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THE DEVELOPMENT OF A COLLABORATIVE RESEARCH PROJECT ON INTEGRATED PEST MANAGEMENT (IPM) IN INDIA

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US/INDO COLLABORATIVE RESEARCH ON IPM IN INDIA

The development of this collaborative IPM research project was initiated at the request of the Indian Council of Agricultural Research (ICAR) with the help of the United States Agency for International Development (USAID). The Indian research management study team of Drs. A.K. Raheja, S.P. Singh and S. Nagarajan, visited the USA in July 1990 and wrote a trip report describing potential collaboration with U.S. Institutions. Also supplied for study before our site visit was "**A Brief Report on Integrated Pest Management**" prepared by ICAR.

The U.S.A. study team of Drs. C.R. Edwards, R.E. Ford and A.L. Steinhauer visited India April 13 - May 04, 1991. The three U.S. scientists and three Indian scientists have worked together closely to prepare this report. The U.S. team travelled throughout India reviewing, assessing and evaluating IPM research, its infrastructure and delivery in place. Our objective is to suggest ways to reorient and upgrade the research infrastructure and competence of scientists and to develop appropriate collaborative IPM research and implementation programs of mutual benefit.

This report was prepared for the ICAR, Krishi Bhawan, New Delhi - 110 001, India, Winrock International and USAID, New Delhi.

LIST OF TERMS

Abbreviations

AICRP	All India Co-ordinated Research Project
AICRPBC	All India Co-ordinated Research Project Biological Control
APAU	Andhra Pradesh Agricultural University, Hyderabad
BCC	Biological Control Centre, Bangalore
CICR	Central Institute for Cotton Research, Nagpur
CPPTI	Central Plant Protection Training Institute, Rajendranagar
DOS	Directorate for Oilseeds Research, Hyderabad
DRR	Directorate for Rice Research, Hyderabad
EIL	Economic Injury Level
ET	Economic Threshold
GBPUAT	Gobind Balabh Pant University of Agriculture and Technology, Pantnagar
HAU	Haryana Agricultural University, Hisar
IARI	Indian Agricultural Research Institute, New Delhi
ICAR	Indian Council of Agricultural Research, New Delhi
IIHR	Indian Institute of Horticultural Research, Bangalore
IISR	Indian Institute of Sugarcane Research, Lucknow
INDO/US	India/United States Collaboration
IPM	Integrated Pest Management
NAARM	National Academy for Agricultural Research Management, Rajendranagar
NCIPM	National Centre for Intergrated Pest Management, Faridabad
NPV	Nuclear Polyhedrosis Virus
PCC	Project Co-ordinator's Cell, Bangalore
RAU	Rajasthan Agricultural University, Experiment Station, Jaipur
SBI	Sugarcane Breeding Institute, Coimbatore
TNAU	Tamil Nadu Agricultural University, Coimbatore
USAID	United States Agency for International Development

EXECUTIVE SUMMARY

The U.S. IPM team visited numerous Indian research, implementation and training campuses and centers operating under the auspices of the Indian Council of Agricultural Research (ICAR) and the State Agricultural Universities. These included facilties in and around New Delhi, Coimbatore, Bangalore, Hyderabad, Nagpur, Hisar, Jaipur, Lucknow and Pantnagar. We reviewed research and training facilities, and held discussions with scientists and administrators. Our principal objective was to evaluate the current status of IPM research and implementations in India, to identify areas where collaboration with U.S. scientists/ institutions could strengthen the overall IPM effort in India, and to recommend specific training, collaboration, and additional resources support that could be funded through the USAID/India project on Management Support Service for agriculture.

Our report identifies areas where IPM research and implementation may be strengthened. These include : 1) a more complete integration of the various crop protection disciplines into more holistic units to deal with pest interactions in both research and implementation of IPM; 2) a greater emphasis on alternatives to pesticides to alleviate over-use of chemicals in crop protection; 3) an increase in expertise in the area of quantitative biology to enable India to develop more precise standards for the purpose of refining ET's, providing accurate survey data for a national data base on pest organisms and natural enemies, generating accurate crop loss assessment data and improving economic estimates on crop losses; 4) greater coordination of the various agencies involved in IPM in farmers' fields; and 5) strengthening specific IPM components, including biological control, germplasm development, biotechnology, genetics, use of pheromones and pesticide resistance management.

This report includes specific recommendations for collaboration, training, and support under Phase One. Should sufficient resources be available we have made recommendations for further activity under Phase Two.

Phase One recommendations are listed in four modules, prioritized below :

1. Biological Control :

Short-term training for scientists in Taxonomy, Exchange of Natural Enemies, Mass Production of Natural Enemies, Parasite Nutrition, Biotechnology, Pheromone Chemistry, Biological Control of Weeds, Biological Control of Soil-borne Pathogens, and Biological Control of Nematodes. Total Trainees = 19.

Reciprocal short-term collaborative visits by U.S. scientists for the Exchange of Natural Enemies, Nuclear Polyhedrosis Virus Production (NPV), *Bacillus thuringiensis* isolation, Aquatic Weeds, Terrestrial Weeds, Insect Nutrition and *Trichogramma* Research. Total U.S. Collaborators = 7.

2. IPM Center :

Short-term training in the area of Database Management. Total Trainees = 2.

Reciprocal short-term visit by collaborating U.S. scientist in the area of Data Base Management. Total U.S. Collaborators = 1.

3. Cropping System IPM :

Short-term training at U.S. institutions for Indian Specialists in Extension IPM, Pesticide Resistance Management, Weed Science, and New Wilt Disease of Cotton and Irrigasted Rice IPM. Total Trainees = 10.

Reciprocal short-term visits by U.S. collaborators in the IPM Implementation, *Heliothis* in Cotton, New Wilt Disease of Cotton, Agronomy/Plant Physiology, Socio-economic, Studies and Crop Loss Assessment. Total U.S. Collaborators = 6.

4. <u>Sugarcane IPM</u> :

Short-term training at U.S. institutions for Indian scientists dealing with Red Rot Disease and the Biological Control of Borers. Total Trainees = 2.

Reciprocal short-term visit by a U.S. Collaborator in Sugarcane Diseases Management.
Total U.S. Collaborators = 1.

Additionally, the U.S.IPM team recommends the acquisition of equipment, supplies and books that are for the most part, not obtainable in India and which are deemed essential to the success of India's IPM Programme.

Finally, we recommend a review of progress under this project in the form of an Indo-US IPM Seminar/Workshop. This should occur 18-24 months after project initiation.

Introduction

The Government of India, through the Indian Council of Agricultural Research (ICAR), has singled out Integrated Pest Management (IPM) as a key technology in the continuing struggle to increase agricultural productivity to maintain gains made in recent decades in the face of an ever-increasing population. Although the technology of the "Green Revolution" has been responsible for the major gains in the past 40 years, many small farmers are unable to take full advantage of high-yielding varieties. Crop protection is frequently a limiting factor in the unevenness of production increases throughout India.

The advent of pesticide technology during the decade of the 1950s, while providing ready solutions to many crop protection problems, resulted in a steep growth in pesticides usage, with the estimated demand for 1991 to be 82,000 metric tonnes technical grade. This pesticide usage, while solving many problems initially, has resulted in the development of significant new problems that must be addressed, including the development of resistance of pests to chemicals, resurgence of other pests, destruction of beneficial organisms that normally keep many potential pests in check, the contamination of food, hazards to human health through both ingestion of contaminated food and through improper use of pesticides, and a general degradation in the quality of the environment.

IPM is a proven technology that utilizes all available pest suppression tactics in a pest management strategy that is economically, socially, and environmentally sound. While not eliminating the need for pesticides, it minimizes use of pesticides through the use of monitoring and the establishment of thresholds for action. Frequently establishing correct thresholds lowers pesticides usage so that natural enemies can once again exert their regulating effects on pest populations, thereby further reducing reliance on pesticides. The integration of host-plant resistance and cultural practices, as well as the application of biological

suppression tactics (i.e., parasites, diseases, etc.) often negates the need for pesticide application.

Since sustainability and environmental quality have been identified by ICAR as key components for growth of agriculture and the protection of India's natural resource base, the intensification of IPM in the protection of crops is mandated. For this reason, ICAR and USAID/INDIA have initiated the pre-project activity addressed in this report.

