of Bacillus thuringiensis. 1/

Insect	Crop(s)
cabbage looper, Trichoplusia ni	vegetables
imported cabbageworm, Pieris rapae	vegetables
tobacco budworm, Heliothis virescens	cotton
grape leaffolder, Desmia funeralis	grapes
fruit tree leafroller, Archips argyrospilas	shade trees
tomato hornworm, Manduca quinquemaculata	tomatoes
California oakworm, Phyrganidia californica	shade trees

1/ From Flint & van den Bosch 1981.

received limited use on rice, but B. thuringiensis var. galleriae is effective in controlling the rice skipper in China, where two spray treatments provide 90% control (Shin Foon 1980).

The viruses developed to date include the nuclear polyhedrosis viruses (NPV's), which have also proven effective in controlling several economically significant species of Lepidoptera (Table 4) and the polyhedrosis viruses of two forest pests, the gypsy moth, Lymantria dispar, and the douglas fir tussock moth Orgyia pseudotsuga.

The NPV's of the soybean looper Pseudoplusia includens (Walker), velvetbean caterpillar, Anticarsia gemmatalis Hubner, and alfalfa looper, Antographa californica (Speyer), all have good potential for control of these insects (Newsom et al. 1980). In many cases these viruses have the advantage over other insecticides in requiring

Table 4. Introductions of NPV into insect populations resulting in lasting control. 1/

Pest	Degree of Success	Location
spruce budworm, Chroistoneura fumiferana	foliage protection over 3 years	Canada
gypsy moth, Lymantrial dispar	approximately 40% control in second year	Sardinia
armyworm Spodoptera littoralis	strong evidence of natural spread and persistence	Crete
cabbage looper, Trichoplusia ni	controlled subsequent generations; T. ni no longer a pest on cotton	Columbia
moths Wiseana spp.	Pasture management maintains control below economic levels	New Zealand

1/ from Burges 1981.

only one in-season application, and persisting through the non-growing season to give good control the following season. Even though NPV's are effective, however, much research remains to be done on the methodology of commerical production. Unfortunately, until this expensive research is complete, commercial industry is unlikely to become interested in marketing insect viruses.

The fungus *Nomuraea rileyi* has toxic effects on several economically significant species of Lepidoptera (Table 5) ranging over a wide variety of several different crops. Due to its wide spectrum of activity, *N. rileyi* has received a great deal of attention in IPM research in the United States, but like other soybean entomopathogens, natural epizootics of the fungus usually develop late in the season after crop damage has occurred. Recent research by Sprenkel and Brooks (1975) however has shown that by distributing pieces of *N. rileyi* infected cadavers of the tobacco budworm, *Heliothis virescens* in soybean fields, earlier and more intense epizootics can be initiated than those occurring normally or with application of spore suspensions.

Table 5. Lepidoptera reported as susceptible to Nomuraea rileyi under normal field conditions. 1/

Insect			
black cutworm,	*Agrotis ipsilon*	soybean	USA
velvetbean caterpillar,	*Anticarsia gemmatalis*	soybean	USA
	Heliothis armigera	cotton	Africa
bollworm,	*H. zea*	cotton, soybean	USA
tobacco budworm,	*H. virescens*	cotton, soybean	USA
European corn borer,	*Ostrinia nubilalis*	corn	USA
imported cabbageworm,	*Pieris rapae*	cabbage	USA
green cloverworm,	*Plathypena scabra*	soybean	USA
soybean looper,	*Pseudoplusia includens*	soybean	USA
beet armyworm,	*Spodoptera exigua*	millet	India
	S. littoralis	cotton	Isreal
	S. littura	tobacco	India
cabbage looper,	*Trichoplucia ni*	cabbage, soybean	Taiwan, USA

1/ from Burges 1981.

Though these results are encouraging, the possibility of direct application of N. rileyi under field conditions is still in the experimental stage and will not be available as an IPM tactic in the near future.

Insect Growth Regulators: Insect growth regulators (IGR's) are chemicals which mimic the insect hormones and enzymes which control growth and cuticle production. One class of IGR's, the juvenile hormone analogues, prevents immature insects from moulting to adults and in so doing prevents the occurrence of a new pest generation. Methoprene (Altosid), a mosquito growth regulator, is the only juvenile hormone analogue currently registered for use in the United States. A second class of IGR's work to inhibit the production of chitin, the major component of the insect cuticle. By applying compounds of this type to insect populations, individuals are unable to moult and eventually die. Diflubenzuron (Dimilin)(R) is the only chitin synthesis inhibitor currently available, but has shown a wide spectrum of activity to several pest insects (Table 6). As with behaviorally modifying chemicals

Table 6: Insects adversely affected by the chitin synthesis inhibitor diflubenzuron

Coleoptera	boll weevil,	Anthomonous grandis grandis Boheman
	citrus rootweevil,	Pachnaeus litus (Germar)
	plum curculio,	Conotrachelus nenuphar (LeConte)
	white firfingered beetle,	Graphognathous spp.
Lepidoptera	spruce budworm,	Choristoneura fumiferana Clemmens
	coddling moth,	Laspeyrosia pomonella (L)
	European corn borer,	Ostrinia nubilalis (Hubner)
Diptera	house fly,	Musca domestica L.
	stable fly,	Stomoxys calcitrans (L).
	horn fly,	Haematobia irritans (L.)

and microbial insecticides, IGR's have great promise as "third generation insecticides", due to their specificity for insects and not vertebrates. Some problems remain to be solved in the timing of application, since the effects of diflubenzuron vary from insect to insect as to which growth stage is most adversely affected.

Autocidal Control: Autocidal control or sterile male release techniques involve the introduction of sterile (chemonsterilized or irradiated) male individuals into a pest insect population to lower its numbers. The success of the technique depends on the female of the field population mating with laboratory-produced sterile males. Through the use of this technique three dipterous pests; the melon fly, *Dacus cucurbitae* Coquillett, the Oriental fruit fly, *Dacus dorsalis* Hendel, and the screw worm, *Cochliomyia hominivorax* (Coquerel), have been eradicated in island habitats only. Attempts to eradicate *C. hominivorax* in inland areas where migration from untreated areas occurs have not been successful. Sterile male release techniques have also been used to prevent the spread of the pink bollworm from southern California into central California, but the value of this procedure has not been documented experimentally. The basic concept of an IPM program is to lower the level of the pest population to a non damaging level— not to eradicate it. For this reason, autocidal control of insects by the sterile male release technique is not a useful IPM tactic.

Conclusions: With the exception of autocidal controls, each of the alternative IPM tactics discussed here hold promise for use in their own way. Due to success similar to those mentioned here, insect sex pheromone research is increasing rapidly in the United States, a trend which will undoubtedly lead to an increased use of the mating disruption technique in IPM programs.

If the pheromones of African rice insect pests can be identified, these compounds will be very useful in IPM programs there. As mentioned earlier, the microbial insecticides, with the exception of B.t., require additional research on production and application methods. Because of their natural occurrence and non-toxicity to non-target organisms, they too can be of great utility in African rice IPM, once their etiology has been worked out. The insect growth regulators also have a place in African rice IPM, but in addition to basic efficacy and time of application research, the effects of these compounds on non-target aquatic invertebrates (shrimp, crabs and lobsters) in the rice agroecosystem will have to be determined.

REFERENCES CITED

Ando, T.K. Kishino, S. Tatsuki, H. Nakajima, S. Yoshida and N. Takahashi. 1977. Identification of the female sex pheromone of the rice green caterpillar, Naranga aenescens Moor (Lepidoptera:Noctuidae, Eustrotiinae). Agric. Biol. Chem. 41:1819-20.

Burges, H.D. 1981. Strategy for the Microbial Control of Pests in 1980 and Beyond. pp. 798-836 In H.D. Burges (ed.) Microbial Control of Pests and Plant Diseases 1970-1980. Academic Press, New York. 949 pp.

Coffman, W.R., H.E. Coffman and E.A. Heinrichs. 1977. Summary report. Visit of the IRRI rice improvement team to the Peoples Republic of China. August 15-30, 1977. IRRI Mimeographed Report, 62 pp.

Flint, M. L. and R. van den Bosch. 1981. Introduction to Integrated Pest Management. Plenum Press, New York. 240 pp.

Henneberry, T. J., J. M. Gillespie, L.A. Bariola. H. M. Flint, P. D. Lindgren and A. F. Kydonieus. 1981. Gossyplure in laminated plastic formulations for mating disruption and pink bollworm control. J. Econ. Entomol. 74: 376-81.

Kanno, H., M. Hattori, A. Sato, S. Takasuki, K. Uchiumi, M. Kurihara, J. Fukami, Y. Fujimoto and T. Tatsuno. 1980. Disruption of sex pheromone communication in the rice stem borer moth, Chilo suppressalis Walker (Lepidoptera:Pyralidae), with sex pheromone components and their related analogues. Appl. Ent. Zool. 15.

Nesbitt, B. F., P. S. Beevor, D.R. Hall, R. Lester and V.A. Dyck. 1976. Identification of the female sex pheromone of the purple stem borer moth, Sesamia inferens. Insect Biochem. 6: 105-107.

Shin-Foon, C. 1980. Integrated Control of Rice Insect Pests in China. 239-250. In Rice Improvement in China and Other Asian Countries. International Rice Research Institute. 307 pp.

Shorey, H.H. 1977. Manipulation of Insect Pests of Agricultural Crops. pp. 353-367 In H.H. Shorey and J.J. McKelvey Jr. (eds.) Chemical Control of Insect Behavior. John Wiley & Sons, New York. 414 pp.

Sprenkel, R.K. and W. M. Brooks. 1975. Artificial dissemination of *Nomuraea rileyi*, an entomogenous fungus of lepidopterous pests of soybeans. J. Econ. INTOMOL. 68:847-51.

Toscano, N. C., A. J. Mueller, V. Sevacherian, T. Niilus and H. T. Reynolds. 1974. Insecticide applications based on hexalure trap catches versus automatic schedule treatments for pink bollworm control. J. Econ. Entomol. 67: 522-24.

PRINCIPLES OF HOST PLANT RESISTANCE TO INSECT PESTS

By

Z.T. Dabrowski
The International Centre of Insect Physiology and Ecology, P.O. Box 30772, Nairobi, Kenya.

The use of resistant cultivars as a method of crop protection has gained acceptance in tropical countries. Host plant resistance is now considered to be one of the primary lines of defence in all pest management programmes for small farmers. Introduction of new resistant cultivar releases farmers from worrying about technological aspects such as timing of application, dosage of a chemical, a biological agent and there is no direct cost to growers. The latter two considerations make the case of resistant plants important to both developed and developing countries, and they should thus form an integrated part of a pest management programme.

Resistant varieties, even those with low or moderate levels of resistance, offer a number of advantages to an integrated control system. The reduction in pest numbers achieved through resistance is constant, cumulative, and practically without cost to the farmer. The reduction in pest numbers makes control by chemical and cultural methods easier and the level of natural biological control required to hold pest numbers below crop-damaging levels need not to be so great (Pimentel, 1969; Maxwell, 1972).

It must be noted, however, that while plant resistance to insects is a highly promising strategy of pest control, it requires sustained long range work and joint action of research by entomologists, agronomists, plant breeders and geneticists, and sometimes plant and insect physiologists and chemists.

Painter (1951) also stressed that resistant varieties are not a panacea for all pest problems. To be most effective they must be carefully fitted into control systems designed for specific pests and into the the plant improvement programmes of particular crops. Other means of pest suppression also must be considered, and these often are the first line of defence against injurious insects.

CLASSIFICATION

The variety is defined as resistant when it shows inherently less damage done by insect pests in nature than one which is suitable for insect survival and multiplication, which is called susceptible. Snelling (1941) included in plant resistance those characteristics that enable a plant to avoid, tolerate, or recover from attack of insects under conditions that would more severely injure other plants of the species. Painter (1951) developed this definition by characterizing varietal resistance to insect pests as "the relative" amount of heritable qualities possessed by a plant which influence the ultimate degree of damage done by the insects. In practical agriculture, it represents the ability of a certain variety to produce a larger crop of good quality than an ordinary variety at the same level of insect population."

Resistance usually is measured by using susceptible cultivars of the same plant species as controls.

Painter (1951) classified mechanics of resistance in host plant to the insect pest into three components:

(1) Preference/non-preference - refers to the group of plant characters and insect responses or to the absence of attractive qualities in plants for the pest to use that particular plant of variety for oviposition, for food or for shelter or for combination of the three.

(2) Antibiosis - refers to adverse effect of the plants on the biology of the insect feeding on them.

(3) Tolerance - refers to a basis of resistance in which the host plant exhibits an ability to grow or reproduce normally or to repair injury to a marked degree in spite of supporting a population approximately equal to that severely damaging a susceptible host.

In practice, it should be noted that the allocation of plant characters into one of these three components is more easy for cultivar showing high level of resistance, in which only one plant characteristic is involved. The allocation is much more complicated if the moderate level of resistance is conditioned by a number of different plant characteristics.

The accumulation of new experimental results on mechanisms of plant resistance to insect pests showed, however, that the Painter's terminology is inadequate to the present state of knowledge and sometimes creates confusion.

Beck (1965), Saxena (1969), Dabrowski (1976a) de Ponti (1977) and Kogan and Ortman (1978) therefore proposed some modifications in the classification and definitions. Dabrowski (1976) and de Ponti (1977) replaced the term non-preference by the term "non-acceptance." Non-acceptance implies that during the orientation and colonization phase the plant is not accepted by the insect pests for feeding, egg laying or for shelter in choice and non-choice situation. Previously, number of scientists referred all of differences found in the preference of one cultivar upon another to resistance, not testing this so called resistant cultivar under non-choice (mono cultivars) situation).

Beck (1965) suggested the exclusion of tolerance from resistance mechanisms because tolerance cannot be used to express allelopathic relationships between the host plant and its associated herbivore fauna. He restricts plant resistance to the collective heritable characteristics by which a plant species, race, clone or individual may reduce the probability that an insect species, race, biotype, or individual successfully uses the plant as, a host. Beck's definition narrows the spectrum of insect-plant interactions to the successful use by the insect of a plant as host, but it excludes the plants ability to recover or repair losses after injury.

Kogan and Ortman (1978) in the other way criticized the conciseness of the term non-preference which is used by Painter (1951) to describe the modality of resistance involving effects of behavioural process that result in avoidance of the plant as food or as an oviposition substrate and with allelopathic relationship established at the animal's sensorial system.

They proposed the term "antixenosis." A Greek work, "xenos" refers to "guest", so antixenosis means something that keeps a guest away and that the resistant host is the bad host. The term antixenosis is parallel to antibiosis.

GENERAL CHARACTERISTICS OF HOST PLANT INSECT RELATIONSHIPS

Successful host plant utilization by an insect unquestionably depends on there being a "proper fit" between the biological characteristics of insect and plant. Both organisms are dynamic systems, subject to temporal changes in physical and physiological properties. The role of particular plant characteristics or an insects-plant relationship is dependent upon the effect of that characteristic on the behavioural and developmental physiology of the insect. Host plant resistance may be viewed as the result of a "partial fit" to a "not fit" relationship between the requirements of the insect and the correlative characteristics of the plant.

Saxena (1969) mentioned four levels of host plant/ insect relationships affecting:

(1) insect orientation,

(2) oviposition,

(3) feeding and

(4) growth and survival on the host plant (Table 1).

Table 1.

TYPES OF RESPONSE OF INSECTS TO PLANTS
(Saxena, 1969)

1. ORIENTATION

Positive Response (Attraction):
resulting in the insects' arrival/stay on plants

OR

Negative Response (Repulsion):
resulting in the insect's avoidance of plants.

Visual and/or chemical characters.

2. OVIPOSITION

Physical and/or chemical characters

3. FEEDING

resulting in digestion of food
Visual, mechanical and/or chemical characters

4. GROWTH AND SURVIVAL

Absence of metabolic inhibitors (toxins)
Digestibility/Absorbability of plant constituents
Nutritive value determining metabolism of
ingested food.

NON-ACCEPTANCE

Plant resistance to oviposition

Among insects that lay their eggs on or near the plants utilized by the progeny, the first point in the insect-plant relationship at which the plant may show resistance is resistance to oviposition. But oviposition is not a simple act; it involves a series of behavioural events. The first component of oviposition behaviour is that of "recognition" and "orientation" to the host plant. Following such orientation to the plant as a whole the insect orients to differnet plant parts in the selection of a specific oviposition site. Deposition of eggs follows; and the insect finally departs from the site of oviposition. Different plant characteristics may influence the initiation and completion of each of these events.

Characteristics that tend to prevent oviposition may do so either by failing to provide the appropriate releasing stimuli for one or more of the behavioural components, or by providing stimuli that inhibit behavioural release. Many examples of plant resistance of the non-acceptance type involve the effect of the plant on oviposition.

Insects seldom oviposit indistriminately over the surfaces of the plant, but characteristically deposit their eggs on selected plant parts. The sites selected sometimes vary in regard to leaf maturity and the presence or absence of reproductive parts.

Tactile, proprioceptive, chemotactic, and visual factors may play a role in site selection and subsequent egg deposition.

Differences in oviposition of Diopsis thoracica females on various rice cultivars were observed by Alghali (1981). The rice cultivar Suakoko 8 received six-fold more eggs than OS 6 (Table).

Oviposition preference and damage of some rice varieties by Diopsis thoracica (Alghali 1981)

Variety	No. of eggs/hill	Tiller damage (in %)
Suakoko	7.2 a	53.5 a
IR 5	6.1 a	38.9 bc
BG 90-2	5.7 ab	31.3 bc
ADNY 11	3.6 b	24.6 c
TOs 4121	3.2 c	44.7 ab
IR 8	3.0 bc	28.8 bc
GH 106-76	2.8 cd	23.0 c
IRRI 12682	2.8 cd	32.1 bv
SD 27	2.0 d	22.1 c
OS 6	1.2 d	54.6 a

Morphological characters of the host plant which appeared to have influenced the attraction of the fly to the plants for oviposition were:

(a) plant height
(b) stem diameter
(c) leaf angles.

A general association between several morphological and anatomical characteristics of the rice plant and resistance to stem borers has been recorded by Pathak et al (1971).

Tall varieties, because of their height, might be more attractive to ovipositing moths. The length and width of the flag-leaf blade were positively correlated with borer susceptibility. In separately conducted ovipositional preference tests these characteristics were positively correlated (r = 0.734 and 0.924, respectively) with the number of egg masses laid (Pathak et al, 1971). A hairy leaf blade surface might act as a physical deterrent for the egg laying moths. However, even the removal of the hairs from the leaf surface of the resistant variety TKM 6 did not make it more attractive for oviposition by the borer moths.

Resistance to oviposition is obviously an important aspect of the overall resistance of plants to insects (Beck, 1965). Few studies, however, have been conducted in which the causal factors contributing to resistance have been identified by critical analysis of field experiments where the resistant lines were grown under non-choice situations.

Plant resistance to feeding

Feeding involves a sequence of stereotyped behavioural components that closely parallels that described for oviposition. The steps in feeding behaviour are:

(1) host plant recognition and orientation;
(2) initiation of feeding (biting or piercing);
(3) maintenance of feeding; and
(4) cessation of feeding, followed usually by dispersal.

Plant resistance may result from the plant's failing to provide the releasing stimuli required for one or more components of the feeding sequence, or by the possession of characteristics having advance effects on feeding activities.

Resistance mechanisms that are directed against insect feeding have usually been classified as examples of resistance of the non-acceptance type.

Dethier et al (1960) and Beck (1965) proposed a terminology with which to deal with insect feeding behaviour and other chemosensory responses (Table 3). "Attractant" is defined as a stimulus to which the insect responds by orienting movements toward the apparent source.

Classification of stimuli influencing different feeding behaviour responses (Beck 1965)

Response	Evoking stimulus	
	Positive	Negative
Orientation	Attractant	Repellent
Orientation	Arrestant	Repellent
Biting or piercing	Incitant	Suppresant
Maintenance of feeding	Stimulant	Deterrent

"Repellents" elicit an oriented response away from the apparent source. An "arrestant" is a stimulus that causes the insect to cease locomotion in close contact with the apparent source. Beck (1965) noted that initiation and maintenance of feeding are known to be separable phenomena. Therefore, he proposed the term "feeding incitant" to describe a stimulus that evokes the biting or piercing reaction; conversely, a stimulus tending to prevent this response is designated as a "feeding suppresant."

Stimuli tending to promote continuous feeding are termed "feeding stimulants"; and those preventing continuous feeding or hastening the termination of feeding are designated as "feeding deterrents."

The resistance of maize to the European corn borer has been shown to be in fact, a resistance to larval feeding. Early instar whorl, and leaf lesions per infesting borer tend to be more numerous and larger on susceptible than on resistant plants (Chiang and Hodson 1953; Beck 1955). The leaves of resistant corn varieties tend to deter larval feeding, with the chemical resistance factor 6-methoxy-benzoxazolinone, acting as a feeding deterrent as well as a growth inhibitor (Beck 1960).

The feeding behaviour of oligophagous insects is more complex and more closely dependent on plant-borne stimuli than is the case with polyphagous forms such as the corn borer or grasshoppers. It follows, thus that plant resistance may operate against the oligophagous insect at more points in the feeding sequence.

IRRI entomologists noted that the green leaf-hopper, *Nephotettix virescens*, the brown planthopper *Nilaparvata lugens*, and the white-backed planthopper, *Sogatella furcifera* exhibited distinct non-acceptance for certain rice varieties (IRRI 1977). This response was gustatory rather than visual mechanical or olfactory, as insects did not show differences in alighting upon different varieties, but their feeding was not sustained on resistant varieties. The females of *Sogatella* hoppers started feeding promptly on the susceptible TN1 plants and feed continuously but on resistant plants they often did not start feeding for the first 20 to 30 minutes and their feeding durations were short (IRRI 1977).

Similarly, brown planthopper females did little feeding on resistant varieties but ingested large quantities of sap from susceptible varieties (Saxena and Pathak 1977). The weight gain

was small on resistant varieties as against susceptible varieties and was related to the amount of sap sucked by the insects from the plants. The reduced fedding by hoppers on resistant varieties is probably due to either absence of feeding stimulants or presence of feeding deterrents or repellents for those pests (Pathak and Saxena 1979).

Non-acceptance was found involved in most of resistant rice varieties to the brown planthopper, Nilaparvata lugens (Pathak 1972; Sogawa 1973; Cheng 1973; Kaneda 1974). The differences in varietal preference were not apparent within the first 6 hours after caging.

Many workers have attempted to identify the specific-causal chemical for the brown planthopper resistance, however, no particular compund was found responsible for a specific deterrent response, except some general inhibitors were identified such as oxalic acid, silici acid, and other aliphatic acids (Yoshihara et al 1979, 1980; Sogawa 1977).

ANTIBIOSIS

Antibiosis includes all adverse effects exerted by the plant on the insects biology, for example survival, development, and reproduction. The effects on the insect take the form of reduced fecundity, decreased size, abnormal length of life, and increased mortality (Painter 1959). The latter appears usually in the first instar or in those stages just preceeding the adult stage.

Biophysical resistance to survival

The physical form and tissue structure of plants undoubtedly influence their utilizability as insect hosts. However, there have been few critical experimental studies of the role of biophysical factors in host plant specificity and plant resistance. Early workers tended to postulate physical causes for varietal resistance in a number of instances in which subsequent research showed resistance to be caused by bio-chemical factors.

Tissue toughness as a result of high silica content was postulated by Sasamoto (1958) to render the rice plant resistant to larvae of the striped rice Chilo suppressalis (Walker).

Pathak et al (1971) listed a number of plant morphological and anatomical characters related to rice resistance to C. suppressalis (Table 4). Each of these characteristics appears to contribute to borer resistance and none by itself appears to be the main cause of such resistance. This relationship was evident in several varieties that reacted as susceptible to the borers even when one of the characteristics they possessed was positively correlated with resistance. Resistance to C. suppressalis has been recorded in rice varieties having leaf sheaths tightly wrapped around the stem, closely packed vascular bundles, thick scelenchyma, and high silica content. These characteristics probably interfered with the boring activity of larvae in the stem as larvae feeding on silicious rice varieties exhibited trypical antibiosis effects and had worn out mandibles (Djamin and Pathak 1967; Patanakamjorn and Pathak 1967).

Table 4: Correlations between rice plant characters and percentages of tillers infested with Chilo suppressalis (Pathak et al 1971).

Plant Character	Correlation coefficient*
Elongated internodes, number	0.632
Third elongated internode, length	0.715
Flag leaf, length	0.798
Flag leaf, width	0.836
Culm height	0.796
Culm, external diameter	
. at half its length	0.672
. at one-fourth its length from the base	0.785
Culm, internal diameter	
. at half its length	0.671
. at one-fourth its length from the base	0.790
Tillers per plant, number	-0.756
Stem area occupied by vascular bundle Sheaths (percentage)	-0.756

Explanation* All values highly significant.

Biochemical resistance to survival

Plant biochemicals that have adverse effect on insect feeding behaviour may thereby reduce the probability for survival particularly among species in which the larval forms are incapable of locating a more suitable host. Insect mortality may then result from starvation, or semistarvation, combined with unfavourable environmental forces. A distinction needs to be drawn between resistance to feeding and resistance that acts by interfering with the physiological processes underlying growth, metamorphosis, and reproduction. Such physiological effects may be caused by metabolic inhibitors in the plant tissues, or by the plant's failing to provide specific nutrients or nutrient balances required by the insect.

Physiological inhibitors: Very young corn plants have long been known to be highly resistant to the establishment and survival of larvae of the European corn borer. Some genetic lines of corn become very susceptible to larval survival as they mature; others retain much of their juvenile resistance (Beck 1965).

The biochemical basis of resistance to first-brood of European corn borer has been identified as 2,4 - dihydroxy - 7 - methoxy - 1,4 - benzoxazin - 3 - one, commonly known as DIMBOA. DIMBOA levels are high in most seedling stage maize plants, but decrease as plant mature. At the mid-whorl stage of development, some lines retain high DIMBOA levels and are resistant to the European corn borer. DIMBOA levels are low in all lines at the time of second-brood infestation: hence DIMBOA is not related to stalk boring resistance.

Nutritional deficiencies: Insect mortality and the retardation of development on resistant cultivars may be caused not only by the metabolic inhibitors in the plant tissue but also by the plants failing to provide specific nutrients or nutrient balances required by the insect.

In order to be fully adequate, a host plant must provide the nutritional factors required by the insect. But the insect is dependent on the plant for much more than nutrients alone; chemostimulants, physical factors, and micro-environmental factors all play a role in determining the adequacy of a given plant as host for a given insect. A resistant plant, therefore is not necessarily nutritionally inadequate.

The resistance of 'Mudgo' rice cultivar to brown planthopper biotype 1 was attributable to its lower asparagine content than in the susceptible variety 'TN1' (Sogawa and Pathak 1970).

In addition, the free amino acid concentration in whole plant extract and xylem edudates is three to four times lower in 'Mudgo' than in TN1' (Sogawa, 1977).

TOLERANCE

Tolerance includes all plant responses resulting in the ability to withstand infestation and to support insect populations that would severely damage susceptible plants. The use of tolerance in resistance studies does require, however, a thorough understanding of the ways in which insects may injure plants as well as the ways in which plants may repair the damage done (Painter 1951). Tolerance response is perhaps more subject to variations as a result of environmental conditions than are non-acceptance and antibiosis. The age and size of plant and size of insect populations strongly influence the degree of tolerance exhibited by none variety in comparison with others.

The general vigour of a plant greatly affects its tolerance to insect attack. More vigorously growing maize was usually more attractive to the ovipositing European corn borer. Ostrinia nubilalis but in hybrid maize the average yield reduction per borer, per stalk, was less than it was in open-pollinated corn (Painter et al 1935).

The insects with chewing mouth parts, as a rule, destroy the plant part attacked so completely that the only type of tolerance that can be developed is that concerned with replacement of regrowth. Such regrowth is often conditioned by the relative stage of maturity during which destruction of plant parts takes place (Painter 1951).

ALGHALI, A.M. (1981): Studies on the relative susceptibility of rice varieties to Diopsis thoracica West (Diptera: Diopsidae). Ph.D. Thesis, University of Ibadan, 184 pp.

BECK, S.D. (1960): The European corn borer, Pyrausta nubilalis (Hübn), and its principal host plantVII. Larval feeding behaviour and host plant resistance. Ann. Entomol. Soc. Amer. 53: 206-12.

BECK, S.D. (1965): Resistance of plants to insects. Ann. Rev. Entomol. 10: 207-32.

CHIANG, H.C. and HODSON, A.C. (1953): Leaf injury caused by first generation corn borer in field corn. J. Econ. Entomol. 46: 68-73.

DABROWSKI, Z.T. (1976 a): Bases of plant resistance to pests (in Polish) PWRL Warszawa pp. 163.

DETHIER, V.G.,; BARTON BROWNE, L. and SMITH, C.N. (1960): The designation of chemicals in terms of the responses they elicit from insects. J. Econ. Entomol. 53: 134-36.

DJAMIN, A. and PATHAK, D.D. (1967): The role of silica in resistance to Asiatic rice borer Chilo suppressalis (Walker) in rice varieties. J. Econ. Entomol. 60: 347-51.

INTERNATIONAL RICE RESEARCH INSTITUTE (IRRI, 1977): Annual Report for 1976, Los Banos, Philippines, 584p.

KANEDA, C. (1974): Present status of studies on host plant resistance to brown planthopper, with special emphasis on the breeding of rice in Japan. Paper presented at the International Rice Research Conference, International Rice Research Institute, Los Banos, Philippines.

KOGAN, M. and ORTMAN, E.E. (1978): Antixenosis - a new term proposed to replace Painter's "Nonpreference" modality of resistance. Entomol. Soc. Amer. Bull. 24: 175-76.

MAXWELL, F.G. (1972): Host plant resistance to insects - nutritional and pest management relationships. In: Insect and Mite Nutrition, Rodriquez, J.G. (Ed) North Holland, Asterdam, 599-609.

PAINTER, R.H. (1951): Insect resistance in crop plants, The Macmillan Co., New York, 520 pp.

PAINTER, R.H.; SNELLING, R.O. and BRUNSON, A.M. (1935): Hybrid vigour and other factors in relation to chinch bug resistance in Corn. J. Entomol. Ent. 28: 1025-30.

PATANAKAMJORN, S. and PATHAK, M.D. (1967): Varietal resistance of the Asiatic rice borer, *Chilo*
3 *suppressalis* (Lepidoptera: Crambidae) and its association with various plant characteristics. Ann. Entomol. Soc. Am. 60: 287-92.

PATHAK, M.D. (1972): Resistance to insect pests in rice varieties. In: Rice Breeding. International Rice Research Institute, Los Banos, Philippines: 325-41.

PATHAK, M.D. and SAXENA, R.C. (1979): Insect resistance. In: Plant Breeding Perspectives. J. Sneep and A.J.T. Hendriksen (Eds). Centre for Agricultural Publishing and Documentation, Wageningen: 270-292.

PATHAK, M.D.; ANDRES, F.; GALACANAC, N. and RAROS, R. (1971): Resistance of rice varieties to the striped stem borer. Int. Rice Res. Instit. Tech. Bull. 11:69.

PIMENTEL, D. (1969): Animal populations, plant host resistance and environmental control. Proc. Tall. Timbers Conf. Ecol. Anim. Control Habitat Manage 1: 19-28.

PONTI de O.M.B. (1977): Resistance in *Cucumis sativus* L. to *Tetranychus urticae* Koch 1. The role of plant breeding in integrated control. Euphytica, 26:633-40.

SASAMOTO, K. (1958): Studies on the relation between silica content in the rice plant and the insect pests. VI. On the injury of silicated rice plant caused by the rice stem borer and its feeding behaviour. Japan. J. Appl. Entomol. Zool. 2: 88-92.

SAXENA, K.N. (1969): Patterns of insect-plants relationship determining susceptibility or resistance of different plants to to insect. Entomol. Exp. Appl. 12: 751-66.

SAXENA, R.C. and PATHAK, M.D. (1977): Factors affecting resistance of rice varieties to the brown planthopper, *Nilaparvata lugens* (Stal). In: Pest Control Council of the Philippines, April 18-20, 1977. Bacolod City, Philippines, pg. 34.

SNELLING, R.O. (1941): Resistance of plants to insect attack. Bot. Rev. 7: 543-586.

SOGAWA, K. (1973): Feeding behaviour of the brown planthopper and brown planthopper resistance in Indica rice, Mudgo. Bull. 4 Lab. Appl. Entomol., Faculty of Agric. Nagoya, University, Chikusa, Nagoya, Japan, 151 p.

SOGAWA, K. (1977): Feeding physiology of the brown planthopper. In: The Rice Brown planthopper. Compiled by Food and Fertilizer Fechnol. Centre for Asian and Pacific Region: 95-116.

YOSHIHARA, T.K.; SOGAWA, K.; PATHAK, M.D. and JULIANO, B.O. (1979): Soluble silicic acid as a sucking inhibitory substance in rice against the brown planthopper (Delphacidae, Homoptera). Entomol. Exp. Appl. 26: 314-22.

YOSHIHARA, T.; SOGAWA, K.; PATHAK, M.D.; JULIANO, B. O. and SAKUMURA, S. (1980). Oxalic acid as a sucking inhibitor for the brown planthopper in rice (Delphacidae, Homoptera). Entomol. Exp. Appl. 27: 149-155.

THE PRINCIPLE OF HOST PLANT RESISTANCE TO PLANT DISEASES

By

J. L. NOTTEGHEM
IRAT, BP. 635,
Bouake, Ivory Coast

A non-specialized researcher reading a work on plant diseases might think that each plant species is attacked by very many microorganisms: fungi, bacteria, virus and mycoplasma, nematodes. However, as he reads on, he will change his mind because he will realize that each specie is only attacked by very few of all the existing micro-organic pests. The most polyphagous pathogens such as Rizoctonia solani which can attack potatoes and rice or the tobacco mosaic virus which can infest more than 100 plant species can only attack a very small number of all the known plant species, and even then, this can only take place under very specific conditions.

Many microorganisms can only infect one species. Infection by pathogemic microorganisms is therefore a relatively rare phenomenon. A plant can only be infected by few very specialized organisms. This is so because the plant can defend itself against most microorganisms while others have a very high degree of adaptation to their hosts. However, this phenomenon can not be attributed to resistance. We shall use the term resistance to define aptitude of a plant to defend itself against a microorganism that can parasitize the species to which the plant belongs.

Some of the defense mechanisms that are used at the initial stage of an attack, for example, during penetration can be the same irrespective of whether it is a parasite or a pathogen. However, during later stages of the disease, the plant uses resistance mechanisms that are specific of parasites.

The concept of pathogenicity implies that at least during one stage of its development, the pathogen survives at the expense of a living organism. This is possible either because the resistance takes place somehow late or because it is inadequate. The zero degree of resistance is that level which enables the pathogen to develop uninhibited, thus systematically leading to the death of the plant. Resistance is therefore considered to be a general mechanism.

A distinction is usually made between two types of resistance, namely vertical and horizontal resistance.

Specific resistance (or vertical resistance, is complete but its effectiveness is limited to certain races of the same pathogen.

General resistance (or horizontal resistance is effective against the entire population of a pest species. By the "aggressiveness" of a pest is meant the pests aptitude to overcome the general resistance of the plant while virulence is the capacity to overcome some of the specific resistance of the host.

Experts in fields such as mycology and virology are quite far apart for their terminology do differ. Thus, virologists call a virus that is capable of multiplying in a plant species virulent, a plant that does not allow a virus to multiply resistant, and a plant that can withstand the presence of a virulent virus without suffering any damage, tolerant. During this discussion, the terms used shall be borrowd from mycology.

2. THE RESISTANCE MECHANISMS OF PLANTS TO FUNGI PARASITES

We shall use the classification that makes a distinction between passive and and active, physical and chemical resistance, even though this distinction is somewhat artificial. Hypersensitivity shall be dealt with separately.

2.1. Passive resistance mechanisms:

During its development, a fungus pathogen confronts physical or chemical obstacles which are the normal constituents of the plant.

The success or failure of a spore is determined as soon as it gets into contact with the host. Studies have shown that depending on the position and quality of the surface of a leaf, a spore has more or less chances of being attached to it.

In the case of rice, it has been observed that erect unlike droopy leaves, retain less spores and water drops that facilitate their germination. It goes without saying that such characteristics are not necessarily determining factors. African upland blast resistant rice varieties such as Moroberekan have broad and droopy leaves.

Once there is a spore on a leaf and if the climatic conditions are favourable, the spore germinates and the mycelial hypha penetrates it either directly through the cuticle or through a natural opening like the stomata. The quality of the cuticle can be an important resistance factor. Silicon is a component of the rice cuticle and Japanese scientists have shown that the resistance of plants can be correlated with the silicon content of tissues.

The silicon content is itself dependent on many factors such as the supply of nitrogen, water, phosphorous, etc., to the plant. In the case of pathogens which necessarily penetrate the plant through the stomata, their number can be important in the susceptibility or resistance of the plant.

Passive resistance is rarely the result of chemical compounds. However, as far as onions are concerned, those with brown peels have resistance to several pathogens (Colletotrichum cirinans, Botrytis cinerea) due to the high catechin content in superficial tissues. On the other hand, substances exuded by the plant favour the growth of the pathogen.

Passive resistance to the development of the pathogen after its penetration has less often been observed.

Structure of organs can play a role in resistance and it has been observed that wheat varieties whose stems contain many sclerenchymas are less attacked by rust.

2.2. Induced resistance:

2.2.1. The formation of morphological barriers:

In very many instances, plant cells can form barriers to restrict the growth of a pathogen. These barriers can be formed by the thickening of the cell walls close to the area infected by the pathogen. It is also possible in the case of trees, to appearance of cell masses producing corky spot or the abundant production of gummosis. These reactions are not specific of a pathogen attack, but they can contribute to resistance. In the case of neck blast attack, for resistant rice varieties, the formation of a barrier by the thickening of the cell walls around the attacked zone can be observed.

2.2.2. The production of anti-fungic substances by the plant

The plant secretes substances which are toxic for the pathogen or which inhibit its growth. Among these substances, the most frequent are phytoalexins and phenolic compounds.

As progress is made in research, it is discovered that the production of phytoalexins is a very widespread phenomenon among dicotyledons. These substances are not specific of pathogen attacks but it has been shown that their secretion by the cells close to the disadvantaged cells can lead to their concentration in great numbers in dead cells. The substances can therefore have effective antifungal action.

Phenolic compunds are also very widespread in the tissues of plants attacked by pathogens. These substances have a fungicidal activity but in concentrations that are not always reached in sick tissues. However, it is considered that they are also substances that can contribute to plant protection.

In the case of rice blast, these two substances have shown to exist. The presence of polyphenols in the tissues which turn brown while forming a kind of border around the leaf lesions has been observed. Furthermore, the inoculation of leaves using spores of *Pyricularia oryzae* causes the secretion of substances that can inhibit the germination of the spores of *pyricularia oryzae* which therefore have an effect similar to that of phytoalexin.

Detoxifying toxins

Toxins are a means of protection produced by very many fungal pathogens. Their role is particularly important for certain diseases such *Helmintosporium sacchari* (sugar cane) or *Helmintosporium maydis* (maize). The pathogens in question produce the toxins specific of the host. This means that the main resistance factor of the host is its ability to detoxify the toxin. Thus, resistant sugar cane varieties have been obtained by regenerating the callus obtained from the cultivation of tissues containing a pathogen culture filtrate. As far as brown leaf disease of rice is concerned, the main protection mechanism of a fungus is not a toxin but its pecticenzymes - *Pyricularia oryzae* produces toxins; some of which are pyricularin, picolinic acid and tenuazonic acid.

Recent work consisting of the cultivation of callus on a medium containing tenuazonic acid have not shown any difference between resistant. (IRAT 13) and susceptible (Aichi asahi) varieties.

2.4. Hypersensitivity:

The phenomenon of Hypersensitivity is a very widespread mechanism which is described as the rapid self destruction of the first or the first group of cells attacked by a pathogen. In fungi, this necrosis inhibits the growth of hypha and often of their lysis. Hypersensitivity can be caused by bacteria and virus. The disappearance of a favourable environment for the life of the pathogen through the necrosis of the cells can not always be advanced as a reason for its inhibited growth. Several authors hypothesize that the very localized production of phenols and phytoalexin could play a determining role.

While it is easy to recognise a typical lesion of hypersensitivity, there are no features that make it possible to distinguish a slightly bigger necrosis which is not a lesion of hypersensitivity. In the case of rice blast, the avirulent strains cause a hypersensitive reaction on the varieties which have corresponding specific resistance.