Background

In 1988, ICAR initiated planning for an IPM program. For various reasons, not pertinent to this report, it has taken almost three years to define the scope of the programme and arrive at the point where specific recommendations can be made. In July 1990, a team of three Indian scientists visited U.S.A. institutions to identify possible collaborators for inclusion in the project. As a result, a team of three scientists from the U.S.A. were invited to review the current status of IPM research and implementation in India, and in concert with their Indian counterparts, recommend action that could be undertaken through sponsorship of USAID/INDIA and ICAR under the INDO/US Project on IPM. From April 13, 1991 to May 04, 1991, the U.S.A. team members visited nine (9) ICAR Institutes, Directorates or Centers and six (6) State Agricultural Universities, as well as the Central Plant Protection Training Institute (CPPTI) and the National Academy for Agricultural Research Management (NAARM), both in the Hyderabad area (see **Appendix I**).

The principal areas that the IPM team was charged with reviewing included IPM activities on rice, cotton, sugarcane, rapeseed-mustard, groundnut and tobacco. We did not review tobacco since we had no opportunity to see any activities on this crop.

Prior to the arrival of the U.S. team members a significant amount of background information on IPM in India was made available through ICAR. Contributions by Indian scientists on components of

the IPM system are well documented in the scientific literature. Capabilities in the areas of biological control of pests, the development of resistant crop varieties, the manipulation of cultural practices to diminish pest incidence, and the use of botanical extracts such as neem seed oil are extensively practised in Indian agriculture. Additionally, crop diversity, intercropping, and the fact that most agricultural holdings are relatively small and intensively managed are all factors that favour the implementation of IPM at the farm level. Indian scientists and extension personnel are all aware of the problems that can result from overuse of pesticides, and the concept of economic thresholds (ET) for pesticide use is well ingrained in the research community. In spite of these factors favouring IPM implementation, pesticide use continues to increase. This increase is largely due to insecticide use, unlike many developed countries where increased pesticides use is largely attributable to the extensive use of herbicides. In India, 70 per cent of pesticides used are insecticides, about 15 per cent are fungicides and only five per cent are herbicides. Annual crop losses due to pests account for Rs.6,000 - 7,000 crores (U.S.$ = 3. - 3.5 billion). The importance of pests to Indian agriculture has been clearly stated by Dr. S. Nagarajan (The Hindu Survey of Indian Agriculture, 1990, see Appendix V).

On arrival in India, the U.S.A. team members and Dr. S. Nagarajan held a brief meeting with Mr. John A. Becker, Director, Office of Agricultural Research and Education, USAID, New Delhi. The purpose of the U.S. team visit and the form of the final report were discussed. Because of uncertainty as to the ultimate level of USAID-funding available to the IPM project, the team was asked to present a series of modules or components that could be prioritized and funded as finances permitted. For this reason, our recommendations include a series of activities under Phase One, plus a Phase Two recommendation that could be pursued in the event that sufficient funding materializes.

Objectives

The objectives of this study team are :

1. To review the status of IPM research and implementation under the auspices of ICAR and the State Agricultural Universities in rice, sugarcane, cotton, rapeseed-mustard and groundnut.

2. To identify areas where a collaborative INDO/US project could enhance Indian IPM research, development, and implementation.

3. To identify, where possible, Indian Institutes, Directorates, Centers or Projects that could benefit from such collaborations.

4. To identify where possible potential U.S. institutions where collaboration would enhance both Indian and U.S. interests.

5. To briefly design project modules that would essentially address the areas and institutions identified in 2, 3 and 4.

Observations

Status of IPM - General :

IPM practised in India focuses heavily on insects for most crops, much less so on plant pathogens (diseases), which generally are controlled effectively through host-plant resistance, with weeds seeming to be of least importance in the IPM scheme. Weeds do serve as a reservoir for plant pathogens and insects from which they are carried or migrate into adjacent crop plants. The administrative 'isolation' of weed science from insect and disease sciences at most research facilities is unfortunate since it must be an integral component of IPM. Nematology appears to be in its infancy in IPM. Fully integrated IPM models were not available for our review. Many components were observed to be operational.

Chemicals will always play a role in IPM. Many efforts are underway to incorporate judicious pesticide use and to allow maximum opportunity for biocontrol tactics to succeed. Development of pesticide resistance in predators, parasites, and pathogens to over-aggressive use of chemicals is addressed to a limited degree in this document even though it is being addressed elsewhere.

Survey and surveillance are key tactics for IPM to function properly. Maximum success will occur when insect, pathogen and weed life tables are developed, made available and incorporated into IPM models. ETs seemed to be surprisingly uniform across many regions. One receives the impression that action thresholds are borrowed from one location for use in another rather than being site specific.

A complex system for technology transfer exists. Some duplication of effort occurs since it appears that Agricultural Universities, Extension and National Institutes/Directorates/ Centers each have some obligation or understood mandate to do adult education. The entire system could benefit greatly from centralizing the focus of education and technology transfer in the Agricultural Universities. In other words, accept the philosophy of allowing universities to be the principal agencies for adult education.

Current use of biotechnology in IPM research was observed primarily in rice programs (e.g., TNAU and DRR) where culture of somatic cells, anthers and protoplasts is a standard technology. Patenting germplasm would appear to be unworkable at present because we understand that International Copyrights have not been adhered to closely in the past.

Great interest surrounds the use of pheromones in IPM programs, both for early detection and for upsetting mating patterns. India has expressed a need to acquire the capability to identify and synthesize pheromones.

Each institution has specific mandates which seem to encourage too much separatism, the antithesis of IPM. Although some were observed, interactions among pest specialists, especially between

agencies and institutes, are weak. A remarkable exception to this is the rather universal use of Trichogramma parasites in most IPM programs. For example, adequate biocontrol emphasis and technology exists but it is not matched by equal coordination/collaboration. An aggressive networking of collaborators in the various administrative levels of governments (both village, state and national) will be required to resolve the current constraints to efficient information flow and sharing of data which are so essential for development of usable IPM models.

For reasons both of time and resource constraints, we propose a two-phase process. We have proposed four modules for Phase One that we believe can be of most benefit to ICAR. Although listed in priority order as we visualize the potential benefits and pay-offs, the modules are meant to be interchangeable for maximum flexibility.

We found an unusually strong biocontrol technology and network operational in India. This strength can and should be enhanced and capitalized upon. If handled judiciously, the wide diversity of crops and of cropping methods places India in a situation ideal for assuming a leadership role internationally in biological control. For this reason, we give it first priority followed closely by enhancement of the activities of the IPM Centre. The Regional Cropping System is placed third, and the Sugarcane module is fourth.

Phase One :

MODULE I - Biological Control of Pests :

Biological control of pests is a key component of IPM. Fortunately, the practice of biological control in India is well advanced, and concomitant with the use of pest resistant germplasm, it forms the basis for current IPM programs in most cropping

systems. Nevertheless, for IPM to become fully effective, further research, development of technology, and improved implementation is necessary to assure the success of IPM programs and to prepare for the certainty of new pests appearing in the future.

Most biological control activity falls within the **All India Coordinated Research Project on Biological Control (AICRPBC)** headquartered in Bangalore, and its 17 Centers located at various ICAR Institutes and Directorates, and State Agricultural Universities. Under Phase One, we recommend strengthening the capabilities of AICRPBC at Bangalore, as well as at some of the Centers. Following are the specific activities where strengthening is recommended.

1. Taxonomy and Systematics :

A repeated message received throughout our visit was the deterioration of support for taxonomy and systematics throughout Indian agriculture. The maintenance of an appropriate cadre of qualified taxonomists is essential to IPM and its component disciplines. Accurate identification of both pests and beneficial organisms is fundamental to the success of any applied program. For the long term, we recommend that ICAR do a study to determine their taxonomic needs and take steps to rectify the current lack of expertise. Immediately, we recommend short-term training for at least two individuals. This training should take place in the U.S. under collaboration with the U.S.D.A. Systematic Entomology Laboratory, Beltsville Agricultural Research Center, Beltsville, Maryland. Also, it would be most appropriate for several younger scientists to attend an intensive short-course on the Taxonomy of Parasitic Hymenoptera offered by the Maryland Center for Systematic Entomology. This course is next offered in June 1992 and is of one week duration. The contact person for this course is Dr. Charles Mitter, Department of Entomology, University of Maryland, College Park, Md. U.S.A. 20742. A possibility also exists that the course could be taught in India for approximately 20 participants. In

this case the course could be offered at an appropriate site in India at a lesser cost as early as November 1991. This would entail bringing up to five U.S. and Canadian experts to India.

2. Introduction/Exchange of Natural Enemies :

Many effective parasites and predators that are not present in India are maintained in culture throughout the world and easily could be brought to India for study and release if appropriate formalities could be established. Conversely, many natural enemies of pests that occur in India may be useful in biological control programs in the U.S. and other nations. Over twenty predators and parasitoids of insect pests have been multiplied successfully in Indian laboratories and established in the field. Ample data are available concerning the relative safety of commonly used pesticides toward these beneficials. Far less emphasis has been placed on antagonists against plant diseases but two or three programs are producing results. We recommend a short-term training visit (one-month) to the Beneficial Insect Introduction Laboratory, U.S.D.A., Beltsville, Md. to establish this contact (contact person is Jack Coulson). This could be followed up by a reciprocal visit of a U.S. collaborator to determine suitable reciprocal exchange of material.

3. Multiplication of Natural Enemies (Biotic Agents) :

A great deal of biological control in India is based on mass rearing of parasites and predators followed by inundative releases into cropping systems at the appropriate time. This is especially true for release of egg parasites *Trichogramma* spp., and also of Nuclear Polyhedrosis Virus (NPV) for control of various Lepidopterous pests. While extensive inundative release of *Trichogramma* is not practised in developed countries because of large land holdings and prohibitive cost, this practice is particularly effective where labour is relatively inexpensive and land holdings are generally small. To date, mass culture of *Trichogramma* is accomplished using eggs of the rice moth, *Corcyra*

cephalonica as the laboratory host. While this method is adequate under present circumstances, should IPM implementation expand significantly in the future, the use of these eggs will be a limiting factor in the provision of sufficient Trichogramma parasites to serve anticipated IPM needs. The development of an artificial diet/artificial egg that would lend itself to bioengineered mass production of Trichogramma is essential. While this technology is not yet available anywhere in the world laboratories in the U.S. and elsewhere are leading the research in artificial diets and nutrition. Collaborative efforts with some of these institutions would greatly assist India in the future.

Similarly, the development of mass production schemes for NPV is a limiting factor in expanding IPM in many Indian crops. Here again, Indian technology is inadequate in that current production technology relies on rearing and infecting host larvae, followed by making crude preparations in the field. For NPV technology to be universally available, appropriate technology for mass production of NPV must be developed. If this should occur, it creates a great opportunity for private entrepreneurs to produce and disseminate this bio-agent in India, with resultant massive acceptance of IPM. Unfortunately, this development will not be easy, but collaborative efforts between Indian and U.S. scientists are more likely to lead to a solution than each group working alone.

There is great interest in India in development of Bacillus thuringiensis as a biological agent for the control of Lepidopterous (and other) pests. To date research has centred on commercially available formulations of B.t. This should continue. However, there are virtually thousands of strains of B.t. that can be isolated from soils in every climatic region of the world. Scientists at the Beltsville Agricultural Research Center in Beltsville, Maryland have developed technology to rapidly isolate various strains of B.t. from soil. These can be assayed for efficacy in controlling endemic pests. It seems logical that locally adapted strains would most likely be effective against local pest species. Accelerated research efforts to isolate and

identify indigenous strains of B.t. should be pursued.

We recommend the following :

1. Two scientists receive short-term training in the U.S. (6 to 9 months) in an appropriate laboratory where artificial (in vitro) rearing of pests and parasites is the main thrust (participant could spend time in more than one laboratory). Encapsulated diets for Chrysopa rearing should also be included.

2. One or two scientists receive short-term training in U.S. relative to NPV mass production and the isolation and evaluation of B.t. strains. The initial indicated laboratory is at the Beltsville Agricultural Research Center (James Vaughan is the contact person). Subsequent further training could be arranged at other laboratories in U.S. (Texas A & M University).

3. A U.S. scientist should visit Indian research establishments researching NPV production and B.t. evaluation (2 to 4 weeks).

4. Genetic Improvement of Natural Enemies, Diseases :

While much has been predicted for the improvement of biological control agents through the use of genetic engineering, we view this important aspect of biology as an essentially basic research area with great promise for the future. The initial flush of optimism for biotechnology has been somewhat dampened due to a variety of legal, social, environmental and other considerations. While this may slow adoption of genetically engineered organisms, it is imperative that India maintain a research base that will be capable of developing effective technology, as well as being in a position to rapidly capitalize on advances from elsewhere. Areas of biological control that can benefit from bioengineering include: development of pesticide resistant strains of parasites and predators; parasites and predators genetically altered to

withstand adverse climatic situations; improved host-finding capabilities; improved storage capabilities for mass produced organisms; more virulent disease organisms (bacteria, viruses, etc.); and other characteristics that could be "engineered" into beneficial organisms to enhance their efficacy.

We recommend that one or two of India's best young scientists in the area of biotechnology immediately receive training assignments of six to nine months in the U.S. Two likely collaborators in the U.S. are Marjorie Hoy at U.C. Berkeley (insecticide resistance of parasites) and David O'Brochta, Department of Entomology, Center for Agricultural Biotechnology, University of Maryland (P-element transfer). Many other laboratories might be selected depending on the Indian scientists' interest and responsibility.

5. Chemical Ecology (pheromones, kairomones, arrestants)

This area of IPM activity, generally considered as the use of behaviour-modifying chemicals for enhanced insect control, is usually not considered as a classical biological control activity. However, we choose to address it here since it has much application to biological control implementation in an IPM system. Particularly important in India now is the use of pheromones, both in monitoring pest populations as a part of survey and surveillance, and as a control measure in trapping male insects and disrupting mating. The major problems facing India are :

1. Lack of facilities for determining the structure of pheromones of many endemic pest species;
2. Pheromone failure occurs and since all pheromones used are imported scientists have no idea whether the formulation contained the appropriate chemicals or lacked essential ingredients (or the correct proportions for local strains); and
3. No facilities for synthesizing pheronomes for mass distribution.

Our recommendation is to invest in a facility that could provide the missing analytical and synthesis research necessary. While this is probably more reasonably done by ICAR, the USAID/ICAR project could help plan this facility. Probably the best, most notable pheromone laboratory in the U.S. is at the Geneva Agricultural Experiment Station, of Cornell University, Geneva, N.Y. Dr. Wendell Roeloffs is the Principal Scientist. We recommend that two scientists visit Dr. Roeloffs' laboratory, one for two to four weeks to determine the necessary equipment improvements to upgrade an ICAR facility, and one person for six to nine months to learn methodology and analytical techniques for pheromone analysis. A subsequent trainee could be seconded at a later date to learn synthesis technology when unavailable pheromones have been identified. Additionally, the USDA Laboratory for Chemical Ecology, Beltsville, Md. would be an excellent collaborator on behavioral modifications and pheromone physiology. Dr. Ashok Raina would be an excellent collaborator.

6. Weed Management :

The biological control of weeds can often produce spectacular successes. This is evident in India by successful efforts in controlling water hyacinth and the terrestrial carrot weed, *Parthenium hysterophorus*, with the release of imported insects that feed specifically on the target weed. Numerous other approaches, particularly in the area of weed diseases (fungi, nematodes and bacteria) should be explored.

A collaborative study program between Indian scientists and U.S. scientists from several institutions should be implemented. This would involve a short term (three to six months) training period for an Indian scientist at the University of Florida Aquatic Weed Control Center, as well as a visit to the University of California for terrestrial weed control. Reciprocal visits by two U.S. scientists for two to four weeks should also be programed, (one in aquatic and one in terrestrial weeds).

7. Plant Diseases Antagonists :

The utilization of plant disease antagonists in the control of plant diseases such as chickpea wilt is being studied in India. Antagonists of the genus *Trichoderma* have shown promising results in the laboratory and greenhouse, but have been generally considered to have limited impact in the field. Perhaps some benefit to Indian researchers could be achieved through collaborations with R.J. Cook, Department of Plant Pathology, Washington State University, Pullman, Washington. At present, even in the U.S. only limited success has accrued with *Trichoderma*.

8. Computerized Data Base and Computer Capabilities :

The headquarters of the AICRPBC in Bangalore needs enhanced computer capabilities for the creation of a natural enemy data base. A database is particularly important in keeping track of available material and appropriate strains for biological control implementations. We believe that database needs can be incorporated into the "upgraded" computer facility envisioned for the NCIPM at Faridabad. However, Bangalore needs sufficient training and equipment to be "on-line participants" in the national IPM database in Faridabad. Our recommendations are listed under the IPM Center module.