2.5. Plant immunity:

The parallel that can be drawn between plant and animal acquired immunity is based on very few analogies. In fact, as far as plants are considered, the protection obtained through preinoculation with a culture filtrate or a non pathogen strain is very often localized and effective for a short time. In the case of cereals, three cases are known; wheat and yellow rust, eyespot of barley and take all of wheat. So far, the same phenomenon has not been demonstrated as far as rice is concerned. The phenomenon of premunition has received very little practical application.

3. RESISTANCE MECHANISMS TO PHYTO PATHOGENOUS BACTERIA

Bacteria do not have the possibility of penetrating actively. They therefore can only infest the host through natural openings or wounds. The epidemis and its cuticle therefore do not play any role, but the density of stomata can play an important role. As far as the resistance mechanisms of the host after penetration by bacteria is concerned, they are similar to those used against fungi.

4. RESISTANCE MECHANISMS TO VIRUSES

Viruses are perfect pathogens which can only multiply within a host. They may be transmitted mechanically but very often a specific insect is an obligatory intermediate host in which the virus can be controlled by using the resistance of theplant to the insect. This is what IRRI has been doing by using rice varieties that are resistant to brown plant hopper, vector of the two Asian viruses.

Viruses do not secrete any toxin or enzyme, and the plant does not set up any morphological or chemical barrier against these intracellular pathogens. In specific resistance, as is the case with fungi, the plant can react through hypersensitivity because the virus is blocked in a small island of dead cells. Cases of resistance where plants do not permit the virus to multiply are also observed as well as cases of tolerance for varieties which can withstand limited multiplication of the virus.

5. CONCLUSION: APPLICATION OF KNOWLEDGE ON HOST PLANT RESISTANCE TO BREEDING

Most of the phenomena that we have just discussed rapidly is based on specific cases. The case of the host-parasite for which all these phenomena were studied are rare. The case of rice-blast is one of these cases but the knowledge gained has not led to the creation of varieties with a high degree of none or the other resistance mechanisms described.

TRENDS AND NEEDS IN BREEDING CROP PLANTS FOR RESISTANCE TO INSECT PESTS

By

Z. T. DABROWSKI
The International Centre of Insect Physiology and Ecology (ICIPE), P.O. Box 30772, Nairobi, Kenya.

Nature of host plant resistance in agriculture

Resistant germplasm suitable for use in agriculture must come from one of two source (or a combination), namely plants which coevolved with the phytophage or those which did not . Harris (1975) characterized these as sympatric and allopatric resistance, respectively. Allopatric resistance was defined as "those heritable qualities possessed by an organism which influence the ultimate degree of damage done by a parasitic species having no prior continuous coevolutionary history with that species of organism" and sympatric resistance was defined by substituting "having a prior" for "having no prior" (Harris 1975). Both terms are meant to describe agriculturally useful resistance consistent with Painter (1951).

This additional subdivision is also necessary to allow for a more complete characterization of the genetic origin of sympatric resistance, which can be obtained in 2 ways (or in combination). If the heritable qualities in the plant mitigating the interaction with the arthropod in the aboriginal situation can be reconstructed or maintained in the agricultural plant so as to reduce the adverse effect of the arthropod in producing the desired resource, then one kind of sympatric resistance is obtained.

This is distinct from selecting genes or gene combinations which are not maintained in the aboriginal gene pool of the plant due to selection pressures exerted by the arthropod, but nevertheless are effective in reducing the adverse effect of the arthropod in producing the desired resource when incorporated into agricultural plants (Harris 1980).

Genes which are part of the aboriginal defense mechanism of the plant and maintained in the natural gene pool due to selection pressures exerted by the arthropod for which resistance is being sought, can be characterized as having coevolved. If, coevolved genes are available for selection at all, it is primarily because plants containing them had a greater probability of producing fertile offspring in the presence of the arthropod than those which lacked them.

Sympatric resistance genes which are not part of the aboriginal defense mechanism of the plant to the arthropod but which can mitigate the adverse effects of the arthropod in agricultural situations, can be characterized as being unselected. These differ from coevolved genes in that their existence in the gene gool is independent from selection pressures exerted by the arthropod and the fact that they are present at all is unrelated to the arthropod.

The concepts of allopatric and unselected resistance should be contrasted with coevolved resistance. Each case of host plant resistance to an arthropod which derives from allopatric or unselected resistance could be unique from every other case because of the fortuitious genetic base for resistance in each case.

There do appear to be many phenotypic similarities among pathogens and arthropods as they interact with plants in a host plant resistance setting in agriculture. However, there is a fundamental divergence of experience between plant pathologists and entomologists regarding the source of germplasm used as the resistant parent in many instances. Harlan (1977) observes that "Geographically, the most rewarding regions to search are those in which the host has been grown for a long time in the presence of an endemic disease", while the opposite appears to be true for resistance to arthropods (Harris 1975). If indeed, plant pathologists are generally utilizing resistance derived from a prior sympatric association of pathogen and plant and entomologists are relying on resistance obtained primarily from plants which have had no prior coevolutionary association with the arthropod resisted, then a common basis for communication concerning host plant resistance to pathogens and to arthropods would be more difficult to establish than commonly imagined. Moreover, resistance mechanisms utilized in agriculture may also in many cases be fundamentally different between disciplines due to the manner in which the source of resistance was derived. The geographic origins of most plant sources of resistant germplasm and the phytophages resisted are presently unknown (Harlan 1977, Harris 1975).

Categories of resistance

Interactions between insects and plants span a wide range of intensities. In terms of the insect, the interaction varies from plants being completely adequate to completely inadequate hosts. Conversely, in terms of the plant species or cultivar, the fewer insect species associated with it, and/or the lower their abundance and the less effect they exert on a plant, the more resistant the plant appears.

Resistance usually is measured by using susceptible cultivars of the same plant species as controls. Only immunity representing complete inadequacy for insects, is an absolute term, but it is rarely encountered in plants within a host species. Plants of a nonhost species would not ordinarily be classified for resistance and therefore would be considered immune. A host plant can be more or less resistant but not immune. An immune plant is a nonhost. Any degree of host reaction less than immunity is resistance; more than immune is impossible. It must be remembered, therefore, that the term immunity does not permit qualifying adjectives such as comparatively, more most, rather, somewhat, or very.

Immunity: An immune cultivar is one that a specific insect will never consume or injure under any known condition. Thus defined, there are few, if any, cultivars immune to the attack of specific insects known to attack cultivars of the same plant species.

High resistance: is demonstrated by a cultivar that has qualities that result in small damage by a specific insect under a given set of conditions.

Low resistance indicates qualities that cause a cultivar to show less damage or infestation by an insect than the average for the crop considered.

Susceptibility: A susceptible cultivar shows average or more than average damage by an insect.

High susceptibility: A cultivar shows high susceptibility when much more than average damage is caused by a special insect.

The terms indicate the classes used by most workers in insect resistance as it is observed in the field, without analysis of the mechanisms involved.

Intermediate resistance is sometimes spoken of as moderate resistance, which may result from one of at least three situations. A cultivar denoted as moderately resistant may consist of phenotypically similar plants, some of which have high and others low resistance because of differences in physiological characteristics. In contrast, a moderately resistant cultivar may be made up of plants derived from a single clone, which is heterozygous for incompletely dominant genes that confer high resistance when homozygous. Moderately resistant plants also may be homoygous for genes which, under given environmental conditions, produce plants that are moderately injured or infested.

Certain phenomena related to resistance, but not necessarily based on heritable traits, were defined and classified by Painter (1951) as follows:-

The term pseudoresistance may be applied to apparent resistance which results from transitory characters in potentially susceptible host plants. Cultivars or crops showing pseudoresistance are important in economic entomology but should be distinguished from cultivars that show resistance throughout a wider range of environments. Three types may be distinguished:

(1) Host Evasion: Under some circumstances a host may pass through the most susceptible stage quickly or when insect numbers are reduced. Some cultivars evade insect injury by maturing early. Early maturity has been used to good advantage in economic entomology. Planting an early maturing cultivar late or other special experiments will indicate whether true resistance is present.

(2) Induce Resistance: This term may be used for the temporarily increased resistance resulting from some condition of plant or environment, such as a change in the amount of water or soil fertility. Such induced resistance may be of great value, but should not be confused with inherent differences in resistance between cultivars or individual plants.

(3) Escape: Escape refers to the lack of infestation of, or injury to, the host plant because of such transitory circumstances as incomplete infestation. Thus, finding an uninfested plant in a susceptible population does not necessarily mean that it is resistant. Even under very heavy infestations susceptible plants will occasionally escape so only studies of their progenies will establish their true relationship.

Two terms originally proposed by Van der Plank (1963, 1968) are used in plant disease literature to describe types of resistance. The terms are equally useful in plant insect literature.

Vertical resistance: This term is used when a series of different cultivars of the same crop infested with a series of different insect biotypes of the same species show a differential interaction. In other words, some cultivars are classified as resistant and suffer less or no damage; others are susceptible when they are infested with the same insect biotype. Biotype specific resistance is another term. Vertical resistance is controlled by major genes or oligogenes and is considered less stable than horizontal resistance.

Horizontal resistance: This is used to describe the ~~situation in which a series of different cultivars of the~~ same crop infested with a series of different cultivars of the same crop infested with a series of different insect biotypes of the same species show no differential interaction. In other words, the level of resistance offered by a particular host cultivar is similar against all insect biotypes, and vice versa. Biotype nonspecific resistance or general resistance are other terms that are used. Generally, horizontal resistance is polygenically controlled and is considered to be stable and permanent.

Moderate resistance (MR) in crop plants is generally recognizable under field conditions and is called field resistance. MR is expressed at a low level and is therefore easily mistaken for susceptibility when the screening test is conducted in the glasshouse with a heavy infestation of the insect pest. In contrast to MR, oligogenic resistance is expressed at a high level and is called true resistance. Takase (1962) differentiated "true resistance" and "field resistance" by considering that true resistance is qualitative or major gene resistance and field resistance is quantitative or polygenic in nature. Yamada (1965) associated field resistance with mature resistance and pointed out that true resistance is race-specific and controlled by a small number of major genes, while field resistance is controlled by polygenes expressed with quantitative characteristics and increasing with the advancement of host age.

Components of a programme for plant resistance to insects

A pragmatic approach must be taken in setting priorities among pests to be considered on a specific crop. Pests may be divided into several categories. A key pest is one that regularly limits crop productivity.

An occasional pest occurs at infrequent intervals but causes severe damage when present. An incidental pest is one constantly present but infrequently damaging. A potential pest is one that might occur with a change in crop and cultural practices. In developing resistance to one pest it is important to evaluate the breeding lines for resistance to other occasional, incidental, and potential pests to guard against the development of susceptibility to another insect.

Progress in the development of plants resistant to insects, as a vital entity in pest management programs, hinges on the concept of a multidisciplinary team. It calls for a cooperative and interactive relationship between the entomologist andthe plant breeders, who generally form the initial team in a plant resistance program. As the program proceeds, complex problems are likely to arise which the initial team of scientists will need in solving. Other scientists should be added to the group as the need for their contributions is recognized. History shows that major progress in th development of resistant varieties has been made when the program of resistance has been the primary responsibility of both the entomologist and the plant breeder, not a secondary activity.

Although entomologists must lead the effort to identify sources of resistance, the plant breeder usually provides the entomologist's seed source. Once the source of resistance has been identified, the involvement of the plant breeder becomes more critical. It is important that a priority be established so that both the entomologist ~~and breeder can work toward advancing the identified source~~ through themany steps necessary to achieve status as a cultivar.

Prior to embarking on a plant resistance program, there must be a significant pool of information on the influence of biotic and abiotic factors on the biology of the pest. This should include information on behaviour, especially in relation to food habits, oviposition, and movement; definition of the parameters of growth and fecundity; and effect of the environment on pest populations. These types of information must be available to design experiments within the range of behaviour and activities of the pest. It is critical to design tests that do not preclude the biological expression of important traits or characteristics of the pest or host.

The availability of a constant and uniform insect population is essential to progress. Attention must be given to identifying the optimum pest population that will permit differentiation among genotypes. An optimum population is not necessarily a maximum population. An insect population may be obtained by (1) intensively managing existing field populations; (2) rearing populations on a natural host in an insectary, greenhouse, or growth chamber; or (3) artificially rearing, for example, many of the lepidopterous pests. Many factors dictate the method used to develop and maintain insect populations. A primary function of the entomologist in the resistance team is to understand the biology of the target species and to manipulate the population so that the infestation level will produce optimum differences among genotypes. Dahms (1972) identified 16 possible criteria used to evaluate insect resistance in plants. The slightly abridged list follows:

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1. Visual evaluation of infested cultivars by observing, for example, retarded growth, lodging, cutting, and discolorization.

2. Determination of the number of surviving plants at various intervals following infestation.

3. Determination of the difference in yield between infested and noninfested plots.

4. Determination of the number of insect adults or larvae attracted to a cultivar when given a free choice.

5. Observation of the comparative effects of forced insect feeding (confinement) on plants or cultivars by measuring length of insect life cycle, mortality , reproductive rates, or molting, for example.

6. Weight of insects after definite feeding period on different cultivars.

7. Determination of the number of eggs laid.

8. Determination of the number of surviving insects and progeny produced.

9. Measurement of the amountof food insects consume.

10. Measurement of the amount of food utilized by the insect.

11. Simulation of insect damage and observation of recovery.

12. Indirect method of evaluation such as measuring root damage by amount of force required to pull a plant out of the ground.

13. Use of plant leaves or flowers in olfactometers to determine attractance.

14. Correlation of chemical factors in plants with insect response.

15. Growth and reproduction potential of insects fed various plant diets containing different plant cultivars.

16. Correlation of morphological factors with injury.

The first four are the most useful in screening a large number of entries. A relative rating scale is usually used in the initial screening process rather than counts of insects.

The essential needs are to identify rapidly material worth advancing and to differentiate intermediates and susceptibles. Traditional rating scales were from 0 to 3 or 0 to 5, with the high number indicating susceptibility. We are using rating scales from 1 to 9. Since it is often necessary to use statistical evaluations, zeros should be avoided. Plant introductions and segregating populations must be evaluated in a manner that will identify plant-to-plant variation when it occurs; single ratings for a plot may be misleading. In studies on inheritance of resistance characteristics, it becomes more critical to **quantify** gradients or levels of resistance.

Success in identifying sources of resistance is directly related to the diversity of germplasm available and the probability of resistance occurring in the host populations. The search for sources of resistance is carried out in a logical sequence: first in adapted cultivars, then in plant introductions and exotic germplasm, and finally in near relatives of the cultivar. The identification of the source of resistance is followed by hybridization, selection in segregating generations, and progeny testing. Special nursery and plant propagation facilities are important for rapid advancement.

In initial studies it is most important to examine a large quantity of diverse material. In these studies it may be essential only to distinguish broad differences in effect on host or pest. Rating schemes with various levels of sophistication or discriminatory power are used. A useful tool in a rating scheme is aset of pictorial standards. Later evaluation studies should permit more precise definition of the level and expression of resistance. It is important that the assay technique represent the insect host relationship as it occurs in the field.

Attention must be given to comparing plant material of the same growth stage or maturity, and to conducting the study at the growth stage when the insect generally attacks the host. Unequal seedling emergence is a major problem if plants are to be screened in the seedling stage. If vegetative plants are compared with those setting seed, the chances for regrowth and compensation are usually reduced in the latter. Strong emphasis on standardization of testing procedures must not be allowed to override the observation by a scientist of a unique event. Consideration must be given to the correlation of resistance in the seedling stage with that in more mature plants.

Resistance is frequently found in primitive cultivars or related speies. The transfer of resistance from these exotic sources may require the use of special genetic manipulation such as cell culture.

The donor parents of rice resistant lines identified by the IRRI scientist (Khush 1978) have poor plant type, typical of tall traditional varieties of the tropics. As a first step the sources of resistance were transferred to improved plant type background characterized by IR 8. This conversion was carried out by crossing the donor parents with an improved plant type parent. Between 1965 TN1, IR 8, IR 24 and IR 262-43-8 were used extensively as improved plant type parents. Several dwarf lines with resistance to disease or insect and having good grains were selected from each cross. By 1970 improved plant type lines with resistance to individual diseases and insects became available.

The crossing program of the IRRI was expanded in 1970 and crosses were made amongst these breeding lines with resistance to different diseases and insects. By the end of 1973, breeding lines with high yield potential and resistent or moderately resistant to as many as five diseases and four insect species became available.

Methods employed in rice breeding for resistance

IRRI plant breeders used the pedigree method of breeding to develop germplasm with multiple resistance (Khush 1978). Selection was based on comprehensive records of the disease and insect reactions of each line, and, in the case of F4 and later-generation lines, also on the reaction of ancestral lines. The bulk method was not used as it did not permit concurrent screening for a number of diseases and insects (Khush 1978). Nor was the backcross method employed extensivoly, because of a lack of suitable recurrent parents in the earlier years. A few backcrosses were made in the crosses with O. nivara for grassy stunt resistance; IR 8, IR 20, and IR 24 were used as recurrent parents. After three or four backcrosses they obtained grassy stunt-resistant breeding lines similar to the recurrent parents, but they lacked resistance to other important diseases and insects. However, those lines could be used as sources of resistance to grassy stunt in the hybridization program. Now numerous breeding lines and named varieties are available that can serve as recurrent parents. But Khush (1978) considers it desirable to develop germplasm with diverse genetic background, so the backcross method is generally avoided.

The pedigree method of breeding is eminently suited to disease and insect resistance programs if resistance is governed by major genes. As discussed in another section most of resistance traits in rice are under major gene control and the pedigree method has been successfully employed. But the pedigree method of breeding is not suitable for traits governed by polygenes. Resistance to stem borers and sheath blight in rice appears to be under polygenic control. For these traits the IRRI is using a diallel selective mating system proposed by Jensen (1970).

The IRRI also exploring the possibility of employing the single seed descent method for improving the traits governed by polygenic variation (Khush 1978). Early generation populations from multiple crosses involving three or four parents having minor genes for resistance are propagated in bulk. Three or four generations are grown in a year. Selection is not practiced during this period. At the F_5 or F_6 stage, the bulk population is exposed to the disease or insect pressure and individuals with better levels of resistance are identified and grown in progeny rows for further evaluation (Khush 1978).

Strategies in rice breeding for resistance

It is obvious that a resistance to one or two diseases and insects in rice varieties is not enough. Modern varieties must have multiple resistance to most of the important diseases and insects prevalent in the ~~area. Therefore, IRRI has endeavoured to develop~~ improved germplasm with multiple resistance to as many as four diseases and four insects (Khush 1978).

The improved plant type lines with resistance to one or two diseases or insects were intercrossed and a large number of topcrosses and double crosses were made to combine the resistance to several diseases and insects. A **through** screening of the segregating populations led to the identification of multiple-resistant lines. In 1969, about 85% of the entries in IRRI replicated yield trials were either susceptible to all the six diseases and insects (blast, bacteria blight, tungro, grassy stunt, brown planthopper, green leafhopper) or resistant to only one of them. On 2% of the entries were resistant to three diseases and insects. The proportion of entries with multiple resistance gradually increased and in the replicated yield trials grown in 1974, 90% of the entries were either resistant to five diseases and insects, or to all six of them.

The disease and insect ratings of IRRI-named varieties and IRRI lines named by the Philippine government are shown in Table 1. The progressive increase in the levels of resistance of the varieties from IR 5 to IR 42 is evident.

Table 1: Disease and Insect Resistance reactions of varieties by IRRI and those named by the Philippine Government (Khush 1979)

	Blast	Bacterial Blight	Grassy Stunt	Tungro	Green leaf-hopper	Brown plant-hopper	Stem Borer	Gall Midge
IR5	MR	S	S	S	R	S	MS	S
IR8	S	S	S	S	R	S	S	S
IR20	MR	R	S	MR	R	S	MR	S
IR22	S	R	S	S	S	S	S	S
IR24	S	S	S	R	R	S	S	S
IR26	MR	R	MR	MR	R	R	MR	S
IR28	R	R	R	R	R	R	MR	S
IR29	R	R	R	R	R	R	MR	S
IR30	MS	R	R	MR	R	R	MR	S
IR32	MR	R	R	MR	R	R	MR	R
IR34	R	R	R	R	R	R	MR	S
IR36**	IR	R	R	R	R	R	MR	R
IR38**	R	R	R	R	R	R	MR	R
IR40**	R	R	R	R	R	R	MR	R
IR42**	R	R	R	R	R	R	MR	R

* S = Susceptible; MS = Moderately susceptible; MR = Moderately resistant; R = Resistant. Reactions based on tests conducted in the Philippines for all diseases and insects except gall midge. Screening for gall midge was done in Asia.
** Named by the Philippine Government.

Variation in insect organisms

The development of resistance-breaking biotypes which are capable of surviving and attacking the resistant varieties is a major problem in breeding for disease and pest resistance.

In nature, it is believed that wild populations of many insects species consist of individuals genetically diverse in their ability to survive on different plant varieties, but of a limited population because of some inherited handicap. In response to continuous association with the resistant varieties having uniform resistant genes over large areas, the insect may develop a resistance-breaking biotype (Painter 1951).

(Pathak, 1970: Pathak and Khush, 1979). It is proven that biotype selection and development is highly probable and more rapid on oligogenic than on polygenic resistant variety. Insect biotypes rarely develop in corn and sorghum which have polygenic resistance while several biotypes have been reported in different aphid species and in Hessian fly to which host resistance is monogenic. Painter (1951) classified insect biotypes into two broad categories. One type is able to feed on a resistant plant because it is larger and more vigorous and having higher parasistic fitness than the avirulent biotype. Another type is generally adapted to the effects of a specific plant gene for resistance.

The BPH biotypes were first recorded at IRRI in 1974 (IRRI, 1975) and recognized through differential varietal reactions. Biotype 1 is the wild population to which Mudgo (Bph 2 gene), Rathy Heenati (Bph 3 gene) and Babawee (Bph 4 gene) are resistant. Biotype 2 is the population selected on Mudgo, hence Mudgo is susceptible but ASD 7 is resistant to it. Biotype 3 is the reverse of biotype 2. Biotype 4 and 5 are BPH populations having virulent genes capable of damaging Rathu Heenati and Babawee whose resistance is governed by Bph 3 and Bph 4 genes, respectively. Bph 3 and Bph 4 are single dominant and recessive genes which segregate independently on Bph 1 and Bph 2 respectively (Lakshiminarayana and Khush, 1977).

Because the development of biotypes endangers the stability of resistant varieties, a dynamic programme of collection and evaluation of germplasm so as to identify resistant donors and analyze them genetically should be developed.

If the varieties with a particular gene become susceptible because new biotypes develop, varieties with a second gene would be available. This sequential release strategy has been employed for resistance to brown planthopper. Thus, five brown planthopper-resistant varieties with Bph were released in 1973 and 1974. In 1976 those varieties started to show susceptibility at some locations in the Philippines. But by that time, multiple disease and insect resistant varieties with the Bph2 for brown planthopper resistance became available and were released as replacements for the varieties with Bph1. There are now available breeding lines with Bph3 and Bph4 for resistance.

The IRRI also trying to pyramid two major genes for brown planthopper resistence. Bph1 and Bph2 are closely linked and cannot be combined. Similarly Bph3 and Bph4 are also **linked.** However, Bph1 and Bph3, Bph1 and Bph4 Bph2 and Bph3 and Bph2 Bph4 segregate independently of each other and can be combined. They envisage that the varieties with two genes for resistance will have a longer useful life (Khush, 1979).

Four known genes for brown planthopper resistance are also being transfered to isogenic backgrounds by backcrossing. The IRRI plant breeders are also looking for additional genes for resistance. When 6 to 8 isogenic lines with different resistance genes become available, they plan to evaluate the fessibility of developing multiline varieties.

For traits that are under polygenic control such as resistance to stemborer they are using a diallel selective mating system proposed by Jensen (1970). This method involves: (1) crossing a number of moderately resistance parents in all possible combinations; (2) intercrossing the F_1 population in all the possible combinations; (3) screening the double cross F_1 progeny for resistance; and (4) intercrossing the selected plants found to have better resistance than either of the parents. The crossing, screening, selection, and recrossing will be continued until minor genes from different sources are accumulated.

CONCLUSIONS

In the screening and breeding programme for plant resistance to insects we should remember that wer are dealing with two biological systems. Therefore the following precautions are helpful to ensure the **efficiency** of genetic analysis for insect resistance:

A genetically uniform population of the insect should be used.

The cultivars to be analyzed and the resistance and susceptible checks should be pure lines.

A suitable technique must be developed for mass rearing healthy insects for the test.

An efficient technique is essential in determining the plant-insect interactions. This technique must permit the evaluation of large volumes of segregating plant materials. Generally, a method that allows the determination of plant reaction to the insect by use of injury ratings is the simplest.

The test should be conducted under uniform environments so that resistance and susceptibility are clearly differentiated.

BIBLIOGRAPHY

Dahms R.G. (1972): Techniques in the evaluation and Development of host-plant resistance. J. Environ. Qual. 1: 254 - 59.

Harlan J.R. (1977): Sources of genetic defense. In: (Ed. R.P. Day). The Genetic Basis of Epidemics in Agriculture 287: 345 - 356.

Harris M.K. (1975): Allopatric resistance: searching for sources of insect resistance for use in agriculture. Environ Entomol 4: 661 - 69.

Harris M. K. (1980): Arthropod - plant interactions related to agriculture emphasising host plant resistance. In: (Ed. M.K. Harris). Biology and Breeding for Resistance to Arthropods and Pathogens in Agricultural Plants. The Texas Agric. Exp. Sta., College Station, Texas and Univ. of California - AID, Pest Management Project: 23 - 51.]

Jensen N. F. (1970): A diallel selective mating system for cereal breeding. Crop Sci. 10: 629 - 35.

Khush G.S. (1978): Breeding methods and procedures employed at IRRI for developing rice germplasm with multiple resistance to diseases and insects. In: Tropical Agriculture Research Center. Symposium on methods of crop breeding. Trop. Agric. Res. Ser. 11:69-75.

Lakshinarayna A. and Khush G.S. (1977): New genes for resistance to the brown planthopper in rice Crop Sci. 17: 96 - 100.

Mochida O. (1977): Taxonomy and biology of Nilapawata lugens (Hom.: Delphacidae). In: Brown Planthopper: A threat to Rice Production in Asia, International Rice Research Institute. Los Banos, Philippines, 369 pp.

~~Painter R.H. (1951): Insect resistance in crop plants.~~ The Univ. Press of Kansas. 520 pp.

Pathak M.D. (1970) Genetics of plants in pest management. In: Concepts of Pest Management. (Ed. Rabb R.L. and Guthrie T.E.). North Carolina State University, Raleigh: 138 - 57.

Pathak M. D. (1977): Defense of the rice crop agains insect pests. Ann. New York Acad. Sci. 287: 287 - 95.

Pathak M.D. and Khush G.S. (1979): Studies on varietal resistance in rice to the brown planthopper at the International Rice Research Institute. In: Brown Planthopper: A Threat to Rice Production in Asia, International Rice Research Institute, Los Banos, Philippines: 285 - 301.

Robinson R.A. (1976): Plant pathosystems. Spring Verlag. Berlin, Heidelberg, New York, 184 pp.

Takase B.N. (1962): Test and screening for resistance in breeding potato varieties resistance to late blight. Recent Adv. Breeding 3: 9-17.

Van der Plank J.E. (1963): Plant diseases: epidemics and control. Academic Press, Inc., New York, 349 pp.

Van der Plank J. E. (1968): Diseases resistance in plants. Academic Press, Inc., New York, 206 pp.

Yamada M. (1965): Breakdown of blast resistance in highly resistant rice varieties derived from foreign varieties. Shokubutsu Booki 19: 231 -- 34.

HOST PLANT RESISTANCE TO DISEASES AS A COMPONENT OF INTEGRATED PEST MANAGEMENT

By

J.L. NOTTEGHEN
IRAT, BP. 635, Bouake, Ivory Coast

INTRODUCTION

The concept of integrated control was developed by entomologists. It is used very sparingly by phytopathologists because the problems of disease and insect control differ on several points. The idea that insects cannot be controlled by the simplistic use of insecticides spread rapidly with the destruction of parasites which play an effective role in limiting pest populations. In the case of plant diseases, there are also natural enemies which develop at the expense of microsorganisms responsible for plant diseases that are called parasites. However, cases of natural enemies are relative rare. An example is coffee rust (Hemileia vastatrix) which can be attacked by this viruses, Verticiluim hemileiae and Cladosporium Hemilaiae or by fungi viruses and phytopathogeneous bacteriophages. However, unlike insects; these natural enemies do not seem to effectively control plant pathogens. Unlike in the use of insecticides, it has never been observed that fungicide treatment has harmful consequences on the equilibrium between a pathogen and a natural enemy or that it caused the proliferation of the pathogen. Fungicide treatments are therefore always undertaken without any attention being paid to their action on natural enemies.

Another consequence of the ineffectiveness of natural enemies is that they have never been used in biological control. Attempts have however, been made to use antagonism by trying to replace the pest with a harmless fungus. Attempts were made with leaf spraying of spores of Trichoderma sp., to control leaf pathogens or by artificially infesting the soil with antagonistic fungi of root fungi pests. These attempts did not yield results that could be applied on a wide scale.

Many studies have successfully lead to the creation of disease-resistant varieties but the appearance of strains capable of over coming this resistance has led to rules of resistance management.

CHOICE OF TYPE OF RESISTANCE

A distinction is made between specific resistance which is total but ineffective for all the races of the pathogens and general resistance which is quantitative but effective against all pathogenic strains. In certain combinations such as rice and sheath blight, or maize and American rust, only general resistance is known. However, it is usually the case that for the same combination plant - pathogen, the two types of resistance coexist and the first factor in the choice of the type of resistance is the life cycle of the disease. In the case of "simple interest" diseases, that is, diseases caused when the pathogen finishes only one multiplication cycle during one plant cycle (false smut of rice, wheat bunt, etc.,) specific resistance is usually used. Let us take the example of a resistant variety which, after inoculation would only suffer 2/3 of the damage to a susceptible variety. The use of a resistant variety would only reduce damage by 1/3 at the end of one season which can be considered as insufficient. On the other hand, in the case of a "compound interest" disease, where a pathogen which completes its cycle several times during one cropping season, let us say six times, the reduction of damage on the susceptible variety would be $(2/3)^6 = 0.087$. The use of the resistant variety would result in the prevention of 91.3% of the losses suffered by a susceptible variety. In "compound interest" diseases, a small general difference can have an important effect. But the choice of the type of resistance also depends on other criteria that we shall examine after analyzing the methods of using each type of resistance.

THE CONDITIONS OF USING SPECIFIC RESISTANCE

Since specific or vertical resistance is complete, it is most often used alone. The problem that has to be resolved has to do with the strategy to be adopted to control the development of virulent strains. Infact, fungi can use sexual and parasexual mechanisms which ensure the recombination of their germplasm which can lead to new strains of the pathogen. It can take a very long time to observe the appearance of this virulent strain. For example, 60 years after using a resistance gene of Fusarium oxysporum cabbage, virulent strains have still not been observed. It may simply take a long time. The cornel gene of bean which shows resistance to anthracnose (Collectotrichum lindemutianum) survived for 15 years. But then it often happens, as in the case of black wheat rust that virulent strains appear at the end of a few years. In this last case, if we know several genes for the same host - pathogen combination, it is normal to find out how best to use them. The different strategies of using specific resistance genes depends on the concept of stabilizing breeding. It has been demonstrated in several cases that a virulent gene is a genetic problem. After the elimination of a specific resistance gene in a host population, it is observed in the pest population that the proportion of the genes possessing corresponding virulence is decreasing. When in such a situation, the frequency of a virulent gene decreases rapidly, this gene is considered to be strong and when it decreases slowly, it is said to be weak. This "strength" or "weakness" can be quantified by the duration of the half life of a gene that is the time necessary for its frequency to decrease by half. Several methods of using resistance can therefore be applied thanks to this phenomenon:

- the rotation of varieties with different resistance genes;
- crop rotation forcing the pathogen with several cycles on an intermediate host;
- cultivation or mixed lines each one with different genes;
- the accumulation of several resistance genes in the same plant.

Whatever is the system used, it is necessary to have strong genes. We would like to examine a few cases of their application to rice diseases. In the case of bacterial sheath blight (due to *Xanthomonas campestris pr oryzae*), 9 specific resistance gene are known. In the tropical zone of Asia, it is especially the Xa 4 gene that has been used, and it was effective for 5-10 years depending on the area. This duration is sufficient for IRRI to envisage proposing the rotation of varieties with the best known genes.

As far as rice blast (*Pyricularia oryzae*) is concerned, 13 genes are known, but they are considered to be between weak and very weak. Using simultation techniques on a computer, Japanese scientists have shown that none of the possible strategies can be applied to known specific resistance genes. They are therefore conducting their research on the use of general resistance.

USE OF GENERAL RESISTANCE

General resistance is quantitative and can be strong or simply average. When general resistance is at a very high level, it can be used alone. When it is only average, it is better to integrate several control methods.

The combination of resistance and agronomic control methods

While it is possible to draw up a simplified list of agronomic control methods, we must bear in mind that there is no general control method and that, in each case, the control method has to be adapted to the characteristics of the reproduction cycle of the pest. The most commonly used methods are the following:

- selection of the best sowing date, that is, sowing at the most unfavourable period for the pest;
- planting crops from the same region at the same time;
- crop rotation, effective especially against pathogens that remain in the soil;

- the judicious use of fertilizers;
- destruction of plant residues; and
- destruction of plants which serve as interseasonal pest hosts.

In the case of blast, it is known that the germination of spores can only take place when hygrometry is very high (97%). Where possible, it is better to sow on a date that can ensure that heading will be in the dry season. However, as far as rice blast is concerned, all the unfavourable conditions for the pathogen are not known, and it is only through local experimentation that the period with the least risk of causing an epidemic can be determined. In actual practice, in certain regions such as the Senegal River Region, susceptible varieties can be cultivated while in other regions it is necessary to use varieties with at least average resistance sown at the best period.

Nitrogeneous fertilizer encourages diseases such as blast and rice sheath blight. Restricting the use of nitrogen can limit losses to a low degree even with varieties that do not have strong general resistance.

The combination of general resistance and fungicides

Colombian rice farmers who usually use fungicides against blast have observe that while two treatments are adequate with certain varieties, others require up to four treatments to protect the crop. In all cases, an increase in general resistance make it possible to space out treatments by a duration that is directly proportional to the resistance measured as the inverse of the regression rate of the epidemic.

THE COMBINATION OF TWO TYPES OF RESISTANCE

When specific resistance is used, it is always combined with a certain degree of general resistance. This level is often low because specific resistance is epistatic over general resistance and so it is impossible for the breeder to take this characteristic into account. The best strategy is therefore to select a variety because of its horizontal resistance and then to incorporate specific resistance through back-cross. The result is a variety which, at the initial stage, has complete resistance, which can help in its extension. When a virulent strain appears, general resistance impedes its development. What then remains is general resistance alone. This is definitely the ideal situation, but it requires great efforts in varietal breeding for resistance.

CONCLUSION

Just a few years ago, when a variety was considered disease resistant, the farmer who was planting it believed he was completely protected. This is true of some host-pest associations. However, we have seen that it is absolutely necessary to define the type of resistance in question and the conditions under which the variety should be used. Either it is specific resistance whose use must take into account the strategy involving several genes, or it is horizontal resistance which, when it is not very high, must be accompained by agronomic control measures or the use of limited fungicide treatments.

THE CONCEPT OF AGROECOSYSTEMS AND THE RICE AGROECOSYSTEMS OF WEST AFRICA

By

A.O. ABIFARIN
Senior Rice Breeder - IITA/WARDA
Liaison Scientist - Monrovia

INTRODUCTION

The interactions and interrelationship of all living plants and animals influenced by the environment in a given ecological niche is an ecosystem. When this unit is related to crop production it is referred to as Agroecosystem. Thus the ecology which is the study of a plant in relation to its environment plays a major role in any agroecosystem. In an ecosystem the constituents of the environment has to be known and studied to understand which aspects are more influential on a rice crop.

Constituency of Natural Environment:

Before we go further it is essential to consider what we mean by natural environment. A general definition of natural environment is "all the climatic, edaphic, and biological factors controlled only by natural forces (unaffected by human efforts) that are operative in a given area". The outline of the sub-division of the above is given below for reference purposes only. The factors are interwoven and can not easily be categorized.

A: Climatic factors:

Weather conditions: hot or cold

Atmospheric factors: Pressure, temperature, humidity, sunshine, etc.

Seasons: dry cold or hot season. Wet hot or cold season.
Latitude and altitude: This is how far north or south of the equator and the elevation or height above the sea level.

B: Edaphic factors:

Type of soil and as influenced by moisture through rains, streams etc. Rivers: Seasonal or perennial underground water as in hydromorphic conditions.
Land topography - gradient: flat or sloppy and how much.

C: Biological factors:

(i) Plants

- general vegetations
- crops
- weeds
- related species of the rice crops
- diseases: fungi.

(ii) Animals

Pests e.g. birds, insects, rodents, crabs etc.
Animals affecting irrigation projects e.g. herd of cattle in paddy fields.
Diseases: nematods, bacteria, virus.

D: Ecology

This is the interaction of factors A, B and C above in varying degrees.

With the above general overview of what natural environment means we shall briefly consider the effect of these natural environmental factors on rice crop in West Africa. The main effects are the existence of different ecosystems for rice. The types of rice cultivation in the different ecosystems are briefly discussed.

DISTRIBUTION OF RICE CULTIVATION

It may be useful to have a general idea first on the total rice production under all the ecosystem in West Africa. Types of rice cultivation varies extensively in the WARDA region and are controlled by climatic, political and economic factors. Statistics based on different types of cultivation are not available for many countries and when available they are not very reliable. Therefore, Table 1 shows the total rice area on country basis.

Table 1: Area under Rice in WARDA Member countries

Countries:	Area x 100 ha:
Benin	10.3
Gambia	22.6
Ghana	43.2
Guinea	472.0
Guinea Bissau	109.0
Ivory Coast	428.0
Liberia	202.1
Mali	
Mauritania	2.0
Niger	26.6
Nigeria	253.0
Senegal	91.6
Sierra Leone	416.0
Togo	15.6
Upper Volta	41.2
WARDA	2,317.2

B. TYPES OF RICE CULTIVATION

There are many types of classifications that have been proposed by different authors. For the sake of uniformity, I am using WARDA classification with little modification.

1. Upland rice cultivation

Upland rice is also called rainfed rice and in some places referred to as dryland rice. Upland rice cultivation is the act of growing rice under unpuddled and unbunded soil. The rice depends solely on rain water or underground for its growth and development. The soil is under an aerobic or unreduced condition for the greater part of the growing season.

Upland rice is often classified into two groups based on topography, in other words land elevation and their slopes:

a. Strictly upland cultivation:

   i. Hill rice
   ii. Flatland

b. Groundwater cultivation with rains. e.g. hydromorphic rice.

Soil type

The soil type of upland rice varies from sandy foam soil to heavy clay soil that is found in hydromorphic conditions. However, under the strict upland cultivation, the soil is well drained, low in fertility and often highly eroded resulting in rapid soil deterioration.

Cultural practices

The traditional slash and burn in a shifting cultivation system is practised. Direct seeding is done. Weeds which constitute a major problem also contribute to the traditional shifting cultivation system.

Biological problems

Birds, rodents and fungus diseases such as blast and yellow brown spots are important problems in various places.

Varietis

Popular varieties being grown in West Africa are OS6, Moroberekan, LAC 23, ROK 3, Iguape Gatoto, 6383, IRAT 13 and many other newly bred or introduced varieties.

Characteristics of Upland Rice

a. Early seedling vigor
b. Low tillering
c. Long and big panicles
d. 100–200 cm in height
e. Susceptible to lodging
f. 100–180 days to maturity
g. Thick and deep root system
h. Drought tolerant
i. Resistance to common African diseases such as blast
j. Possession of drought escape and avoidance mechanism .

Importance of upland rice cultivation

In Sierra Leone, Liberia, Ivory Coast and Nigeria, upland rice is very important. In the region, it occupies 65% of total rice cultivation.

2. Lowland rice cultivation

This is the type of rice cultivation done in soil which is submerged to a major or minor degree during a considerable part of the growth period.