MODULE II - IPM Center

The NCIPM was conceived and established two years ago. It had a modest beginning with a mandate to be issue oriented. Until it becomes housed properly with a resident director in place, it will develop slowly. Initial objectives are to create a national database for ETs in each agroclimatic zone, generate data on yield loss assessments, design pest distribution maps, do epidemiological and population dynamics studies for model development, and evaluate current control measures and plant protection needs. Much of the activity in this national centre relies on the need for adequate computer equipment and technology. The various data banks of

incidences of predators, parasites, pathogens, diseases, insects, weeds and nematodes must be collected in a format useful to both researchers, teachers, extension personnel and government agencies. These data must be collected on standardized questionnaires used by all scientists whose jobs include survey and surveillance. All of these data must then be stored in a manner easily retrievable by anyone who has need for this information.

Essentially two major problems exist that the NCIPM must resolve immediately. The first problem entails the form in which information is supplied to the National Data Base. Essentially, data acquisition forms must be designed and standardized for each crop. This should be done with input from investigators from all regions, and from both researchers and extension personnel who can address the problems in acquiring accurate information. Although not easy, it will determine the ultimate usefulness of the database.

Secondly, the technical people at the NCIPM must be thoroughly grounded in database management and the use of the necessary software. Much of the needed computer training is available in India, but there should be an attempt to train at least two more staff in the U.S. There are a large number of institutions where operational insect survey databases are functioning. At least two of these should be visited. We recommend the University of Kentucky and Michigan State University. It would be advisable for a U.S. collaborator to visit NCIPM within the next 12 months (e.g., Dr. Grayson Brown, U.Ky.)

MODULE III - Regional Cropping System

Cotton, a high cash value crop, and one in which IPM is strongly emphasized due to current major insecticide usage, has two major pest problems. *Heliothis* (in two agroclimatic regions) and both **spotted bollworm** and **whitefly** (in four regions) pose significant challenges. The **jassid** (in five regions) is a problem

in three regions and **Spodoptera** and **aphids** both cause significant concern in two regions.

Rice creates an even greater IPM challenge due to 16 major or significant insect and disease problems. **Blast, brown plant hopper, leaf blight** and **stem borer** each occur in five or more regions. The **leaf folder** is serious in one region. Other diseases and insects are serious in one or two regions, especially **bacterial leaf blight, Gundhi bug, white tip** and **gall midge.**

A pilot IPM program (described below) provides the most effective way to educate farmers about the concepts of IPM and how to utilize all knowledge available in an integrated system.

Development of Village-Based Pilot Pest Management Programs :

Common denominators to all pest management programs are real time surveillance/monitoring of pest populations and their damage, and use of ET's and appropriate application of management strategies. In highly developed countries, the infrastructure usually provides timely monitoring to quickly analyze survey data for forecasting models, and to rapidly disseminate pest advisories action. In lesser developed countries, such as India, some, if not all of the above may be difficult to achieve, thus making its implementation a real challenge. To increase success and the possibility of wide-scale adoption of IPM, a pilot IPM program should be initiated to develop and fine tune the mechanism for crop and/or cropping system pest management.

Recommended Crops :

Our observations suggest it most appropriate to develop pilot programs for cotton, rice, and sugarcane. Where these three are grown in the cropping system/or where other crops are grown in combination with one of these three it is essential to include all crops. In some regions both sugarcane and rice are grown in combination. These along with cotton provide for a good mix for pilot program development.

The appropriate location for a cotton, sugarcane, and rice pilot program would be in Tamil Nadu where a program utilizing biosuppression is already underway. This program has already achieved some level of success and farmer acceptance of the pest management concept appears to be good. A local sugar mill provides considerable support. It is a focal point for area farmers. Any program in this area should be closely tied to efforts of the ICAR, TNAU, Extension/State Government of Tamil Nadu, Village Administration, and the sugar mill. Since cotton is the heaviest user of pesticides (54,000 metric tonnes in 1990) and pressure from pest species is considerable, and often yield-limiting, it is essential to initiate a pilot program which includes this crop. We believe it would be appropriate to organize an additional program in the State of Maharashtra near Nagpur. The location of the ICAR, CICR, and the pressure from pests on cotton production in this area, makes this an ideal location. One drawback is the distance to a source for biocontrol agents, although some production for research and limited evaluation purposes is now handled at CICR and TNAU. The establishment of a commercial rearing facility in this region would increase the possibilities for proper utilization of biologicals.

Organization at the Village Level :

At least two villages should be included as a unit for each cropping system (i.e., sugarcane, rice, cotton). An IPM extension agent should be located in each village, should work independently of the village extension official, but must keep him informed of project results since he will need help in organizing local farmers. The IPM agent will be responsible to the Pilot Project Coordinator and Crops Supervisor, as designated by ICAR. The IPM agent will hire and train locals to monitor (scout) fields. The 'scouts' will be responsible for making pest counts and assessing damage in farmers' fields and monitoring light, pheromone, sticky and other traps (as needed). The scouts will meet each morning, or perhaps evening if more appropriate, to deliver the scouting forms

for the last 24-hour period. The IPM agent will review these with the scouts and give instructions for their upcoming field visits. To ensure that the scouts are monitoring the fields properly, the IPM agent will spot check fields and compare his data to that of the scouts. As appropriate, the IPM agent will advise farmers on the need for biological, cultural, mechanical and/or chemical control. The IPM agent will be responsible for organizing field data and entering it into the computer. These data will be used to track pest activities over time, to make general advisories for contiguous areas not being scouted, to provide a record of pest activities during the growing season, and to evaluate at the end of the growing season for possible project revisions.

Personnel :

Pilot Project Coordinator - as designated by ICAR	(1)
Crop Supervisors - Coordinate the activities of the extension IPM Agents as designated by ICAR	(2)
Extension IPM Agents - responsible for Village Programs	(4 - 8)
Scouts - responsible for field monitoring	(To be determined)

Training :

The Project Coordinator and Crop Supervisors will be responsible for training the Extension IPM Agents. We recommend that the training be coordinated by the Central Institute for Plant Protection Training (CIPPT). It will be the responsibility of the IPM Agent to train the scouts. Scout training can be through the local ICAR facilities or perhaps the State Agricultural University.

All trainees should be trained in pest and damage recognition, use of appropriate survey techniques, data reporting, etc.

Survey Form :

A standardized survey form for the appropriate crops will be required. The form will contain information related to field identification, date of survey, crop type, stage of crop

development, time of sampling, weather conditions at time of sampling, plant condition (good, stressed, etc.), pests noted (insects, plant pathogens, weeds, etc.) and level, beneficial organisms present, etc. The forms should be carbonless and provide for 3 copies. One copy should be given to the farmer, one should be retained by the IPM agent, and the other mailed to the Crop Supervisor.

Field Record Database :

A database should be established for recording and analyzing field information. Microcomputers will be needed to accomplish this. One microcomputer with 40-80 megabytes of storage will be required for each cropping system location (2 total).

Several databases have been developed in the U.S. and these could easily be adopted for use in this program. (University of Kentucky and Michigan State University).

Use of ETs :

Where available, established ETs will be used. A management guidelines sheet for each cropping system should be developed listing pest/damage and ETs. ETs should be evaluated and adjusted accordingly. Multiple pest ETs should be developed and utilized where appropriate.

Pest Models :

Models of pest population development are extremely useful in implementation programs. Where appropriate, life tables should be constructed and used for forecasting pest activity. Where not available, local effort should be made to gather appropriate information for life table construction and model development.

Irrigated Rice :

We saw a need to maintain the monsoon-dependent irrigated rice IPM system, which has developed with the assistance of UNDP, and to keep it evolving. We recommend that the system be standardized to

enable collection of comparable incidence and damage data which would be meaningful across several agroclimatic zones. Training should be done in 1) survey and surveillance of incidences of blast, leaf folder and stem borer to aid in developing models for predictive purposes, 2) establishment and updating of ETs, 3) enhancement of communication network systems, and 4) development of the use of light traps, spore traps, pheromones, etc. to aid in correlating counts obtained for forecasting or predictive modeling.