Lowland rice can be sub-divided into two groups:

a. Mangrove rice cultivation with associating salinity and acidity problems.

b. Freshwater cultivation with small and negligible problems.

a. Mangrove rice cultivation

This is done on cleared mangrove forest. The soil may and may not be subjected to sea tide. The soil is high in organic matter with possible acidity and salinity problems.

There are two types of mangrove cultivation; those with and without tidal effects.

(i) Without tidal effects

These are relatively far from the coast and the crop here do not suffer from salinity throughout the growing period.

Soil

Soil during the growing season is free from salt. It is always under anaerobic or reduced condition.

Cultural practices

Old seedlings of up to six weeks or more are transplanted.

Biological problems

Birds, rodents, crabs and diseases are important.

Varieties

Varieties such as ROK 5, BD 2, DA 29, Pokkali 9 Sri Malaisia etc. are grown. Yields range from 1.5 - 2 tons/ha.

Importance

Mangrove rice cultivation without tidal control is not very important. It is practised only in some part of Senegal, The Gambia and Sierra Leone. It represents about 25 percent of total mangrove paddy areas.

(ii) With tidal effects

The rice field is subject to the sea tides; flooding and draining twice a day. This type of cultivation is found along the coast and in the low lying parts of estuaries. The tide water is salty throughout the year. There is therefore a need for protection of the rice paddy under this condition.

Soil

The soil with inadequate protection and management is likely to be saline, acidic and suffer from mineral toxicity and imbalances. Weeds are of relatively lesser problem on this type of soil.

Cultural practices

The laborious mangrove clearing has to be done first. The two types of major trees are *Rhizophora racemosa* and *Avicennia nitida*. Clearing of the former is more difficult because of their prop-roots. The water logged soils drainage is also difficult to manage.

Transplanting of old rice seedlings is also done here.

Biological problems

These are similar to those mentioned for without tidal influence.

Varieties

Varieties are similar to those listed above. There are wide range of local varieties in addition. Yields are from 1.5 to 2.5 tons/ha.

Characteristics of Mangrove Swamp rice:

1. Tolerance to salinity
2. Tolerance to acidity
3. Tolerance to crab damage
4. 1-2 meters in height
5. Over 130 days in maturity
6. Tolerance to late transplanting
7. Low to medium tillering.

Importance and extent

The area under this type of mangrove rice is about 75 percent of the total mangrove cultivation.

cultivation is found in Guinea Bissau, Guinea, Sierra Leone, The Gambia, Senegal and Nigeria.

b. Fresh water rice cultivation

There are many sub-divisions of this type based on the level of water controlled.

i. Types without water control
   e.g. floating rice cultivation, swamps "Bantafaro". "Fadama" and "Boliland" cultivation.

ii. Types with partial water control practiced in some government large projects and semi-developed swamp.

iii. Types with complete water control
   e.g. irrigated rice cultivation.

(i) Types without water control

There are many sub-divisions under this category but the floating rice is used as an example.

Floating rice cultivation

Factors favouring this type of cultivation are land topography, rivers flooding and rapid rise of water level. The cultivation is found in major beds of streams, flood plains or in deep basins. Water depth varies from 1-6 meters and the water rise may be more than 2 centimeters a day.

Soil

The soil is dry at the beginning of the cropping season. In fact, it is like an upland soil except that the soil is usually heavier. It may be clay or alluvial soil.

Cultural practices

Rice is often directly seeded though transplanting is done in some parts of West Africa. Weeds, especially wild rices, are very important.

Biological problems

Birds, diseases and insects are of economic importance.

Varieties

Tall varieties, especially those with elongation genes, kneeling ability etc., are found under this type of cultivation: *Oryza glaberrima* are abundant under this ecology. Average yields are from 1-1.5 tons/ha. Important varieties are: Khao Gaew, MSP 11, DM16, Mali Sawn, Nang Kiew and many other local varieties.

Characteristics of floating rice:

1. Rapid elongation of internodes
2. One or more leaves are kept above the water surface
3. Generally very tall. Depending on the depth of water height may vary from 2 - 6 meters.
4. Kneeling ability of the culms
5. Easy rooting at the nodes.
6. Aerial branching of some varieties
7. Medium to strong dormancy
8. Medium to strong threshability
9. Drought resistance.

Importance and distribution

Floating rice is not generally important throughout the member countries but is very important in the Gambia, Mali, Niger and present to some extent in Nigeria and Sierra Leone.

Other types of fresh water rice cultivation without water control are found in other parts of West Africa. An example is under-developed swamps in many parts of Liberia and Sierra Leone.

(ii) Types with partial water control

Most of the so-called irrigated rice projects and semi-developed swamps fall into this category. Poor leveling, unreliability of water pumps, lack of water due to breakage of dams or bunds and drought, poor planning and general inefficiency in operations are responsible for these types of rice cultivation. If most of the above factors are eliminated, water control will be possible.

Soil

The soil varies in texture and fertility. Problems also range from mineral defficiency to toxicity.

Cultural practices

In some countries, rice is directly seeded either dry or pregerminated. However in many other countries, transplanting 3-4 week old seedlings is practised. Weeds are serious problems under this type of cultivation.

Biological problems

Birds, rodents, insects, diseases and water borne diseases such as those caused by round worms and schistosoma.

Varieties

Semi-dwarf (60 - 120) varieties are grown in these conditions. There are other local improved tall varieties found under these types of cultivation. Yields are low and range from 1.5 - 2.5 tons/ha.

Importance and distribution

This type of cultivation can be found anywhere in West Africa especially wherever attempts are made to introduce irrigational system of rice cultivation without satisfying essential conditions for water control. They are however commonly found in Mali, Senegal, Nigeria and Liberia. This type of cultivation accounts for about 3 percent of total rice area in West Africa.

(iii) Types with complete water control

This is the most ideal type of rice cultivation. There are four main conditions for water management:

- Good levelling of paddies with bunds;
- Water supply at all times by gravity or pumping;
- Control of water depth in the paddies
- Ability to drain water from the paddies at any growth stage for any operation.

Soil

Types of soil also vary but clay loamy soil is preferred for water retention. There are some mineral defficiency and toxicity problems but draining and soil management help to reduce these. A major limiting factor is the cost of initial development and maintenance. This is one of the reasons why most irrigated fields are often with poor water control.

Cultural practices

Land levelling and puddling are done under this type of cultivation. In most places seedlings of 3-4 week old are transplanted. Weeds are controlled by water, herbicides and some hand weeding.

Biological problems and varieties are as described above under B(ii). Yields are however higher with an average of 3.5 tons/ha for West Africa.

EXERCISE

Participants are to make a table classifying the type of rice cultivation in their individual countries based on the lecture's classification. The table should give at least the following information.

1. Type of rice
2. Where each type is found
3. Area of production
4. Important varieties and average yields
5. Major problems.

R E F E R E N C E S

WARDA 1979: Research Department 1979 Annual Report, Central Printing Inc., Monrovia. Viii, 99 p.

WARDA 1980: Occasional paper No.2, July, 1980 Types of rice cultivation in West Africa Development Department, 23 pp. mimeo.

WARDA 1979: Rice Statistic Yearbook (abstracts) 3rd edition, October, 1979. 50 tables.

THE MAJOR PEST PROBLEMS OF IRRIGATED, UPLAND AND MANGROVE SWAMP RICE ECOSYSTEMS IN THE HUMID TROPICAL, GUINEA SAVANNA AND SAHEL CLIMATE ZONES

By

M. Agyen-Sampong
WARDA Special Research Project
Rokupr, Sierra Leone

The major ecosystems of West Africa generally run east-west and the low land of the wet forest zone near the equator shifts first into Guinea savanna then to Sudanian savanna and then to desert as one proceeds north. Usually the climates are characterized by a fairly well marked alternation of wet and dry seasons rather than total rainfall. Thus the main climate belts are:

(i) northern very short monomodal rains associated with long periods of hot/dry weather and cold seasons with long sunshine;

(ii) area of bimodal rainfall separated by a short dry spell and a longer cold dry period; and

(iii) coastal area with long heavy monomodal rains.

Although rice is cultivated under these different climatic and ecological conditions in the region between latitude 5-16°N, depending on the level of the water regime and management, various factors, temperature, rainfall light wind - combine during the growth of the rice plant to influence the bionomics of the insect developing thereon and therein in the region. Thus, both macro and micro climate affect the development and intensity of rice insect pests. The interaction of all the environmental factors affect birth rates, death and dispersal and so cause populations to fluctuate in size and position.

Climate as a Limiting Factor of Distribution

Generally, the prevalence of the same species of rice pest varies with the major climatic zones (Table 1). The distribution of the 18 recorded lepidopterous rice stemborers in West Africa (Agyen-Sampong, 1979) is largely governed by climate although they are widely found in the whole region.

Chilo spp., were recorded in different countries in both the savanna and humid tropics. The taxonomy of *Chilo* spp., often present difficulties and most of the available information are without specific names. Out of the six *Chilo* spp., recorded by Bleszynski as having been collected from Nigeria, only one, *Chilo zacconius*, was common on rice (Akinsola unpublished). Uncertainties exist as to the exact identification of *C. zaleukos* Blesz, *C. aleniella* (Strand) and *C. phaesoma* Mort and there is need for more taxonomic studies on *Chilo* spp.

Table 1: Prevalence of rice pests in the major climatic zones

INSECTS	HUMID TROPICAL	GUINEA SAVANNA	SUDANIAN SAVANNA
Orseolia oryzae	-	xx	xx
Chilo zacconius	x	xx	xx
Chilo diffusilineus	xx	xx	x
Chilo spp.	x	x	x
Maliarpha separatella	xx	xx	x
Sesamia calamistis	x	x	-
Sesamia botanephaga	xx	x	-
Diopsis spp.	xx	xx	x
White flies	-	xx	xx
Mites	-	xx	xx
Locust	-	x	x
Termites	xx	xx	x
Armyworm	x	x	x
Grain suckers	x	xx	x

xx = Common x = Not Common

With the use of light traps and dissection of infested rice stems, Tavakilian (1977) determined the distribution of Chilo spp in Ivory Coast. Of the six species recorded, C. diffusilineus was the most numerous and widely distributed throughout the country in both rain forest and savannas. Chilo zacconius, the second numerous species, was confined to the north in the Guinea (relatively moist) and Sudanian (dry) savanna.

The two Chilo species tended to attack rice on upland than in irrigated field. Bleszynski (1970) similarly noted that the range of zacconius overlaps that of dffusilineus in West Africa. The rest of the Chilo species in Ivory Coast were found mainly in the rain forest and Guinea savanna of the central belt. They were C. aleniella, Chilo mesoplagalis (Hampson), Chilo psammathis (Hampson) and Chilo perfusalis (Hampson).

In Nigeria, C. zacconius appeared to be predominant in the Northern Guinea savanna and also occurred in the high forest zone (Akinsola unpublished).

Maliarpha separatella is another major stemborer of rice in West Africa. The genus contains only one species considered as a pest of rice and has not been recorded as a pest of any other gramineceous crop. It is widely distributed, occurring in all the rice ecologies in the different climatic zones, particularly in the Humid Tropical and Guinea Savanna.

Of the two species of Sesamia, S. botanophaga is commonly found in the forest zone while S. calamistis is confined mainly to the savannas. The grain suckers - (Stenocoris southwoodi, Riptortus spp., Mirperus sp. Aspavia sp. Diploxys spp) are recorded on rice crop especially during the milk stage, ~~in all the climatic zones but more~~ prevalent in Guinea Savanna.

Termites of different species attack the stem of young rice crop during short dry spells. Mostly in the upland field of the humid and Guinea savanna.

With recent increases in rice cultivations in the Sahelian belt, white flies (aleyroidids) and mites (tetranychids and phytoseiids) have become prevalent and often cause extensive crop loss in the hot dry season of April to July. In 1973 Chia-hwa reported of severe damage caused by white fly (Trialeurodes oryzae) to rice crops in Chinese Agricultural Mission farms at Bobo in Upper Volta. In the irrigated rice farms in the River Senegal Valley, yield losses 25-40 per cent were caused by Aleurocybotus sp. indicaus (Diop 1979). In Kou Valley, Upper Volta and in Kaedi, Mauritania, aleyroidids have already been observed as pests of rice.

The adult white fly is mealy white-winged insect and its scale-like larvae feed on the rice plant. They could be found on the plant from seedling to maturity, and the symtom of attack is the black fungus development on the vegetative parts and the eventual withering and wilting of the plant. Many weeds serve as alternative hosts and seasonal outbreak depends on the climatic and environmental conditions - high temperature and low humidity. Thus higher infestation occurs in the hot dry season than the hot wet season.

The spider mites suck and produce copious webbing on the rice plant and thrive under the same climatic conditions as white flies. They have been observed on Chinese varieties in Guede, on DJ 684D in Richard Toll, Senegal (Diop, 1978). Amblyseius sp. (Phytoseiidae) and Olygonychus sp. (Tetranychidae) were found in paddy fields of Senegal River Region (Diop, 1980).

Gall midge, orseolia oryzae, is well established in Guinea and Sudanian zones (WARDA 1979). It is found in countries or parts of countries which lie in these zones. For example, it is one of the most serious and widespread rice pest in Upper Volta on irrigated, rainfed or low land rice (Bonzi, 1980).

Outbreaks are more serious when the first rains are early and then followed by a relatively long drought which delays the planting time. The first generation of the gall midge occurs on grass weeds and when rice comes it is heavily infested. Late crop planting can be severely infested especially if it is in an irrigated zone. Its infestations are fairly localised and usually correspond to fairly strict ecological conditions. The extent of infestation may be related to the host plants, the amount of rain - especially at the beginning of the rain season and the succession of rice crops grown at a given locality. Little is known about pest/host plant relationship which is essential in control strategy.

Aestivation - Diapause and Climatic Factors

The region is generally marked with definite wet dry seasons. The hot dry periods may be detrimental to insect life. Thus many insects are known to overcome unfavourable periods by undergoing a state of dormancy - aestivation - diapause. For example, in northern Ghana, rice grasshopper, Hieroglyphus daganensis Krauss lays eggs in pods in the soil and undergo embryonic diapause during the season form October/November to about July of the following year, which is about the beginning of the rain season when flushes of grass are abundant (Agyen-Sampong, 1975).

Rice stemborers diapause in larval form. Rearing of field collected Maliarpha separatella Rag. larvae at Rokupr, northern Sierra Leone, indicated that they started to undergo diapause as mature larvae in October, towards the end of the life cycle of the host-plant. The intensity of diapausing increased sharply in early November reaching a peak about mid-December. The diapausing larvae started to emerge in December at the time non-diapausing borers terminated emergence. The termination of diapause reached a peak in June at the beginning of the rainy season, and tailed off in August/September. Field-collected larvae reared in the laboratory, could remain in diapause for as long as 251 days, however, majority (72.3%) stayed in diapause for 180-220 days.

Moistened conditions appeared to hasten termination of diapause. The role of environmental factors in the induction and termination of diapause in rice stemborers in West Africa is improperly understood. There are indications, however, that these factors acting severally or jointly affect both the host plant and the insect pest in anticipation of unfavourable conditions for feeding and growth.

Six larval parasites of *M. separatella*, namely, *Rhaconotus* sp., *Rhaconotus scirpophagae* Wilkinson, *Phanerotoma major* Bruce, *Goniozus* sp, *Eurytoma* sp and *Venturia crassicaput* (Morley), develop within the borer larvae, and the emergence of these parasites continued into the dry season months. It is not known for certain whether these parasites again attack the diapausing larvae.

Effect of Climate on Seasonal Abundance

The marked dry and wet seasons of the region and a combination of various factors, such as temperature, rainfall and humidity of the climate, influence the seasonal abundance. Generally, insects are numerous during the wet season when rice is grown in the region, hence more rice pests. High populations of rice stemborers usually occur in the wet season and the following were noted by several workers: *C. diffusilineus* in Ivory Coast (Tavakilian, 1977); in Sierra Leone, (Agyen-Sampong, unpublished); *C. zacconius*, in Nigeria (Akinsola, 1975); in Senegal, Diop, 1978); *M. separatella*, in Sierra Leone (Agyen-Sampong, 1979); in Nigeria, Akinsola, 1979; in Ivory Coast, (Tavakilain, 1977); Pollet, 1977); and *Sesamia calmistis* Hamp. in Nigeria, (Akinsola, 1975). With the maturity of the rice crop at the rains, population of most adult stemborers decline. The larvae in localities with well marked dry season undergo diapause while ~~at Dauhenya. In Ghana for example, where rice cultivation is~~ continuous under irrigated conditions, the larvae have no resting period (Agyen-Sampong, unpublished). An example of direct link between rice insects and rainfall is with outbreak of African armyworm, Spodoptera exempta which is widely distributed in West Africa.

It sporadically attacks graminaceious weeds and crops, including rice in localised areas. Odiyo (1976) reported that African armyworm out-breaks occurred during rains after prolonged dry seasons. The author noted that armyworm out-break in Sierra Lone during June, 1979, appeared during the beginning of delayed rainy seasons. No rainfall was recorded in the preceding May at Rokupr and elsewhere in the country it was below normal.

Analysis of Africa black beetle, Heteronychus oryzae, light trapped in northern Sierra Leone revealed its first appearance in June at the attack farmers' seedlings in June (Agyen-Sampong, 1979). Unlike many rice pests, mite and white flies are abundant in dry season in Sahelian zones during hot dry period of May/June (Diop, 1979).

Under the same climatic condition, rice could be cultivated in different ecologies such as upland lowland irrigated and swamps; under these different habitats, different species show relative abundance (Table 2). For example, Diopsis thoracica West, are always numerous in localities with high humidity, thus they are serious pest in the humid tropical zones and in certain specific humid areas of dry tropical zones. In any locality, irrigated and inland swamps rice tended to be highly infested with Diopsis sp than the upland.

Table 2: The Relative occurrence of insect pests in different ecologies in a Climatic zone

INSECTS	UPLAND	LOWLAND	MANGROVE SWAMP	IRRIGATED
Scirpophaga sp.	x	xx	x	xx
Maliarpha separatella	x	xx	xxx	xx
Chilo diffusilineus	xx	x	xx	x
~~Chilo zacconius~~	~~xx~~	~~x~~	~~x~~	~~x~~
Sesamia spp.	xx	x	x	x
Diopsis spp.	x	xx	xx	xxx
Nymphula depunctalis	-	xx	x	xxx
Orseolia oryzae	-	xx	-	xx
Pelopidas mathias	x	xx	xx	xx
Nephotettix sp.	x	xx	xx	xx
Cofana sp.	xx	xx	xx	xx
Grain suckers	xx	x	x	xx
Termites	xx	-	-	-
Epilachna similis	xx	x	x	x

xxx = Abundance xx = Common x = Not comon

At Boucke, Ivory Coast (Tavakilian, 1977 and Pollet, 1977) noted that C. diffusilineous and Sesamia spp were common stemborers of rainfed rice as compared with M. separatella and Scirpophaga sp which often attacked irrigated field rice. Maliarpha separatella is the most predominant stemborer in the mangrove swamps in Sierra Leone, Warri in Nigeria. Casamance in Southern Senegal, The Gambia and Guinea Bassau. However in localised areas, Chilo sp could be quite predominant. At Kinbeka, an area within the mangrove swamps of southern Sierra Leone, Chilo diffusilineous outnumbered M. separatella. Scirpophaga sp were occasionally recorded from the area. Maliarpha separatella infestationis usually extensive in rice crop field where water stands for longer periods during the growing seasons, for instance in irrigated, mangrove swamp and in deep water rice fields. However, Akinsola (per. common) noted that M. separatella was the major stemborer species in the upland rice-growing conditions of the forest zones in Nigeria.

The Chilo species common in the mangrove swamps of Casamance is C. zacconius while C. diffusilineous the predominant species in Sierra Leone. This might due to the difference in the rainfall regimes. The average annual rainfall in Casamance is about 1500mm while that of the mangrove swamps of Sierra Leone is 3000mm. As noted above C. zacconius is predominant in savanna zones where there is less rainfall and C. diffisulineous common in the Humid Tropics.

Near Rokupr, Sierra Leone, as at Boucke, C. diffusilineous and Sesamia sp. were the common stemborers which attacked upland rice. Epilachna similis is also prevelent on young upland rice crop in Sierra Leone.

Caseworm, *Nymphula depunctalis* (Guen), gall midge, *Orseolia oryzae*, leafhoppers, *Nephotettix* spp, leaf folders, *Pelopidas mathias* (F), *Borbo fanta* Ev. have been observed to be prevalent in irrigated and swamp fields in the region while grain suckers are frequently recorded on upland and irrigated rice crops.

In brief, gaps exist in our knowledge as regards the various climatic parameters that influence the distribution, development and population dynamics of many rice pests. Much of the information in the literature is only observational and relatively general; definite information is needed on the ecology of rice pests.

With different climatic zones in the region where rice is grown, studies on climatic factors on population dynamics of rice insects in a given area should be emphasized. The sporadic appearance of African armyworm in localised areas in the region and the recent importance of white flies and mites on rice crop in Sahelian zone, are not well understood.

REFERENCES

Agyen-Sampong, M (1975): Hieroglyphus daganensis Krauss (Orthoptera, Acrididae), a new pest of rice in northern Ghana, Ghana Jnl. Agric Sci. 8, 249-253.

Agyeh-Sampong, M. (1978): The Ecology of Rice Stemborers in West Africa. Presented at Inauguration of Africa Association of Insect Scientists at International Centre of Insect Physiology and Ecology (ICIPE), Nairobi, Kenya, December 5-8, 1978.

Agyen-Sampong, M. (1979): Ecological Basis of Rice Pest Management in Mangrove Swamps of Northern Sierra Leone. Paper presented at WARDA Seminar on "Integrated Mangement of Rice Diseases and Insect Pests" at Bobo-Dioulasso - Upper Volta - September 17-22.

Agyen-Sampong, M. and Akinsola, E.A.: Development and Intensity of Rice Pests in relation to climatic factors in West Africa. Paper presented at WARDA Workshop on Environmental Constraints on Rice Production in West Africa 15-19 September 1980. Banjul, The Gambia.

Akinsola, E.A. (1975): Present Status of Different Rice Stemborers in Parts of Nigeria. The Rice Entomology Newsletter, IRRI No. 3, 28.

Akinsola, E.A. (1979): Guidelines of Integrated Management of Insect Pests of Upland Rice in West Africa. Paper presented at WARDA Seminar on "Integrated Management of Rice Diseases and Insect Pests" at Bobo-Dioulasso- Upper Volta - September 17-22.

ANONYMOUS (1980): Classification of types of rice cultivation in West Africa. WARDA Technical Bulletin, Vol. 2(1) 5.

Bleszynski, S. (1970): A Revision of the World Species of Chilo Zincken (Lepidoptera: Pyralidae). Bull Br. Mus. nat. hist. (Ent.) Vol. 25 (4) 195 p.

Bonzi, M. (1980): Rice Entomology in Upper Volta. WARDA Annual Rice Review/ARR/80/7. Monrovia.

Chie-Hwa, (1973): Survey on the Rice Pests at Bobo Area in Upper Volta - monographs.

Diop, T. (1978): Entomological Problems in the Rice Areas of SAED-monograph p. 15.

Diop, T. (1980): WARDA, Special Research Project, Richard Toll, Entomology Report.

Odiyo, P.O. (1976): A Forecasting System for the African Armyworm. Proceedings of the 3rd Scientific Meeting of the International Centre of Insect Physiology and Ecology. ICIPE, Legon, Ghana - 23-26 November.

Poliet, A. (1977): Les Insectes ravageurs du Riz en Cote d'Ivoire. II - La Faune Rencontree sur Riz irrigue en Cote d'Ivoire centrale (Kotiessou). Cah. ORSTOM, ser. Biol, Vol. XII, No. 13-23.

Tavakilian, G. (1977): Le Genre Chilo en Cote d'Ivoire. Cah. ORSTOM. Ser Biol., 13 (1) 47-54.

WARDA (1979): Report of Monitoring Tour 1977-1978. Rice Research Review 79/18 Monrivo.

STATUS AND PROSPECTS OF RICE INTEGRATED PEST MANAGEMENT IN THE HUMID TROPICAL ZONE

By

M. Agyen-Sampong
WARDA Special Research Project
Rokupr, Sierra Leone

The Humid Tropical Zone run generally east-west along the coast streching roughly between latitude 5-10°N characterised by alternate wet and dry seasons. The dry months vary from one to four or more.

Within this climate Zone, different rice ecosystems exist - mangrove swamp, irrigated, upland, boli and inland valley swamp. The inter reaction of the climate and the ecosystem influences the prevalence of the pests in the rice field (Agyen-Sampong, 1982).

The major rice pests of economic importance in the Humid Tropical Zone include; Maliarpha seperatella, Chilo diffusilineus, Sesamia spp. Diopsis thoracica and Grain suckers, Hirperus sp. Riptortus spp, Aspavia armigera Stenocoris sp.

With the increase in rice production in the humid tropical, adequate and inexpense insect control is essential to suppress these major pests to achieve significant and sustained yields. Pest control approach which integrate different methods would be appropriate one.

The development of rice insect pest management systems in the region is at various stages. Nevertheless most components are in research phase in fragmentations or isolated form in various Research Institutes.

In the region the peasant rice farmers do unknowingly practise cultural control only - burning and digging of rice stabbles. However, on big commercial institutional controlled farms insecticides are still the primary component of control.

STAGE OF COMPONENTS DEVELOPMENT

Sampling:

Efficient sampling techniques are essential first step into rational IPM programme. It is a means of providing information for making IPM decision. Several sampling techniques have developed or adopted for use and the type depends on species involved. Some of the methods of collecting rice pests and factors influencing sampling programme have discussed (Agyen-Sampong, 1982).

Crop loss assessment and economic threshold

There is limited information in the Humid tropical of the relationships between population density (and/or plant damage) and yield loss.

In Ghana, Agyen-Sampong (1976) recorded yield loss of about 30% in irrigated rice due to lack of stemborer protection, and yield losses of one ton of paddy per hectare was also recorded in Ivory Coast due to insect pest (Breniere, 1977).

In the mangrove swamp of Northern Sierra Leone, studies of the relationship between stemborer infestation of *Maliarpha separatella* and crop yield on farmers' fields revealed different and complex relationships from farm to farm. Of the ten sets of data collected from ten farms, five exponential curves, one quadratic curve and two straight lines best describe the results.

Two other sets of the data showed no relationship. Different factors interplay to influence crop loss assessment due to M. separatella. These are shown in the various curves of the relationships of yield and stem infestation. The exponential relationship where crop loss decreases with increases in infestation appears to be more realistic than the straight line relationship.

Diopsis: At Ibadan, Nigeria, Alghali (1980) showed that there was a positive correlation between the number of eggs laid and the amount of damage by D. thoracica on rice tillers. However, he further demonstrated that the level of damage of the rice as indicated by the number of "dead heart" may bear no direct relationship with actual loss in yield as measured by grain weight, thus it is not useful index for crop loss assessment due to the compensatory tillering of rice crop. The degree of compensation varies with different varieties. Of the ten varieties of which their relative susceptibility to Diopsis damage were rated, crop losses ranged from 1.9% (Suakoko 8) to 54.2% (Tos 4121).

At Rice Research Station, Badeggi, Nigeria, Diopsis infestation caused yield reduction of 5.0% and 19.0% respectively to BG 90-2 and FARO 25 (Akinsola, 1980).

Rice bugs: In a preliminary studies, Agyen-Sampong and Fannah (1980) reported the following relationship between grain weight (gm/500 grains) and percentage grain damage:

Aspavia on ROK 5

$$Y = 10.15 - 0.12\,x \quad (r = .98^{**})$$

Aspavia on CP 4

$$Y = 9.91 - 0.11\,x \quad (r = -.99^{**})$$

Stenocoris sp on ROK 5

$$Y = 9.2 - 0.15\,x \quad (r = -.90^{**})$$

It is evident that little progress has been made in the development of crop loss assessment and economic thresholds for major pests of rice in the humid tropics. We need to refine them and work further on the different growth stages and on the different varieties grown in the various ecosystems.

Forecasting

To predict in advance of possible build-up or outbreak of the pest is a useful tool in pest control. Nevertheless, forecasting systems have not being effectively developed in the region.

Light trap catches could be used to forecast African black bettle Heteronychus oryzae infestation in northern Sierra Leone. The bettle sporadically attack rice seedlings. They usually first appear in light traps early June quickly reaching peak population before the end of the month and decline suddenly by early July. There is another gradual population building in November with a peak in December. The early population build-up which leads to the peak in June is of importance in northern Sierra Leone. The farmers' crop are in the seedling stage in May and June and sudden appearance of the population could lead to extensive crop damage, as was witnessed during an outbreak of the bettles early June, 1977, around Rokupr (Agyen-Sampong 1977).

Research has to be developed to know the varied factors involved in forecasting system of recent outbreaks in the region of such pest as army worm Spodoptera exempta.

Chemical Control

Insecticides are still often used in Government/ Institution based farms as prophylactic treatment against major rice pests and when outbreaks (e.g. armworms) occur. However, in a pest management scheme, selective insecticides and modification of application techniques to lessen the disruptive action of the insecticide are some of essentials to make insecticides fit into the scheme.

Extensive insecticides have been evaluated in the region for effectiveness against the various rice insect pests. For example, at Djibelor, Southern Senegal from 1969-1972, six insecticides effective against leaf-eater and grain suckers were selected through field screening, spraying on eight occasions during the season. Granules of lindane, birlane, azodrine and furadan, applying 2-3 times were found most effective against borers (ISRA, 1977).

In the mangrove swamp ecology, the rice farmer's stay away from their farms after transplanting and return there only at the time of harvest. In this ecosystem the soil is muddy and sticky and difficult and unpleasant for regular visits. A method of insect control being developed at WARDA, Rokupr holds promise against the dominant stemborer Maliarpha separatella Furadan (1.0 kg ai) broadcast on seedlings a week before transplanting and later applied once in September/October before pest adult population reach peak suppress infestation.

Chemical control methods must essentially be developed to suit different rice ecosystems in the humid tropics.

Varietal Resistance

Source of plant food as a factor of regulating pest abundance is significant in agriculture - crop varieties which are attacked less than others lose in yield.

Most of the varietal resistance work has been mainly screening a large number of germplasm of the rice for resistance to the major pest.

At IITA three varieties, SML 81B, W1263 and Taitung 16 were reported to be tolerant to the attack of Sesamia calamistis and Chilo zacconius. At Rokupr preliminary screening of over 1000 rice varieties against Diopsis and Maliarpha attack was done under natural infestation (WARDA, 1978 and 79) and over twenty varieties have been recorded as tolerant, however, detailed studies which involved the use of larger numbers of the pest under control environment is lacking in the region. However, mass rearing techniques of some of the major pests have been started - Chilo spp - IITA, Ibadan, Nigeria, IRAT, Bouake, Ivory Coast Sesamia sp IITA. ICIPE has initiated mass rearing technique on Maliarpha separatella in Nairobi, Kenya.

Biological Control

Rice insect pest in the region have a complex natural enemies of which little is known. Attempt has been made in isolated places and times to document the indigenous natural enemies of the rice pests. About 40 families and 70 species of the parasitoids of 20 rice pests have been scatteredly recorded in the literature.

Twenty species of egg and larval parasites of seven species of rice pests have recently been recorded at WARDA, Rokupr.

Two egg parasites Telenomus sp (predominant species) and Pediobius telenomi, parasitised Pelopidas mathias leaf folder, at a rate of more than 70%.

Maliarpha separatella larvae were the most heavily parasitised among the rice pests, possibly because they were the predominant pest. Of the thirteen larval parasites, eight were reared from M. separatella. Phanerotoma major Brues and Venturia crassicaput (Morley) accounted for about 67 percent parasitisation during the two seasons of 1978 and 1979 (Agyen-Sampong 1980).

These natural enemies together with other suppresive forces regulate the rice pest population and these could serve as a focal point pest management system around Rokupr.

Systematic study, conservation and manipulation of natural enemies for control of rice pests have to be emphasised. The study of natural enemies should include predator and entomphthoraceous fungi of which little is known in the region.

Cultural Control

Cultural methods restrict or prevent pest damage by reducing pest population thus, a useful component of pest management. They are generally economical and widely applicable. However, as cultivation practices improve cultural control methods should be developed and tested in different rice ecosystems.

Destruction of rice stuble after harvest: In the mangrove swamp where burning of stubbles is not feasible due to daily tidal flooding of the field, slashing of the rice stubbles at base drastically reduce the hibernating *Maliarpha* larvae population. However, for the practice to be useful all farmers in extensive area should be involved since *M. separatella* can fly long distances.

Time of planting: Early transplanting of both short and long duration varieties in the mangrove swamps of northern Sierra Leone escape the peak infestation of *Maliarpha* and *Chilo* infestation. The susceptible stages of growth of the crop miss the peak period of the stemborer attack when rice is transplanted in July than later transplanted rice in August and September. Short duration varieties transplanted early are attacked far less than the long duration varieties.

Fertilizer application: As has been noted with other insect pests, higher nitrogen fertilization led to higher levels of stemborer infestation of *Maliarpha* in the mangrove swamps. Resistant varieties responsive to fertilizer application would be ideal in the future.

Plant spacing and Stemborer Infestation: Recent priliminary studies of different spacings - 10cm x 10cm. 15cm x 2cm, 20cm x 30cm and 30cm x 30cm, at WARDA, Rokupr indicated that closer spacing led to lower *Maliarpha* infestation in the mangrove ecosystem. The reason for this is not obvious. However, farmers tended to transplant at wider spacing and this observation might be useful in formulating future control strategy.

PROSPECTS

As noted above, work on components of pest management programmes have been started in the region at various levels in different research institutions.

However, a lot of fundamental information on the ecology and biology on the rice pests and their natural enemies are needed in different locations for development of IPM programme.

In general, in the humid tropics the regulating factors of parasites, predators and pathogens have a greater role on the numerous pests recorded in rice fields, most of them are left in the status of low level secondary pests. Furthermore in most of the rice ecosystems the level of pesticide use is not high and thus there has been relatively little disturbance. These reasons make IPM an appropriate and workable in the humid tropic of the region.

Often as in developed countries, a long period of preparatory work is required for a pest management for background knowledge of population dynamics of the pest complex and the related ecosystem.

Ideally detailed knowledge could be useful but obtaining it for all the major rice pests could be time consuming and technically difficult for the region to afford. Experience from many countries show that even partial utilization of the concept could be advantageous (Haskell, 1977). Practical pest management is "a matter of common sense backed by experience, imagination and appreciation of relevant research needs" (Way, 1977) and there is no need to know all about the pest ecology.

Therefore some of IPM components developed could be tried on large plot scale, the results of which could be used to establish research priorities for more effective pest management systems.

Further prospects of IPM programme also depend on full co-operation of extension services along-side the research. - Thus training personnel at various levels in the IPM.

Administrators and policy makers must be educated to create awareness among them about the importance of IPM.

Farmers are also to be educated gradually and re-orientated to consider IPM as part of farming cultural practice.

REFERENCES

Agyen-Sampong, M. (1976): Varietal Resistance and other Integrated Pest Control Components as Factors of Rice Varietal Improvement in West Africa. WARDA. Second Varietal Improvement Seminar. Sept. 13-17, 1976, Monrovia.

Agyen-Sampong, M. (1977): Outbreak of Heteronychus oryzae in rice seedlings near Rokupr, Sierra Leone. IRRN 2:6 p.16.

Agyen-Sampong, M. (1980): Parasites of Rice Pests of Mangrove Swamps of Northern Sierra Leone. WARDA, Technical Newsletter Vol 2. No. 2 pp. 1-3.

Agyen-Sampong, M. (1982): Sampling methods for rice insects paper presented at a short course on Rice Integrated Pest Management, January 10-28, 1982. WARDA, Monrovia, Liberia.

Agyen-Sampong, M. and Fannah, J.S. (1980): Dirty Panicles and rice yield reduction caused by bugs. IRRN, 5:1 pp. 11-12.

Akinsola, E.A. (1980): Effects of Infestation by Diopsis thoracia (West.) on Rice Plants. WARDA, Technical Newsletter Vol 2 No.2 pp. 3-4.

Alghali, M.A. (1981): Studies on the relative susceptibility of rice varieties to Diopsis thoracica West. Diptera, Dropsidea. Ph.D. Thesis of University of Ibadan.

Breniere, J. (1977): The main rice parasites in West Africa and their control. WARDA Seminar on Plant Protection for the rice crop. May 21-26, 1973, Monrovia.

Haskell, P.T. (1977): Integrated Pest Control and small farmer crop protection in developing countries. Outl. Agric. 9(3): 121-126.

International Institute of Tropical Agriculture (1974): Annual Report.

Institute Senegalais de Recherches Agricoles (ISRA). Bilan de Sept Annees de Recherches Rizicoles a la Station de Djibelor (1967-1974).

Way, M.J. (1977): Integrated Control - practical realities. Outl. Agric. 9(3): 127-135.

INTEGRATED PEST CONTROL IN RICE PRODUCTION IN SAHELIAN SUDAN

PROSPECTS AND POSSIBILITIES FOR RESEARCH

By

J. BRENIERE
IRAT, Montpellier, France

This paper does not deal with the integrated pest control definitions given for each crop in the current course, nor with the various control measures available. The protection of any crop should as much as possible be based on the study of the relationship between the crop and its pests within the agroecological system: plant reaction to the constraints of climate, soil, cropping conditions, living organisms that generally affect its development: population dynamics of pests as well as the factors which favour or affect their development.

All those interactions - climate, soil, plant-pest relation and natural enemies of pests form a complex which should at least be partially studied to determine the methods by which the farmer can control the damages caused by the pests to the plant. This step will lead to the utilization of control measures adapted to each situation which in effect is the essence of integrated control.

ASPECTS OF CULTIVATION AFFECTING PEST BEHAVIOUR

The wet conditions of the rice field in itself constitute an agrosystem that especially favours a large concentration of fauna. The rice plant remains green and turgid throughout its development and is both a source of shelter and food. Before tillering when it has a grassy appearance, rice is susceptible to leaf-feeding pests; however, the seedling-beds are densely populated only very severe attacks could bring about irreparable damage to the crop.

Tillering therefore plays an important compensatory role when a part of the stem is destroyed. By contrast, booting followed by heading is a delicate stage. Water requirement is then very important and even a partial breakdown in sap transportation in the narrowest part of the panicle's peduncle may result in the wilting of the whole panicle.

During maturation, the water requirement is relatively low and the stem reserves are good therefore damages to the lower part of the stems or the roots will have a minor effect on the harvest. By contrast, at this stage, any damage done directly to the panicle or the grain by the sucking of a hemipeteron (bug) can have a lasting effect on the quality of the paddy and even reduce yield.

These general remarks show the imprtance of determining and understanding the interactions between elements of the ecosystem in order to define control strategies. To be more concrete and more specific we shall use the Sudanese-Guinean zone of Casamance as a reference.

The research conducted there can be divided into 4 phases.

Phase 1: Study of the pests

The initial studies revealed the existence of a few major pests: at the beginning of vegetation (seed bed and beginning of tillering), the Coccinella Epilachna similis which someti[illegible]s cause very extensive leaf damage during sporadic outbreaks i[illegible] followed by the diopsid, Diopsis thoracica from the early to the middle stages of tillering, then the lepidopterous rice stemborers of the genera: Chilo, Maliarpha and Sesamia, and the cecidomyid (midge) Orseolia oryzae.

The studies have primarily covered population dynamics of pests as well as the pesticides used against these pests. In recent years, more information has been gathered on these pests.

It has been observed that some secondary insect pests can develop into serious pests and sometimes replace major ones. This is true of the Coleoptera, family Chrysomelidae, sub-families Hispinae and Alticinae, (Trichispa, Altica and Chaetocnema genera); Heteroptera, Pentaomidae (Diplozis) which suck grains, the Homoptera Cicadellidae and Delphacidae (potential vectors of viruses diseases of rice in Asia presently non-existent on the African continent), a pseudococcidae, Thysanoptera and even the acarid (mite), Tetranychidae which can spread in off-season rice fields especially during the dry season.

There is, therefore, every reason to design integrated control techniques on the basis of a specific number of problems given that these problems can vary in time and space. It is for this reason that diopsids are especially found on irrigated rice but rarely on upland rice in the remote areas of wet low-lands, the borers Chilo and Maliarpha were very abundant during 1970-74 but have diminished over the past few years. Maliarpha typical of the genus Oryza is particularly abundant on the irrigated rice when rice cultivation spreads over a greater part of the year (2 to 3 harvests per year).

Phase 2 - Assessment of Losses due to Pests

It has often been said that one of the fundamental aspects of integrated control is the decision-making based on an assessment of the economic threshold; i.e. the population level at which the control measure is economically justified. This assessment is considered a prerequisite to any rational approach towards control.