MODULE IV - Sugarcane :

Sugarcane production will continue to expand more in some regions. Major problems include borer as the primary one in two of the eight agroclimatic regions, white fly and phsilla in three regions and red rot, white grub and smut in one region.

On first examination, sugarcane IPM appears to be significantly more effective than IPM in most other cropping systems. Among the reasons for this is the influence of sugar factories in selection of varieties, production and dispersal of natural enemies of pests, and overall a workable communications network with sugarcane farmers. Also accounting for the relatively effective sugarcane IPM program is the excellent plant breeding program in India that has produced numerous pest-resistant varieties with good yield potential to red rot, several borers, and white grub. Even so, it is commonly estimated that annually 10-15 per cent of cane is lost in pests, with additional losses attributable to pests as a result of reduced sugar content. Furthermore, a large number of soil-inhabiting pests are controlled with chlorinated hydrocarbon pesticides (HCH, Aldrin, Heptachlor, and Lindane or gamma HCH), products that are know to have significant negative environmental consequences and which are banned in many countries of the world. Termites, white grubs and shoot borers are several soil pests that are targeted. Also, HCH is still used for leaf hopper control, as well as grasshopper and other defoliators. Adequate alternative to HCH must be found for these pests.

Also compounding the situation in sugarcane production are estimates that India will need to increase total sugar productions by 50 per cent by the year 2000. It is highly unlikely that this increased production target can be reached by improved germplasm and expanded cultivation without a significant reduction in pest losses. Effective uses of genetic material currently available must be combined with increased emphasis on biocontrol tactics. An even greater effort is needed to distribute by new releases or to enhance multiplication of parasites and predators through cautious use of pesticides based on regular methodical survey and surveillance information.

Integration of Pest Management Tactics :

The various pest management tactics that have been developed in the pest research activities of the scientists in the Indian Institute for Sugarcane Research (IISR) and Sugarcane Breeding Institute (SBI), namely resistance to various insects and pathogens, cultural control, mechanical control, biological control, and chemical control, from the basis for the development of an integrated research program. The various research findings of the pest disciplines should be combined for the development of a unified research/demonstration activity.

At least six hectares of land should be set aside for this program. The researchers working on the various pests should join together as a team to develop this activity. Many of the elements important to sugarcane are in place and ready for application. Significant data and facts are available to be used in constructing an action model.

Advanced Training :

Many young scientists working in sugarcane pest management in India would benefit from interactions with U.S. scientists. The IPM team recommends that one Indian scientist working on the identification of races of the red rot pathogen be sent to Louisiana State University and/or USDA University of Florida for

six months to learn how to do race typing.

Additionally one Indian scientist should spend three to six months at Louisiana State University interacting with U.S. scientist working in insect biocontrol.

Phase Two :

Although not less important, the modules in Phase Two are held for further consideration until IPM has been well established in the Phase I crops and cropping system.

MODULE V - Rice :

Genetic host resistance and breeding technology are available and well established through International Centers (such as IRRI). The pest problems are listed in Module III. Ample opportunities exist for more exploration for beneficial organisms and for enhancement of those already endemic. A great need exists for more basic research on life histories to enable their eventual commercialization. In terms of education and technology transfer rice enjoys already a significant pilot project conducted by the Directorate of Extension Education, TNAU. The IPM innovation consisted of cultural, chemical and biological methods used on 10 pests. An "IPM Adopted Village" of 100 farmers and a "Non-adopted Village" of 100 farmers were compared. The IPM village farmers were more aware of IPM, had a better attitude about IPM, and they used fewer prophylactic sprays.

MODULE VI - Groundnuts - Oilseeds :

Leaf miner and rust cause serious production constraints in two or more agroclimatic zones. White grub and caterpillar, although not major pests in all zones, occur in four or more zones and can result in significant losses. White fly and root knot nematode must be carefully monitored for potential outbreak increase. More research is needed on grub biocontrol by bacteria

and fungi. Another area of interest was to isolate and identify white grub beetle attractants.

MODULE VII - RAPESEED-MUSTARD :

The aphid is omnipresent on mustard. It requires attention from IPM specialists to assist farmers from losing a crop. White rust is a limiting factor to certain areas of India. Basic research is needed to understand the nature of primary and secondary infection plus environmental/climatic factors which influence disease epidemiology.

MODULE VIII - PULSES :

Heliothis is a key constraint to production wherever chickpea is grown. It should be possible to manage this pest during the process of implementing general IPM programs involving its control in other crops in the intercropping or rotation crop system.

Problems :

Many problems and challenges await the implementation of IPM. No one individual can do it alone nor can one institution or administrative unit. Therefore it is imperative to empower others on how to share in the network on which IPM scientists have come to rely. You may have to buy into other scientists, other agencies, other governments and even into commercial businesses. The expertise has to be found wherever it exists regardless of source of funding or government bureaucracy.

Solutions

How? What tactics are used? 1) Joint appointments where 2 or more agencies share the cost of a specialists salary where both can share some control over that individuals time and effort. 2) Adjunct appointments where it may be impossible or illegal to share salary.

Recommendations

- Bring weed control into the central thrust of IPM.
- Enhance nematology studies in all crops.
- Create joint appointments for individual scientists between research and extension and between Agricultural Universities and National Centers/Institutes for mutual benefit.
- Seek all manner of collaborative arrangements both formal and informal among appointments, Plant Pathologists, Entomologists, Nematologists, Weed Scientists, Agricultural Engineers, Agricultural Economists, to enable IPM maximum opportunity to succeed.
- Send young scientists for 3-6 months of study to maximize their upgrade in scientific techniques.
- Receive U.S. Professors on sabbatic leaves.
- Expedite mutual exchange of biological agents such as already agreed upon with the USDA.
- Arrange 2-3 week visits for senior scientists.
- Receive U.S. Ph.D candidates who have international interests to do portions of their dissertation research on Indian crops (about 6 months).
- Increase efforts to continuously research and update ETs for all major pests on the target crops.
- Resolve the Administrative constraints which prevent the ready and easy joint planning, collaboration and implementation of weed science and cropping system plans as a cohesive part of IPM.

Appendix - I

Acknowledgements

We gratefully acknowledge the assistance of more than one hundred scientists who helped in uncounted ways in providing literature, oral presentations, guidance and excellent hospitality. Most notably, our thanks to our ICAR and Winrock International hosts. Drs. S. Nagarajan, A.K. Raheja and S.P. Singh were invaluable travelling companions. We ask the following leaders to express these sentiments to each of their scientists who contributed to making this trip memorable and productive.

Institutions Visited, Locations, Subject and Key Contact

Date	Institute	Location	Subject	Key Contact
April 1991				
16th	GBPUAT	Pantnagar	Biocontrol	Dr.A.K.Mukhopadhyay
16th	HAU	Hisar	Mustard, Cotton, Rice	Dr. H.C. Sharma
16th	RAU	Jaipur	Groundnut, Cotton, Sugar-cane, mustard	Dr. Gupta
18th	TNAU	Coimbatore	Cotton, Rice, Sugarcane	Dr. S. Jayaraj
19th	Cotton-Proj. AICCP	"	Cotton	Dr.V.Sundaramurthy
20th	SBI	"	Sugarcane	Dr. M. Naidu
22nd	BCC	Bangalore	Biocontrol	Dr. S.P. Singh
24th	DRR	Hyderabad	Rice	Dr. E.A. Siddiq
24th	DOS	"	Oilseeds	Dr. V.R. Rao
25th	APAU	Rajendranagar	Cotton	Dr. M.V. Rao
25th	CPPTI	"	IPM	Dr.V.T.Sundaramurthy
25th	NAARM	"	IPM	Dr. K.V. Raman
27th	CICR	Nagpur	Cotton	Dr. A.K. Basu
29th	NCIPM	Faridabad	IPM	Dr. A.K. Raheja
30th	IISR	Lucknow	Sugarcane	Dr. G.B. Singh
May 1	IARI	New Delhi	IMP Components	Dr. S. Nagarajan

Appendix II

Equipment Needs

The US IPM team recommends the acquisition of the following equipment, books and supplies. These resources are deemed essential to the success of the IPM program and to the best of our knowledge most are not obtainable in India.

The NCIPM will serve as a central facility for housing much of this equipment for joint use by staff associated with the various programs modules. This is necessary since it will not be possible to duplicate these items at all locations.

(See next page for Tables)

Appendix II (contd.)