One readily realises that it is very difficult to assess the economic injury level. In fact, it depends on the ability of the plant to overcome the insect's attack which varies according to the pest, the phenological stage of the rice crop being attacked, the resistance or tolerance threshold of the variety concerned and the economic factors of productivity.

If this level is defined as the population level at which pest control is justified, it will then be necessary to determine the desired control measure and what it amounts to in terms of inputs (insecticides, the labour required for application, for example). These factors should then be compared with the expected yield increase. This economic injury level should also be correlated with the ecological tolerance threshold which is the level of pest population below which this control no longer makes it possible to contain the obnoxious predator or parasites at an effective level. The economic injury level is a major factor in determining the optimum efficiency rate of natural enemies.

Practically speaking, it is impossible to attempt a complete analysis of the ecosystem. The economic injury assessment could account for only a part of the elements of the system and could only be restricted to providing common solutions to common problems.

For example, in order to determine the economic advantage of a proposed chemical control method following the results of experiments conducted in agricultural stations, it will be necessary to undertake actual field experiments using pairs of treated and untreated plots that are widely distributed over the area that is to be protected. A comparison of the yields of a series of these pairs will provide an initial approximation of the potential benefits of these treatments. However, it will be necessary to correlate this approximation with that of the level of damages as well as the major pests dynamics; the efficiency of the treatment will obviously depend on the level of parasitic pressure that the plant was subjected to.

It was observed that the assessment of the economic injury level cannot be a prerequisite to the studies leading to the implementation of integrated control.

However, it appears to be the outcome of a collection of biological and ecological studies required for a sound knowledge of the inter relations in the ecosystem.

Phase 3 – Study on Chemical Control

After defining the main objectives which include, species of target pests as well as the type of rice cultivation and after studying the main biological features of these pests, it is necessary to investigate whether chemical control can bring about satisfactory improvement.

This study can only be undertaken with a perfect control of rice cultivation: this includes more or less complete water control, varieties that are productive and resistant to diseases, adequate fertilization to ensure a relatively high productivity potential when pest damages are avoided. Initial studies will be conducted in an agricultural station by trying to adopt methods that are as close as possible to existing ones or those that can serve as a model for extension. The objective of the insecticide trials will be to compare various active ingredients, their formulation, dosage, and treatment schedule.

From this stage on, it will be necessary to include a series of observations on the development of pests dynamics in the trials both on the treated and untreated control plots. In fact, it will require more than a single yield comparison exercise to determine the pest against which the products have acted, or the time when the treatment was most effective.

The chemical control measure to be incorporated into an integrated system should as much as possible be limited to a restricted number of treatments for economic reasons, to prevent their destructive effects on useful fauna, to avoid the development of resistant strains to the pesticides and the outbreak of resistant secondary pests.

Therefore, from the initial trials onwards, it is adviseable to investigate the most favourable period to apply a control measure against one or more major pests at the peak period of their population as well as the time when the plant is most fragile. This was done in Casamance where each insecticide trial was accompanied by a series of observations on the dynamics of pests found on trial plots and the surrounding area.

For example, the rice stemborers of the genus Chilo exist in two successive generations on a single rice field. The first generation appears during tillering causing the death of a number of tillers which is partly replaced by compensatory tillering. The second generation appears during heading when panicles (white panicles) are likely to be destroyed by young caterpillas without any reaction from the plant. In this case, chemical control should be envisaged mainly from the mid-tillering to heading stages (treatment recommended in Casamance is 30 and 60 days after transplanting.) On the contrary, if it involves an area with a high incidence of diopsids, it will be necessary to protect it earlier because diopsids only destroy rice at the early tillering stages.

SELECTION OF INSECTICIDES AND APPLICATION METHODS IN AN INTEGRATED SYSTEM

Some active insecticidal chemicals though effective, should be avoided because frequent usage results in an outbreak of secondary pests. This was the case of Sevin in Upper Volta which after two years of intensive usage few years ago, brought about large outbreaks of an aleuridid (white flies) which was till then practically unknown in rice cultivation. Similarly DDT causes greenfly outbreaks and some pyrethroids results in mite infestation.

Liquid spray of foliage are effective against external pests: (defoliators - insect pests of leaves) but significantly affect predators and entomophagous insects. The number of dressings over short periods should be limited. By contrast, in order to control stemborers, sprays should be repeated 5-6 time because they have a low residual effect to ensure satisfactory protection.

The number of treatments when granulated formulation is used in rice fields is limited to 2 or 3 if systemic or parasystemic products are used for their effect on the plant can be felt for 2-4 weeks. Besides the reduction in the number of treatments, in the case of granules, there is no direct contact between the insecticide and the free forms of egg parasites, larva-feeding species and most predators. This was verified recently in Ivory Coast where the use of granulated carbofuran brought about only a small reduction in the number of predatory spiders on the treated rice fields. Lindane, Carbofuran, Chlorfenvinphos and Quinalfos are all effective in granulated form against stemborers. On the other hand, they have turned out to have a very slow effect on certain leaf-feeding insects with very rapid proliferation: (Nymphulinae and grain pests).

Research is presently being conducted on specific insecticides which only cause as little harm as possible to pests natural enemies.

Bacillus thuringiensis specific to Lepidoptera is completely safe for Hymenoptera and Diptera which are the major parasites. Since the bacterium only acts by ingestion, it can only affect leaf-feeders (defoliators) but has a minimal effect on stemborers.

In conclusion, integrated pest control in rice cultivation may include the use of insecticides under the following conditions:

1. Their use should be restricted to rice fields whose production potential is such that the yield increase resulting from the effect of the treatments is significantly higher than the costs involved.

2. The number of treatments should be reduced to the required minimum and applied only at the specific periods.

3. The chemical and the method of application should have the least possible effect on the natural enemies and should neither cause the development of resistant pest strains nor favour the outbreaks of substitutes.

Phase 4 - Assessment of the role of natural enemies

The outbreak of insect pests results in the proliferation of their natural parasites, animal predators or pathogens. Some of them are enemic, but generally have a delayed effect (at the end of the season) when their host populations have reached their peak and damage has already been done. Initially therefore, these natural enemies, do not seem to have any useful effect.

A closer examination shows many things taking place from the beginning of the larva's life: the egg parasites are less conspicuous than the larval parasites but are more effective because they serve as a deterrent. This is true of Trichogramma parasites on the eggs Lepidoptera and Scelionidae (4 species identified on stemborers in Casamance).

The role of predators is still more difficult to assess. In rice fields their importance is of increasing significance. Spiders are very abundant. They feed on a large number of larvae of all types of insects living in the rice fields(both harmful and harmless ones).

It is very difficult to determine the destructive capacity of a predator, for besides the diversity of preys, some of them are not entirely consumed. This results in great variability depending on the beaviour of the predator which changes according to the abundance of existing preys.

There are very little studies on these problems. We would, however, like to draw attention to the research conducted in Thailand by Yasumatsu who observed that the spiders of the genus Tetragnatha consume a large number caterpillars of lepidopterous rice stemborers. This predation may be diverted from the desired objective when the spiders used other preys like the larvae of chironomids which often abound in the mud of rice fields. The larvae of Chironomidae though harmless are indirectly undesirable to the farmer.

Irrespective of the complexity of these mechanisms and the difficulty posed by analysing the merits of useful fauna, the important role played by the latter in limiting pests even during outbreaks should not be ignored.

It has often been observed that there is a very high level of egg parasitism, over 80%, when the egg density is high. The useful effect, though delayed, is undeniably felt. Thus, efforts should be made to encourage it.

For example, the parasitism of eggs of Scirpophaga by Telenomus is always high in West Africa and very well seems to be the main reason why the adverse effects of Scirpophaga is minimal in Africa. Similarly, the sudden outbreaks of the Lepidoptera, Hesperid, the deadly leaf pests (defoliators) are almost always contained from the secondgeneratinn onwards by a chalcid of the genus Brachymeria which affects almost 100% of the larva population.

To protect natural enemies, one must first of all avoid destroying them by ensuring a judicious and limited use of the pesticides (insecticides and herbicides). It is also necessary to identify them by carrying out an inventory on the fauna and determining the role of each.

In Casamance, forexample, the list of natural enemies of major pests increases each year. More than 30 species of parasites of Hymenoptera on stemborers, diopsids and cecidomyids of rice have been identified. These studies should determine the role played by each of them. The characteristics of the ecological niche used should be defined. This includes the stage of the host-parsite, the ability to affect the host, parasitism dynamics in relation to that of the host, the life expectancy of the parasite in the absence of the host, the range of its hosts and ultimately the movement cycle from one host to another. Evidently, there is still very little information on all these factors and for the moment, very fragmentary observations should suffice.

However, some simple data can be extracted from these observations:

- An egg parasite is potentially more important than larvae or nymphal parasite.

- A polyphagous parasite is more effective than a monophagous in so far as the insect pests that we are concerned about is its favourite host. The survival capacity of the polyphagous parasite during off-season will in fact be better than that of the monophagous parasite.

- A predator with a rapid cycle and a remarkable host-searching ability will be more interesting than one which develops slower or is not perfectly adapted to the rice biotype.

- Observations of this type associated with the knowledge of parasites of the same pests or similar species living in other continents (mainly in S.E. Asia), will make it possible to propose biological control measures so as to introduce useful species likely to occupy a neglected "ecological niche" from one country to the other.

- With this objective in view, some projects have been planned. One of them has started in Casamance, Senegal. It involves the introduction of the parasite Apanteles flavipes on the stemborers of the genus Chilo.

Studies are also being conducted in Senegal on Trichogramma which feeds on a wide range of pests but whose behaviour according to the species or race is stable enough to necessitate research on the best adaptable strains to the rice area as well as the pest eggs that they are likely to meet. Multiplication of these parasites before they are released is absolutely necessary if attempts at introducing these parasites are to be successful.

It is necessary to undertake a series of ecological and biological studies as well as to formulate methods of breeding hosts and their parasites. This has been achieved in some cases - in stemborers of gramineae for example. As far as other pests are concerned, we still do not have adequate means to ensure large-scale multiplication of their parasites.

International links should be further strengthened to facilitate exchanges and to acquire a better knowledge of control possibilites.

PATHOGENS AFFECTING INSECTS

There is very little materials on pathogens affecting insects of rice pests. Advanced research on cotton lepidoptera can serve as a model. Bacteriological and virological laboratories should be created in Africa to deal with these subjects and to extend them to major rice pests.

The new discoveries of baculovirus properties should serve as an incentive to thoroughly explore these possibilities. These microorganisms are quite polyphagous and can multiply themselves rapidly after dissemination among the crops. They can, therefore, have more interesting results than that of Bacillus thuringiensis which is not likely to multiply after dissemination. However for now, these are mere speculations and future undertakings.

Phase 5 -- Varietal resistance

To return to integrated control proposals that are more readily accessible, one should recall that the selection of resistant varieties to insects takes place when a new set of varieties is adopted.

Rice resistance to insects is never absolute as it is to certain diseases.

Selection should, however, take into account the differences in susceptibility of the varieties under study. It was observed that, generally, increased yield triggers off increased insect attacks.

If caution is not exercised, there is the risk of selecting susceptible varieties and losing the benefits of expected increases. The antibiotic factors, some of which are already known, should be investigated to correlate them with the physical or chemical characteristics of the plant such as tissue durability, silica quantity, stem thickness, tilling capacity, season duration, etc. However, correlations are generally numerous and a single characteristic cannot determine a selection method.

In Casamance, as in Ivory Coast, it was decided to incorporate the observations on varietal susceptibility to major rice insects into each varietal selection programme. For this purpose, a distinction should be made between antibiosis per se and attractiveness or preference which is only a relative factor without much use.

Firstly, there should be a susceptibility classification of traditional varieties.

Practically-speaking group trials will be conducted in adjacent rows in which it will be possible for varieties to show differences due to attractiveness as well as antibiosis. Replications with various sets of varieties can partially correct the effects of attractiveness among varieties. Observations on selected varieties should be made on larger acrage. Field studies are important for they are conducted under natural conditions which cannot be replaced. The results obtained for trials on small acrage are to be viewed with caution. A large number of replications will be necessary (at least 8) to modify the variations occurring in such tests. Secondly, the tests will be confirmed by monitored infestation trials in order to have an homogenous pests population. Thirdly, the trend in mortality rate during the pest's development will be observed to confirm the antibiotic qualities of already selected varieties. The objective in this phase is to look for varieties which can serve as resistance-carrying types to be introduced in selection programmes.

In Casamance, at present, experiments are only centred on the first phase. The second phase is in the preparatory stages and covers resistance in *Chilo* spp. In Ivory Coast, the first two phases are underway and the third under preparation.

OTHER RESEARCH ACTIVITIES TOWARDS INTEGRATED PEST CONTROL

Pheromones: Supervised chemical as well as biological control require a good knowldge of population dynamics. One of the possible means of assessing population dynamics is the trapping of adults to determine the difference in population density, before the appearance of damage.

Light traps attract a considerable number of insects but are unselective and inconsistent (variations in lighting, wind effect on attractivity, influence of the moon).

The use of sexual attractants is a highly superior step. Pheromone, a substance released by the sexual glands of one of the sexes attracts the other sex of the same species. Generally, it is the female pheromones which attract the males from the distance thereby facilitating mating. Studies on pheromones of Lepidopterad undertaken over the past few years have led to the analysis of pheronones released by each species as well as to the manufacture of synthetic products which can be used in traps. It is for this reason that synthetic pheromones of several Lepidoptera of cotton and vegetable have recently been developed.

This year with the assistance of INRA and IRAT, trials of several specific phenomones formulae of *Chilo zacconius* have been undertaken by ISRA at Ziguinchor, Senegal. One of them has proved effective. Its requirements for use will be studied this year. Other studies are underway to investigate the pheromones of other African rice stemborers.

INTEGRATED AGRONOMIC IMPROVEMENT

Agronomic improvement which tends to facilitate plant growth as well as increased productivity helps to give the plant a better resistance to pest attacks. Thus it will be possible to contain, to a certain extent, potential damage due to defoliation if adequate water supply is ensured and rapid growth at the beginning of vegetation is facilitated.

Every aspect that is conducive to tillering should be investigated when there is a danger of attacks by diopsids, stemborers or gall-midges, An application of ammonium sulphate at the mid-tillering stage can act as a stimulant to adequately compensate the plant for lost tillers.

Some polyphagous insect pests invade the rice fields from outside or feed on grass weed growing in canals and drains. This is the case of armyworms (*Spodoptera exigua*), mites and the coccinella *Epilachna Similis*. Monitored observations, weed control or possible insecticide treatments can contribute to contain some of these infestations.

Pest control by agronomic methods can also be accomplished by the following:

Short duration flooding of a seedbed or rice field during tillering can help eliminate the attacks of chrysomelids Hispinae (rice lice) or most leaf feeders.

On the other hand, the drying up of a rice field invaded by *Nymphula* spp. is an effective means of eliminating the caterpillars which are aquatic..

After harvest, the caterpillars of *Maliarpha separatella* which hibernate in stem bases could be eliminated either by stubble ploughing, drying up the tufts, or if possible flooding the stubbles to accelerate degradation.

It will also be adviseable to remove off-season rice regrowths in rice fields, canals and surrounding drains, as well as wild rice (*Oryza barthii* and *O. longistaminata*) which is a food substitute and a host for most rice insect pests.

All these operations adapted to each agroecological system complement each other and if carried out can effectively contribute to containing of the spread of certain pests.

CONCLUSION

Integrated pest control in rice cultivation in Africa is still at its initial stages. Despite the availability of basic scientific data, an in-depth knowledge of agroecosystems and interactions between plants, pests and their biological environment will still require extensive research to perfectly design models of control techniques integrating all the components of the system. Although this cannot be achieved in the near future, we can, however, follow general guidelines which in each case will permit the use of the best possible solutions by avoiding errors resulting from the incompatibilities of some of these solutions.

ESTABLISHING AND USING ECONOMIC THRESHOLDS

By

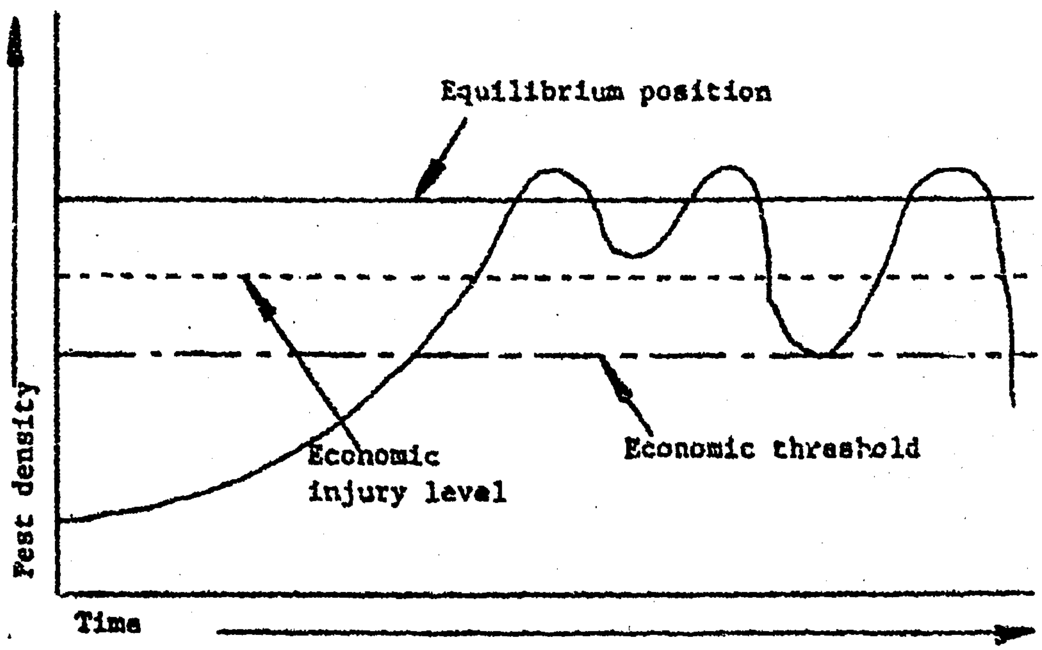
Dale G. Bottrell
University of California, Berkeley
Consortium for International Crop Protection
2288 Fulton Street, Suite 310
Berkeley, California 94704, USA

ECONOMIC THRESHOLD EXPLAINED

As noted in another paper at the training course (Dale G. Bottrell, Principles of Integrated Pest Management), integrated pest management (IPM) assumes that each of the reputedly harmful species in a cropping ecosystem has a population level below which there is no economic injury. The population level that determines whether the pest organism has attained "real" pest status is called the "economic threshold." Here, economic threshold is defined as the density of a pest population below which the cost of applying control measures exceeds the losses caused by the pest (Stern, 1973; Glass, 1975).

To establish the economic threshold, the "economic injury level" first must be determined. The economic injury level is the point at which a pest population begins to cause economic loss. As illustrated in Figure 1, the economic injury level is slightly greater than the economic threshold level. This difference in population densities provides a margin of safety for the time that elapses between when the threatening infestation is detected and when the pest control treatment is applied (Stern et al., 1959).

Figure 1 Relationship of economic threshold and economic injury level



In other words, the economic threshold is the point at which the treatment must be applied to prevent a pest from reaching the economic injury level.

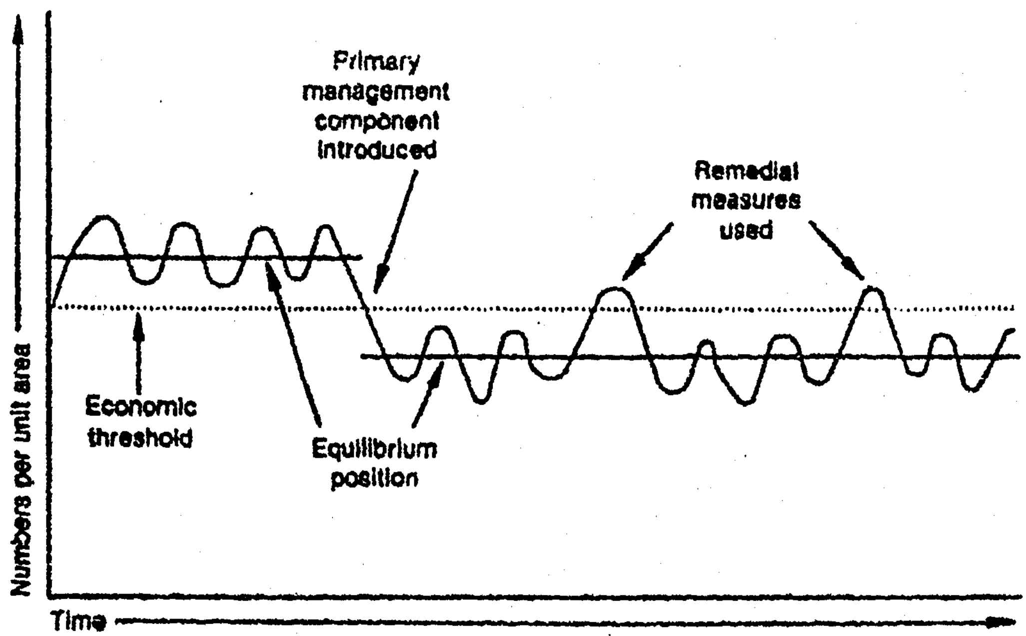
Key pests--those serious species which recur at regular, and often fairly predictable, intervals (refer to training course paper by Dale G. Bottrell, The Key Pest Concept)-- generally exceed tolerable levels each year in the absence of control actions. That is, their average density, known as "equilibrium position," exceeds the economic threshold. Integrated pest management efforts aim to manipulate the environment so to reduce a key pest's equilibrium position permanently to a level lower than the economic threshold, as illustrated in Figure 2. This reduction may be accomplished using three primary management components, singly or in combination:

— Deliberate introduction and establishment of natural enemies (parasites, predators, diseases) in areas where they did not previously occur.

— Utilization of pest-resistant varieties of crop plants which cause a reduction in the pest's equilibrium position or which simply tolerate the pest at equilibrium position.

— Modification of the pest environment in such a way as to increase the effectiveness of the pest's biological control agents, to destroy its breeding, feeding, or shelter habitat, or otherwise to render it harmless. Examples include crop rotation, destruction of crop harvest residues, and soil tillage.

Figure 2 Lowering the equilibrium position of a pest



Source: Rabb (1978)

Utilization of the best combination of natural enemies, resistant varieties, and environmental modification may eliminate the need for further action against many key pests except under unusual circumstances. Nearly permanent control of key arthropod and disease pest of some agricultural crops, for example, has been achieved by integrating such cultural practices as plowing and timing of irrigation with pest-resistant crop varieties and conservation of natural enemy populations.

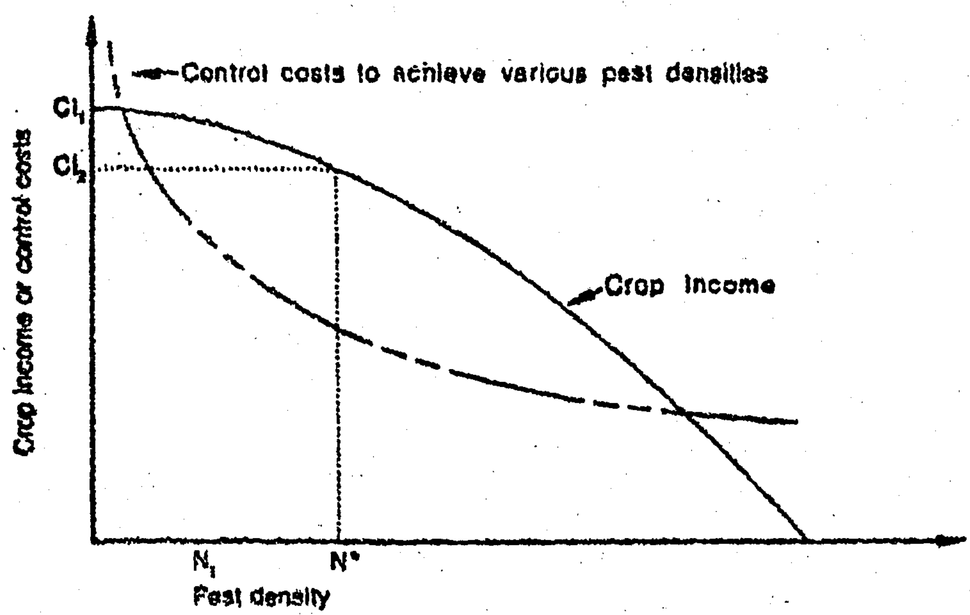
For the occasion when the key pests have flared up or the secondary pests are out of control, remedial measures must be taken (see Figure 2); pesticides may be the only recourse. In integrated pest management programs, selection of the pesticide, dosage, and treatment time are carefully coordinated to avoid ecological disruptions and other problems associated with the improper use of pesticides. Economic thresholds serve to identify when and where the remedial measures such as pesticidal treatments are truly justified.

COST CONSIDERATIONS

Figure 3 depicts a simplified economic threshold for a crop pest. The net crop income decreases at an increasing rate as pest density increases above a crop tolerance level (N_1). Control costs to achieve various pest densities are represented by the curved broken line.

The economic threshold (N^*) is the pest density (or amount of plant damage) at which incremental costs of control just equal incremental crop returns. At N^* some crop income is sacrificed ($CI_1 - CI_2$).

Figure 3 Hypothetical economic threshold



Source: Carlson (1971)

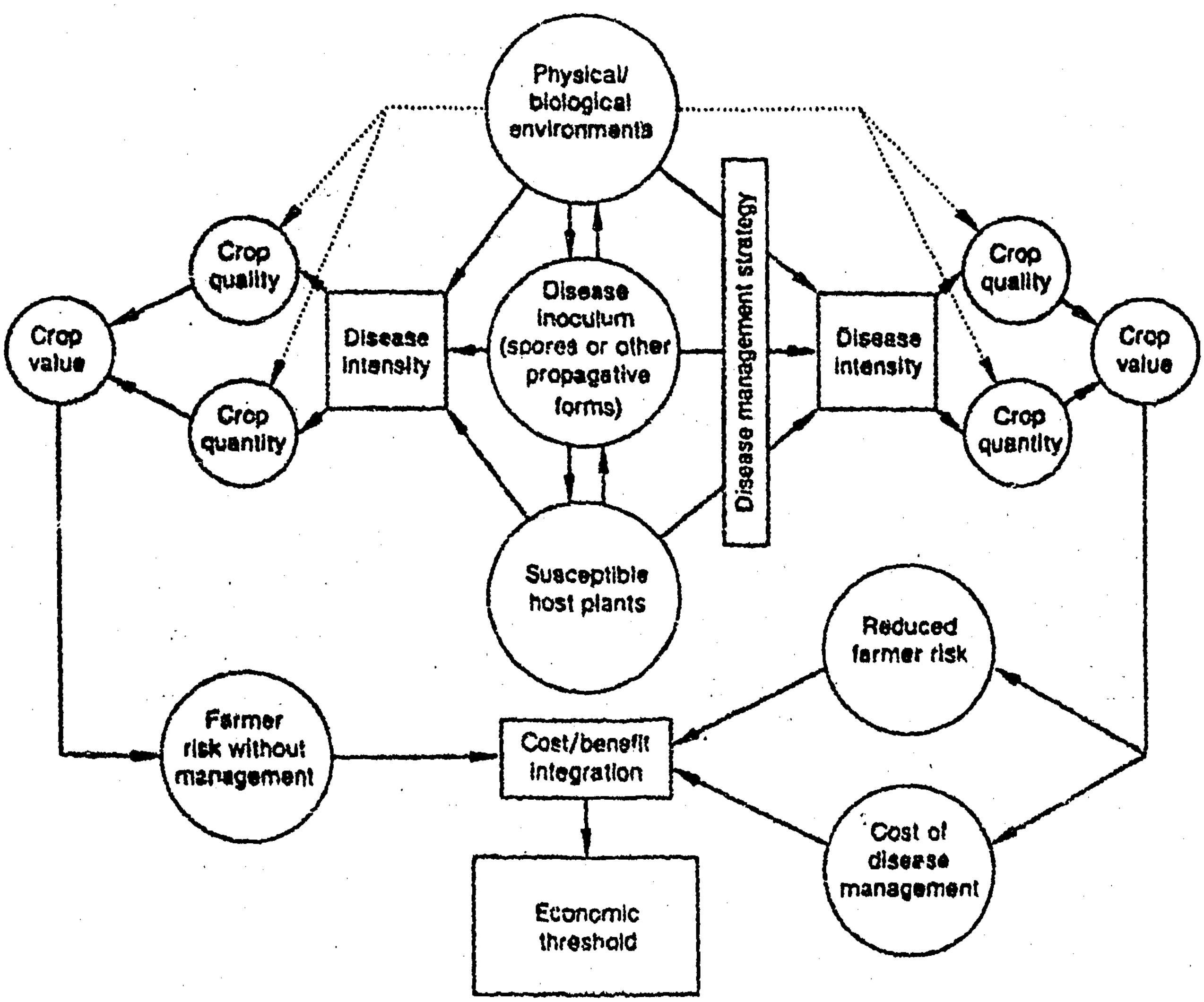
Above N* the farmer would fail to get additional crop revenue in proportion to the greater cost of control. If controls are initiated successfully at the tolerance or damage threshold (N_1), zero damage would occur but the costs of control would not be justified (Carlson, 1971).

The concept of the economic threshold is actually much more complex than this illustration; economic thresholds must accurately reflect many complex and interacting variables (Figure 4). Ideally, they are based on accurate assessments of the potential damage, the human risks and uncertainties involved, and the ecological, sociological, and external economic costs of control.

Determination of economic thresholds is especially complex when more than strict profit-loss relationships are involved (Stark, 1971). For example, damage that causes nutritive losses or adversely affects the usability or palatability of a food product is far more important than damage that merely affects appearance.

Establishing economic thresholds is even more difficult when a crop is attacked by a complex of pests. When a crop is attacked by a pest complex, growers may ask what should be done when the crop is infested by pest species, A,B,C, and D, none of which has reached the economic threshold but each of which may be within one-half to three-fourths of it. Are the effects of multiple infestatinns additive, synergistic, or antagonistic? These basic questions have received far too little attention, and experimental techniques required for research on economic thresholds for pest complexes have lagged. A substantial research effort is necessary to fill this void in knowledge (Glass, 1975; Main, 1977; Stern, 1973).

Figure 4 Factors that determine the economic threshold for a plant disease pest



Source: after Apple (1977)

RESEARCH REQUIREMENT

There are no standard techniques for dtermining the relationship of pest damage (or pest infestation) level and crop loss, as required to establish economic threshold. Some of the commonly used techniques are discussed.

Small Plot Techniques

A common procedure of entomologists involves the use of small experimental field plots, situated side by side, each subjected to a different level of insect density. Different levels of pest attack are achieved by artificially infesting the plots' plants (e.g. infesting plants in the field with insects reared in the laboratory) or by controlling the densities of the natural infestations. Probably the best known method involves the use of small, replicated experimental plots that become naturally infested with insect pests; each receives a different level of insecticide treatment, usually producing from 0-100 percent control. The method has wide application but the choice of experimental design is critical (Stern, 1973). Small experimental plots may be a poor choice if the pesticide treatment influences plant growth or yield. For example, the use of some systemic insecticides may give increased yields, independently of the insect infestations; therefore, the yields of the control (check or untreated) plots are disadvantaged, regardless of the pest densities that develop in them. Other pesticides may be phytotoxic and may cause yield losses; yields of the treated plots therefore may be disadvantaged if these pesticides are used.

Another error in experimental design is the use of small plots situated side by side without sufficient space between any two plots to buffer insecticidal spray drift from one to the other (Stern, 1973). The insecticidal drift may not be sufficiently potent to kill the pests in the control plots, but it may kill insect natural enemies residing in them and thus unleash the pests that the natural enemies regulated; this would give treated plots a yield advantage.

To get realistic results, the experiments should be conducted on farmers fields; the plots should be buffered from control practices being used on the farmers' fields. All variables (e.g., soil fertility, irrigation level, tillage) but the techniques being used to vary the level of pest infestation should be held constant (Stern, 1973). The samples must be sufficiently large and must be taken uniformly over the plots. Small samples may suffice if the pests are uniformly distributed over the field and plant growing conditions are uniform. Lack of uniformity in distribution creates special problems when establishing economic thresholds for nematodes. Because of differences in soil pattern and the relative immobility of nematodes, nematode distribution within a field may be highly variable (Barker and Nusbaum, 1971). It is useful to seek advice of statisticians, crop physiologists, and others who may offer suggestions on choice of experiments to establish economic thresholds. It is particularly important that crop economists are contacted. They should be taught the principles of economic thresholds and should be consulted about the economic realities of threshold values which are to be adopted by the farmers.

Cage Techniques

A widely used technique in economic threshold studies on insect pests is to place screen cages over field plants and to introduce various numbers of pests into the different cages. The cage technique may also be used in studies on other invertebrate pests (e.g., slugs and snails), and rodents, for example. However, some cages may drastically change the microclimate around the plants, leading to erroneous results.

Simulated Damage

Numerous investigators have attempted to simulate pest injury by removing or injuring leaves or other plant parts. Simulation techniques have been devised that mimic injury by insects, diseases, and rodents, for example, and have wide application. However, the simulated damage may not adequately mimic the damage of some pests. Insects may persist over a period of time or inject a toxin that does not produce an effect for a relatively long time after being injected. Some diseases and insects attack only the margins of a leaf or another small habitat area and some attack only leaves of a certain age. Mechanical injury that simulates injury by one pest species may predispose the plant to injury by a different pest species that is attracted to the injured plant parts. Therefore, the damage simulation technique should be used only after the behavior and ecology of the pests and their interactions with the plants are well-known.

Quantitative Models

Mathematical models of plant growth, crop yield, and pest population dynamics offer much potential in sharpening the approach to the establishment of economic thresholds. Computer models that provide a theoretical explanation for the self-limiting effect of injurious or competitive organisms on crop yield have been developed. The number of these models is increasing. Yield loss caused by pests (dependent variable) may be expressed as the sum of linear functions of other (independent) important variables. Such models are particularly useful if they provide estimates over time of loss and account for changes in weather, plant growth, value of crop, and other variables.

Interpreting the Results

To compute economic thresholds requires regression of yield reduction on pest population level. If y represents loss (expressed as a percent of crop yield, for example) and x the pest population level (e.g. numbers of pests per meter of plant row, per 100 plants, or per hectare) or the plant damage level (e.g. percent leaf area damage, percent damaged stems), then in its simplest form, the relationship would be linear; in other words the level of loss would be directly related to the level of the pest population or pest injury. For example, when x is 1 and y 10 (10 times greater than x), then when x is 1.1, y is 11 (still 10 times greater than x), and so on. However, levels of pest damage and crop damage may not—and, in fact, often are no—perfectly correlated and the relationship of plant damage and yield reduction may not be linear.

Statisticians should be sought before attempting to design the experiments and to interpret the results.

Case History Study for Rice

The following summarizes a study by Poché et al. (1981) to determine the relationship of rice damage by rats and yield loss in Bangladesh: The effects of simulated rat damage (stem cutting) or IR 8 rice yield was examined. Fields were subjected to four damage levels: 0 (control, 10, 25, and 50 percent of the stems cut. A modified split-plot sampling design was used with ten 1 square-meter plots tested at each damage level in three growth stages: tillering, booting, and maturity. Each of the 120 plots (2.400 hills) was harvested and yields compared by Analysis of Variance and Least Significant Difference (LSD) tests. Ten percent of all stems removed during tillering stage produced growth compensation and a higher yield resulted. Trends in rice yields for different damage levels showed that the later damage occurred, the greater the yield loss. An LSD analysis of yields for the damage levels revealed no significant differences during tillering. At booting, significant differences (P less than 0.05) in yields were noted with more than 10 percent of the stems cut. At maturity, yields for all damaged levels differed significantly (P less than 0.01). The results of this study demonstrated that rat damage in ric up to the booting stage did not affect yield significantly. From an economic standpoint, rodent control by field baiting before booting stage is not recommended in monsoon rice.

This example illustrates the importance of the effect of plant maturity on economic threshold determination. The economic thresholds must be adjusted to account for changes in seasonal crop growth.

MONITORING REQUIREMENTS

To the farmer or crop protection specialist, an economic threshold is merely a guage to determine the need for remedial control measures. Monitoring the pest populations and the natural control factors can establish the need, or lack of need, for these measures. Population monitoring is conducted in a variety of ways. The most common method consists of field surveys of pest control scouts or the farmers themselves, using various techniques which are discussed in various other papers at the training course. When surveillance shows that a pest population is rising to damaging levels, despite the presence of natural controls or the primary management components such as resistant rice varieties, steps may be necessary to prevent significant crop damage. The economic threshold tells the farmer or crop protection specialists when to apply the remedial measures. Remedial measures that cause minimum disruption to the natural enemies should be selected. It is unwise to rely on any control method that disrupts the natural control system even temporarily unless there is great certainty that the target pest can be permanently eliminated or unless other alternatives fail.

STATUS FOR RICE PESTS

It is certain that many rice pests can cause devastating losses if allowed to go unchecked (Barr et al., 1975).

However, at what point remedial action is called for, or whether it might be delayed or entirely omitted, has not been established for many rice pests. Most of the work on economic thresholds for pests of tropical rice has involved insect pests inhabiting tropical Asia (FAO, 1979; Dyck, 1978). There has been little work to establish economic thresholds for plant pathogens, nematodes, and weeds.

Establishing and using economic thresholds involve much work and often considerable expense (Glass, 1975). The economic thresholds must be constantly revised to account for changes in crop growth, crop varieties, natural enemy populations, management practices, marketing standards, and commodity prices, for example. However, even crude thresholds are better than none, especially for sporadic pests and those to which the rice plants have a reasonably high tolerance. Learning the characteristics of rice plant grwoth and crop development and keen observation of the pests for several generations are important first steps. Initially, IPM programs can be based on crude economic thresholds. But the thresholds should be constantly examined and refined, if needed, as additional information and experience become available.

LITERATURE CITED

Apple, J.L. 1977. The theory of disease management p. 79-101. In J. G. Horsfall and E.B. Cowling (Eds.), Plant disease: and advanced treatise. Vol. 1. How disease is managed. Academic, New York.

Barker, K.R., and C.J. Nusbaum. 1971. Diagnostic and advisory services, p. 281-301. In B. M. Zuckerman, W.F. Mai, and R.A. Rohde (Eds.), Plant parasitic nematodes, Vol. 1. Academic, New York.

Barr, B.A., C. S. Koehler, and R. F. Smith. 1975. Crop losses—rice: field losses to insects, diseases, weeds, and other pests. UC/AID Pest Manage. and Related Environmental Protection Project. Univ. Calif., Berkeley. 64 p.

Carlson, G.A. 1971. Economic aspects of crop loss control at farm level, p. 2.3/-2.3/6. In L. Chiarappa (Ed.), Crop loss assessment methods. Food and Agr. Organ., Rome.

Dyck, V.A. 1978. Economic thresholds in rice. In Proceedings, Short Course on Integrated Pest Control for Irrigated Rice in Southeast Asia, held in the Philippines, October 16-November 18, 1978. (Manuscript IPC/SP/50, 10 p.)

Food and Agriculture Organization of the United Nations. 1979. Guidelines for integrated control of rice insect pests. FAO Plant Production and Protection Paper 14, Rome. 115 p.

Glass, E.H. 1975. Integrated pest management: rationale, potential, needs and implementation. Entomol. Soc. Amer. Spec. Pub. 75-2. 141 p.

Main, C. E. 1977. Crop destruction—the raison d'etre of plant pathology, p. 55-78. In J. G. Horsfall and E.B. Cowling (Eds.). Plant disease: an advanced treatise. How disease is managed. Academic, New York.

Poché, R. M. E. Haque, M. Y. Mian, P. Sultana, and M. A. Karim. 1981. Rice yield reduction by simulated rat damage in Bangladesh. Tropical Pest Management 27: 242-246.

Rabb, R. L. 1978. A sharp focus on insect populations and pest management from a wide-area view. Bull. Entomol. Soc. Amer. 24:55-61.

Stark, R.W. 1971. Integrated control, pest management, or protective population management, p. 111-129. In Toward integrated control. U.S. Dept. Agr. Forest Service Res. Paper NE-194.

Stern, V. M. 1973. Economic thresholds. Annu. Rev. Entomol. 18:259-280.

Stern, V. M., R. F. Smith, R. van den Bosch, and K. S. Hagen. 1959. The integrated control concept. Hilgardia 29:81-101.