Sl.	Equipment	Project	Location
1.	Controlled Soil Temp Tanks - Soil borne organisms	Biocontrol	GBPAU, Pantnagar
2.	Computerized video-camera/ microscope	Biocontrol	Bangalore
3.	Controlled Environment Chambers (number to be determined)	Biocontrol	Bangalore
4.	2 Microscopes with digitizer for computer image storage plus PC computer with 40 megabyte memory	Biocontrol IARI	Bangalore New Delhi
5.	4 Agroclimate Weather Recording Stations - IBM compatible	Biocontrol IARI Cropping systems Cropping systems	Bangalore New Delhi Nagpur Coimbatore
6.	2 Caramate Slide Projectors/Screen viewer	ICAR Biocontrol	New Delhi Bangalore
7.	Books, US Press Generic Rs.200,000 Supplies, chemicals, etc.		
8.	2 Mini-Fermenters to multiply fungal pathogens from M/s.L.H. Fermentation Corp., 3563 Ardean Rd., Harward, CA 94545, U.S.A.	Biocontrol	Bangalore
9.	Computerized Acoustical Detectors	Biocontrol	Bangalore
10.	4 Data Logger Field Information Computers		
11.	2 MacIntosh II SC Computers with 80 megabyte memory and with color monitors each with a Laser printer	Biocontrol IPM Center	Bangalore Faridabad
12.	2 IBM Computer with 80 megabytes memory each with a Dot matrix printer	Cropping systems	Coimbatore Nagpur
13.	2 Multi-Fax machines	Biocontrol IPM Center	Bangalore Faridabad
14.	3 Portable Li-Cor Leaf Area Meters	IPM Center	Faridabad Lucknow Coimbatore
15.	1 Large Li-Cor Leaf Area Meter	IPM Center	Faridabad

Appendix III

Table I : Short-term Training/Visits for IPM

MODULE I : BIOCONTROL

	Technical Training Subject	Location	Duration	Trainees Number
A.	Taxonomy/ Systematics	USDA Systematic Entomology Laboratory, Beltsville, MD.	3-6 mo.	2
B.	Exchange of Natural Enemies	USDA Beneficial Insects Introduction Laboratory, Beltsville, MD.	1 mo.	1
C.	Artificial Diets Insect/Parasite Nutrition	to be determined	6-9 mo.	2
D.	NPV Mass Production; B.t. isolation	Insect Pathology Laboratory, Beltsville, MD.	6 mo.	2
E.	Biotechnology	to be determined	6-9 mo.	2
F.	Pheromone Chemistry	Department of Entomology, N.Y. Agri. Expt. Station, Cornell Univ., Geneva, NY.	2-4 wk. 6-9 mo.	2 2
G.	Biocontrol of Weeds	University of Florida University of Arkansas University of California	3-6 mo. 2-3 wk.	2 1
H.	Biocontrol of Soil borne Pathogens	Dr.R.J. Cook, Washington State Univ., Pullman, WA	3-6 mo.	2
I.	Biocontrol of Nematodes	Dr.(Mrs.) Susan, University of Maryland	3-6 mo.	1

MODULE II : IPM CENTER

	Technical Training Subject	Location	Duration	Trainees Number
A.	Database Management	University of Kentucky Texas A & M University Michigan State University	3-6 mo. 3-6 mo.	1 1

Appendix III (contd.)

Table I : Short-term Training/Visits for IPM

MODULE III : CROPPING SYSTEMS

	Technical Training Subject	Location	Duration	Trainees Number
A.	Extension IPM Specialist	Texas A & M University Purdue University University of Illinois	3-6 mo.	2
B.	Pesticide Resistance Management	Mark Whalon Michigan State University	3-6 mo.	2
C.	Weed Science Specialists	Harold Coble North Carolina State Univ.	2-3 wk.	1
D.	New Wilt Disease of Cotton/Genetic incompatability	to be determined	3-4 mo.	1
E.	Irrigated Rice IPM	to be determined	3-6 mo.	2

MODULE IV : SUGARCANE

	Technical Training Subject	Location	Duration	Trainees Number
A.	Red Rot Disease-Host Genetic Resistance	USDA of Florida, Canalpoint, FL Louisana State University, Baton Rogue, LA	3-6 mo.	1
B.	Insect Biocontrol Borers	Louisana State University, Baton Rogue, LA	3-6 mo.	1

COORDINATION

Subject	Scientists	Duration	Number
Joint INDO/US Seminar Monitor Progress every 2-3 yr.	Nagarajan, Raheja, Singh	1-2 wk.	3

Appendix IV

Table 2 : Short-term Collaborative Visits by US Scientists

MODULE I : BIOCONTROL

	Technical Expertise	Expert's Institution	Duration	Number
A.	Exchange of Natural Enemies	USDA Beneficial Insect Laboratory, Beltsville, MD	1 mo.	1
B.	NPV Production; *B.t.* strain identification	USDA Insect Pathology Laboratory, Beltsville, MD Dr. Ignoffo USDA Geneticist, Texas A&M University, Dr. Atman	1 mo.	1
C.	Aquatic Weed Biocontrol	University of Florida	2-4 wk.	1
D.	Terrestrial Weed Biocontrol	to be determined (University of Arkansas)	2-4 wk.	1
E.	Insect Nutrition Biocontrol	USDA, Weslaco, Tx. Dr. David A. Nordlund	3 wk.	1
F.	*Trichogramma*	USDA, Weslaco, Tx. Dr. Wm.C. Nettle	3 wk.	1

MODULE II : IPM CENTER

	Technical Expertise	Expert's Institution	Duration	Number
A.	Database Management	University of Kentucky	2-4 wk.	1

Appendix V

Pest management

Integrated approach vital

S. NAGARAJAN, Assistant Director-General, (Plant Protection), ICAR, New Delhi, explains that the need for an integrated pest management strategy arises from an awareness of environmentally friendly and loss-preventive aspects.

MINIMISING avoidable losses is one way of enhancing foodgrain production. Crop losses are caused by a variety of living organisms that feed, parasitise and compete with the crop plants. Diseases are caused by fungi, bacteria, viruses, insects nematodes, competitive weeds, rodents, birds and a score of other organisms. The wide variety of pests and pest control techniques complicate the decision-making process of the farmer.

A pest is any organism that causes economic loss in terms of human welfare resources which may be a plant or animal raised for food or fibre. Pests are part of the total eco-system wherein they survive on species that tend to be abundant and enable to keep ecological diversity. In man made agriculture, loss from pests is very high. In India alone, annual crop losses are estimated at Rs 6,000 to 7,000 crores. Of this, losses from weeds are 33 per cent and from diseases 26 per cent, from insects and rodents 26 per cent and birds, nematodes etc., account for the rest. More than 70 per cent pesticides used are insecticides, 12 – 15 per cent fungicides and about 4 – 5 per cent are weedicides. The emphasis in tackling the loss arising from pest needs an orientation on the basis of constraints.

Pesticide usage trend

Of the total 90,000 tonnes of annual pesticide usage, only 63 per cent is for agricultural purposes and the rest for malaria control and various other programmes. The nearly Rs 600-crore agro-pesticide market is concentrated in Andhra Pradesh, Karnataka, Gujarat and Punjab accounting for 76 per cent of the sale for use in cotton, paddy, jowar and wheat crops. These four crops use 80 per cent of the pesticides sold in India and fruits and vegetables account for nearly 10 per cent. Of the more than 77,000 pesticide distribution points, more than 70 per cent are owned by private traders in Andhra Pradesh, Tamil Nadu, Uttar Pradesh, Gujarat and West Bengal.

Though the national use of pesticide per hectare is less compared to the developed nations, there are pockets within India where usage is very high. In Guntur district of Andhra Pradesh, during 1987, one tonne of pesticide formulations/130 ha of cotton or 157 ha of chillies were sprayed. In apple, a tonne of fungicide is sprayed for every 1000 tonnes of apple produced. As the pesticides leave residues that persist in the environment and contaminate the food chain, over-usage of pesticides is a potential environmental hazard. Judicious use of chemicals as a component of integrated pest management is the safest means of pest control.