SAMPLING METHODS FOR RICE INSECTS

By

M. Agyen-Sampong
WARDA Special Research Project
Rokupr, Sierra Leone

The techniques for sampling insect populations is one of the first principles an entomologist learns to enable him know what species and numbers of insects found in an area. Sampling is only a tool which the entomologist uses to obtain information, which cannot be got through any other way.

Insect population may be sampled to determine economic thresholds to make meanful Integrated Pest Management decisions, life/population tables, population distribution, pest intensity and density/yield (crop loss assessment).

Factors that influence sampling programme in a field of rice include:

a. Ecosystem created by the growth of rice e.g. seedling, tillering and milk stages.

b. Behaviour, Life cycle, habit of insects e.g. Nocturnal, or diurnal flight activities; stemboring, leaf eating or sucking habits.

c. Purpose or type of sampling - Extensive, covering a large area or intensive involving sampling of a single population in a limited area.

d. Distribution of population - e.g. random aggregated or uniform type of distribution.

e. Sampling unit, selection and size of area under studings (sampling unit for higher densities might not be suitable for lower densities).

f. Sequential sampling.

Method of sampling

In sampling, whole population cannot be measured, so small portions of pupulation is removed in a sample and taken as representative of the whole population. Representative sample is sometime difficult to obtain. However, information obtain through this sampling considerably reduces time, effort and expense.

The following are some of the methods of collecting insects and assessing insect populations:

Insect sweep nets
Mouth aspirators
Traps e.g. sticky, light, sex pheromone traps
Suction machines
Counts per unit effort
Visual counting
Products of insects e.g. galls, faeces
Measuring damage done by insects
Estimation of parasitism and predation.

Definitions:

There exists technical vocabulary of any sampling programme:

A "sample" consists of a small collection drawn from a larger "population" about which information is desired. The sample observation (n) in the sample is referred to as "sample size," while the physical composition and magnitude of a single sample is called the "sample unit". e.g. Sample unit might be 5 sweeps with a sweep net; a sample size of 10 units would then imply 10 sets of 5 sweeps each.

Units pertaining to the rice plant are:

1. Stem (or portion of a stem)
2. Cluster (or group of stems)
3. Hill (a natural group of cluster of stem)
4. Cluster or group of hills.

Units pertaining to borers and parasites are:

1. Individual egg-mass, larva, pupa and adult.
2. Cluster or group of egg-masses, larvae, pupae or adults.

Unit pertaining to area.

1. Plot (various sizes or shapes).

The arithmetic mean ($\bar{x}$) is the most commonly used and is computed by

$$\bar{x} = \frac{1}{n} \sum x_i$$

where x_i represents the ith of the n observations. The measure of spread among the n observations is the "standard deviation" (s), which is computed by

$$s = \sqrt{\frac{\sum x_i^2 - \frac{1}{n} (\sum x_i)^2}{n - 1}}$$

The "variance" (s^2) is simply the square of the standard deviation while the "standard error" ($S\bar{x}$) is

$$S_{\bar{x}} = \frac{s}{\sqrt{n}}$$

While the standard deviation is an expression of the spread among observations, the standard error is mean of the distance from $\bar{x}$ to the true mean of the population being sampled.

Several ratios are used that compare the spread among observations to the observed means. The "coeficient of variation" (CV) is defined as

$$CV = s/\bar{x}$$

A more useful ratio is the $S_{\bar{x}}$ to the $\bar{x}$, which entomologists usually refer to as "relative variation" (RV):

$$RV = (S_{\bar{x}}/\bar{x})(100).$$

CV and RV are useful in sampling programmes because s increases as $\bar{x}$ increases and they are unitless hence comparable regardless of the sample unit used (Ruesink 1980).

For comprehensive account of specific sampling methods and techniques relevant to ecological studies consult, Southwood (1978); Nishida and Torii, (1970) and Cochran, (1963).

<u>Adult stemborers and Armyworm, Caseworm, rice bugs, Heteronychus Oryzae etc.</u>

Although light trap catches, are usually influenced by wind, rainfall, temperature and humidity, they however provide a relative measure of adult populations of stemborers, armyworms, caseworms, rice bugs, and other insects. The insects are trapped because of their nocturnal flying activities. The use of light trap presupposes that the trap catches are directly proportional to the moth population in a given locality for a given species although lunar effects may influence the trapping rate.

Due to differences in phototactic responses between species, the number of insect trapped do not however indicate species composition in a given area. There are many variatinns in design and construction of insect light traps especially the electrically powered or battery types. Although efficient, they are not suitable for immediate use in many rice fields. Main electricity is not often available near rice fields and maintenance of batteries for light traps can lead to recharging problems. A simple trap developed at WARDA Special Research Project at Rokupr which could be used in remote fields consists of hurricane lamp hung over a bowl containing a solution of 10% percent formaldehyde or 20 percent ethly alcohol which is lit daily at sun-set and insects trapped sorted out weekly. Shed is built over the light trap to protect it from the weather.

Trapping data collected at Rokupr over two seasons for Maliarpha separatella, the most predominant stemborer of the mangrove swamp are shown in Fig. 1. The population changes of Stenocoris southwoodi, Heteronychus oryzae and Rhaconotus sp., are also shown as are: Adult Diopsis, rice bugs - Stenocoris sp, Riptortus sp., Aspavia, Diploxys, grasshoppers - Hieroclyphus daganesis and Conocephalus sp.

Insect sweep net: In using the sweep net, the operator walks through the crop holding the net stretched straight in fron with the opening always facing the plants to be sampled. The operator moves forward sweeping the seep net so that the opening of the net passes through the foliage. This one forward stroke is followed by a quick backstroke over the same vegetation. Each stroke of the net is counted as one sweep.

Number of insects caught in a sweep is affected by the age or height of crop, weather, behaviour of insect, operator etc. Depending on the size of the plot ten or twenty sweeps may be taken.

Stemborers - larvae and pupae

Maliarpha separatella, *Sesamia* sp. *Chilo* sp and *Diopsis* sp., are the common stemborers in the region and their larvae behave different from each other. *Chilo* spp. predominantly stay in the middle and upper parts of the plant and cause "dead-heart" and "white-heart". While *Maliarpha* occupies the lower parts of the stem. *Diopsis thoracica* usually attacks young plants and causes "dead-heart".

One of the sampling procedures for sampling levels of infestation by rice stemborers is a formula developed by Onate (1965). This formula commonly used in S.E. Asia could be applicable to *Diopsis*, *Chilo* sp., and gall midge in the region.

$$\text{Percent infestation} = \frac{\text{No. infested hills}}{\text{No. hills observe}} \times \frac{\text{No. infested tiller}}{\text{100 Total No. tillers in infested hills}} \times$$

100 hill samples selected at random can be utilised to sample more fields and areas in a given time or a unit area e.g. 2 sq. m may be used.

Another formula developed by Gomez (1972) sought to minimise the error if infestation is very low:

$$P = \frac{I}{nx + (N-n)y} \times 100$$

where;

P = Percent incidence

I = Total number of infested tillers from all infested hills in the sample plot.

n = Total number of infested hills.

x = Average number of tillers per hill from infested hills.

N = Total number of hills in plot (both infested uninfested), and

y = Average number of tillers per hill from 10 uninfested hills.

Since infestation of Maliarpha usually does not show any outward symtoms, a more accurate but laborious method involves selection of a certain number of hills and dissecting all tillers.

WARDA Special Research Project at Rokupr sample insects on following basis:

(1) 240 hills selected at random per 55 x 40m plot; for population dynamic studies: weekly sampling.

(2) All hills in randomly selected one - metre-squares sampled for crop loss in farmers' fields.

(3) 60 hills/4 x 5 metre plot in experimental trials.

Egg Masses

Sample size is usually high and varies with the plot size and the extent of infestation:

hills are examined for egg masses.

In S.E. Asia the sample sizes varies from 100-500 hills per replicate.

At WARDA, Rokupr 250 hills per replicate are used.

Leaf feeder:

Epilachna similis: The adult density in rice fields could be assessed by light trap or sweep net which could trap both the adults nymphs. Severe damage is caused by both the adult and nymphs.

The damage caused by the feeding activities on the young plant by both the adult and nymphs may be determined visually by percentage damage per unit area.

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Spodoptera exempta (armyworm): Out-breaks, sporadically, occur in various parts of the region. WARDA, Rokupr sampled randomly armyworm damage by the use of half-metre quadrant. Number of seedlings and armyworms per quardrant is counted.

Nymphula sp. (Caseworms)

Density and damage may be assessed by sampling per unit area of the larvae/cases on the rice as well as on water surface. Sampling unit must be selected careful since wind might carry larvae and cases to one side of the field.

Visual assessment of percentage leaf damage may be calculated. Orseolia oryzae (Gall midge) - Onion or silver shoot damage is assessed as dead-heart/white head. (Refer stemborers). The total number of onion shoots in a unit area is expressed as percentage of the total tillers in that area.

Heteronychus oryzae: (African black beetle): The adult population can be monitored in light traps but the damage caused by the adults to young seedling is assessed by a metre or half-metre quadrant.

The adult insects move below the soil surface and damage the stems of seedlings below ground level by nibbling, leaving the attacked parts fibrous which consequently cause the leaves to wither and turn brown.

As a result of recent increases in rice cultivations in the Sahelian zone, white flies (aleyroidids) and mites (tetranychids and phytoseiids) have become prevalent and often cause extensive crop loss in the hot-dry season of April to July. Virtually no detailed population studies of both white flies and mite on rice have been undertaken.

The following are suggested sampling procedures.

White flies

Adults: The adult white fly is mealy white-winged and with its scale-like nymphs they suck from the rice plant. The adult population may be monitored in the rice field with the use of sticky or water traps placed about the level of the crop.

Eggs nymphs and pupae: Except the first instars all the developmental stages are sessile. A good study of absolute and stratified random sampling programme could be established to monitor the populations based on counts of individuals on parts of rice plant.

Spider mites: The pests spin copious webbing on the plant, hence commonly called "spiders".

Direct observations and counts are made from randomly selected leaves either through hand lens or with unaided eyes. Without magnifying glass, accuracy is sacrificed, and this method is not suitable at high mite densities. However, the method is useful for field surveys to know patterns of occurrence in the field.

Two leaves/hill weekly from 5-10 randomly selected places in a plot/rice field.

10-20 "infested" leaves randomly selected from each plot in small plot experiment. Samples are placed in pint jars/plastic bags and count immediately adults, nymphs and eggs under magnifying glass in the lab., otherwise, keep in refrigerator until you are ready to count. This method is time-consuming.

Parasitoids: Parasitism is determined by the percentage of the pests from which parasites are reared. The population of some adult parasites could be sampled by light traps and sweep nets e.g. *Rhaconotus* sp. *Phanerotoma major* Brues - parasites of *Maliarpha separatella* at WARDA, Rokupr.

Predation: At WARDA, Rokupr, densities of spiders and reduviids in rice fields have been estimated by the use of sweep net.

Conclusion

In WARDA region little work has been done to evaluate statistically various sampling techniques being practiced. Our knowledge on patterns of pest occurrence in the field, density/intensity changes, seasonal abundance of pest, crop loss assessment, economy threshold etc., is limited. We need to develop sampling procedures which would give reliable data.

REFERENCE

Cochran, W.G. (1963). Sampling techniques, Second Edition. John Wiley and Sons, Inc., New York 413pp.

Gomez, K.A. (1972). Techniques for field experiments with rice. Laycut/Sampling/Sources of error. IRRI. Los Banos, Philippines. 46pp.

Nishida, T and Torri, T. (1970). A handbook of field methods for research on rice stemborers and their natural enemies. International Biological Programme Handbook No. 14. London: 132 pp.

Onato, B.T. (1965). Estimation of stemborer damage in rice fields. Phil. Statis. 14(3): 201-221.

Ruesink, W. G. (1980). Introduction to Sampling Theory. In Sampling Methods in Soybean Entomology. (Ed.) Kogan, M. and Herzog, D.C. Springer - Verlag. N.Y. 587p.

Southwood, T.R.E. (1978). Ecological methods with particular reference to the study of insect populations. Halsted Press, New York. 524p.

WARDA (1978, 1979). Annual Report, Special Research Project, Rokupr.

SAMPLING METHODS FOR RICE DISEASES

By

V. A. AWODERU
WARDA, P.O. BOX 1019, MONROVIA
LIBERIA

INTRODUCTION

A sampling method is a procedure of appropriately selecting sample units in such a way that these units may best represent the population to which they belong (Le Clerg *et al* 1966). Little or no work has been done on sampling methods for rice diseases as in insects. Diseases can only be sampled by taking sample units at random in a given rice field and in three to four replicates in such a way that the assessment of such samples can be statistically analysed. Obtaining a representative sample is a difficult task to perform and great care must be taken when sampling a field for disease incidence. When sampling the points to note include (Dyck, 1978):

(a) area of the field size of the plot
(b) population of the crop
(c) relative or absolute sampling
(d) pattern and time of sampling
(e) sequential sampling
(f) number of samples
(g) effect of sampling on the whole population
(h) uniformity of sampling
(i) disease distribution
(j) growth stages of the plant and the climatic condition under which sampling is being carried out.

Evaluation of severity of diseases within the samples is based on:

(a) type of infection or lesion
(b) size of lesion or lesion area expressed as a percentage of total leaf area of seedling or adult plant
(c) number of lesions
(d) degree of stunting
(e) number of hills/plants affected
(f) spore production from lesions
(g) degree of wilting.

In these lecture therefore, an attempt is made to discuss the basic concepts involved in rice disease sampling the characters involved in the evaluation of diseases, scales developed for assessing diseases and the growth stages for disease assessment in the rice plant.

BASIC CONCEPTS IN SAMPLING

Population and sample

For sampling in replicated trials, Gomez and Gomez, 1976 indicated that each experimental plot is a population. The population value is the plot value, which will be estimated from a few sample plants taken from each plot.

Sampling Unit

The unit in which actual measurement of a character is made (e.g. disease incidence) is referred to as sampling unit. For replicated trials where the plot is the population (hills in rice) the sampling unit must be smaller than the plot.

Some commonly used units are: (i) leaf, (ii) a plant (iii) a group of plants and (iv) specified area. A good sampling unit must be (a) easy to identify (b) easy to measure and (c) fairly uniform. The sampling unit that can satisfy these features may vary with the crop planted, the character to be measured, and the cultural practice to be used. For example in assessing disease incidence, the area of leaf damaged may be appropriate, number of spots on the leaves may be taken into consideration, number of hills affected per plot can be calculated and possibly the type of lesions developing on each cultivar can also be taken into consideration. For replicated experiments, sample units have to be considered for each replicate.

Sample Size

Sample size refers to the number of sampling units to be measured in each population. In replicated trials, sample size specifies the number of plants per plot to be measured for diseases or the number of leaves on which lesions will be counted per plant or the number of hills to be assessed per variety for disease incidence. The choice of sample size depends on the size of the variability of the character to be measured and the level of precision required of the estimate (Gomez and Gomez, 1976).

Sampling Design

A sampling design is the mode by which sample units are selected from the population. There are three commonly used designs in sampling:

(i) Simple Random Sampling

Simple random sampling means that each of the units (plants, leaves or hills) in the plot is given the chance of being selected to compose the unit. This can be done in many ways. One procedure is to number all the leaves on the plant, all the plants/hills in a plot from I - X and select at random numbers by:

(a) using a random number table
(b) by drawing cards
(c) by throwing dice
(d) or by any other operations that serve the same purpose.

In doing this, one has got to determine how many hills are to be sampled per plot.

(ii) Multistage Sampling:- depends on which disease has to be sampled. For example for false smut and white head the number of panicles infected per plant can be counted but panicle itself cannot be taken as a sampling unit. One has to take the number of panicles infected per plant into consideration and the number of plants per population. This type of sampling is taken as a two-stage sampling with "hills" or "plant stands" as the primary sampling unit and panicle as the secondary unit. This method can be extended to three or more stages. In estimating leaf area damaged by the disease, "hills" may be considered as primary unit, "tiller" as secondary unit and leaf as tertiary unit.

(iii) Stratified Random Sampling

In stratified random sampling, the plot is first divided into sub-sections and then simple random sample units are selected from each of these sub-sections.

Such sub-sections are referred to as strata. For example, for a rice plot consisting of about 200 hills, the plot can first be divided into 2 strata each consisting of 10 x 10 hills from each stratum. Ten to twenty plants/hills can then be selected from each stratum.

GROWTH STAGES OF RICE FOR DISEASE SAMPLING

1. Nursery or Seedling period before transplanting 30 - 35 days after planting.
2. (a) Vegetative or transplanting period
   (b) Reproductive or flowering period
3. Ripening or maturation period
4. Harvest period

DISEASE CHARACTERS IN DISEASE SAMPLING

Lesion Types

Fernando *et al* (1961) described lesion types as ranging from A to F as enumerated below. Ou (1961), described 8 lesion types. These descriptions are specifically for rice blast (*Pyricularia oryzae* (cv). However, Ou's classification combines both lesion type and leaf area damaged. Anon, 1980, described scoring scales for fungal, bacterial and virus diseases of rice and this pamphlet can be obtained directly from the International Rice Research Institute, Los Banos, Philippines on request.

Infection or lesion types as described by Fernando et al (1961)

Infection Type	Sympton (Size, shape and colour of lesion)	Grade of resistance to fungal development
A	No lesion or very minute brown lesion which is smaller than 0.5 mm	Highly Resistant (HR)
B	Minute brown lesion, 0.5 to 1 mm^2	Resistant (R)
C	Small brown lesion, with or without greyish brown centre, 1-3mm^2 in area	Moderately Resistant (MR)
D	Medium size lesion with or without greyish brown centre, 3-8 mm^2 in area	Moderately Susceptible (MS)
E	Large brwon lesion with greyish brown centre over 8 mm^2 in area	Susceptible (S)
F	Medium to large, dull greyish green, greyish-white, pale green or water soaked lesion, with or without purplish brown margin; or pale white lesion.	Highly susceptible (HS)

Figure 1 provides a standard scale of lesion size in sq.mm. lesion shape expressed as length/breadth (l/b).

Lesion area expressed as percentage of total leaf area of seedling

The standard 1 to 6 in Figure 1 are used for estimating by eye the lesion area as a percentage of the total leaf area. Lesion of types A and B just described as Highly Resistant (HR) and Resistant (R) are estimated to cover near 0% of the total leaf area of the seedling and are accordingly rated as 0.

The standards 1 to 6 are ratings for lesion areas varying from 0.5 to 55% of the total leaf area as shown below:

Grade or Rating	Lesion area as percentage of total leaf area
0	0
1	0.5%
2	2%
3	5%
4	11%
5	25%
6	55%

In describing the variety for its blast susceptibility the rating 0 to 6 or the lesion area percentage itself may be used. Lesion Number: A visual assessment of lesion number can be made irrespective of lesion size or type. For instance, the number or lesions can be described as none (0), few (f), many (m) or numerous (n). Lesion number is dependent on varietal resistance to fungal entry, sporulation, the angle of drooping of leaves and stage of growth. On the other hand for accuracy, lesion number can be counted.

Stunting:- Is a symptom that can accompany leaf blast or ligula blast. The damage caused by leaf blast on a variety which is liable to stunting can be more severe than on a variety which shows no stunting, even though the lesion area percentages may be same in each case. Stunting is therefore of importance in susceptible varieties and may be denoted by (s), or when stunting is severe by (ss).

Ou's Classification of disease reaction in rice

Group 1:	Only small brown specks of pin-head size are produced on leaves, few or many, sometimes unrecognizable, no necrotic spots.
Group 2:	Slightly larger brown specks, about 0.5 mm in diameter, no necrotic spots.
Group 3:	Small roundish, necrotic, grey spots about 1-2 mm in diameter, surrounded by a brown margin which is roundish or tends to be elliptical; the lesions may be many but leaves are not killed.
Group 4:	Typical blast lesions, elliptical, 1-2 cm long with large necrotic, grey centres, brown or reddish brown margin usually relatively few on a leaf, less than 5% of the leaf area is damaged.
Group 5:	Many large blast lesions, as in group 4 or larger, the upper portion of one or two leaves of a seedling of 4 or 5 leaves may be killed by coalescing of lesions, the total area killed however does not exceed 25%.
Group 6:	Lesions as in Group 5 but more numerous, so that one or two leaf blades may be completely withered and the total area killed may be 50%; the colour of the margins of lesions often show less brown colour but tend to yellowish or greyish brown.
Group 7:	Large, quickly expanding lesions, the margins mostly grey with a brown tinge; most of the expanded leaves are killed but young ones remain, typically 75-80% of the leaf area is killed.

Group 8: Large quickly expanding lesions, entirely grey, leaves are completely killed.

Evaluation of Diseases

The International Rice Testing Programme (IRTP) of the International Rice Research Institute in 1980 proposed the use of 9 groups of disease reaction in classifying the degree of resistance to blast and other diseases in rice. The are variation of the above scales.

Leaf Scald and Brown spot is assessed on the basis of leaf area affected. False smut is scored on the number of florets infected. Neck Blast is also assessed on the number of panicles infected. Kresek i.e. bacterial blight on the seedlings is based on the number of hills affected.

All viruses and virus-like diseases are systemic (Anon 1980) a common scale is therefore used for assessing them. The assessment is based on the number of hills affected. The scales used are the same as described above.

Determination of the Susceptibility Index (SI)

In the determination of host plant resistence to diseases, it might be necessary to classify reaction into Resistant, Intermediate and Susceptible, at this point the computation of the SI becomes important. The index is computed from the formula (Anon, 1968).

$$SI = \frac{Nr + 3Ni + 5Ns}{Nr + Ni + Ns}$$

where Nr, Ni and Ns are the numbers of resistant, intermediate and susceptible reactions exhibited by the rice cultivars.

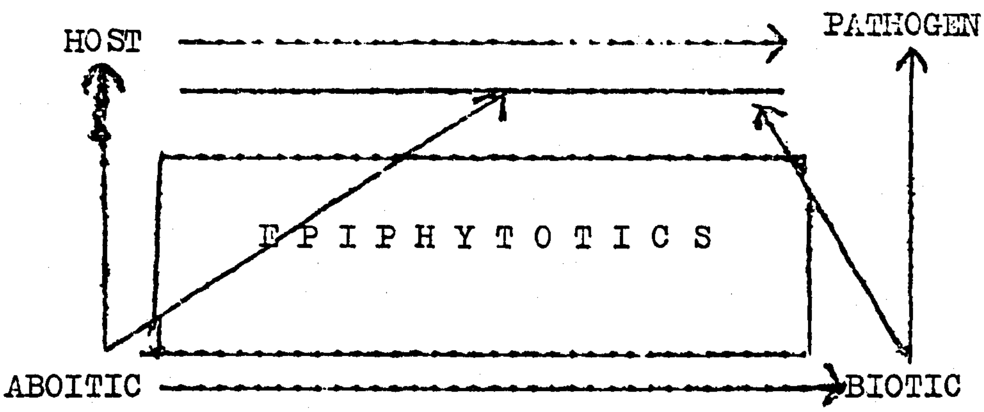
The minimum Index (1.0) means that the variety is resistant, the maximum index (5.0) means that the cultivar is susceptible. The reactions of the varieties based on the indices can be classified as shown below:

Index	1.0 – 2.4	Resistant	(R)	R
	2.4 – 3.4	Moderately Resistant	(MR)	Inter- mediate
	3.5 – 4.4	Moderately susceptible	(MS)	
	4.5 – 5.0	Susceptible	(S)	S

Environmental Factors and Sampling

It has been established that for diseases to occur there must be a susceptible host and a virulent pathogen. In addition to these the abiotic factors (climatic conditions – temperature, rainfall, relative humidity, sunshine hour, available moisture) and biotic factors must be conducive to successful infection. These four characteristics of infection are combined in what is described as a rectangle of infection (Fig. 3). The interactions of these climatic or environmental factors in a generation of plant infection is shown in Fig 4. It is therefore suggested that for purposes of telling a complete story about disease sampling, records of temperature, humidity and rainfall should be taken. These might help to explain differences in the behaviour of a particular cultivar in different localities of the same country or in different countries. Tests for resistance in rice cultivars may have to be made three or four consecutive times before any meaningful conclusion can be drawn from the results.

Fig. 3: FACTORS INVOLVED IN AN EPIPHYTOTIC



SAMPLING OF RICE PLOTS FOR AIR-BORNE PATHOGENS

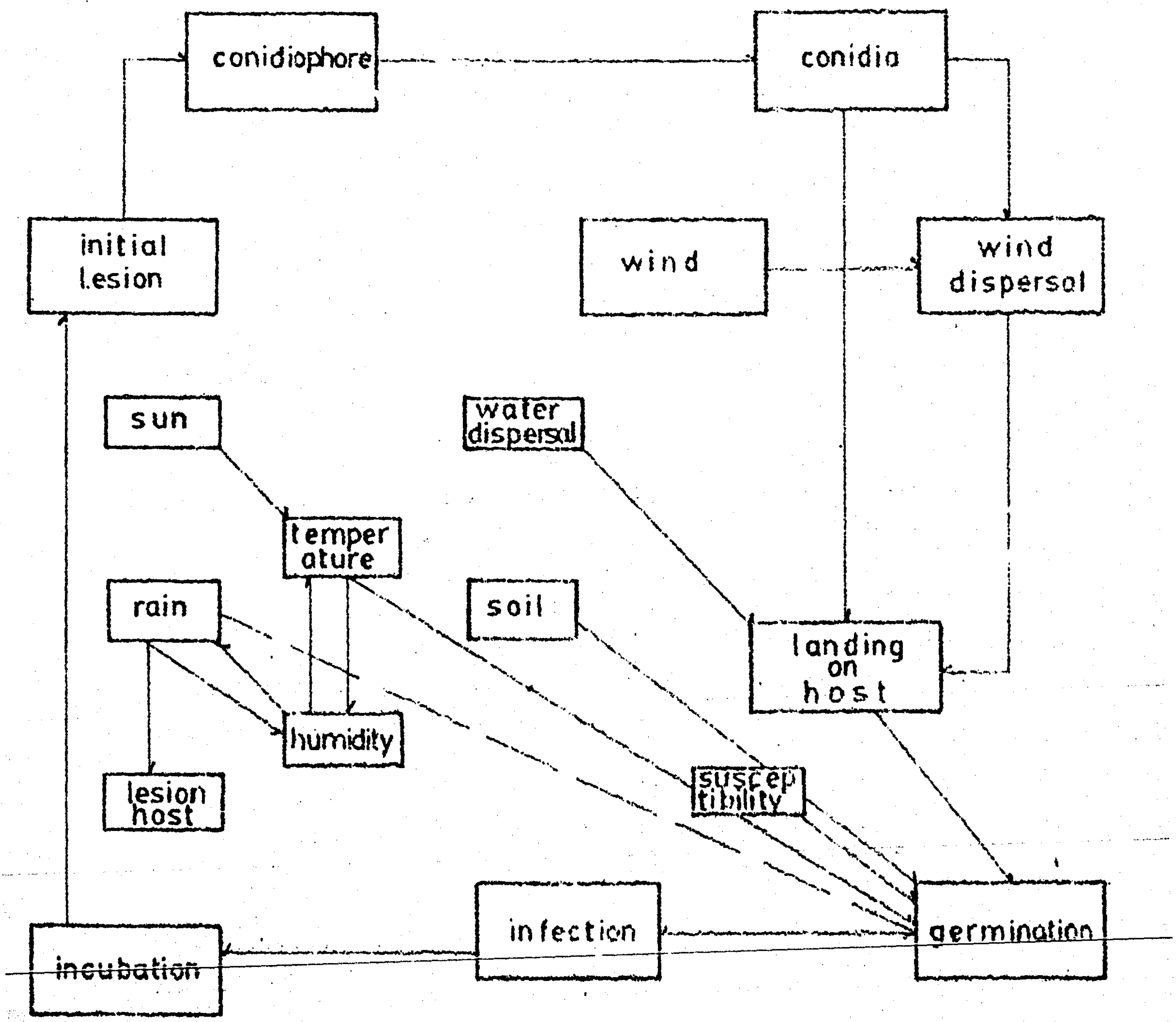
(i) Sequential planting of rice varieties

When it is desired to find out if a disease could develop through out the year, susceptible rice varieties and a resistant variety could be planted monthly on bin beds at the rate of 2 oz, seeds per sq. yard. Seed should be sown in drilled rows 2 in. apart. Each plot should be 48 in. X 24 in. Fertilizer application should be carried out normally and scoring of disease infection carried out 35 days after planting using the scale described above before a new set is planted.

(ii) Sampling of the air for pathogen propagules

The sampling of the air for the conidia of pathogens could be carried out over the rice plots described above with the Hirst spore trap (Hirst, 1952). This is done in order to find out if there is any correlation between the incidence of the blast disease on these rice varieties with the relative amount of conidia in air above the plots as determined by the Hirst spore trap.

FIG. 4 INTERACTION OF FACTORS DURING ONE PATHOGEN GENERATION



The diurnal variation in the conidial release in the pathogen from rice plants in the nursery or field can also be determined with a Kramer-Collins spore sampler (Kramer and Pady, 1966).

(iii) Identification and counting of the conidia of Pathogens deposited on the slide

When the conidia of the pathogen are small and hyaline, it is necessary to mount the slide in 1 percent cotton blue in lactophenol before examination. The coloured spores on the slide remained unstained but all the hyaline spores including those of *P. oryzae* would be stained blue. The conidia of pathogen are differentiated from the other hyaline spores by their distinct shape.

The deposit on the slide should be examined under a microscope at a mangification of X 500. Conidia will be counted along 5 traverses parallel to the direction of movement of the slide. An average concentration over 24-hr., periods will be estimated. The number of conidia obtained are converted to an estimated number per cubic metre of air as shown below: Volume of air taken in by the trap = 10 litres/min. of $0.6m^3$/hr.

Fraction of trace scanned at 100 u wide traverses parallel to the direction of movement = 1/140

Volume of air sampled in 24 hours = $14.4m^3$

No. of conidia trapped in 24 hours = $Y \times \frac{140}{14.4}$

= $Y \times 9.72$

(Where Y is the average number of conidia counted on the slide).

(b) Sampling with the Kramer-Collins spore trap

The Kramer-Collins spore trap uses the same principle as the Hirst spore trap. The trap consist of a sampling chamber with a cover, a vacuum pump. A relay and a flow meter. A spring wound clock motor served as the timing and slide advancing mechanism. Air enters through a 2.5 cm tubes, which narrows down to a 14mm x 0.75mm orifice. This accelerates the speed of the air as it is drawn in through the slit.

The sampler is made to suction-sample the air at the rate of 0.8 cub fit. per minute, so that the particles in the air impinged on the slide. A rocker arm with adjustable set screw activates a microswitch controlling the pump. A four-sided Cam attached allowed four samples per hour with each sampling lasting $2\frac{1}{2}$ min. The slide advancing mechanism was operated by aone-lobed cam on the shaft of the clock motor which allowed the slide to advance once in an hour. In this way, 24 bands would be deposited on each slide each day.

Mounting of the slides, identification of conidia of pathogen and the scanning of the slides are done as for the Hirst spore Trap. Conidia are counted along each band and the number of conidia deposited per hour or per day is estimated as shown below:- Let Y be the number of conidia deposited in 1 band in 10 minutes

Vol. of air sucked per minute = $0.8 ft.^3$

$\therefore$ No. of conidia deposited per ft. 3/hr

$$= \frac{Y \times 60}{80 \quad 10} \text{ Conidia/ft. 3/hr.}$$

Let P be the total number of conidia deposited in 24 bands in 240 minutes ∴ No. of conidia per ft.^{3} per day.

$$= \frac{P}{112} \times \frac{24 \times 60}{240} \text{ conidia/day/ft.}^3 \text{ of air.}$$

The Kramer-Collins spore sampler is used in the blast nursery because it would sample intermittently, thus giving an hourly deposition of conidia 2 mm apart. This makes it easy to estimate the amount of conidia deposited on the slide every hour of the day and every day during the period the trap is operated. The Hirst spore trap on the other hand operates continuously for a period of 24 hours so that a continuous band 48mm in length is formed on the slide.

Sampling Rice Seeds for Seedborne Pathogens

This technique is commonly used when seed health need to be determined. It involves the grouping of rice seeds to be tested and from each group 400 seeds are then planted in humid petridishes.

Planting: Usually previously sterilised disposable planting petridishesare used 9 cm filter paper are placed in side the 9 cm petridishes. Then few drops of sterile distilled water are added to a stage that the filter paper is well soaked to produce the humid environment needed for the fungal propagules on or in the seeds to germinate and grow when the plate is covered up. Then 25 of these seeds are selected and arranged on the soaked filter paper in the plate in circles of fifteen seeds (15) at the periphery of the filter paper, nine (9) on the inner circle and one (1) at the centre of the filter paper. The petriplate is then covered up. The seeds so planted are then incubated under fluorescent daylight tubes for ten days. Sixteen plates (16) of four hundred (400) seeds are to be sampled for each cultivar.

After 10 days the seeds are then inspected under the stereoscopic x 50 microscope for the growth of pathogens. The percentage seed occurrence is then determined as the number of seeds having the growth of the desired pathogen (X) on the overall population of the seeds (400) tested.

$$\text{Percentage} = \frac{X}{400} \times \frac{100}{1}$$

$$= \frac{X}{4}\ \%$$

This sampling method is particularly good for seedborne fungal pathogens. The bacterial infection could have been over-shadowed and as the above method is modified.

Sampling for Seedborne bacterial diseases

The procedure is the same as above except that a medium is now used instead of the soaked filter paper. (nutrient agar or broth). The ooze or sliny exudate from each seed is then mounted on a slide to confirm the nature and identity of the bacterium.

REFERENCES

ANON (1968): New pathogenic races and physiologic races of Pyricularia oryzae originating from single lesions, IRRI Annual Report, 1967 pp. 86-89.

ANON (1980): Standard Evaluation System for Rice, International Rice Testing Programme (IRTP) July, 1980 published by the International Rice Research Institute, Los Banos, Philippines.

DYCK, V.A. (1978): Sampling Rice Insects. A paper presented at a short course on Integrated Pest Control for Irrigated Rice in South and South East Asia. October 16 - November 18, 1978. IPC/SP/59.

FERNANDO L.H., OKAMOTO, H. & PADMANABHAN S.Y. (1961): Report of a Working Party on the Establishment of Uniform Blast Nurseries. December, 1961.

GOMEZ, K.A. AND GOMEZ, A.A. (1976): Statistical procedures for agricultural research with emphasis on rice pp. 239-254. Published by the International Rice Research Institute, Los Banos, Laguna, P.O. Box 9333, Manila, Philippines.

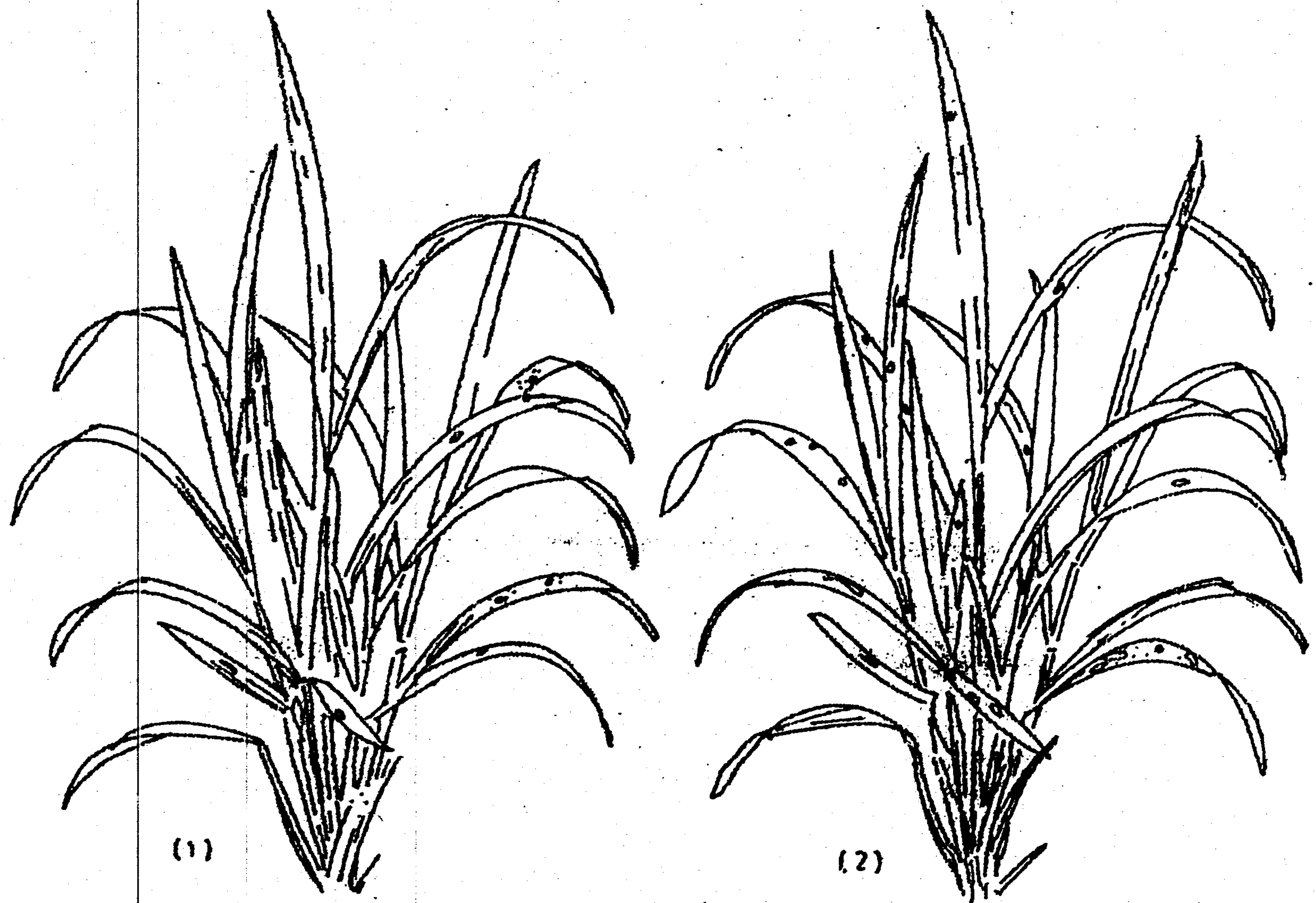


Fig. 1. Standards (1 to 6) of lesion area
expressed as percentage of total leaf area

Fig. 1 (cont'd) Standards (1 to 6) of lesion area expressed as percentage of total leaf area.

Fig. 1 (con'td) Standards (1 to 6)
of lesion area expressed as percentage
of total leaf area.

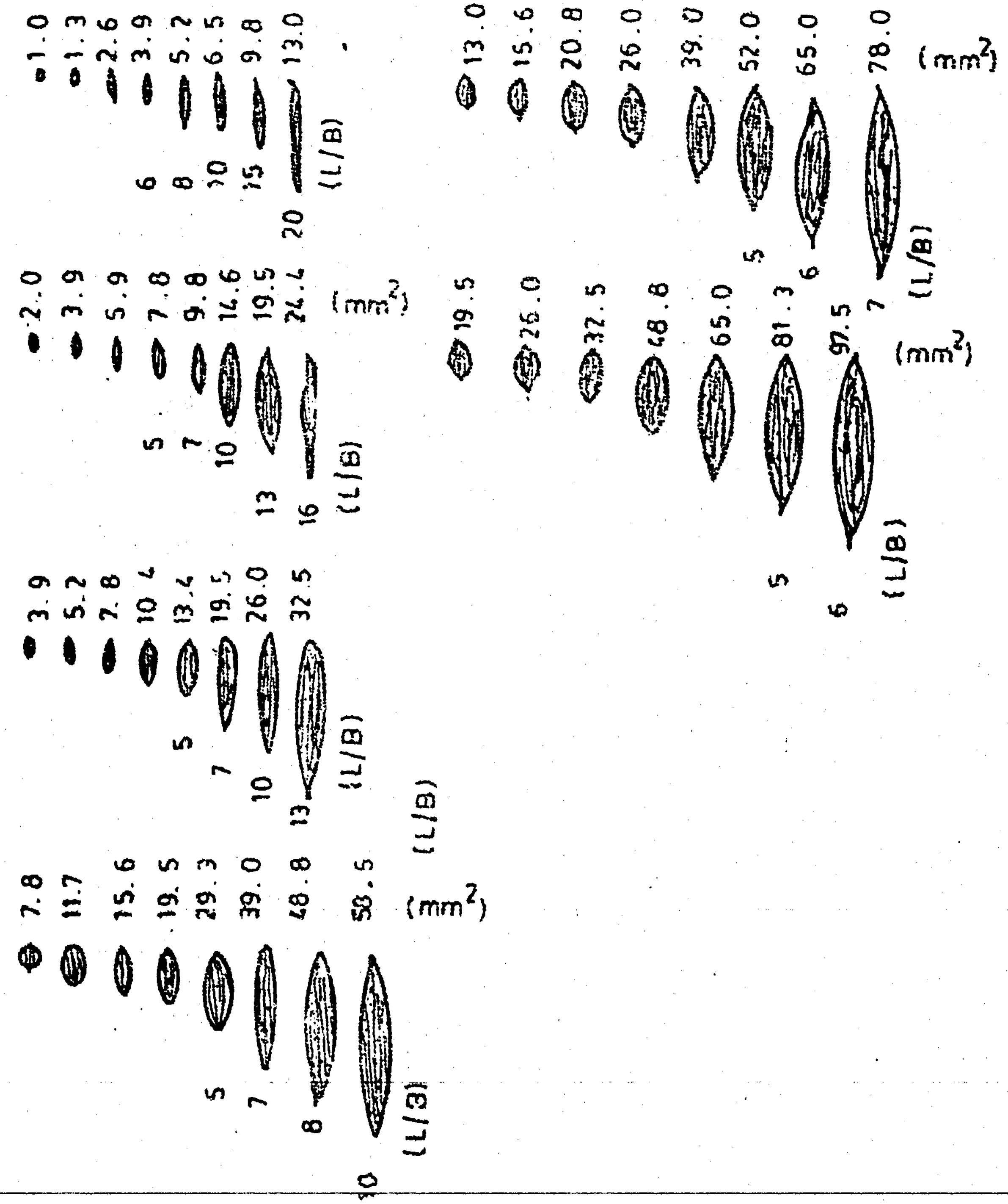


Fig. 2 — Standard scale of lesion size (in mm^2) and lesion shape (length / breadth)

THE LIMITATIONS AND BENEFITS OF PESTICIDES

BY

Patricia C. Matteson
University of California, Berkeley
Consortium for International Crop Protection
2288 Fulton Street, Suite 310
Berkeley, California 94704, USA

After World War II, DDT became widely available for insect control and was quickly followed by a number of other organochlorine pesticides. During the next 20 years, these insecticides were joined by the organophosphates, the carbamates, the natural and synthetic pyrethroids, and other classes of insecticidal materials. Hundreds of compounds in thousands of formulations are available and have been used by all of us to protect our food, our possessions, and ourselves from insect damage. Some examples:

Organochlorines 1) DDT and relatives
2) Cyclodienes (HCH, lindane, aldrin, dieldrin)

Organophosphates (malathion, diazinon)

Carbamates (propoxur, carbaryl, carbofuran)

Pyrethroids (decamethrin, cypermethrin, permethrin, fenvalerate)

The rapid developments in insecticides were paralleled by new discoveries of compounds effective for plant disease and weed control. In the latter case, the search was escalated by rising labour costs that made hand-weeding too expensive, and the discoveries of 24-D, atrazine and later chemicals provided selective herbicides that contributed to the efficiency of labor inputs.

The new pesticide technology ushered in a wide range of compounds for other pest control problems. Products for rodent control, fish control, nematode control and a host of other needs are available with formulations designed for practically any conceivable need (McEwen and Stephenson, 1979).

The development of modern pesticides has brought many benefits, and their use has steadily increased. With increasing experience, however, has come the realization that pesticide use can entail serious hazards to human beings and their environment, and that injudicious use in agricultural and public health contexts can be counterproductive. This paper describes the benefits and limitations of pesticides with the exception of effects of pesticide use on human health and the environment, which is discussed in a separate section of these proceedings.

Pesticides are a powerful tool. They are effective, reasonably economical, adaptable to most situations and fast-acting. They are the only possible control measure for pest population which have already reached the economic threshold level.

There is a proven favourable cost-benefit ratio in using insecticides for some major pests, and without the insecticides available today, profitable production of certain crops would not be possible. Seed treatment chemicals to control insects and diseases in cereal seedlings, beans, and a host of other large-seeded vegetables reduced seed requirements per acre and provided greatly improved crop stands (McEwen and Stephenson, 1979).

Herbicides can have many evident benefits: they eliminate the threat of crop loss to weeds during excessively wet weather when mechanical cultivation and hand labor are not effective; a substantial reduction in the use of fossil fuel energy is achieved when herbicides are substituted for mechanical cultivators; the practice of minimum or no tillage of crops produced on soils with favourable physical properties, made possible by the use of herbicides, conserves soil moisture and reduces soil erosion; grower options in choice of crops and crop rotations may be substantially increased by controlling weeds with herbicides; finally, herbicides are usually more cost effective than human labor (Bottrell, 1979).

The early success of DDT against insect vectors of important world diseases such as plague, yellow fever, and malaria was outstanding. Residual treatment of homes in malaria zones resulted in the eradication of malaria in 37 countries by 1972 and a drastic reduction in cases in an additional 80 countries, affecting 1.5 billion people. The economic benefits of the number of ill days converted to working days through this program is phenomenal (McEwen and Stephenson, 1979).

At the same time, there are major disadvantages to virtually complete reliance on chemical pesticides of the types now available. They will not permanently resolve any of the problems. The uncoordinated attack on small segments of pest populations is, at best, a temporary control measure. We can expect major pests to be a continuing threat to production or health year after year, requiring essentially the same input in control costs, and at the same time, suffering the same degree of damage that occurs despite such control efforts.

Expenditures for pesticides have risen even though there has been no improvement of the pest situation. In 1955, the pesticide portion of the cost of agricultural production was 1%, and by 1968 it had risen to 4.6% (Neumeyer et al., 1969). Total agricultural expenditures for pesticides were 93% higher in 1976 than in 1971 (Bottrell, 1979).

It is not realistic to hope for selective ways to control every pest, nor is there justification to attempt to manage the total population of every pest. Thousands of species of minor, local or sporadic importance justify control only when and where necessary. For such species, the use of pesticides as needed may offer the most practical solution. However, perhaps 90% of the losses to insects and 90% of chemical insecticides used today involve only a few (in the United States, no more than 100) of the most important pests or closely allied pest complexes. The extent of losses caused by these and other key pests, based on past history, can be predicated with reasonable accuracy. Through intensive research it seems probable that ecologically acceptable means of attacking populations of many major pests throughout ecosystems can be developed that will virtually eliminate the damage they cause (Knipling, 1979). This is the goal of integrated pest management research and implementation programs.

Rising expenditures for pesticides, as mentioned above, are an especially severe problem in developing countries.

Third World governments and farmers generally do not have adequate cash to purchase pesticides and application equipment, and necessary extension, supply and maintenance services are undependable or nonexistent. This sort of expensive imported technology is often inappropriate, and dependence on it should be minimized.

Pesticides may have unexpected harmful effects on sprayed crops. Phytotoxicity is often obvious, but sometimes symptoms are subtle. In California recently, it was noted that lettuce and strawberry yields were reduced in plots that had been sprayed to keep them free of insect pests. Researchers found that the chemicals used were adversely affecting photosynthesis and transpiration rates (Sances et al., 1981). On the other hand, pesticides can stimulate crop yield. Carbofuran and other systemic insecticides have this effect on some cereals.

Resistance to pesticides on the part of pests is a major problem that arises with repeated use of chemicals. It most commonly results from the biochemical capacity of a pest organism to convert a pesticide into products that are not toxic to the organism. Strains evolve which are capable of surviving exposure to dosages to which an earlier generation was susceptible. Surviving individuals of one generation pass the resistance character on to the next generation. Upon repeated exposure to a pesticide, genetically resistant individuals constitute an increasingly larger part of the pest population. Eventually, if every generation is exposed to a pesticide that selects for resistance, the population may contain largely resistant individuals (Bottrell, 1979).

Cases of resistance in arthropod pests of crops, animals and man proliferated almost exponentially in the decades following the introduction of synthetic organic insecticides, leading to the current situation of at least 428 species that have developed strains resistant to one or more pesticides in areas where chemical control has been practiced intensively. In addition to its frequent occurrence in insects and mites, resistance is also encountered in plant pathogenic bacteria and fungi, and has especially affected the performance of systemically acting fungicides and bactericides. More recently, cases of resistance appeared in a small number of weed species toward triazine herbicides, and there are early indications of some resistance in plant parasitic nematodes toward residual carbamate insecticides. Thus, resistance has emerged as a problem of actual or potential significance in all areas of pest control (Georghiou, 1981).

Whereas tolerance is often nonspecific, resistance is usually specific to one insecticide or group of insecticides. There are exceptions, however. For instance, cross-resistance between pyrethroids and DDT has been observed repeatedly (Georghiou, 1980) and selection of housflies or mosquitoes with organophosphorous compounds results in high DDT resistance as well as high cyclodiene resistance in houseflies (Winteringham and Harrison, 1959; Brown and Abedi, 1960).

Some species of insects are more resistance-prone than others, and strains may differ in their susceptibility. Resistance may first appear in a local population and then spread.

When spraying with a certain pesticide is discontinued, resistance will slowly decline in field pest populations. However, if the pesticide is used again, resistance is very quickly regained. For all practical purposes, an insecticide is unusable after a high degree of resistance has been elicited. In general, the degree of resistance to a certain insecticide rises slowly through a "latent period" and then increases rapidly. This is because resistance usually involves a polyfactorial genetic system. It takes time to accumulate resistance alleles, which are initially very rare, to support the main resistance gene by replacing a number of genes of minor effect with alleles that carry more vigor or are more compatible with the resistance gene. Once these supporting alleles have preaccumulated, resistance to other insecticides will develop more quickly. Resistance to a given pesticide is occasionally observed to have an upper limit (Brown, 1971).

Resistance arises most quickly when a wide area is contaminated with a residual, very toxic pesticide for a sedentary pest which has many generations per year. Conversely, the appearance of resistance is delayed when nonpersistent compounds are used in relatively circumscribed area, so that pest insects can immigrate from surrounding untouched populations, and when some generations of the pest are untreated (Brown, 1971; Georghiou, 1980).

The use of pesticide mixtures is sometimes suggested, but this assumes that no pest individuals are resistant to all of the chemicals used, and has been known to simply lead to multiple resistance. Rotation of pesticides has been proposed, allowing a high proportion of resistant individuals to disappear between applications of any one pesticide.

In addition, there are negatively correlated insecticides, for which resistance to one confers vulnerability to the other. Some DDT-resistant houseflies have shown increased sensitivity to malathion, and there are other examples (Metcalf and Fukuto, 1961). Researchers are experimenting with pesticide synergists that inhibit detoxification enzymes, but none are available thus far that are effective under field conditions (Brown, 1971; Georghiou, 1980).

Chemical insecticides applied to control insects and mites frequently have deleterious effects on the natural enemies (i.e. beneficial predators, parasites, or disease-causing organisms) that regulate the "target" pests. They may also disrupt the actions of natural enemies that regulate nontarget organisms sharing habitats with the target pests. The resulting effects are referred to as target pest resurgence and induced secondary pest outbreak.

Target pest resurgence is the rapid increase of the target pest population following application of an insecticide, often to a level higher than existed prior to the control measure. Because the pest's natural enemies usually recover considerably more slowly from pesticide treatment than do the pests, the pest population may reach a much higher level than before treatment. In addition, the insecticide may disrupt food chains important to the target's natural enemies, thus causing them to starve, migrate or cease to reproduce. Induced secondary pest outbreak refers to the flareup of potentially harmful nontarget organisms to pest status following pesticidal destruction of their respective natural enemies (Smith and van den Bosch, 1967; Smith, 1970; Bottrell, 1979).

A somewhat analogous problem is the phenomenon known as "weed species displacement," which is caused by extensive use of herbicides in crops. The target weeds are replaced by unaffected species which may cause even more severe problems. These are often annual andperennial grasses or "volunteer" crops (NAS, 1975; Bottrell, 1979).

Pollinators are another category of beneficial insects that is often harmed by pesticides. The annual value of bee-pollinated crops is more than $1 billion (Metcalf, 1975). Bee poisoning has become increasingly common, as many insecticides are highly toxic to bees and are especially deadly if applied during the bloom period when the crops are inhabited by large populations of honeybees and important wild bee pollinators. Herbicidal destruction of bee forage plants may produce even more harmful effects (Johansen, 1977; Bottrell, 1979).

(Also please see "Impact of pesticides on human health and the environment," this volume.)

REFERENCES

Bottrell, Dale G. 1979. Integrated pest management. Council on Environmental Quality, Washington, D. C. 120 p.

Brown, A. W. A. 1971. Pest resistance to pesticides, p. 457-552. In R. White-Stevens (Ed.), pesticides in the Environment, Vol. 1, Part II. Marcel Dekker, Inc., New York. 629 p.

Brown, A. W. A. and Z. H. Abedi. 1960. Mosquito News 20:118.

Georghiou, G.P. 1980. Insecticide resistance and prospects for its management. Residue Reviews 76:131-45.

Georghiou, G.P. 1981. The occurrence of resistance to pesticides in arthropods. An index of cases reported through 1980. FAO, Rome. 172 p.

Johansen, C.A. 1977. Pesticides and pollinators. Ann. Rev. Entomol. 22:177-192.

Knipling, E.F 1979. The basic principles of insect population suppression and management. USDA Agriculture Handbook No. 512. Science and Education Administration, Washington, D.C. 659 p.

McEwen, F.L. and G. R. Stephenson, 1979. The use and significance of pesticides in the environment. John Wiley & Sons, New York. 538 p.

Metcalf, R.L. 1975. Insecticides in pest management, p. 235-273. In R.L. Metcalf and W. Luckman (Eds.), Introduction to insect pest management. Wiley-Interscience, New York.

Metcalf, R.L. and T.R. Fukuto. 1961. Bull. World Health Organ. 24:670.

National Academy of Sciences, 1975. Pest control: an assessment of present and alternative technologies. Vol. I. Contemporary pest control practices and prospects: the report of the executive committee. Washington, D.C. 506 p.

Neumeyer, J., D.G. Gibbons, and H. Trask. 1969. Sales of pesticides will top $3 billion by 1975. Chem. Week. 104:38-68.

Sances, F.V., N. C. Toscano, M. W. Johnson, and L. F. LaPre. 1981. Pesticides may reduce lettuce yield. Calif. Agric. 35(11-12): 4-5.

Smith, R. F. 1970. Pesticides: their use and limitations in pest management, p. 103-118. In R. L. Rabb and F. E. Guthrie (Eds.), Concepts of pest management. North Carolina State Univ., Raleigh.

Smith, R. F. and R. van den Bosch. 1967. Integrated control, p. 295-340. In W. W. W. Kilgore and R. L. Doutt (Eds.), Pest control-biological, physical and selected chemical methods. Academic, New York.

Winteringham, F. P. W. and A. Harrison. 1959. Nature 184:608.

PANEL DISCUSSION ON POST-HARVEST ASPECTS OF RICE PEST CONTROL

INTRODUCTION

The question of storage pests of rice, though of significance, was deliberately excluded originally in the programme for the short course. Reasons for the exclusion were two-fold. Firstly, the duration of the course made it mandatory that priorities be placed on choice of subject matters. Secondly, compared with field pests, storage pests of rice are of less importance in present day West African rice situation.

Participants at the course during one of their numerous informal meetings, however, indicated a desire to have the subject treated no matter how briefly. The demand led to the setting up of a panel consisting of four members, each requested to address and briefly highlight a particular aspect of the subject in order to stimulate discussions.

The panelist were:

1. Mr. M. A. Larinde, Seed Technologist WARDA, Fendall.
2. Dr. I. Akintayo, Training Officer/Entomologist, WARDA, Fendall.
3. Dr. Kenmore, Postdoctoral Fellow IRRI, Philippines.
4. Dr. E.A. Akinsola, Entomologist, WARDA, Monrovia.

In fairness, it must be stated that the panalists had very little time to prepare their presentations which are given in the following pages.

POST-HARVEST CROP LOSSES OF RICE IN WEST AFRICA

By

M. A. LARINDE
WARDA., FENDAL, LIBERIA

INTRODUCTION

Post-harvest crop losses constitute an important, but often neglected and underestimated factor which contribute to a decrease in the world food supply. The value of post-harvest crop losses depends on the purpose for which the crop is being cultivated, food grain or seed. Losses in seed crop is more than that of grain for two main reasons - seed carry more premium than ordinary grain and a down-graded seed may still be converted to use as food but not vice versa.

Post-harvest as defined by Harris et al (1978) means losses after separation from the medium and site of immediate growth or production of the food. Post-harvest crop losses thus commence from the time the crop is harvested and continue through such stages as drying, processing (for food or seed) and storage (holding, in transit, during distribution in the Warehouse, retailers shop and consumers house or shed prior to cooking or seeding. This contribution will focus mainly on post-harvest losses of seed rice with just casual reference to rice grain.

Types and causes of losses

Post-harvest losses could be grouped into two broad categories - direct (when grain/seed is lost to the environment through shattering or is physically consumed by pest) and indirect (loss in quality).

Indirect losses take many and varied forms which range from mechanical injury (bruising, cracking etc) to loss of viability or even complete deterioration (spoilage) which renders the crop useless for either seeding or cooking.

Direct post-harvest losses

Detailed examination of stages between rice harvesting and milling on the peasant farm as given by the FAO (1979) will throw light on the degree and nature of losses sustained at different times.

(i) Harvesting:- Delayed harvesting result in seed shattering while the impact of the combine harvester or the jerk of the blade (sickle) during hand harvesting also add to this loss. Most of these grains shed on the paddy field are picked up by rats and rodents; some are eaten and the rest stored in their burrows. Mammals are also known to bite through the rice plant at its base and carry off whole panicles. Hoards of as much as 4 kg., of stolen grain have reportedly been dug out from burrows of rats and rodents.

(ii) Threshing:- More grains are lost from bundled paddy while it is being carried from the field to drying floor. Traditionally, threshing is achieved by beating the harvested panicle with a club (motar) or by beating the panicle on some solid structures. In the mechanized system, various types of threshers exist. Since all the grains are not at the same stage of maturity, some grains may still remain on the discarded threshed panicle thus representing another small loss.

(iii) Drying:- The threshed grains are spread to a depth of 5 to 7cm on the drying floor for sun-drying or at different layers (depending on the machine type) in a dryer. During this process the seed/grain is turned constantly on the drying ground and if enough care is not taken at this stage, birds and some pestiferous mammals will pick up some more grains. Inefficient drying may also result in loss of viability or even spoilage in the dryer.

Losses from harvesting to drying stages have been estimated at between 4 to 10 percent depending on the climatic conditions under which crop has matured and has been harvested.

(iv) Storage: Mammalian pests as well as arthropods and fungi also consume paddy in storage and cause considerable reduction in the paddy weight, 5-20 percent of the overall weight loss has been reported (Gorgetti-Neto 1979). The activities of these storage pests are influenced by the sanitary condition of the storage room as well as the temperature and relative humidity of storage environment.

Below 10°C and 40°C R.H. (8% M.C. in cereals) insect will not be active. In West Africa as in most of the tropics) temperature are likely to be well above 10°C and unless the moisture content of stored seeds is kept at a low level, insect pests can cause considerable damage when other control measures are not taken. The principal ways in which insects can affect stored seeds are listed below:

a) Adult or larva damage/kills embryo of seed by its feeding activities.

b) Insects may introduce fungi which are harmful to seed.

c) Webbs may be spun or cocoons constructed necessitating clearing with some loss of seed.

Indirect losses

Indirect losses are influenced by three main factors; relative humidity (moisture content of seed), temperature and the condition of seed/grain at storage. Such losses may occur at any of all the post-harvest stages.

i) Relative humidity (seed moisture content) and temperature are the most important factors causing indirect post-harvest losses and of the two factors, relative humidity is the more important. Besides the direct effect these two factors have on seed/grain, they also influence the activities of storage insects and fungi. At high relative humidity and temperature the reproduction of these pests are favoured resulting in increased infestation by insect pests while fungal attack also increases rapidly. Heat from the respiratory activities of fungi also produce "hot spot"/"local heating effect" which may even result in combustion. In addition, storage mold like Aspergilus spp. downgrade stored grain/seed by producing aflatoxin which is carcinogenic. With few exceptions, the activities of both insects and fungi (molds) are known to be grossly reduced at relative humidity of about 65% (about 13% M.C. for rice) and 15°C (59°F).

ii) Seed/Grain Factor also influence the extent of indirect post-harvest losses. Cracked or bruised seed (from handling operations) are more susceptible to storage pests attack than wholesome seed/grain.

Loss estimation

Statistically sound economic loss estimates are very difficult to obtain thus most of the figures on post-harvest losses are based on "guestimation" of experts. Difficulty in obtaining true loss estimate is due to the fact that they are affected by many variables such as location and season.

Rice post-harvest losses in West Africa have been put at 6-24 percent, with the following break down percentages - Drying 1-2 on-farm storage 2-10, parboiling 1-2 and milling 2-10 (Lindbald, 1976). According to WARDA (1981), the total paddy production in West Africa for 1980 was about 2.8 million tons. Applying the conservative estimate of 6 percent loss to the 1980 paddy production figure for West Africa the over all loss will be approximately 168,000 tons. This represents a considerable loss considering the fact that the bulk of rice produced in WARDA region is still at the peasant farmer level. Also the fact that the 15 West African countries imported a total of 1.66 million tons of rice in 1980 (WARDA 1981) shows that a drastic reduction in post-harvest losses might be another way of moving the region faster towards self-sufficiency in rice production.

Traditional Rural drying and storage in West Africa

Patterns of traditional methods have marked similarities across WARDA region. This range can be roughly classified into three based on the agro-climatic conditions prevailing especially during and after ripening of the crop. This climate pattern determines the type of structures as described below:

i) Sahel zone - This is characterized by distinct dry season coinciding with the crop ripening phase. In these places some form of solid wall container is prevalent e.g. mud walled granary of Niger is similar in constructional details to the "Rhumbu" of northern Nigeria. In this zone drying problem is less (if any) after the maturity of the crops which are rapidly removed from the field into storage. Further storage in mud-walled bins offer protection from many, but not all storage harzards (Anon, 1979).

ii) Moist-forest zone - this is characterized by unfavourable weather condition (high rainfall or humidity and high temperatue) at the time the crop is ready for harvest. Hence drying (especially sun drying) is a problem and seeds are subjected to serious pest attack while being left on the field for natural drying . Traditional structures are characterized by having slatted walls or some means permitting the free movement of air through the storage grains to allow for natural drying as the season progresses.

iii) Savanna zone - In these areas dry season coincides with the ripening of crops but in some years rain may persist beyond the optimum harvest day. In this zone, the situation is more complex and farmers tend to opt for freely ventilated type structure. However, it has been pointed out that the pattern of relative humidity in this area nevertheless is basically favourable and crop rapidly dries, inspite of the occasional rain storms, to a level suitable for storage in more protected mud-walled or solid containers (Anon 1979).

Reduction of Post-harvest losses

Reduction of post-harvest losses can only come about by inter-disciplinary approach in which losses occurring at different post-harvest operations are reduced. Strategies already worked out by pest control scientists for other crops may be applied to the rice crop with some modifications.

For indirect losses of post-harvest crops, greater attention need to be focused on the storage segment as this has been reported to account for about half of the total loss. Regardless of the kind of struture or method, good storage must perform the following:

i. keep grain cool and dry
ii. protect grain from insects
iii. protect grain from rodents
iv. retard the activities of storage fungi.

As pointed out by Lindblad et al (1976), the four conditions above are achieved by the observation of the following good storage practices:

1. Drying seed well to about 13% before storage.
2. Putting only wholsome clean seed into storage.
3. Keeping the seed cool and protected from large changes in outside temperatures.
4. Protecting the seed from insects through strict observance of good hygene, application of insecticide (if need be) and/or by putting the seed into airtight storage.
5. Water proofing the buildings and containers as much as possible, especially when seed are to be carried over for more than one planting season.
6. Making sure containers are rodent proofed in all ways possible.
7. Checking seed in store periodically to ensure that there is no infestation.

LITERATURE CITED

Anonymous: 1979. Unpublished Report on work carried out in Nigeria up to June 1975; FAO African Rural Storage Center. TF/AFR/45 (DEN).

FAO 1979. The Post-harvest. pp. 48.1 Rome, Italy.

Gorgetti-Neto, A. 1979: Post-harvest losses; extent of the problem. Food and Nutrition bulletin, 1(3), Pp. 34-37.

Harris, Kenton. L. and Carl 3. Lindblad. 1978. Post-harvest grain loss assessment methods. American Association of Cereal Chemists. ISBN 0-913250-14-7.

Lindbald, Carl and Laurel Druben. 1976. Small farm grain storage. VITA publication manual series number 35E.

WARDA: 1981: Rice Statistics Year Book: West Africa Rice Development Association, Box 1019, Monrovia, Liberia.

PEST OF STORED RICE

By

I. AKINTAYO
WARDA, FENDALL, LIBERIA

INTRODUCTION

Moulds, insects and rodents are among the important agents responsible for the deterioration of rice and other stored products. In order to control these agents effectively, we need to know their habits, and their environmental needs. With this knowledge, we can then device the most effective and economical control measures.

Rice may be stored as paddy (raw or parboiled) or as milled rice (raw or parboiled). All these forms are attacked and damaged in storage by moulds, insects and rodents. Paddy (raw) is the most stable form in which rice may be stored.

In this lecture, we will discuss only about insect as pest of stored rice.

General behaviour

Insect pests of stored rice may either be primary pests (i.e. insects that can attack undamaged or previously uninfested rice) or they may be secondary pests (i.e. insects that prefer damaged or previously infested rice). Adult insects lay eggs loosely in the stored rice or in crevices in the grain or in small holes bored in the rice grain with the mouth parts. The eggs hatch into larvae. The larvae feed on the rice grains and are responsible for most of the damage suffered by stored rice.

The pupae develop into adult insects. The larval and pupal stages may be passed inside or outside the rice grains.

Optimum conditions for the development of these insects are temperatures within the range of 28° - 35°C and relative humidities in the range of 60-70 percent. Duration of development under optimum conditions is within 20-40 days.

Among these insects, the more common are:

1. Sitophilus spp.(Coleoptera, Curculionidae)
   S. oryzae and S. zeamais (Rice and Maize weevils respectively)

Both are primary pests of paddy and milled rice. They are the most important insect pests of milled rice. These weevils can also attack rice in the field before harvest.

The adult female bores a hole in the rice grain and then lays the egg into the hole. It seals the hole with a mucilaginous substance. Each female may lay 300 - 400 eggs. The larva hatches from the egg and remains inside the grain. It feeds and moults several times and then changes into a pupa. The pupa changes into an adult which bites its way out of the grain. Duration of the life cycle is 30 - 40 days under optimum conditions (28°C and 70% rh). Adult weevils may live for 4-5 month.

2. Rhyzopertha dominica (Coleoptera, Bostrychidae)
   (The lesser grain borer)

Primary pest of paddy and milled rice. Not very successful on milled rice. It attacks rice in the field before harvest. Both adults and larvae are voracious feeders.

Damage caused to the rice grain is more irregular than that caused by rice and maize weevils.

Eggs (300 - 500/female) are laid singly or in clusters in stored rice. The first stage larva enters the grain through cracks in the husk or feeds on the dust produced by the boring of adult insects. The larva is unable to penetrate the intact husk. The life cycle is completed either within the rice grain or in the grain dust. Under optimum conditions (34°C and 50-60 RH), development time is about 25 days.

3. Sitotroga cerealella (Lepidoptera, Gelechiidae) **(Angoumois grain moth).**

Primary pest of paddy and milled rice. It attacks rice on the field before harvest. It is an important pest of paddy especially where rice is stored unthreshed. Where paddy is stored in bulk, the activity of this insect is limited to the surface layer . Damage is caused by the larva only.

Eggs are laid singly or in groups on the surface of paddy in the field or in storage. Each female lays about 50-100 eggs. The first stage larva borers into the grain where it remains until it is fully grown. Before it pupates, the larva bores a channel to the surface, leaving a thin layer of husk. Duration of the life cycle is about 35 days under optimum conditions (26°-30°C and 70% RH).

4. Tribolium castaneum (Coleoptera, Tenebrionidae) (Red flour beetle).

Secondary pest of milled rice. Paddy with major husk damage may also be attacked. Adults and larvae feed on the exposed surfaces of grains.

The female lays eggs at random in the stored rice. Each female may lay 400-500 eggs. Eggs hatch into slender larvae with white and yellow bands. Under optimum conditions (35°C and 70% RH), duration of the life cycle is about 20 days. Adult beetles may live for over one year.

5. Oryzaephilus surinamensis (Coleoptera, Silvanidae) (Saw-toothed grain beetle).

Secondary pest of milled rice. Adults and larvae feed on previously damaged grain.

Each female lays about 300 eggs. The eggs are laid loosely in the stored rice or are deposited in crevices in the grain. Each egg hatches into a small worm-like larva which moves freely in the stored rice, feeding as it goes. The mature larva pupates in a delicate cocoon-like covering constructed by joining grains together with a sticky secretion.

TYPE OF DAMAGE CAUSED

Infestation of stored rice by insects may lead to:

(i) reduction in quantity due to feeding of adult insects and larvae.

(ii) reduction in quality. The higher the standards set by the consumer, the greater the loss potential is. The mere presence of insects in rice may cause complete rejection by some consumers.

CONTROL

Methods for controlling insect pests of stored rice may be divided into two main group (i) non-chemical and (ii) chemical control methods.

1. Non-chemical control methods

These methods are very important especially in our region where pesticides are either too expensive or not easily obtainable. Some of these methods of control may be listed as follows:

a) Pre-harvest methods

i. Maintain a clean field.

ii. Grow resistant varieties. Resistance of rice varieties to primary storage insect pests appears to be based on the prevention of kernel entry by the larvae.

iii. Harvest rice at the right time.

iv. Avoid harvesting and threshing methods that lead to husk damage.

b). Post-harvest methods

i. Clean stores and containers before new grain is stored.

ii. Rice which is not infested should not be stored close to infested rice.

iii. Store rice as paddy.

iv. Store in airtight containers.

2. Chemical control methods

Insecticides for use in stored products insect control should have, among others, the following characteristics:

i. Low mammalian toxicity in relation to the dosage levels required in practice.

ii. Moderate persistence.

iii. Broad spectrum insecticidal effectiveness.

The insecticides used are either contact insecticides or fumigants.

STORAGE PESTS OF RICE AND IPM

By

E. A. AKINSOLA
WARDA, MONROVIA, LIBERIA.

Proper crop storage has a vital role to play in the gigantic agricultural programmes embarked upon by some West African countries. It is very essential to preserve the quality and quantity of all cereal crops produced for as long as required so that they can be available for human consumption throughout the year. The self-sufficiency objectives of many countries have not yet been achieved and storage problems tend to be overlooked. The situation, however, is that even the subsistence farmer who keep a bit of his crop both as food and as seed for planting, the research worker who tries to maintain viable germplasm and the government seed multiplication units, all need to protect their commodity from post-harvest pest devastation.

Losses may involve physical destruction or relate to social standards. Physical damage in rice involves weight loss and loss in milling yield. The agents causing substantial losses are:

- insect infestation
- mould infection, and
- rodent infestation.

A close observation of the local farmer reveals that he practices certain techniques aimed at protecting his grains from post-harvest pests. Most West African rice farmers parboil their rice. It has been said that parboiled milled rice is less susceptible to infestation than raw milled rice.

This is due to the toughness imparted to the grain by the parboiling process. Other methods adopted by peasant farmers to protect their grains include storage on raised platform above the fire place in the kitchen where heat and smoke discourage insect infestation. The process also ensures adequate drying which prevents mouldiness. Some farmers mix dried pepper with their grains. Village - level storage may also involve cribs which are designed to provide adequate ventilation. Rodents are prevented from entry either by use of slippery materials such as bamboo for constructing the legs of the crib or by use of rodent guards.

How does IPM come into this? Let us recount a few of the fundamental principles of IPM. The mere presence of a pest species does not justify action for cOntrol. When control measures are required, the use of non-chemical control agents is emphasized first and chemical pesticides used as a last resort. IPM avoids complete or heavy reliance on any one control method.

Elements of pest management can be seen in the peasant farmers' techniques. However, these practices need to be scientifically investigated and improved upon where necessary. The length of time the grains need to be stored may determine level of control measure to adopt. The grains should be checked constantly. Timely harvest and sanitation also go a long way to minimize post-harvest losses. When there is need for chemical control, apply such chemicals like pyrethrium which has low mammalian toxicity.

A carefully developed strategy for the control of post-harvest pests based on the principles of integrated pest management would ensure that losses are reduced and maintained at levels below economic threshold while at the same time eliminate hazards posed by too much reliance on pesticide use. Prevention and suppression actions need to be taken. The implementation of such a strategy would benefit both the small peasant farmer and the large rice production schemes. Rice deficits in many countries in West Africa would be minimized to a large extent through integrated pest management.

EXAMPLE OF EXPERIMENTAL APPROACHES TO THE ASSESSMENT OF YIELD LOSSES IN CROPS DUE TO PLANT DISEASES

By

M. D. THOMAS
University of Liberia
Monrovia, Liberia.

Example 1: Leaf scald of rice, *Rhynchosporium oryzae* (From M.D. Thomas, unpublished).

a). 1979 in Sierra Leone at 2 locations, 3 km aprt.
Design: paired plots, (treated and untreated), replicated 6 times for 2 cultivars, ROK 16 and PN 623-3 in separate experiments. No guard rows between plots. IMAT 8, a susceptible cultivar planted around the perimeter of the experiments.

Plot size and seed rate: 6 x 2 m plots; seeds drilled at 80 kg/ha, 20 cm between rows.

Treatments: treated plots received 4 sprays of the systemic fungicide benomyl at regular intervals, beginning at maximum tillering up to maturity, at the rate of 0.33 kg a.i/ha. Untreated plots allowed to be infected from natural inoculum.

Disease assessment: Percent leaf area infected at dough stage from the 4 top leaves from 18 randomly chosen fertile tillers; averaged and expressed as disease severity per plot.

Yield: Whole plot, except single border rows, expressed as kg/ha at 14% grain moisture content.

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b) 1980 in Sierra Leone at 2 locations in the North, 3 km apart, and in 1 location in the East 359 km away.

Design: Randomized complete block replicated 4 times. Four guard rows, 20 cm between rows, of ROK 3 a resistant cultivar, planted around each plot; 40 cm wide path between guard rows and plots.

Disease assessment: Percent leaf area infected from the 3 top leaves from all tillers of 8 randomly chosen plants from each plot at 2 to 7 times during the growing season.

Yield: Harvested central row of each plot. Yield components taken were, weight of 1000 kernels and number of kernels per panicle from 1 m^2 area.

Duration: 2 growing seasons.

Example 3: Corn leaf blight (Northern) *Helminthosporium turcicum*. From A.D. Raymundo and A.L. Hooker. 1981. Plant disease 65:35-327.

Design: Randomized complete block, replicated 4 times, using 3 hybrids.

Plot size and seed rate: 2 rows of 4 plants. Rows 76 cm apart, 38cm between hills, with 2 plants/hill.

Treatment: Each plant inoculated with 10 ml of a spore suspension containing 55,000 conidia/ml of *H. turcicum*. Each hybrid planted in a check block isolated from the disease block, but in same general area.

Disease assessment: Percent leaf area infected in each row, recorded weekly starting at silking. (Did not mention which leaves were assessed).

Yield: Ears from each row (except end plants) bulked and expressed as quintels/ha. Yield components - weight in grams of 500 kernels from each plot.

Duration: 2 growing seasons.

NOTE THE FOLLOWING: 1. Use multiple-point model (several disease readings); superior to critical-point model (single disease reading).

2. Calculator, progress or rate of disease from either slope of graph with log x/1-x (% leaf area infected as a proportion of healthy tissue) as y axis, and time as x axis, or from the eqution for r given in 1(b) above.

3. Use guard rows to reduce interplot interference.

4. For rice and similar cereals, use 2 top leaves (flag and next successive leaves) for disease assessment.

ECONOMIC EVALUATION OF RICE

Pest Control Procedures

By

C. Michael Smith
Louisiana State University
Baton Rouge, LA 70803 U. S. A.

In the development of any integrated pest management (IPM) program, consideration must be given to the economic costs and benefits associated with insect pest control. As a result, the concept of the economic injury level (EIL) has developed for use in IPM. The EIL is the injury level at which the cost of insect control is compensated for by a resulting increase in crop yield (Kiritani 1980) or the lowest pest population density that will cause crop injury significant enough to justify artificial control procedures (Stern et al 1959). A closely related concept is the control or economic threshold (ET) (usually lower than the EIL), which is the density at which control measures should be applied to prevent pest populations from reaching the EIL. Most simply stated, the ET is the injury level which separates an acceptable from an unacceptable degree of damage (FAO 1970). Since a rice production system is part of both agroecological and socioeconomic systems, the ET can fluctuate in time. Changes in the value of the rice crop, cost of control and the degree of damage inflicted by insect pest(s) (as influenced by insect density, plant tolerance and insect virus-vector relationships), can all determine the ET and EIL.

Sampling Rice Insect Populations: The accuracy and success of both the ET and EIL are heavily dependant on reliable insect surveillance (trapping) techniques and in-field sampling of populations or plant damage. These techniques will vary in relation to the insect pest, type of crop (upland vs lowland and geographic location in which the crop is grown. Regardless of sample size or area, a sample should be an accurate representation of the insect or plant population from which it is drawn. Knowledge of the spatial distribution of the pest insect (clumped or random), amount of labour available to take samples and urgency with which control decisions have to be made are the factors which usually dictate the sample size. Insect populations can be sampled using direct or indirect methods (FAO 1979), including actual counts of insects per unit area, relative counts (insects per sweep or per minute of collection) and indirect insect counts based on insect activity on the plant, i.e., white heads, dead hearts, hopperburn, defoliation.

A variety of light trap designs and power sources (kerosene or elertric) have been developed to predict stemborer population outbreaks in rice, since infestation of plants usually begins within 5-10 days of the peak moth flight. Though light traps have been used extensively in China in the past Shin-Foon (1980), reports that use of the traps is being eliminated due to the expense of operation and heavy collection of beneficial insect populations. As more are identified, borer sex pheromones will be very useful in borer population monitoring, and due to their specificity, should not adversely affect beneficial insects.

For several years, a sampling technique developed in the Philippines was used to estimate rice stemborer damage (Onate 1965 in FAO 1979).

$$\%\ \text{Borer Infestation} = \frac{\text{No. Infested Hills}}{\text{No. Hills Observed}} \times \frac{\text{No. Infested Tillers}}{\text{Total No. Tillers In Infested Hills}} \times 100$$

This is a relatively fast and accurate method which is applicable to both white head and dead heart damage. Research at the International Rice Research Institute however, has shown that due to plant growth response to infestation, infested plants have more tillers than non-infested plants. Gomez (1972) proposed the following formula to compensate for the plant growth response:

$$\%\ \text{Borer Infestation} = \frac{\text{No. Damaged Tillers In A Sample Area}}{\text{Total No. Tillers In All Damaged Hills} + \text{Total No. 5 Paires Of Undamaged Hills}/10^{*} \text{ Total No. Undamaged Sample Area}} \times 100$$

Several sampling methods including sweep net, visual counts and light traps have been used to trap various species of leafhoppers and planthoppers (FAO 1979), though only winged forms are collected in light traps. Other pests such as rice bugs (Leptocorisa and Oebalus spp.) and lepidopterous larvae (leaf-rollers, armyworms, skippers, caseworms) can be sampled by sweep net sampling or direct in-field plant counts.

Economic Thresholds of Rice Insect Pests: Damage to rice by stem borers is closely correlated to yield losses. In the case of the African white rice borer, *Maliparpha separatella*, a close relationship has been demonstrated between larval infestation and grain loss (Fig. 1).

Similarly, research on grain yield reduction by the yellow stemborer, Tryporyza incertulas, in Indonesia indicates that each 1% of damage results in an approximate 1% yield reduction (Soejiton 1977).

Good correlations also exist for the relationship between leafhopper and planthopper damage and yield loss in rice. A sweep net sampling technique developed in Japan has been used to calculate grain losses related to brown planthopper, Nilaparvata lugens, populations (Fig. 2). The relationship is linear up to a midpoint until insect crowding apparently begins to affect hopper feeding. Similar reduction estimates have also been calculated for populations of the white back planthopper, Sogatella furcifera. If untreated, populations of 10 hoppers/100 sweeps in the tillering stage can cause up to 10% yield loss. Infestations of 10 or more hoppers/100 sweeps can cause from 40-90% yield reduction, depending on the degree of plant damage (FAO 1979).