No single method of pest control has given a lasting solution. When grown over a large area, resistant varieties break down. Pesticide overuse creates environmental problems, bio-amplification of the residues in human fat and resurgence of pests and results in development of pesticides-tolerant strains of the organism. The time-tested cultural procedures such as growing mixed crops and crop rotation, have been replaced by intensive farming. Changed agronomy, mono-cropping, cropping sequence, lack of temporal and spacial hurdles have all contributed to pest abundance. It is realised that there is urgent need to evolve a coherent pest management programme that is environmentally friendly and yet able to curtail loss. From out of this concern has emerged a new strategy called the "Integrated Pest Management" (IPM). The IPM is an integrated and planned execution of different pest management strategies and tactics with the sole objective of reducing losses from pests with minimum ecological implications.

Agronomic implications

Agronomic adjustments help in the avoidance of pests by modifying the microclimate. For example, flooding the banana field for quite some time, prior to fresh planting, minimises the severity caused by *Fusarium oxysporum f.sp. cubanee*. Addition of organic amendments such as green manuring or neem cake at one tonne/ha of rice crop substantially reduces the severity of sheath blight caused by *Rhizoctinia solani* and the population of the root feeding nematodes that predispose the plants for infection. Against most of the soil-borne diseases, organic amendment reduces the disease severity.

Healthy planting material

Use of high quality certified seeds free from disease is one of the primary means of disease control. Presence of degenerative virus diseases in potato progressively reduces the yield, if farmers use the same seed stock from year to year. The northern hills along the Himalayas, above 2,300 m Asl provide the needed climate like intermittent rain, wind, high humidity, low temperature and good exposure that suppresses the aphid (insect) population. As a consequence, viral diseases do not spread. Sero-indexing of the planted tubers for freedom from viruses, periodic roughing, timely spray of insecticides and fungicides are combined. Haulm cutting permits production of high quality disease free tubers. The most notable research accomplishment of the CPRI, Shimla, in the recent past, is the development of a technology for the production of disease-free seed potato tubers in the Indo-Gangetic plain.

The easy availability of good quality disease-free tubers has reduced the number of sprays needed to raise a healthy crop and increased the yield substantially. Similarly, the machinery for hot steam therapy developed by IISR, Lucknow, has permitted mass treatment of sugarcane sets and the elimination of virus diseases.

A premium

Creation of severe artificial epiphytotic conditions has enabled screening of parental and early generation material and in the release of a number of resis-

tant varieties. These varieties are the core of IPM activity targeted to curtail crop loss. The following pest-resistant varieties have found acceptance by farmers.

Pest-resistant varieties

S. No.	Crop	Variety	Tolerant/resistant Attributes
1.	Pigeon Pea	Mukta, Sharda Bahar	Wilt tolerant sterility mosaic
2	Chick Pea	Gaurav, BG 261	Ascochyta blight
3.	Urd bean	Co 4 ADT 3	Powdery mildew (PM) Leaf crinkle
4	Mung bean	Pant M3, ML 337 Co 4	Yellow mosaic virus Tip blight, PM, root rot
5.	Rice	Vikram, Phalguna Vikas, Ratna Mansarovar Srinivas	Gall midge Stem borer Brown Pant Hopper blast, sheath blight Tungro, sheath blight

Gene deployment, varietal mosaic, multilines, etc., are the various techniques to increase the life span of a variety.

Virus diseases

A number of crops, particularly legumes and vegetables, are plagued with serious viral diseases. Viruses are extremely small in size and spread by contact, wounds, seed grafts, insects, etc. A number of insects such as hoppers, aphids and white fly transmit the virus from a diseased plant to a healthy one. Some viruses become persistent in the vector. Vectors are not always serious pests but, in low population densities, are enough to spread the viral disease over the field. Host resistance, serodiagnosis based production of disease-free planting material, cross protection and control of vectors are the primary means of management of viral diseases.

Pest threshold levels

Diseases need not always cause loss. When the severity is less and confined to the lower leaves, it results in premature senescence of non productive leaves. Therefore, a minimum threshold level of pest population is needed to inflict loss. That is, if the threshold level can be predicted, using statistical and computer models, timely action can be taken to cut losses. In South India, the green gram (urad bean) leaf crincle virus (ULCV) is spread by both seed and white fly. Usage of even two per cent infected urad seed can result in 45 per cent disease incidence at the pod formation stage. Against viral diseases that are seed-borne, using disease-free seed, control of the vector and roughing the infected plants form the IPM strategy.

Seed set infection of even two per cent is sufficient to cause an epidemic in mature sugarcane crop if the intervening period has favourable weather conditions. Sugarcane diseases like red rot, wilt, grassy stunt and ratoon stunting could be checked through heat therapy. Exposure to moist hot air for four hours at 50°C is now widely recommended to produce disease-free sets. Such aerated steam therapy has potential application against a number of seed transmitted plant viruses.

Weeds act as collateral hosts for insects and crop pathogens at a time when the main crop is not available. Weeds compete with crop plants for water, nutrition and space. A majority of the seasonal weeds have identical germination and crop growth requirements and either the seeds that are shed before harvest or the weed seed that get mixed with grain at thrashing time serve as a means of perpetuation. Traditionally, the Indian farmer had been using weeds as fodder to cattle and some as leafy vegetable. Owing to labour constraint, weedicide use is increasing at 15 per cent a year.

The main weedicide markets are Punjab and Haryana and Andhra Pradesh and Tamil nadu are also picking up. Wrong use of weedicide would lead to environmental pollution, weedicide tolerance and resurgence of other weeds, which may affect the succeeding crop. Use of Butachlor and 24-D is the highest in rice-wheat rotation areas of north-west India. There is need to understand weed biology and integrate manual, biological and chemical means of weed suppression. Identification of chemical molecules that affect the tropical weeds is another area calling for exploratory studies. One way of avoiding chance introduction of exotic pests through imported seed and planting material is through vigorous quarantine tests. The Plant Protection Adviser to the Government of India and the Directorate of Plant Protection Quarantine and Storage enforce very strictly the statutory requirements. They also operate a number of biological control field stations apart from keeping a constant vigil on the desert locusts.

Biological control

Weed control through insects has been successful primarily in respect of weeds occurring in wastelands, water bodies, etc. The water hyacinth is a succulent, rapidly multiplying exotic weed which grows menacingly in ponds, canals and reservoirs, choking water movement and increasing the drying up of water bodies owing to transpiration by plants. The weevil, *Neochitina eichorniae* and *N.bruchi* are proving to be effective biocontrol agents in many of the warmer parts of our country. The common water weed in Kerala, *Salvinia molesta* is checked by the weevil, *Crytobagus salviniae* the 'Congress grass, *Parthenium* by the beetle, *Zygogramma biocolorata*. These are some of the recent achievements in biocontrol of weeds.

There is an array of fungal pathogens and insects that are specific to weeds occurring in the cultivated field. There is great potential for exploitation of these organisms for achieving non-chemical means of weed suppression. An integration of weed pathogens (Mycoherbicides) and insect pests will be the appropriate methodology for lasting weed control.

Insect predators, parasites and pathogens

More than 500 species of fungi are insect pathogens and have the potential for even marketing them as myco-insecticides. Of these, *Metarhizium anisopliae* is the important one that can be mass-cultured, using coconut water in the medium. It infects Pyrilla, white grubs, aphids, the fungal spores of mycelial mat. These can be stored for long and are highly compatible with any pesticide. Inoculated adults of *M.anisopliae* at 250, very effectively checked *Pyrilla perpusilla*, other fungal pathogens such as *Verticillium lecanii*, *Fusarium Spp.* and bacteria such as *Bacillus popilliae* needs to be fully harnessed as insecticides.

Oryctes beetle that infects coconut by Baculovirus reduces its longevity and fecundity. Over a period of

A pheromone trap in a cotton field in Coimbatore district of Tamil Nadu. The use of hormonal sex attractants helps in assessing the population dynamics of the pest and taking up timely spraying operation.

time, the beetle population gets reduced as it happened in the Andaman islands. In pulses, the Nuclear Polyhedrosis Viruses (NPV) of *Heliothis* have given promising results. The effectiveness of NPV increases when 0.025 per cent tannic and boric acid are added for every 100 larval equivalents. Such preparations of *Spodoptira litura* NPV and the *H.armigera* — NPV have proved their field utility. There are nearly 300 types of NPVs that are specific to each insect and primarily pathogenic on Lepidopterans.

Commercial preparations of NPV are not yet available in India. The emphasis in biological control of insect pests of sugarcane has been on the Pyrilla, stem borers and scales. Augmentation of the shoot-borer parasitoid *Sturmiopsis inferens* in the sugar mill areas of Chengleput and Thanjavur districts of Tamil Nadu brought the pest population under check. About 40 to 60 per cent of the naturally occurring pests are controlled through various parasites, predators and pathogens that assist in suppressing the pest population.

Release of the parasite *Trichogramma japonicum* at10/sq.m. at 10 days interval,starting from 20 days after transplantation of rice, reduces stem-borer infestation and increases the yield by six to seven per cent.

The sugarcane internode borer is an important pest in south India. The thick sugarcane canopy comes in the way of effective plant protection operation. Release of 50,000 *Trichogramma*/ha./week helps in satisfactory control of pests. Such releases also suppress the rice stem borer and, at 2,00,000 eggs/ha./week, *Trichogramma* minimises the damage due to cotton boll worm and tomato fruit borer *Chrysopa scelestes* is an effective predator of a number of aphids, mites and thrips. The technology for mass multiplication of this predator has been indigenously developed. Biological control of insect pests holds great promise.

Biocontrol of diseases

Very good control has been achieved against *Pythium* damping off *Sclerotium rolfsii*, *Rhizoctonia solani* and *Fusarium oxysporum* by using biocontrol fungi such as *Trichoderma hazarianum* and *Gliocladium virens*. Seed treatment with biocontrol agents and changing the soil along with organic manure suppress the increase of soil-borne diseases and increases yield. A number of fungi hold promise for the control of nematode pests as well.

Botanical and biorational control

In the last few years a number of companies have come out with pesticide formulations, having plant products of neem, pongamia, datura, etc. These products which are safe can be explored to control post-harvest damage. According to unofficial estimates, nearly Rs. 2-3 crores worth neem and botanicals were sold last year alone in the rural market. ITC has come out with RD Repellin, a botanical pesticide, and there are a few more less well-known brands in the market. It is time to bring in quality and registration requirements for these products as well.

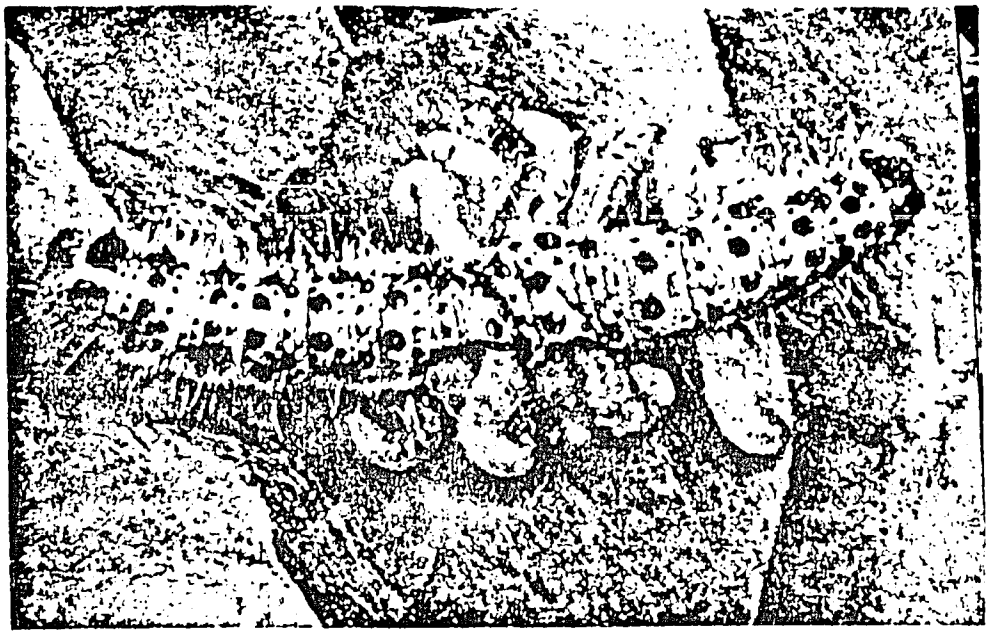
Trapping the population of moths, using hormonal sex attractants called pheromone or growth inhibitors as keromones or through light traps, helps in assessing the population dynamics of the pest and taking timely spray operations. This new approach of threshold population-based management strategy using either biorational or synthetic pesticide, will lead to sustainable agriculture.

Educating farmers

Pesticides are biologically active substances, designed to kill pest population by their toxic or deleterious effects. If the level of pesticide residues exceeds certain limits, they can prove hazardous and get into the human system through the polluted plant and animal-based food and upset the delicately balanced ecosystem. The problem of pesticide residues and biomagnification can be suitably prevented if farmers strictly follow the safe waiting period. The vegetable and fruit growers need to be educated on the implications of violating the wetting period. Stipulating these requirements under the Environment Act will call for strict punishment of the violators.

Need for better spraying

The simple hitchback, semi-automatic knapsack sprayers are cheap, easily serviceable and ideal for small farms. In the tropics this is the most common plant protection machinery. By 2000 A.D. India alone would need eight million power sprayers and dusters of two HP engines. At the moment, indigenous production hardly meets 50 per cent of the demand. There



A larva of cabbage caterpillar, Pieris brassicae, parasitised by Apanteles glomeratus. Biological agents come in handy for effective pest management without polluting the environment.

is scope to go in for delivery systems that are light and possessing better nozzle regulation facilities.

Pesticides are generally applied in the form of spray. Seed dressers, dusts, fumigants, granules and baits are also in use to suit the control of various types of pests. If the droplet size is large, it would result in poor coverage, less penetration and more chemical usage to attain the same level of control. By reducing the droplet size, using the appropriate nozzle and power sprayer, from the same amount of suspension, eight times more droplets are produced with better coverage and a greater degree of pest control. Unfortunately, a majority of Indian farmers are totally ignorant of the need to have a better spray system or pesticide delivery procedure. In the hills where water is to be carried a long way or in the desert, ultra low volume spray is handy.

With the demonstration of better solubility, retention and efficacy of pesticides owing to the addition of adjuvants such as sel-wet 99, against apple scab, the sale of adjuvant in Himachal Pradesh has substantially increased. With an expenditure of Rs. 20 lakhs for adjuvants in Himachal Pradesh, the effectiveness of the fungicide spray schedule to control apple scab has been substantially increased. As a result of IPM extension activities, there is growing awareness of the need for spreaders, stickers, adjuvants, etc.

Weather based prediction

The population build up of pathogens and insect pests depends on favourable weather requirements of temperature, rainfall, leaf wetness and other parameters. By monitoring, weather forecasts are made and farmers are advised to spray or not to spray their crop. Prediction-based spray schedule substantially reduces the number of sprays needed and adds to greater profits.

The All-India Co-ordinated Project on Apple Scab gives timely forecast for the orchards in the Srinagar valley, Kullu and the upper hills of Himachal Pradesh and western U.P. For control of apple scab alone, fungicides for Rs. 7 crores are used per year and any attempt to rationalise usage is an advantage. Prediction system and computer models have been developed and tested for wheat rusts, potato late blight and others. For plantation crops and commercial crops, such models can be of great use.

IPM-based rural employment

As plant protection operations demand technical skill and timing of the combat operation, many private agencies have shown interest in commercialising IPM. Though the multinational companies dominate the pesticide industry, small private biological control laboratories and cooperative sugar mills selling or marketing biocontrol agents have come up in the southern States. With handsome gains, they are still in business. In Tamil Nadu, private agro-clinics and contractual farm sprayings are done. These entrepreneurs also can promote mushroom growing, bee keeping and other means of economic occupation, as part of their business.

Economic mycology

Though some fungi are plant parasites, a number of them are beneficial to man as biocontrol agents of insects, and nematodes and in the production of fermented food and edible mushrooms. The huge agricultural waste can be used as substrate for the production of edible mushrooms. In addition, mushroom growing supplements the farmer's income.

There are a number of species of fleshy and edible fungi called mushrooms. Through selection, cultures of *Agaricus bisporus* and *A.bitorquis* have been identified and they are high-yielding and temperature-tolerant. A high-yielding NCB 6 of *A.bitorquis* that could grow at 22-26°C and yield high quality button mushrooms, has been identified.

With an effective, efficient and structurally cohesive and aggressive plant protection strategy alone, the national agricultural production can be stepped up by 30 per cent. To achieve this, formulating a national plant protection programme is necessary and here the IPM holds the key to successful and sustainable food production.