The quality of the rice crop may also be dependent on the degree of insect infestation. Kiritani (1980) demonstrates a linear relationship between population densities of Nezara viridula and Leptocorisa chinensis and husked rice quality in Japan (Table 1). Though the effect of N. viridula was about 50% less than that of L. chinensis, doubling the populations of each insect lowered the quality of the infested rice crop by one grade. Dyck (1978) summarized the presently used ET for some of the major rice insect pests (Table 2). These thresholds are based on either plant damage or insect populations; the latter usually employed when insect are easy to sample.

In the Southern United States about 30% of the rice grown is treated with carbofuran granules for control of rice water weevil, Lissorhoptrus oryzophilus larvae. Control costs in Louisiana alone are about $1.7 million annually. This practice produces an approximate 10% yield increase and causes a net increase in profit of about $25 per acre above the cost of control. Using current cost and production figures, Robinson (1980) developed the following EIL for L. oryzophilus in Louisiana.

Cost of carbofuran = 20 LB/AC X 35¢/LB = $7/AC
Cost of application (airplane and flagmen) $3/AC
Total cost of control $10/AC

Crop loss due to 1 L. oryzophilus larvae/9cm^3 root sample X Value of rice crop L. oryzophilus crop loss

($ 34.2 LB/A) X ($ .08/LB) = $ 2.74/AC

EIL $\frac{\text{Cost of Control}}{\text{Cost of Loss}} = \frac{10/AC}{2.74/AC} =$ 3.65 larvae/9cm^3 root sample

One of the most comprehensive studies involving the cost vs benefits of carbofuron based insect control as well as aspects of fish culture in rice production was conducted by Heinrichs et al (1978). Results of this study (Table 3) not only demonstrate that root-zone application of carbofuron enabled harvest of fish populations, but they also point out that consideration should be given to other harvestable organisms in the rice agroecosystem when insect EIL's are being established.

REFERENCES CITED

Dyck, A.V. 1978. Economic Thresholds in Rice. In Proc. Regional Training Seminar on Integrated Pest Control for Irrigated Rice in South and Southeast Asia. October 16-November 18, Maligaya and Los Banos, Philippines.

FAO. 1971. Crop Loss Assessment Methods. FAO-Commonwealth Agricultural Bureau. Alden Press, Oxford.

FAO. 1979. Guidelines for Integrated Control of Rice Insect Pests. FAO Plant Production and Protection Paper 14. 115 pp. FAO, Rome.

Gomez, K. A. 1972. Techniques for Field Experiments in Rice. Layout/sampling/sources of error. International Rice Research Institute. Los Banos, Philippines. 46 pp.

Heinrichs, E.A., G.B. Aquino and R. Arce. 1978. Root-zone applicaton of carbofuron in rice-fish culture. Int. Rice Res. Newsl. 3(5): 16-17.

Kiritani, K. 1980. Integrated Insect Pest Management for Rice in Japan. pp. 13-22. In International Symposium on Problems of Insect Pest Management on Developing Countries. Tropical Agricultural Research Center (Japan). Tropical Agriculture Res. Series. No. 14. 162 pp.

Robinson, J.F. 1980. An Economic Injury Level for the Rice Water Weevil in Louisiana. Louisiana Rice Research Board Presentation. January, 1981.

Shin-Foon, C. 1980. Integrated Control of Rice Insect Pests in China. pp. 239-250. In Rice Improvement in China and Other Asian Countries. International Rice Research Institute. Los Banos, Philippines. 307 pp.

Soejitno, J. 1977. Relation between rice stemborer, Tryporyza incertulas and yield of rice variety Pelita I-1. Int. Rice Res. Newsl. 2(4): 6.

Stern, V.M., R.F. Smith, R. van den Bosch and K.S. Hagen. 1959. The integration of chemical and biological control of the spotted alfalfa aphid. I. The integrated control concept. Hilgardia 29:81-101.

Table 1: Relationships of husked rice quality to population densities of two plant bug species. 1/

Grade (% of spotted grains)	No. Adults/50 Net Sweeps	
	Leptocorisa chinensis	*Nezara viridula*
1 (0.1)	6	2
2 (0.3)	17	5
3 (0.7)	39	13
Subgrade (0.8)	---	---

1/ From Kiritani (1980).

Table 2: Economic thresholds for some major rice insect pests in South and Southeast Asia. 1/

Insect	Threshold
Stem borers	› 10% dead heart (up to 30 DT)
Brown plant hopper	› 10 insects/hill
Green rice leafhopper	› 20 insects/hill
White-back planthopper	› 10/100 net sweeps
Gall midge	5-10% of plants with galls (during tillering)
Leaf folder	10-15% damaged leaves (during grain fill)
Rice skippers	5-10 damaged stems/100 plants

1/ From Dyck (1978).

Table 3: Effect of root-zone application of carbofuran on yields of rice and fish in the Philippines (Heinrichs et al 1978).

Application rate a/ (a.i./ha)	Cost of insecticide application ($)	Rice yield b/ t/ha	Fish c/ Yield (kg/ha)	Value ($/ha)	Income (4)
No insecticide	0	4.1	155	127	701
Broadcast					
1kg at 3 DT	30	4.3	141	115	687
1kg at 3,23 43 & 63 DT	120	4.9	0	0	566
Root zone					
1 kg at 3 DT	46	5.1	166	136	804
2 kg at 3 DT	92	5.6	150	123	815

a/ a.i. - active ingredient; DT - days after transplanting.

b/ Means not followed by a common letter differ significantly at P = 0.05.

c/ Seeded 7 days post insecticide application (3000/ha).

d/ Income = (value of rice + value of fish)-insecticide and application costs.

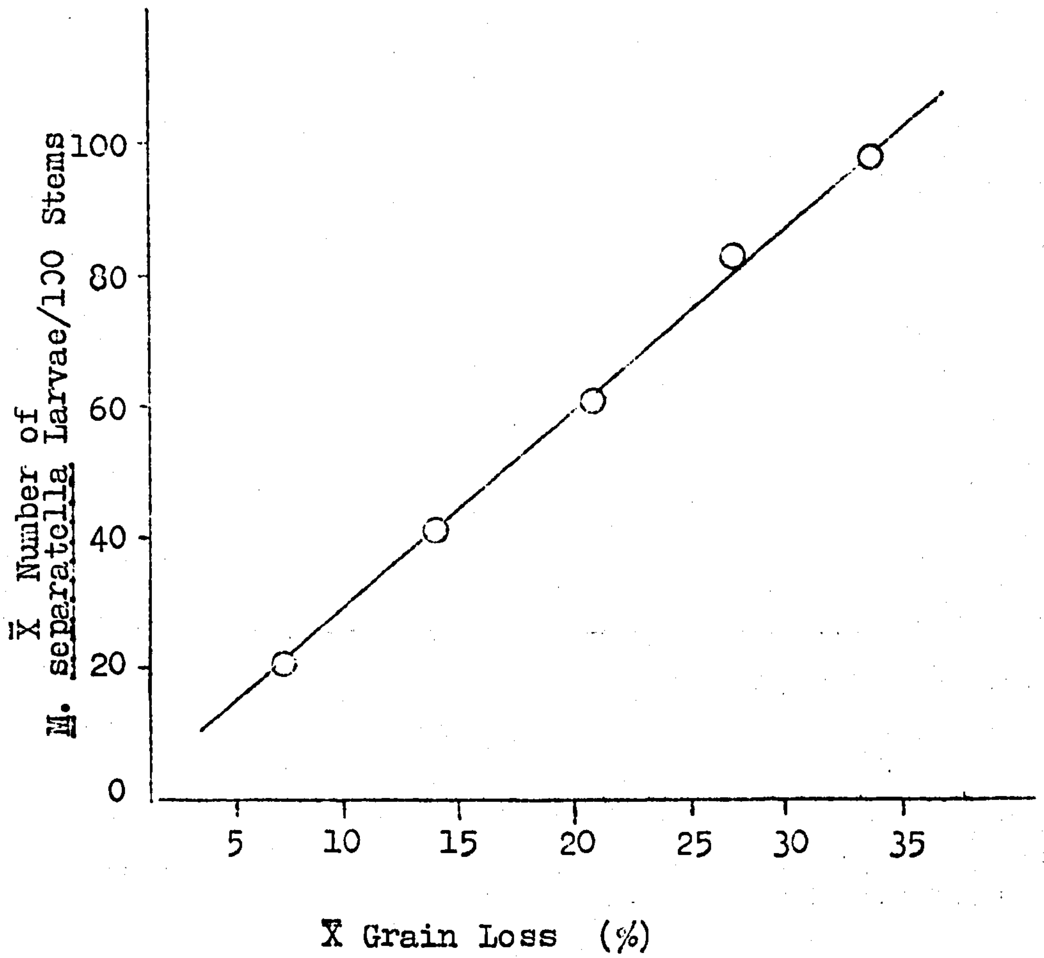

Figure 1: Relationship between larval infestation of African white rice borers and rice grain loss (FAO 1970).

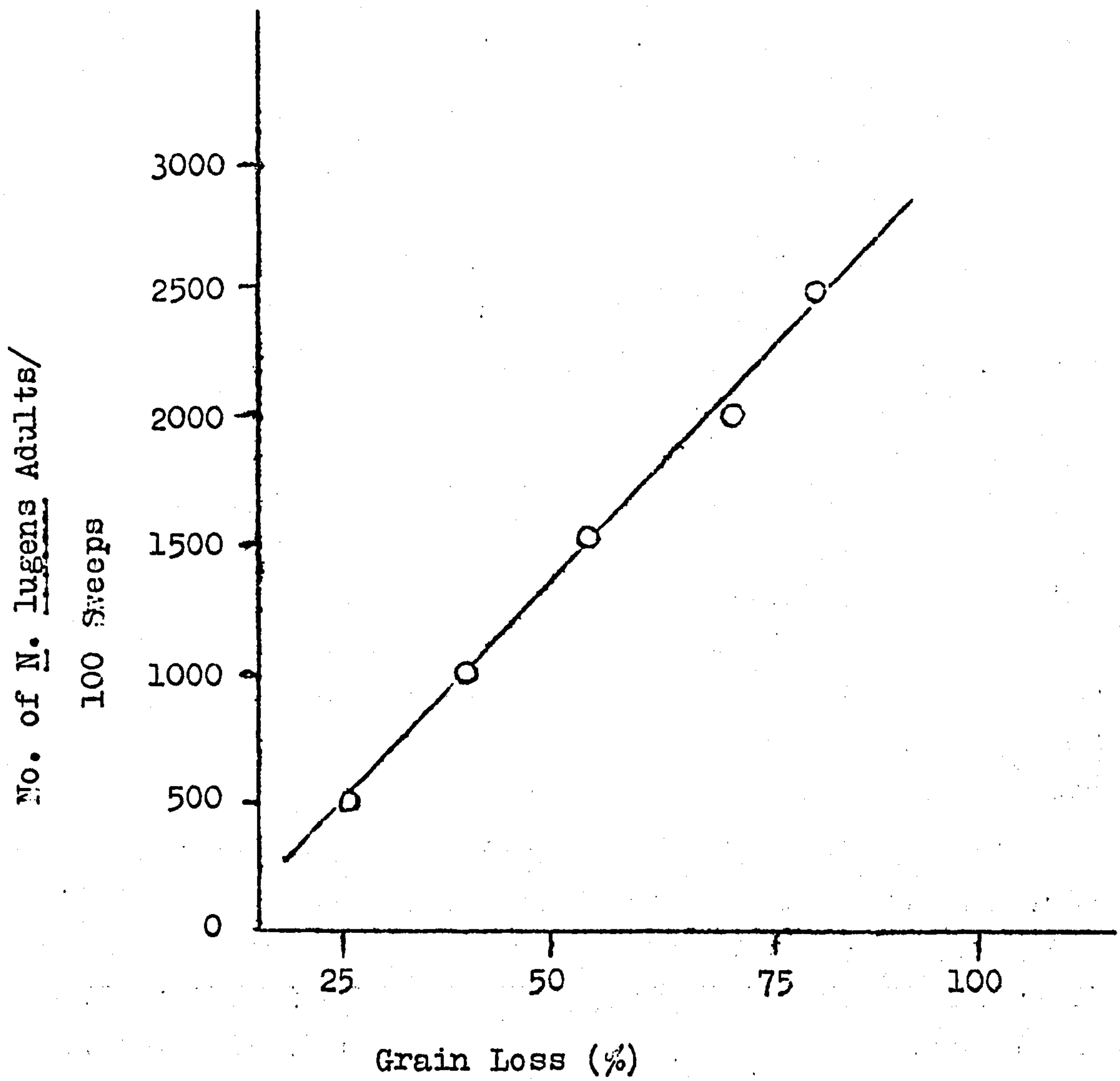

Figure 2. Relationship between rice grain loss and *Nilaparvata lugens* population levels.

INTEGRATED PEST MANAGEMENT IN A GLOBAL PERSPECTIVE: PROGRESS AND PROBLEMS

By

Dale G. Bottrell
University of California, Berkeley
Consortium for International Crop Protection
2288 Fulton Street, Suite 310
Berkeley, California 94704, USA

The past 5 years have seen an explosion in the literature on integrated pest management (IPM). The misuse, overuse, and unnecessary use of chemical pesticides have been major factors in the rapid growth of interest in IPM—and quite appropriately, since the IPM concept seeks to minimize the disadvantages of the materials and to maximize their advantage. Robert L. Metcalf (1980) designated 1976 as the beginning of the "Era of IPM," in commemoration of the International Congress of Entomology held in that year. He reported that during the Congress the concept "clearly came of age."

Brader (1979) reviewed development in integrated pest management in the less developed countries (LDCs). Young (1979) and the Special Issue of the International Organization for Biological Control of Noxious Animals and Plants (IOBC, 1981) provided additional discussions on the subject. The Special Issue compiled the papers presented at the Conference on Future Trends of Integrated Pest Management held in Bellagio, Italy, May 30–June 4, 1980. FAO (1979) and Kiritani (1979) are recommended for information on developments in IPM in rice. Haskell et al. (1979) reviewed the worldwide socio-economic constraints to crop protection.

THE INTERNATIONAL ORGANIZATIONS' ROLE: HISTORICAL PERSPECTIVE

A meeting sponsored by the Food and Agriculture Organization of the United Nations (FAO) in 1959 to review the role of pesticides in agriculture was probably the single most significant stimulus for IPM at the international level (Brader et al., 1980). A recommendation of the meeting's participants was that "governments initiate or intensify research which will lead to the harmonizing of chemical and biological control practices." This recommendation clearly supported the "integrated control" concept. In that same year, the now classic publication "The Integrated Control Concept" by Vernon M. Stern, Ray F. Smith, Robert van den Bosch, and Kenneth S. Hagen (1959) appeared in Hilgardia. The publication had a significant, albeit slow, impact in rousing the interest of entomologists in integrated control.

In response to the recommendation from the 1959 meeting, FAO created the FAO Committee of Experts on Pesticides in Agriculture in 1962. This Committee formed a series of FAO Working Parties on Pesticide Residues, Resistance to Pesticides, and Official Control of Pesticides (Brader et al., 1980).

In 1963, The Twelfth Session of the FAO Conference (the governing body of FAO) recommended that FAO emphasize an integrated approach to plant protection. In October 1965, the Director General of FAO convened the Symposium on Integrated Pest Control at FAO in Rome.

The conferees endorsed the use of the term "integrated pest control" and recommended that a "panel of experts on integrated pest control be established ..." In 1966, FAO's Director General established a panel of experts on integrated pest control to serve as a statutory advisory body to FAO. In 1979, the panel became an advisor to both United Nations agencies, FAO and the United Nations Environment Programme (UNEP), under the title "FAO/UNEP Panel of Experts on Integrated Pest Control." The panel considers the term integrated pest control to be synonymous with integrated pest management. Ray F. Smith of the University of California, Berkeley and Executive Director of the Consortium for International Crop Protection, has served as Chairman of the Panels since 1974. Brader et al (1980) discussed the composition of the Panel and its activities.

The FAO/UNEP Panel advises and assists the Director General of FAO and the Executive Director of UNEP in formulating and executing policies and programs related to "integrated and environmentally sound approaches to pest control in agriculture." One important activity has been to develop a series of guidelines and "how-to" manuals for the development and implementation of IPM. The Guidelines for Integrated Control of Rice Insect Pests" (1979), for example, was developed under the Panel's guidance. Similar guidelines have been developed for cotton, sorghum, and maize. All are available in English and one or more other languages. Guidelines now are being developed for soybean, groundnut (peanut), and sugarbeet (Brader et al., 1980).

The FAO and FAO/UNEP Panels have initiated several major IPM projects through the FAO/UNEP Cooperative Global Program for the Development and Application of Integrated Pest Control in Agriculture. The Global Program is coordinated by FAO, and the Panel serves as the technical advisory body. Three major projects in IPM are now operating under the Global Program:
(1) the CILSS[1] IPM research project in basic food crops in the Sahel of Africa, (2) the Southeast Asia seven-country program in rice IPM, and (3) the cotton IPM program in North Africa and Near East. They were initiated, respectively, in 1979, 1980, and 1977. The projects are being funded by various donor agencies.

The three projects of the FAO/UNEP Global Program are the largest coordinated international effort to develop comprehensive IPM systems for agricultural crops. Their long-term objective is to develop ecologically based systems of pest management for the crops under consideration. The projects are emphasizing adaptive research, carried out mostly on farmers' fields, farmers' demonstrations of promising IPM techniques, and training as required to increase the indigenous capacity in IPM in the participating countries. Although it is too early to determine the impact of these projects in advancing IPM, the research and operational advances represent a trend toward more rational management of agricultural pests in the LDCs.

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[1]CILSS = Comité Interétats de Lutte Contre la Sécheresse au Sahel/Interstate Committee for Drought Control in the Sahel.

The FAO/UNEP Panel has probably been the single largest stimulus in advancing the concept of integrated pest management in the LDCs. The International Organization for Biological Control of Noxious Animals and Plants, Centre for Overseas Pest Research, U.S. Agency for International Development, and various other international organizations have also contributed in advancing IPM in these countries.

Some of the agricultural centers of the Consultative Group for International Agricultural Research (CGIAR) have major programs in plant protection. Two CGIAR centers —the International Rice Research Institute (IRRI) andthe West Africa Rice Development Association (WARDA) have major responsibilities to rice production. In recent years, IRRI has contributed significantly in advancing the concept of IPM in rice and developing research leading toward improved systems of rice pest management. The West Africa Rice Development Association (WARDA) is becoming interested in advancing IPM in rice in West Africa as evidenced by the Association's effort in the past two and one-half years to begin a regional program in rice IPM in the WARDA member countries.

Various national institutions in the LDCs also have contributed significantly in developing and implementing IPM. For example, the Malaysian Agricultural Research and Development Institute has been a key leader in advancing the IPM concept in Malaysia. Other national institutions in the LDCs in Asia, Africa, and Latin America have played similar leadership roles.

STATUS OF IPM IN THE DEVELOPED COUNTRIES

The status and prospects of integrated pest management in the developed countries were discussed in IOBC (1981) which is recommended for a more comprehensive discussion on the subject.

USA

Major progress has been made recently in the USA, particularly in agriculture where public research and extension agencies have taken steps to develop and demonstrate IPM concepts and techniques. To date, the largest national research effort to develop integrated management of crop pests relates to insects and mites. Major emphasis has been placed on cotton, citrus, deciduous fruits, soybean, and alfalfa, which account for approximately 70 percent of the insecticides applied annually to U. S. cropland. It is estimated that prototype IPM systems now available or being developed for these pests could reduce the quantity of insecticides currently used for their control 40-50 percent in the next 5 years and perhaps 70-80 percent in the next 10 years, with no reduction in present crop yield levels. Farmers in some regions have already begun to adopt these systems.

It has been demonstrated that in some areas of Texas cotton may be produced with 50-75 percent less insecticide. Moreover, the IPM system incorporates early maturing cotton varieties that require 80 percent less fertilizer and 50 percent less irrigation water than the later maturing varieties.

The system has increased participating farmers' profits more than $100 per acre (from $62 to $170). The Texas Pest Management Association, a nonprofit farmer-administered organization, was recently formed to promote increased use of IPM systems on cotton and other crops.

Since 1971 the Cooperative Extension Service has been demonstrating the advantages of integrated pest management on a wide variety of field crops and livestock operations. The objective of the demonstrations, conducted on some 25 crops and in cattle feedlots, is to introduce farmers and livestock managers to IPM concepts and techniques. For nearly every crop included in the demonstrations in over 30 states, pesticide use has dropped significantly without a sacrifice in yield or quality and with increased profit to the farmer. The demonstrations in cattle feedlots have shown a reduction in the use of chemical pesticides and and an increase in the daily weight gain and feed efficiency of the animals.

Equally encouraging results have been achieved in IPM programs directed against pests affecting urban areas, public health, and forests. In California, an IPM program significantly reduced insecticide use on city-owned shade trees. Before the program was initiated, approximately 16 percent of the five-city tree population (462,000) was treated for pests. Under the IPM program, only 0.08 percent of the trees were treated with chemical pesticides, and approximately 1 percent were treated with the insect disease agent Bacillus thuringiensis.

With the number of chemical treatments reduced to 7 percent of the preprogram days, the pests were effectively managed. These results illustrate the potential for reducing pesticide use in urban areas, a significant source of contamination in rivers and other aquatic systems in metropolitan regions.

Results from mosquito control districts in California show IPM potential in public health programs. Incorporating physical, biological, cultural, and chemical methods, the system has provided effective mosquito control while significantly reducing pesticide use. In 1962--the peak year of pesticide application in the districts—615,000 pounds of insecticides were used; with integrated pest management, only 63,000 pounds were applied in 1976, a 10-fold decrease. Labor and material costs have been cut and environmental pollution is negligible.

Intensified efforts are underway to develop integrated management schemes for forest pests, particularly insects. The approach has been to develop, evaluate, and implement management systems that are environmentally safe and to provide the knowledge necessary to prevent or suppress pest outbreaks. In 1976, a disease-causing virus was registered for use against the Douglas-fit tussock moth, and in 1978 registration of another virus was granted for control of the gypsy moth—the moths are two of the nation's most serious forest insect pests. Another biological control, the disease agent <u>Bacillus thuringiensis</u>, was recently registered for use against the Douglas-fir tussock moth.

Registration of these biological agents is significant, because the Douglas-fir tussock moth and the gypsy moth have accounted for a substantial portion of the insecticides used in forests in the past 2 decades.

Bottrell (1979) reviewed the status and prospects of IPM in the USA and discussed the obstacles to widespread use of the strategy. Of all the sectors, agriculture has benefited the most. However, few operational pest management programs are truly integrated. Because of technical, economic attitudinal, and possibly other barriers, IPM has not been used for a wide variety of pests and resources. Chemical herbicides and insecticides are still the "backbone" components used to manage weeds and insect pests. Most of the IPM programs have been developed for single pests (e.g., one insect species) or for closely related pests (e.g. several insect species). Efforts to develop multipest IPM schemes, synchronized with and integrated into optimal crop production systems, have just begun.

Europe

IOBC (1981) summarized the situation in Europe as follows:

"In Europe, concerted studies on integrated control have been promoted since 1956 by the International Organization for Biological Control. Difficulties experienced with the appearance of spider mite resistance to pesticides in the fifties stimulated detailed investigation on the preservation of natural enemies, mainly in apple orchards and vineyards.

This research has gradually expanded to include all major crops and as a consequence it became possible to develop more precise and less prodigal systems of pesticide use, generally called supervised control, in which economic threshold values for pests were used, more selective pesticides were applied as far as available, and reliance was placed on improved forecasting systems.

The next step, based on an approved knowledge of supervised control, was the development of integrated control systems, which in addition to the requirements for supervised control call for deliberate use of biological and biotechnical methods.

The final development should lead to integrated production which is the most advanced system as it takes into account, in addition, all aspects of cultivation, including the choice of crop and variety, cultural measures, soil management, weed control, etc.

After more than 20 years of research in deciduous fruit growing the most striking advances have been made in apple production, for which integrated control is sufficiently advanced to be generally introduced in European countries. The economic returns have proved to be higher than in conventionally protected orchards. However, the introduction of the system is making slow progress.

In 1975 a first attempt to introduce an integrated production scheme was made in Switzerland on 200 hectares of apple orchards. Since then, Growers' Associations in the Rhone Valley in France have developed such systems which, however, remain in their experimental stage.

The second most advanced sector is glasshouse crop protection for which integrated systems are in practical use, mainly in the Netherlands, United Kingdom, and Finland. Although there are still new problems arising, such as the upsurge of hitherto minor pests, these systems are being exploited widely. A conservative estimate indicates that in these countries 40-50 percent of the tomato and cucumber crops under glass are protected in this way.

Considerable developments have also taken place in grapevine, maize, oilseed rape, citrus, and, to a lesser extent, in wheat and vegetables, but for these crops the stage of integrated control has not yet been reached and there are still unresolved problems imposing limitations.

This short survey is an illustration of the remarkable collaborative efforts which are made mainly through IOBC Working Parties.

The various phases leading from purely chemical control to integrated pest management and even to integrated production, as exemplified by fruit growing, represents the general trend followed in Europe. It is anticipated that with the recent support of this approach by the European Community technical progress as well as general acceptance of these systems will be increased."

Other Developed Countries

The status of integrated pest management in Canada, Australia, New Zealand, and other developed countries is generally similar to the situation described for the USA and Europe. Good progress has been achieved in some crops where the governments have emphasized the IPM approach. However, it is generally believed that farmers in the developed countries use more pesticides than necesary, and a variety of obstacles slow the progress of IPM in all these countries.

STATUS OF IPM IN THE LDCs

Brader (1979) used examples to show that integrated pest management has been applied successfully to both small farm and estate cropping situations in the LDCs. IOBC (1981) reported that "the Developing World provides the earliest examples of the deliberate introduction of IPM programmes." One of those examples cited in the IOBC report was an integrated insect control program introduced into cotton in the Canete Valley of Peru in the 1950s. This program was highly successful, and it has been well documented (refer to Smith and van den Bosch, 1967 for references to the documentation). Its adoption by cotton producers in the Valley led to a rapid striking reduction of the cotton pest problem. Before the integrated program, the Valley's cotton industry was threatened by insect pest outbreaks brought on by misuse of insecticides. As a result of the integrated program, the insecticide problem was corrected, cotton yields rebounded, and the pest situation returned to normal in 1 or 2 growing seasnns.

Brader (1979) and IOBC (1981) also gave other examples of successful IPM programs in the LDCs. Most of these involved nonfood crops—cotton, cocoa, oil palm, olive, and coconut. In general, IPM has lagged in the basic food crops in comparison to IPM in cash crops.

IPM has received more attention in rice than in any other food crop. However, the CILSS IPM research project in the Sahel is emphasizing research in IPM for millet, sorghum, maize, rice, and other food crops grown by subsistence farmers in the Sahel.

Perhaps the concept of integrated pest management and its application have advanced further in the People's Republic of China than in any country. Plant protection now has high priority in China, and integrated pest management has been popularized and is increasingly practiced by many communes. The Chinese are working to apply pest control in context with the total agricultural scheme, all activities being directed toward a food harvest (NAS, 1977).

A delegation of U. S. entomologists concluded, after visiting China in 1975, that: "Clearly, the Chinese have progressed beyond levels attained in the United States both in widespread enthusiasm for integrated control and, in many respects, in the application of the ecological principles fundamental to its development. The development and application of cultural control methods were exemplary in many instances. The terms "pest management" or "integrated pest management" were virtually never used by our Chinese colleagues; the term used was "integrated control" (NAS, 1977).

IPM IN RICE

Kiritani (1979) and the Proceedings of the "Short Course on Integrated Pest Control for Irrigated Rice in South and Southeast Asia" (Anon., 1978) held in the Philippines in 1978 reviewed the status of integrated pest management in rice in Asia. FAO (1979) provided additional information on the subject. Various papers of this WARDA training course discussed the status of IPM in rice in Africa and also Southeast Asia.

These discussions clearly showed that IPM has not advanced very far in the crop. Most emphasis has been on developing disease and insect resistant rice varieties, selective chemical control measures, and improved pest surveillance and forecasting systems. These measures have facilitated more efficient use of insecticides in limited areas. For example, near Cuttack, in Orissa, India, the number of insecticidal applications per rice crop has been reduced from 3-4 to about 2 (Brader, 1979). The Indian farmers have been regularly involved in implementing the IPM program near Cuttack. Other limited efforts to develop IPM systems for Asian rice have also been promising, and the national governments of the major rice countries have endorsed the concept of IPM as the preferred strategy for combatting the pests of rice.

The Southeast Asian rice IPM program being developed under the FAO/UNEP Global Program for the Development and Application of Ingegrated Pest Control in Agriculture is the first organized effort to develop comprehensive systems for IPM in rice in developing countries. It is too early to determine the impact of this effort on advancing IPM over a wide area, but the Project represents a rational trend toward ecological-based systems of pest management.

NEEDS IN RICE

Traditional rice culture, characterized by small farms, polyculture (growing of rice and one or more crops simultaneously on the same field in the same year, under upland conditions), local, unimproved varieties, little or no artificial fertilizers, pesticides, or other inputs, and minimum tillage, is still practiced by a substantial portion of rice farmers typical of those in West Africa and Southeast Asia. The rice usually is consumed entirely by the human inhabitants on the farms where produced. Yields are very low, and there are no organized methods of pest control; pests simply are tolerated or protection of the crop depends on natural control factors and rare pesticidal treatments. The farmers have access to limited capital and technology, often are illiterate or barely literate, and have virtually no knowledge of the benefits or the limitations to pest control practices.

However, high yielding varieties, irrigation, mechanization, fertilizers, and other modern innovations are being introduced into these rice growing areas. The rice yields have increased, often significantly so, and the increases have provided incentives to develop other rice improvement techniques that would miximize the yield potential. Pesticides, particularly insecticides and herbicides, are being used in these areas.

Modernization and expansion of rice in developing areas such as West Africa promise to yield inestimable benefits for millions of people.

However, the change from traditional rice culture to a more productive state should not and cannot be based on the intensive use of agricultural pesticides. It has been estimated that if all rice farmers in Southeast Asia used pesticides at the same rate as Japanese farmers, they would use more than the current annual world production (Anon., 1974). The economic resources and infrastructures needed to acquire and use these tools are not generally available (Glass and Thurston, 1978).

Integrated pest management specialists committed to keeping pesticide use low therefore should become more active partners in efforts to increase rice production in West Africa and other developing areas. It is especially important that teams of disciplines—agronomists, plant breeders, insect and disease control specialists, sociologists, economists, and others—be involved in the formative stages of rice production and rice protection.

The role of social scientists, educators, and economists is especially important in IPM efforts in the developing countries. Even when the IPM strategy exists, it may be extremely difficult to sell to farmers who are accustomed to chemical control another approach. These individuals must first be shown that the IPM strategy will adequately achieve an objective they consider to be important—i.e., lowering the costs, increasing the yields, or another.

Then they must be taught how to implement the strategy. Though IPM can be implemented by farmers, they initially may resist implementing the strategy because they feel awkward in doing something new. Then, the IPM strategy must be made compatible with the existing social-economic-political structure of the community. Persons properly trained in the various social sciences are essential ingredients in all of these efforts.

Maintaining Genetic Diversity

For some years now, geneticists have worried about the worldwide loss of genetic diversity among plant crops. Maintaining genetic diversity is vital for two reasons. The first is the vulnerability of narrow germplasm to insect pests, diseases, and climate change. When huge hectares are planted with a single variety or a few closely related varieties, entire harvests can be wiped out by one disease or by the resurgence of an insect pest. Similarly, the harvest becomes terribly sensitive to any change in climate. When the massive use of insecticides is constantly upsetting predator-prey relationships and changing the mix of insect populations, the planting of fewer and fewer varieties is particularly ominous.

Second, there is the need to preserve the genetic resources from which plant breeders can create new strains tailored to changing environments. Only from the large genetic pool that has evolved over eons can new plant characteristics—of disease and insect pest resistance, length of growing season, water and fertilizer requirements, soil and sun needs, protein content, and so on—be drawn.

Public Health Considerations

The institutions involved in the development of rice pests management programs and policies share many of the same concerns as the institutions involved in public health programs—improved nutrition, worker safety, and environmental protection, for example. Yet efforts of the rice pest management specialists could give rise to a conflict which efforts of the public health specialists, if efforts of the two are not coordinated. The heavy use of insecticides in rice could have particularly negative impacts on public health. Aside from the potential direct harmful effects of insecticides on human health, the chemical materials may aggravate certain disease vectors or intermediate hosts of disease organisms. In the Gezira Scheme of Sudan, the use of the insecticides DDT and malathion on cotton has so modified the mosquito habitat as to result in the evolution of insecticide resistant malaria mosquitoes, thus adding to human health problems.

A few years ago the battle against malaria seemed to have been won. However, now, despite vigorous anti-malaria campaigns, the disease has made a comeback, as recently discussed by Chapin and Wasserstrom (1981). The resurgence of the disease has been paralleled by intensified agriculture and increased use of insecticides. The relationship in pesticide use in rice and malaria has not been studied adequately in West Africa. The effects of other pest management practices in rice such as habitat modification are not well understood either.

Any effort in pest management in rice in the region should emphasize the importance of synchronizing and integrating policies and programs in rice pest management with those in public health pest control so as to avoid practices which aggravate the problem of malaria and other public health diseases.

Some Innovations Cannot Wait for the Experts

Small farmers do not depend on government research and extension officials as much as donors commonly seem to assume. Farmers in the LDCs are better innovators than generally recognized. Glass and Thurston (1978) and Brammer (1980) cited examples which show just how successful some of the innovations carried out by LDC farmers themselves have been. Brammer concluded that the government officials' lack of attention of these innovations has retarded agricultural development.

It is important that researchers and extension officers become aware of farmer innovations in rice which impinge on new IPM programs that may evolve for the crop. The growing of rice in mangrove swamps, rice intercropping with vegetables, the crue and decrue systems of matching varieties of appropriate harvest maturity and resistance to rising and falling flood waters of the great West African rivers—these are just a few of the innovative methods developed by traditional African farmers. Many of the methods still are being used today. These methods could have evolved, in part, due to the need for combatting pests. Studying them under actual farmers' field conditions is therefore important.

Extension could use the farmers' fields as demonstration sites, and could organize demonstrations of emerging new practices in other areas where conditions are similar. This accelerated pace of research and extension could lead to a more rapid increase in agricultural production. Inevitably, too, the spinoff in enhanced mutual respect engendered between officials and farmers would produce additional benefits in production through greater career interest and farmers' cooperation. As Brammer (1980) stated, failure to include farmers in development efforts is " a waste in opportunity... for a mutual interest in finding solutions to agronomic problems."

LITERATURE CITED

Anon. 1974: FAO report of an ad hoc session of the FAO Panel of Experts on Integrated Pest Control. Rome, October 15-25. 24 p.

Anon. 1978. Proceedings, Short Course on Integrated Pest Control for Irrigated Rice in South and Southeast Asia, held in the Philippines, October 16-November 18.

Bottrell, D.G. 1979. Integrated pest management. Council on Environmental Quality. U.S. Govt. Printing Office. 120 p.

Brader, L. 1979. Integrated pest control in the developing world. Ann. Rev. Entomol. 24: 225-254.

Brader, L., E.J. Buyckx, and R.F. Smith. 1980. Past and present activities of the FAO/UNEP Panel of Experts on Integrated Pest Control. Bul. Entomol. Soc. Amer. 26: 432-435.

Brammer. 1980. Some innovations don't wait for experts. Ceres. March-April. FAO, Rome. p. 24-28.

Chapin, G , and R. Wasserstrom. 1981. Agricultural production and malaria resurgence in Central America and India. Nature 293: 181-185.

Food and Agriculture Organization of the United Nations. 1979. Guidelines for integrated control of rice insect pests. FAO Plant Production and Protection Paper 14, Rome. 115 p.

Glass, E. H., and H. David Thurston. 1978. Traditional and modern crop protection in perspective. BioScience 28: 109-115.

Haskell, P. T., T. Beacock, and P. J. Worthy. 1979. Worldwide socio-economic constraints to crop protection, p. 39-41. Proceedings of Symposia, IX International Congress of Plant Protection, Washington, D.C., August 5-11, 1979. Vol. 1, Plant Protection: Fundamental Aspects. Copyright, Entomol. Soc. Amer. Burgess, Minneapolis.

IOBC. 1981. Conference on future trends of integrated pest management, Bellagio, Italy, May 30-June 4, 1980. IOBC Special Issue Int. Organ. Biol. Control Noxious Animals and Plants. Centre for Overseasc Res., London. 75 p.

Kiritani, K. 1979. Pest management in rice. Ann. Rev, Entomol. 24:279-312.

Metcalf, R.L. 1980. Changing role of insecticides in crop protection. Ann. Rev. Entomol. 25:219-256.

National Academy of Sciences. 1977. Insect control in the People's Republic of China. CSCPRC Rep. No. 2. Nat. Acad. Sci. 210 p.

Smith, R.F., and R. van den Bosch. 1967. Integrated control, p. 295-340. In W.W. Kilgore and R.L. Doutt (Eds.), Pest control--biological, physical, and selected chemical methods. Academic, New York.

Stern, V.M., R. F. Smith, R. van den Bosch, and K. S. Hagen. 1959. The integrated control concept. Hilgardia 29:81-101.

Young, W.K. 1979. Pest control in the developing counteries--now and in the future, p. 27-29. Proceedings: Opening session and plenary session symposium. IX Int. Congress Plant Protection, Washington, D.C.

AGROECOSYSTEM TEAM REPORTS

INTRODUCTION

Of all food crops, rice has the greatest capacity of adapting to the most varied ecological conditions. Cultivation of rice in West Africa ranges from the coastal humid tropical areas with slight changes in temperature and long heavy monomodal rains to the dry Sahelian areas of the north with strong daily and seasonal temperature fluctuation and very short monomodal rains. Based on the water regime, five types of rice cultivation exist. These are rainfed upland, irrigated and lowland swamps, mangrove swamps, deep-flooded and floating rice ecosystems.

With such a diversified ecosystem, it is to be expected that pressures exerted on the crop by both the biotic and abiotic components of the environment will similarly vary. In the case of pests, differences exist in terms of prevailing pest species and also in their relative severity.

Course participants were organized into three teams; upland rice, irrigated rice and mangrove rice with the aim of pulling their experiences together in order to develop status reports and recommendations concerning present state of knowledge, research requirements, training needs, regional and local, and needed mechanisms to improve dialogue among rice specialists working in the various agroecosystems. Regretably, there was no team report on deep-flooded and floating rice since none of the participants claimed to work on that ecosystem. This is a pointer to the fact that very little is known about the ecosystem.

Reports submitted by the three teams are presented in the next few pages.

REPORT OF THE IRRIGATED RICE ECOSYSTEM TEAM

"IRRIGATED RICE AGROECOSYSTEM IN WEST AFRICA: PROSPECTS FOR THE DEVELOPMENT OF AN INTEGRATED PEST MANAGEMENT PROGRAMME"

INTRODUCTION

Rice is the major staple food in West Africa. There is a constant increase in demand for rice because of several reasons. There is a continuous upward trend in population growth. Worker income has increased over the years. Because these factors have put greater demands on rice production its supply has always fallen short of demands. For example, in 1980 the total amount of rice available for consumption in the WARDA region was 1,674,000 tons whereas consumption amounted to 2,987,000 tons. The amount imported in the same year was 1,313,000 tons. To reverse this trend, a lot could be done in terms of management. Bringing new land under cultivation, particularly for irrigated rice, would mean considerable investment. But this investment could prove useful in the long run because of the promise this method of rice culture holds for increasing production. Irrigated rice is grown throughout the region and this ensures maximum utilization of our water resources. Inputs required for cultivation and crop management are costly and this calls for a search for new and better approaches that would enable farmers to derive stable yields from their plots in as economical a manner as feasible.

GOVERNMENT POLICY ON RICE PRODUCTION

Seeing the importance of rice as a staple food crop, Governments have generally shown keen interest in the increased production of this crop. This interest is demonstrated by the amount of help given by the various governments to farmers engaged in rice production.

In some countries the government is responsible for land preparation, supply of fertilizer to farmers, and pest control operations, and these services are paid for by the farmers at highly subsidized rates after harvest. The harvested rice is sold to governmental agencies - as in Upper Volta and Ghana - at fixed prices. Seed multiplication and distribution are also usually the responsibility of the governments acting through seed multiplication units. In Upper Volta, however, seed multiplication and distribution are done by selected farmers. Advice to the farmers regarding rice production is given by government extension agents.

The importance governments attach to rice production is also evidenced by the presence in the region of bilateral and international agencies involved in promoting increased rice production. Such agencies, like the West Africa Rice Development Association (WARDA), United Nations Agency for International Development (USAID), Food and Agriculture Organization (FAO), Canadian International Development Agency (CIDA), Organization de Mise en Valeur la Fleuve Senegal (OMVS), the World Bank, and the Peoples Republic of China, provide financial support for projects related to rice production. These agencies also provide high level personnel under whom the host country counterpart personnel receive training and work experience. Training farmers in the methods of rice production is - in some cases - another task undertaken by these personnel. Governments hosting or cooperating with these agencies contribute certain amounts of money as well as counterpart personnel for the implementation of these projects.

These efforts by governments are, nevertheless, not without their setbacks. There are loopholes in communication with the farmers. Qualified personnel and machinery adapted for our conditions are lacking. There is sometimes poor coordination of efforts between national governments and cooperating bilateral and international agencies. Agricultural credit to farmers is inadequate and at times non-existent. The marketing structure is disrupted in some countries where farmers sell their rice to government agencies at low prices fixed by these agencies. Seeing this as a major disadvantage, such farmers would rather sell their produce to private individuals and non-governmental concerns. Moreover, poor infrastructure makes marketing a problem to reckon with.

METHODS OF RICE PRODUCTION

Irrigated rice is grown on small individual plot generally ranging in size from 0.3 - 2.0 hectares. Preparation of land is carried out with the aid of tractors, power tillers, OX-drawn ploughs, and also manually with hand hoes. Seedling are grown on prepared nurseries, usually located in the vicinity of the rice fields. When seedlings are big enough to be transplanted the seed beds are properly watered the day before their removal to facilitate removal. The seedlings are transplanted manually in rows. Planting is usually staggered in most countries, but in Nigeria and some parts of Senegal, synchronized planting is practised. Irrigated areas are characteristically located near water reservoirs like rivers, dams, tributaries, lakes and lagoons, which act as the principal sources of water.

Water is conveyed to rice fields with the help of water pumps and in some cases through gravitation. Since proper water management is an important part of irrigated rice production, water level is regulated according to the growth stage of the crop. During times of fertilizer and pesticide application, the quantity of water needs to be strictly regulated to achieve good results. Improved rice varieties, adapted for irrigated conditions and selected and recommended by local research institutions, are grown. Harvesting is done manually with knives or sickles and threshing is carried out with foot-operated threshers or by beating. The crop cycle ranges from 1-2 per year.

PEST PROBLEMS

Key Pests

Insects:

Stemborers (*Chilo* sp., *Maliarpha* sp.) *Diopsis* sp.
Gall Midge (*Orseolia oryzae*) - in Upper Volta.

Birds:

Quelea quelea (in all the countries except Gambia, Mauritania and Guinea Bissau)

Ploceus cucullatus
Golden Sparrow - in Northern Nigeria.

Diseases:

Pyricularia oryzae

Weeds:

Cyperus sp.

Oryza longistaminata (in Mali, Senegal and Gambia.

<u>Occasional Pests</u>

<u>Insects:</u>

Grasshoppers
Locusts
Adelpherupa sp.
Scirpophaga sp.
Riptortus sp.
Rice stink bugs
Rice hispa

<u>Potential Pests</u>

<u>Insects:</u>

Sesamia sp.
Nymphula sp.

<u>Diseases:</u>

Helminthosporium
Xanthomonas transluscens
Rice Yellow Mottle Virus (RYMV)

It is important to note that varying intensities of these pest problems exist in the region because of differences in annual rainfall, temperature and humidity, factors that influence the abundance and distribution of different pest species. In Mauritania, for example, it is interesting to know that insect pest and disease problems are minimal relative to other parts of the region.

CURRENT CONTROL MEASURES

Generally chemical control is practised. In certain countries chemical application on the farmers' fields is done free of charge, except in Ghana and Upper Volta where farmers pay for these services in cash at subsidized rates. In Guinea Bissau, Mali and Senegal spraying is done, and in Gambia and Nigeria by spray brigades only. Some of the insecticides in common use include fenitrottion, malattion and diazinon. Fenttion and racciumin are used in Nigeria for bird and rodent control respectively. Certain cultural control methods are practised by farmers. These include delaying planting time, ploughing or tillage, pulling out ratoons and feeding crop residue to livestock, burning crop residue and hand pulling for weed control. Resistant varieties are used in some parts. These include Ikong Pao and Durado Precoce which show resistance to blast.

DEVELOPMENT OF AN IPM PROGRAM

In an attempt to develop an effective and viable Integrated Pest Management Program for irrigated rice culture in the region we need to ask ourselves certain questions. Why is there a need for IPM in the region? What approaches are we going to take to implement such a pest management program? To answer the first question it is evident that irrigated rice culture requires a considerable amount of investment. Inputs are becoming more and more expensive. There is a need to reverse the continuing heavy reliance on chemical pesticides in order to create a healthy environment and thereby prevent hazards to humans, livestock, wildlife and fish.

In addition to high costs, chemical pesticides create problems like pests resistance, secondary pests and pest resurgence. It is therefore almost imperative to develop and implement a pest management program that is not only cost-effective but also capable of increasing rice production in the region with minimal environmental disruption. This goal IPM would serve as a good candidate.

To provide an answer for the second question it is important to note that in order to develop and implement an effective and successful Integrated Pest Management program the principles and concepts involved should be well understood. Having identified the real or key pest problems it is important to establish a knowledge of the irrigated rice agroecosystem and how its different components interact. In developing tactics the farmer should be at the centre of the program. Teaching him the various control options, with cultural practices as the core of the program, and performing field trials on his farm would serve as valuable tool in evaluating the economic and sociological components of the program. Organizing the farmers into groups under the supervision of extension agents would be a means of selling IPM to the farming community, for this will serve as a mechanism that assures group planning and action in any given pilot area. The exploitation of other mass comminication media such as the radio could be done to give an added dimension to stir up interest among the farmers.

The role of pest surveillance and forecasting in IPM programs is of tremendous importance. An effective program would call for the establishment of surveillance and forecasting systems on national or subregional scales that provide reliable information. There will also be a necessity to create quick and efficient delivery systems for the timely acquisition of inputs and delivery to target areas. An evaluation system with a set of Criteria would also need to be set up to determine the degree of success of the various tactics employed.

Evidently research cannot be divorced from an IPM program. Inter-disciplinary cooperation between entomologists, plant pathologists, nematologists, weed control specialists and other specialists is desirable for a proper coordination of efforts. Studies into life histories of pests, determination of economic thresholds, evaluating the role of natural mortality agents and breeding for pest resistance including biocontrol are some of the research activities that can be carried out to support IPM.

The implementation of IPM cannot be done in the absence of a crop of trained manpower. Short and long term training on specialized aspects of IPM is imperative for the success of IPM in the region.

CONSTRAINTS TO IPM AND THEIR POSSIBLE SOLUTIONS

There is no doubt that obstacles exist in attempts to develop an IPM program for irrigated rice in the region. There is a scarcity of adequately trained manpower and materials needed to carry out a successful pest management program.

The farmers who should be at the Centre of the program are not well trained and dialogue with them is necessary to convince them to embrace the practice of pest management. There is little or at times no communication or coordination of efforts by the different specialists whose interdisciplinary cooperation is vital in the smooth running of IPM programs. Economic thresholds, one of the major supportive tools of IPM are not established and it will require some time and effort before these are established for major rice pests in the region. The information delivery and extension networks are in most cases ineffective. The presence of spray brigades and the practice of providing free pesticide applications for the farmers are also major obstacles.

To cub these obstacles training for Crop protection personnel, spray brigades and farmers needs to be intensified. Communications between various specialists should be strengthened and more attention given to improving the information delivery and extension networks.

CONCLUSION

The importance of rice as an important food crop in our region cannot be overlooked. With the ever-increasing population the demand for rice is going to continue to rise. Consequently there is an imperative need to adapt practices that can assure not only increased production but also self sufficiency in the WARDA region. Irrigated rice is promising in this regard because of its high yield potential. But to ensure a steady and continuous increase in yield we need to keep a watchful eye on insect pests, diseases, weeds and other pests which compete with us for much of what we grow.

The current approaches to controlling these pests, which place increasing emphasis on chemical pesticides, are usually expensive and environmentally undesirable. It is therefore logical and worth the while to try a pest management system that is economical as well as safe for our environment.

RECOMMENDATIONS

The irrigated rice agroecosystem team has adopted the following recommendations:-

- Training -- both local and overseas - should be provided for IPM research and extension personnel and farmer-education on the principles and concepts of IPM initiated. Seminars and Workshops on IPM should be further encouraged by international agencies engaged in rice production such as WARDA, so that such activities could act as a forum where various specialists working in various agroecosystems could exchange information and formulate better IPM strategies.

- Research relevant to Integrated Pest Management should be supported and encouraged by all countries in the region as well as organizations like WARDA.

- Governments in the region should establish and strictly apply phytosanitary regulations.

- All attempts should be made to inform and convince competent administrators and politicians about the concepts and benefits of IPM.

- Extension services and input delivery systems should be improved to ensure better information delivery and availability on inputs needed for executing IPM programs.

- Water Management should be properly mastered and carried out as is required for the better management of the irrigated rice crop.

CONTRIBUTORS TO THIS REPORT

MARK UKWUNGWU	-	Nigeria
SAWADOGO ABDUSSALAN	-	Upper Volta
SANKUNG B. SAGNIA	-	Gambia
BABOULARR CHAM	-	Gambia
MORO TRAORE	-	Mali
OUMAR BARRY	-	Senegal
ALFREDO JOSE DA SILVA	-	Guinea Bissau
SAIMARE ABDOULAYE	-	Mauritania
KWASI ANPOFO	-	Ghana
DAUDA ALIYU GARKIDA	-	Nigeria.

MANGROVE SWAMP RICE AGROECOSYSTEM IN WEST AFRICA: PROSPECTS FOR AN INTEGRATED PEST MANAGEMENT PROGRAM

COMPILED BY . SAHR N. FOMBA - Sierra Leone
CAMILO BALDIE - Guinea Bissau
AUGUSTINE A. CHILAKA - Nigeria
ANGELA EJALE (Miss) - Nigeria
WIALLIAM SETTLE - USAID/Senegal

INTRODUCTION

Mangrove Swamp rice cultivation constitutes one of the several types of rice agroecosystems in West Africa. In relative terms however, only about 100,000 ha out of 2.3 million hectares of riceland is grown to this type of rice culture with the potential for further development several times more than that already developed. The importance of this rice agroecosystem varies in importance from one country to the other; in Guinea Bissau about 80% of rice cultivation is mangrove, whereas in Sierra Leone, only about 4-5% of the total area sown to rice is of this type. Other countries with mangrove swamp rice cultures are Senegal, the Gambia, Guinea-Conakry and Nigeria. The Scarcies Rivers Basin of northern Sierra Leone constitutes one of the most intensely cropped riceland in the West Africa subregion under peasant level technology. Although the present proportion of riceland in the subregion accounted for by mangrove swamp is small it could assume greater importance in the future when more virgin mangrove forests, for example in Southern Sierra Leone and in Nigeria are developed for rice cultivation, particularly with the inherent stability in yields provided adequate cultural practices aimed at conserving soil fertility with minimum disturbance of the delicate balance in the ecosystem, are observed.

But in order to improve on the present level of productivity of these swamps in the sub-regions, the following universal constraints must be solved:- (1) inadequate labour at peak seasons; (2) availability of credit facilities/inputs during operation times; (3) suitable varieties with requisite resistance to the pest and soil problems of this ecosystem; (4) adequate extension services; (5) transportation on land and water must be made accessible and adequate; (6) relevant research addressed to problems on the farmer's fields, must be carried out.

I: GOVERNMENT POLICY ON RICE PRODUCTION

The stimulus to rice production is sound Government Policy. Government policy on rice production varies from one country to the other and this is not exclusive to any one type of rice culture considering the diverse nature of West African rice lands except in some countries where limitation of climate, and consequently soil types limit production to one major type e.g. Guinea Bissau with mainly mangrove type rice cultivation. The government can influence rice production either through direct production by use of state farms or by supporting agricultural development projects which have rice as one of the component crops ro by direct assistance to private farmers through the mechanism of credits and provision of inputs; or by encouraging cooperating farming practices.

But one of the most important mechanisms of stimulating rice is through marketing policy. The government stipulated pricing policy may either serve to stimulate or depress rice production depending on whether the prices being offered are strong incentives to farmers to grow more.

The government can also stimulate rice production through provision of requirable infrastructures such as good networks of feeder roads so that farmers could bring their produce to markets in the urban centres; good storage and milling facilities and standard measures for retailing the produce. Apart from pricing policy the private sector can also provide good milling facilities provided good returns are realized from these ventures, for example, in Sierra Leone. The overall effect of sound pricing policy is not only to stimulate rice production and achieve self-sufficiency but also to conserve scarce foreign exchange by cutting down or eliminating importation of rice. The government can also significantly stimulate rice production by supporting relevant research activities and by establishing an efficient information and extension service. This will aid in educating the farmers on the innovations and findings being evolved by the research sector/department. The extension personnel will also deliver such inputs as fertilizers, pesticides on time and instruct on their proper use. While the above is far from exhaustive it should give an idea on how a sound government policy on production will go a long way towards meeting the national objective of self-sufficiency in rice production, where this is feasible, economically.

II. METHODS OF PRODUCTION

In the mangrove swamp ecology the initial clearing of the virgin forest is a capital and labour intensive operation. How this is done varies from country to country. For example in Sierra Leone, the whole operation is in the hand of individual farmers. Government assistance in meeting the cost of the operation will go a long way in increasing the area cultivated for rice, particularly in the south of the country. With respect to Nigeria which has vast areas of untapped mangrove forest, the land clearing is a government operation. After the initiation land clearing of the original vegetation, mainly Rhizophora and Avicenia spp., the land is left to fallow so that the stumps and vegetation could rot that is under the traditional land clearing methods, before rice is planted there. Mechanical clearing is hampered on the other hand by the soft nature of the soil which prevent the use of heavy machinery.

Land preparation is by the hoe, usually with a long handle in the case of Sierra Leone. Labour is often hired for this purpose. Usually only ploughing is done; but occasional harrowing is also observed. Under experimental condition a single axle power tiller has been found to be very effective in cultivating the land. In Northern Sierra Leone, farmers showed a great deal of enthusiasm for this innovation particularly as it cuts down the amount of labour and aids weed control. Water control is practised in some mangrove swamp areas, e.g. Guinea Bissau either by building dykes or by ridging.

In Sierra Leone, mangrove swamps as well as in Nigeria, limited or no water control is practised on farmers fields. The advantage of water control is that more crops of rice could be grown per year. On the other hand, drying up of mangrove soils could lead to problem of acidity and other toxicity related problems.

Mangrove swamp rice is transplanted rice; nurseries are often prepared on dryland and uplands under rainfed conditions, in semi-wet condition where ground water level is high or in wet nursery beds. The latter needs stringent water control, and is the least used by farmers, if used at all. In Sierra Leone, the first two types of nurseries are generally found. The nurseries are usually prepared between May and June with transplanting taking place in July - August or even September/October. In Guinea Bissau, transplanting takes place in July provided sufficient rains have fallen to back the salts. In Nigeria, transplanting is done in June - July. Age of seedlings at transplanting varies between 4-8 weeks, depending on the country and traditional practice used by the farmers. Generally after transplanting which is a labour-intensive operation, a slack period occur between October/November in the case of Sierra Leone. However, limited weeding is practised in the associated swamps. In Guinea-Bissau, constant watch is kept on dykes and these are repaired as the need arises so as to preclude entry of salt water into the paddies.

Harvesting is usually carried on in December/ January. This is done by cutting panicles with a scythe .

The harvested crop is tied into sheaves and stock on temporary raised mounds in the swamp. Sometimes it is threshed there before transported for final storage in the village or taken to urban centres for further processing, for example, parboiling and milling. Harvesting is another labour-intensive operation, often necessitating the presence of the farmer on the field in temporary abodes until it is completed. The produce is transported by head or river transport to the villages from the swamps.

III. PEST PROBLEMS

A pest is an organism that adversely affects the rice plant such that it suffers damage to either its vegetative parts, e.g. stem, leaves, rots or its reproductive organs, causing a reduction in yield or grains or quality of the grains. Pests can be classified into three categories as follows: (a) key pest(s); (b) potential pest(s); and (c) occasional pest(s).

A key pest is one that causes economic damage, year in, year out, and therefore should be controlled, for example crabs in Sierra Leone and Guinea Bissau; seedling blast (*Pyricularia oryzae*) in nursery beds of Sierra Leone and *Helminthosporum oryzae* in the field; possibly *Maliarpha separabella*, and weed Paspalum vaginatum in Sierra Leone. A potential pest is one that is already present in the ecosystem but does not appear to be doing economic damage under the present level of technology.

For example, the stemborers, leaf hoppers and leaf eaters in general; several fungal diseases such as leaf scald (Rhynchosporuim oryzae), narrow brown leaf spots (Cercosporea oryzae), sheath blight (Corricuim tasalaii) sheath rot (Acrocylindrium oryzae) and udbalta (Eshalis pallida) and birds. An occasional pest occurs infrequently but when it does so often economic damage is caused for example armyworms (Spodoptera spp.) on nursery beds and the caseworm (Nifuphulu depunctalis) in the swamps, particularly where standing water is pund.

IV. CURRENT CONTROL METHODS OF PESTS

A control method is the practice or a combination of practices which is used to reduce the damage caused by a pest. Under the present level of farmer's technology, two main control practices can be identified thus: (a) varietal resistance, through the use of local varieties which have more or less coevolved with the pest populations or selected for adverse soils; and (b) cultural practices which reduce the level of infestation or infection by pests. For example, the growing of eight weeks old seedlings in most mangrove swamps of Sierra Leone helps to reduce the damage to seedlings by crabs; crabs damage younger seedlings by shredding the stem. The building of bunds in Guinea Bissau and the neighbouring countries in the northern mangrove swamps of West Africa, prevent salt water from entering the paddy fields, thus protecting the plants from the effect of salinity. Salt tolerance is also often found in local cultivars.

Similar protection is provided by growing rice on ridges such that the root zone does not reach the toxic salts. In the dry season, the water is let into the fields and this suppresses the level of weed infestation, in Guinea Bissau.

Generally weed control is achieved by thorough land preparation using hoes with long handles, in the case of Sierra Leone. Water control is not practised as such in Sierra Leone. Date of planting is also very important. Since most varieties grown in this ecosystem are photoperiod sensitive, they all come to flowering at more or less the same time. Thus damage caused by birds is spread over the entire area.

Pesticide application with the exception of Guinea Bissau, and perhaps the Sene Gambia, is not widely used in this ecology. In Guinea Bissau, spray brigade of the crop protection unit often sprays with malathion at the rate 0.4 kg a.i./ha. Whether this rate of application is based on sound ecological reasons and economic thresholds is not known for certain. In experimental plots, several weedicides and insecticides have been tried in several places. The use of Carbofuran granules to control stemborers, such as pretreatments on nursery beds prior to transplanting has been tried. Considering the dynamic nature of this ecosystem with twice daily flooding in the case of Sierra Leone mangrove rice fields and the potential for environmental hazards and concern for human health, any large scale use of pesticide should be based on the least dangerous methods of application; and minimum rates of application. Judicious use of fertilization to avoid build up of pests in all categories should be recommended.

V. DEVELOPMENT OF AN INTEGRATED PEST MANAGEMENT PROGRAM (IPM)

An integrated pest management program can be defined as the control practice which uses sound ecological principle, level of economic damage caused by the pest, and takes cognizance of consequence of this package of control measures on society. The shift towards the development of IPM program has become even more urgent because of the development of pesticide resistant biotypes and strains of pests and pathogens thus leading to the problem of resurgence of key pests after they have been controlled only for short periods. Indiscriminate use of pesticides in an ecosystem also leads to killing of beneficial insects and predators thus allowing build up of potential pests into key pests. Environmental hazards such as pollution of rivers, which in our situation not only provide water for drinking but also as a major source of our protein diet, and actual effect on the health of the human population, make the development of IPM programmes which aim at minimizing pesticide use, even more imperative. The mangrove swamp rice agroecosystem provides an ideal condition for the development of IPM programs because (a) a considerable stability already exists in the host/pest relationship; (b) cultural methods for managing the ecosystem have already been evolved by the farmers themselves and (c) the use of local cultivars with high level of adaptable characters to the pests and adverse soil environment of this ecosystem already exists.

However, to make this rice ecosystem more productive, some innovations such as the use of improved varieties with suitable characteristics, use of nitrogen fertilization and other relevant practices will have to be encouraged.

In order to set up an IPM program in the mangrove rice agro-ecosystem, a thorough survey should be done to establish a clear picture of the best situation on farmers' fields. This will enable us to define what the key pests are; this information together with information on the national enemies of the key pests will enable us to proceed to defining the economic thresholds and economic injury level or rough estimates of these. Further information on the socio-economics factor relating to the forming community such as size farm family, availability of labour outside of the family credit facilities, inputs (pesticides) and status of government extension services, should enable us to establish a sound IPM program. In the mangrove swamp rice agroecosystem for an IPM program to succeed with minimum costs to the ecology the core practice should be the use of resistant variety (with stable resistance with cultural control practices, biological control and minimum use of pesticide as the secondary control measures. This will most likely minimise disturbing the equilibrium that more or less exists between host/pest combinations under farmers field condition.

VI: CONSTRAINTS TO INTEGRATED PEST MANAGEMENT AND THEIR POSSIBLE SOLUTIONS

To be able to apply an IPM program, a certain level of education is necessary. The basic principles of an IPM program must be communicated to the farmer. It is also necessary to stop indiscriminate spraying of pesticides without first establishing what the key pests are and when it is necessary to apply a control measure, that is defining the economic threshold and economic injury level. One way to effect a change in the indiscrimanate use of pesticides is to remove subsidies on them. Free pesticides means more use of pesticides because the farmer is not paying for them. Failure of extension workers nurture confidence of farmers in them; this can be avoided if extension workers are more reliable. Availability of relevant research data on optimum rates of application, methods of application, and frequencies of application, of pesticides, are also obstacles to development of IPM programs. Often chemical companies (and Barkers) promote sale and use of pesticides without consideration to actual needs. The chemical companies will still be in business even if IPM programs are established, but perhaps more selective chemicals with less deletorious effects on beneficial insects and Predators and on the environment, will have to be developed. The use of obsolete spraying equipment will have to be discouraged so that only required doses of pesticides are applied. Time of operation will also have to receive considerable attention in order of application of pesticides.

VII: CONCLUSION

An integrated pest management program can be established in the mangrove swamp rice agroecosystem because farmers already practise a sound cultural control and use of locally adapted varieties, for example P So Kent, Pa Nylon, and ATANHA. The use of improved varieties with adequate resistance and quality grains for example, CP 4, ROK 5, BD 2, and RH 2 is gradually gaining grounds. In Guinea Bissau, ROK 5 is reported to be very popular. But any use of pesticides will have to be minimumin order not to disturb the delicate host/ pest balance already in existent and to avoid polluting the environment.

VIII: RECOMMENDATIONS

(a) Training: IPM programs require trained specialists, in order to continue to formulate and devise effective means of implementation. Farmers also require training in the principles and pratice of IPM programmes. However, this should be simple enough for them to comprehend without compromising the fundamental principles. Workshops should be organized to bring together farmers, extension workers, research workers and policy makers for better communication and understanding of each others problems and how to solve them.

(b) Research Requirements

To make IPM effective, research program should be multidisciplinary so as to include a Plant Breeder, Plant Pathologist, Entomologist, Weed Scientist, Soil Scientist, Agricultural Economist; Agronomist/Extension Specialist and a Social Scientist.

This should facilitate a realistic approach to solving farmers' problems and make for a sounder IPM program. Collaboration at national, regional and international levels should be encouraged in order to make better use of scarce resources and more effective IPM programs.

(c) Other Requirements

Credit facilities should be provided for the purchase of needed inputs such as fertilizers. Development of virgin mangrove swamps should either be undertaken by government or subsidized by government when done by individual farmers because it is capital intensive. Transportation should be developed both on land and water. Pricing policy should be equitable so as to encourage farmers to grow more rice and thus reduce importation with a consequent saving in foreign exchange. Adequate publicity through mobile cinemas (where available), radio, television, posters and news papers on the merits of IPM program should be launched/mounted. Importation of pesticides from advanced countries should be done only when recommended by a competent research organization. Studies on the application rates, frequencies of application, toxicity, retention in the environment under tropical conditions should also be carried out; effect on beneficial insects and predators should also be monitored and assessed.

Central to the practice of an IPM program is the establishment of an economic threshold and economic inqury level for the key pest(s). These values should be revised and improved upon as conditions changes since host/pest relationship is a dynamic one.

(d) Mechanisms of Dialogue among rice specialists

In order to promote communication and dialogue among rice specialists (a) seminars and (b) workshops should be organized from time to time. This will bring together researchers, extension workers and policy matters and enable them to formulate new ideas and improve on existing IPM programs.

ACKNOWLEDGEMENTS

We gratefully acknowledge the use of several sources for the information contain herein, particularly WARDA publications.

DISCUSSION

1. A question was asked whether crabs were edible and their possible cropping. It was observed that there was some prejudice against eating some crabs in Sierra Leone. This was thought to indicate low social status. However, in Guinea Conakry and Guinea Bissau, all the crabs were edible. On the question of cropping crabs, there was nothing being done but since they are abundant in this ecology, they must be well adapted, and hence their large numbers.

2. A question was asked on varietal resistant studies on crabs. It was noted that varieties with tough sheaths could tolerate crab damage better than those varieties with sapple sheaths, e.g. CP 4 (tolerant) and Pokali (susceptible).

PROGRAMME FOR THE SHORT COURSE ON RICE INTEGRATED PEST MANAGEMENT IN WEST AFRICA 10-28 JANUARY, 1982

9-10 January (Saturday & Sunday)

Arrival and Registration of participants.

11 January (Monday)

Opening Ceremonies

08.30 - 09.00	:	Registration.
09.00 - 09.15	:	Welcome address - Mr. D.K. Awute, Director of Training.
09.15 - 09.30	:	Orientation to WARDA objectives in relation to Training - Mr. Sidi Coulibaly, Executive Secretary.
09.30 - 10.00	:	Administrative matters, Travel, Finance/ Food/Dormitory Services, Health/ Recreation facilities - Mr. E. Cole, Acting Chief, Training Centre.
10.00 - 10.30	:	B R E A K
10.30 - 11.00	:	Objectives of the course modus operandi - Dr. E. A. Akinsola.
12.00 - 13.30	:	L U N C H
13.30 - 14.30	:	Origins of IPM - Dr. D.G. Bottrell
14.30 - 15.00	:	B R E A K
15.00 - 16.00	:	The Importance of IPM in Rice Production in West Africa - Dr. E.A. Akinsola.
16.00 - 17.30	:	Meeting of Implementation Committee.

12 January (Tuesday)

09.00 - 10.00	:	Experience with Green Revolution in Rice in South East Asia - Dr. P. Kenmore.
10.00 - 11.00	:	Discussion
11.00 - 11.30	:	B R E A K

12 January (Tuesday)

11.30 – 12.30	:	Methods of Plant Disease Control Dr. M. Thomas.
12.30 – 14.00	:	L U N C H
14.00 – 16.00	:	Categories of Insect Pests/Key Pest Concept – Dr. P. Matteson.

13 January (Wednesday)

09.00 – 10.00	:	Categories of Plant Diseases: Nature and Causes – Dr. O. Esuruoso.
10.00 – 11.00	:	Influence of Environment on Distribution and Dissemination of Plant Pathogens – Dr. O. Esuruoso.
11.00 – 11.30	:	B R E A K
11.30 – 12.30	:	D i s c u s s i o n
12.30 – 14.00	:	L U N C H
14.00 – 15.00	:	Methods of Insect Pest Control – Dr. M. Ndoye.
15.00 – 16.00	:	Integrated Weed Management in rice in West Africa – Mr. W. Godderis.

14 January (Thursday)

09.00 – 11.00	:	Weed Collection and Identification – Mr. Godderis/Akobundu.
11.00 – 11.30	:	B R E A K
11.30 – 12.30	:	Major weeds in Rice Ecosystems in West Africa – Dr. Akubundu.
12.30 – 14.00	:	L U N C H
14.00 – 15.00	:	Methods of Weed Control with special emphasis on non-chemical methods – Dr. Akobundu.
15.00 – 16.00	:	Weed collection and Identification continued.

15 January (Friday)

09.00 - 10.00	:	Principles of IPM - Dr. D.G. Bottrell.
10.00 - 11.00	:	Crop Loss Assessment, Economic Injury Levels and Economic thresholds - Dr. P. Matteson.
11.00 - 11.30	:	B R E A K
11.30 - 12.30	:	D i s c u s s i o n
12.30 - 14.00	:	L U N C H
14.00 - 15.00	:	The Importance of Population Dynamics; Monitoring and Damage assessment - Dr. P. Kenmore.
15.00 - 16.00	:	Examples of experimental approaches to the assessment of yield losses in crops due to plant diseases. - Dr. M. D. Thomas.

16 January (Saturday)

09.00 - 13.00	:	Sum-up weeks activities what was accomplished - Dr. B. Ouayogode.

17 January (Sunday)

Free Day

18 January (Monday)

09.00 - 10.00	:	Assessment of rodent damage in field rice and rodent control procedures - Dr. O. Funmilayo.
10.00 - 11.00	:	Assessment of bird damage in field rice and bird control procedures - Dr. O. Funmilayo.
11.00 - 11.30	:	B R E A K
11.30 - 12.30	:	Status of crop protection in West Africa - Dr. R. Kumar.
12.30 - 14.00	:	L U N C H
14.00 - 15.00	:	Pesticide use in IPM programmes - Dr. C. M. Smith.

15.00 - 16.00	:	Management of natural enemies in IPM programmes -- Dr. Peter Kenmore.

19 January (Tuesday)

09.00 - 10.00	:	Promising alternative approaches to pest control -- Dr. C. M. Smith.
10.00 - 11.00	:	Principles of host plant resistance to insect pests - Dr. Dabrowskt.
11.00 - 11.30	:	B R E A K
11.30 - 12.30	:	Principles of host plant resistance to plant diseases - Dr. Notteghem.
12.30 - 14.00	:	L U N C H
14.00 - 15.00	:	Host plant resistance as a component of IPM - Dr. Notteghem.
15.00 - 16.00	:	The limitations and benefits of pesticides - Dr. P. Matteson.

20 January (Wednesday)

09.00 - 10.00	:	Integrated Pest Control in Rice Production in the Sahelian Sudan: Prospects and Possibilities for research - Dr. J. Breniere.
10.00 - 11.00	:	Lepidopterous Borers of rice in West Africa: Biology, Damage and Control - Dr. J. Breniere.
11.00 - 11.30	:	B R E A K
11.30 - 12.30	:	The major pest problems of irrigated, upland and mangrove swamp rice ecosystems in the humid tropical, Guinea savana and Sahel climate zones - Dr. M. Agyen-Sampong
12.30 - 14.00	:	L U N C H
14.00 - 15.00	:	Status and prospects of rice integrated pest management in the humid tropical zone - Dr. M. Agyen-Sampong.
15.00 - 16.00	:	Trends and needs in breeding rice for host plant resistance - Dr. Z. Dabrowski.

21 January (Thursday)

09.00 - 10.00 : The impact of pesticides on human health and the environment - Dr. P. Matteson.

10.00 - 11.00 : Establishing and using economic threshold - Dr. D.G. Bottrell.

11.00 - 11.30 : B R E A K

11.30 - 12.30 : Sampling methods for rice insects - Dr. M. Agyen-Sampong.

12.30 - 14.00 : L U N C H

14.00 - 15.00 : The concept of agro-ecosystems and the rice agroecosystems of West Africa - Dr. A.O. Abifarin.

15.00 - 16.00 : Morphology and growth stages of rice - Dr. A.O. Abifarin.

22 January (Friday)

Field trip to Central Agricultural Research Institute, Suakoko.

23 January (Saturday)

Meeting of Agroecosystem teams.

24 January (Sunday)

Free Day

25 January (Monday)

09.00 - 10.00 : Sampling methods for rice diseases. - Dr. V.A. Awoderu.

Preparation of rice agroecosystem team reports and recommendations.

26 January (Tuesday)

09.00 - 12.30 : Sampling procedures - Dr. M. Agyen-Sampong, Dr. Akinsola and Mr. Bangura etc.

12.30 - 14.00 : L U N C H

14.00 - 15.00 : Cultural methods available for controlling rice insect pests and diseases - Dr. C.M. Smith.

27 January (Wednesday)

08.00 - 09.00	:	IPM in rice in South-Southeast Asia - Dr. P. Kenmore
09.00 - 10.00	:	The movie "The Insect Alternative"
10.00 - 10.30	:	B R E A K
10.30 - 12.30	:	Panel discussion on post harvest aspects of rice pest control - Mr. M. A. Larinde Dr. I. Akintayo Dr. P. Kenmore Dr. E.A. Akinsola.
12.30 - 13.30	:	L U N C H
13.30 - 14.30	:	Irrigated Rice Team Report - Mr. Mark Ukwungwu.
14.30 - 15.30	:	Upland Rice Team Report.
15.30 - 16.30	:	Mangrove Swamp Rice Team Report - Mr. S. N. Fomba.

28 January (Thursday)

08.00 - 10.00	:	Verbal evaluation and assessment of course by all trainees and trainee designee.
10.00 - 10.30	:	B R E A K
10.30 - 12.00	:	Graduation and closing ceremonies: Address by Executive Secretary - Mr. Sidi Coulibaly. Course evaluation - Dr. I. Akintayo Presentation of Certificates - Representative of US Ambassador.

R E F R E S H M E N T S

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WEST AFRICA RICE DEVELOPMENT ASSOCIATION
REGIONAL TRAINING CENTRE
FENDALL, LIBERIA

1982 RICE PEST MANAGEMENT COURSE

LIST OF PARTICIPANTS

COUNTRY/NAME	POSITION AND ADDRESS
BENIN	
1. Amadji Firmin	C.S.A., Department de la Recherche Agronomique, BP. 884, Cotonou, Benin.
2. Katary André	Ingénieur agronome, Laboratoire de Défense des culture, BP. 128, Porto Novo, Bénin.
GAMBIA	
3. Sankung B. Sagnia	Scientific Officer, Crop Protection Service, Yundum Experiment Station, Yundum, The Gambia.
4. Baboucarr Cham	Scientific Officer, Crop Protection Service, Yundum, The Gambia.
GHANA	
5. Kwasi Ampofo	Research Officer, Crops Research Institute, Box 3785, Kumasi, Ghana.
GUINEE	
6. Fodo Camara	Directeur Regional de la Protection des Végétaux - Dabola, BP. 84, R.P.R. Guinee.
7. Aboubacar Bangoura	Directeur Regional Protection des Végétaux - Boffa. B.P. 7, R.P.R. Guinée.
8. Alpha Oumar Baldé	Directeur, Régional Protection des Végétaux - Koundara, R.P.R. Guinée.
GUINEA BISSAU	
9. Alfredo José da Silva	Chef du Investigacai no CENEMAC (DEPA) M.D.R. C.P. 71, Bissau, R. Guinea Bissau.

10. Camilo Camissa Baldé	Chef di Recherce au Caboxanque DEPA M.D.R. C x71, Bissau, Guinea Bissau.

<u>HAUTE VOLTA</u>

11. Sawadogo Abdussalam	Chercheur (Nematologiste) Project Protection des Végétaux, B.P. 403, Bobo-Dioulasso.
12. Sere Yacouba	Phytopathologiste, Station de Recherche de Farako Ba, BP. 32, Bobo-Dioulasso.

<u>MALI</u>

13. Moro Traore	Ingénieur Phytopathologiste en service à la section de Rechereche sur les cultures vivrières et oleagineuses (SRCVO) Bamako Sotuba BP. 438 "PROJET LUTTE INTEGREE CILSS"

<u>MAURITANIE</u>

14. Soumare Abdoulaye	Coordonateur de la Recherche au CNRADA, Kaédi, BP. 22, R. Islamique de Mauritanie

<u>NIGERIA</u>

15. Angela Ehale (Miss)	Research Officer (In Training) Agric. Biology Dept., University of Ibadan, Nigeria.
16. Dauda Aliyu Garkida	Higher Agric. Supt. (Field Officer) Federal Department of Pest Control Services. PMB. 1638, Maiduguri, Borno State, Nigeria.
17. Chilaka A. Augustine	Higher Agric Supt. (Field Officer) Fed. Department of Pest Control Services, PMB. 1400, Enugu, Anambara State, Nigeria
18. Ukwungwu Mark	Research Officer, National Cereals Research Institute, Rice Research Station, Badeggi, PMB. 8, Bida, Niger State, Nigeria.

<u>SENEGAL</u>

19. Abdou Sagna	Division Agro-Vulgarisation, PIDAC BP. 282, Ziguinchor, Senegal.
20. Oumar Barry	I.T.A. en service au Centre de formation, Phytosanitaire, Centre de formation Phytosanitaire BP. 49, Dakar.

SENEGAL

21. Samba Diaw	Ingénieur des travaux agricoles en service au Centre de Recherches rizicoles de Djibelor, Département phytopatholigie BP. 34, Ziguinchor.
22. Souleymane Gaye	Ingénieur des travaux agricoles. Assistant de recherche à la station de recherches rizicoles à Djibelor, BP. 34, Ziguinchor.
23. Seugne Alioune Thiam	Chercheur en Service à i'Institut de Technologie Alimentaire. Section Stockage des grains, BP. 2765. Dakar.

USA/SENEGAL

24. Castleton, Carl W.	Training Officer, USAID Regional Food Crop Protection Project, BP. 49, Dakar.
25. Settle, Willaim	Country Project Officer (Entomologist) USAID Regional Food Crop Protection Project, BP. 49, Dakar.

SIERRA LEONE

26. Sahr N. Fomba	Research Officer (Plant Pathology, WARDA Mangrove Swamp Rice Project, P.O. Box 7, Rice Research Station, Rokupr, S/Leone.

TOGO

27. Dossekou Messan	Malherbologiste, Service Protection des Végetaux, BP. 1263, Lome, Togo.
28. Agbobli Comlan Atsu	Docteur phytopathologiste, Direction de la Recherche Agronomique, BP. 2312 Lome, Togo.

LIST OF LECTURES

Abifarin, A.O.
WARDA, P.O. Box 1019, Monrovia, Liberia.

Akinsola, E.A.
WARDA, P.O. Box 1019, Monrovia, Liberia.

Aintayo, I.
WARDA, P.O. Box 1019, Monrovia, Liberia.

Awoderu, V.A.
WARDA, P.O. Box 1019, Monrovia, Liberia.

Akobundu, I.O.
IITA, PMB. 5320, Ibadan, Nigeria.

Bottrell, D.G.
CICP, 2288 Fulton Street
Suite 310 Berkeley, California, U.S.A.

Breniere, J.
IRAT - Montpellier, France.

Dabrowsky, Z.T.
ICIPE, Box 30772, Nairobi, Kenya.

Esuruoso, O.F.
Dept. of Agric. Biology
University of Ibadan, Ibadan, Nigeria.

Funmilayo, O.
Department of Agricultural Biology
University of Ibadan, Ibadan, Nigeria.

Godderis, W.
WARDA, B.P. Box 1019, Monriva, Liberia.

Kenmore, P.
IRRI, P.O. Box 933
Los Banos, Philippines.

Kumar, R.
University of Legon, Accra, Ghana.

Matteson, P.C.
CICP, 2288 Fulton Street
Suite 310, Berkeley, California, U.S.A.

Ndoye, Mbaye
Projet de Lutte Integree
CNRA BP. 51, Bambey, Senegal.

Nottenghem J.L.
IRAT BP. 635 - Boucke, Ivory Caost.

Ouayogode, Bakary
IDESSA - BP. 635, Boucke, Ivory Coast.

Agyen-Sampong, M.
WARDA, Special Research Project,
Rokupr, Sierra Leone.

Smith, C.M.
Louisiana State University
Baton Rouge, Louisiana, U.S.A.

Thomas, M.D.
University of Liberia
Monrovia, Liberia.

EAA/eka/