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Integrated Pest Management in Indian Agriculture

Editors

Pratap S. Birthal
O. P. Sharma

NATIONAL CENTRE FOR AGRICULTURAL ECONOMICS AND POLICY RESEARCH (NCAP), NEW DELHI, INDIA

NATIONAL CENTRE FOR INTEGRATED PEST MANAGEMENT (NCIPM) NEW DELHI, INDIA

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Foreword

Agricultural production in India increased dramatically during the last four decades, leading to an era of food self-sufficiency. The remarkable growth was achieved through the uptake of newer technologies in the form of high yielding crop varieties, chemical fertilizers and pesticides, as well as from the expansion of cropped area. Nevertheless, the growth in agricultural production needs to be sustained to meet the food demand of ever increasing population. Since the prospects for bringing additional land under cultivation are limited, growth in agricultural production has to come from productivity increases. In other words, technology will be a key to future growth of agriculture.

Insect pests, diseases and weeds inflict enormous losses to the potential agricultural production. Anecdotal evidences also indicate rise in the losses, despite increasing use of chemical pesticides. At the same time, there is a rising public concern about the potential adverse effects of chemical pesticides on the human health, environment and biodiversity. These negative externalities, though, cannot be eliminated altogether, their intensity can be minimized through development, dissemination and promotion of alternative technologies such as biopesticides and bioagents as well as good agronomic practices rather relying solely on chemical pesticides. India has a vast flora and fauna that have the potential for developing into commercial technologies.

Plant protection research has generated many technologies using flora and fauna. A few have been standardized for commercial application, and are claimed to provide better pest control and crop economics than the conventional chemical control, when used in conjunction with other pest control measures. The strategy is often referred to as 'Integrated Pest Management'. Nevertheless, the adoption of biopesticides and bioagents remains extremely low owing to a number of factors relating to technology, socio-economic, institutional and policy. The papers presented in this volume examine these factors, and suggest measures for large-scale adoption of these technologies. We hope this volume will be of immense use to the policymakers, researchers, administrators and farmers.

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Editors

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Integrated Pest Management in Indian Agriculture: An Overview

Pratap S. Birthal[1]

Introduction

Over the next three decades, production of foodgrains in India has to increase at least 2 million tonnes a year to meet the food demand of the growing population (Paroda and Kumar, 2000). In the past, agricultural production increased through area expansion and increasing use of high yielding seeds, chemical fertilizers, pesticides and irrigation water. Now, prospects of raising agricultural production through area expansion and application of existing technologies appear to be severely constrained. Land frontiers are closing down, and there is little, if any, scope to bring additional land under cultivation. Green revolution technologies have now been widely adopted, and the process of diminishing returns to additional input usage has set in.

Concurrently, agricultural production continues to be constrained by a number of biotic and abiotic factors. For instance, insect pests, diseases and weeds cause considerable damage to potential agricultural production. Evidences indicate that pests cause 25 percent loss in rice, 5-10 percent in wheat, 30 percent in pulses, 35 percent in oilseeds, 20 percent in sugarcane and 50 percent in cotton (Dhaliwal and Arora, 1996). The losses though cannot be eliminated altogether, these can be reduced. Until recently, chemical pesticides were increasingly relied upon to limit the production losses. Pesticide use in India increased from a mere 15 g/ha of gross cropped in 1955-56 to 90 g/ha in 1965-66. Introduction of green revolution technologies in mid-1960s gave a fillip to pesticide use, and in 1975-76, it had increased to 266 g/ha, and reached a peak of 404 g/ha in 1990-91 (Birthal, 2003). Although, there is a paucity of reliable time-series information on pest-induced production losses, anecdotal evidences suggest increase in losses (Pradhan

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1983, Atwal 1986, Dhaliwal and Arora, 1996), despite increase in the pesticide use. The paradox is explained in terms of rising pest problem, technological failure of chemical pesticides and changes in production systems. Nevertheless, pesticide use has started declining since 1990-91, reaching 265g/ha in 1998-99, without much affecting the agricultural productivity (Birthal, 2003).

The declining trend in pesticide use in agriculture during the 1990s can be attributed to central government's fiscal policy and technological developments in pest management. During 1990s, taxes were raised on pesticides and phasing out of subsidies was initiated. Programmes on training of both the extension workers and farmers in the Integrated Pest Management (IPM) were started throughout the country. In fact, the Government of India had adopted IPM as a cardinal principle of plant protection in 1985. Notwithstanding these initiatives, adoption of IPM has not been encouraging as biopesticides capture hardly 2 percent of the agrochemical market.

This overview provides a synthesis of the papers presented at the workshop and identifies technological, socio-economic, institutional and policy issues important in making IPM work under field conditions.

Available Technologies

Research has generated new technologies using naturally occurring enemies of insect pests (parasitoids, predators and pathogens) for use in IPM. Some important commercially available products include *Trichogramma, Bracons, Crysoperla carnea*, *Crytaemus montrouzieri*, *Bacillus thuringiensis*, *Bacillus sphaericus*, Nuclear polyhedrosis viruses (NPV) and *Trichoderma*. In addition, a number of plant products such as azadirachtin (neem), pyrethrum, nicotine, etc. are also valuable as biopesticides. In India, more than 160 natural enemies have been studied for their utilization against insect pests (Singh, 1997). Technologies have been standardized for multiplication of 26 egg parasitoids, 39 larval/nymphal parasitoids, 26 predators and 7 species of weed.

The Directorate of Plant Protection and Quarantine, Ministry of Agriculture, Government of India, has evolved location-specific IPM packages for both the *Kharif* and *Rabi* crops in consultation with IPM experts from the Indian

Council of Agricultural Research, State Agricultural Universities, and the State Departments of Agriculture.

Technical Efficacy

For IPM to be a success, it must be sound on technical and economic parameters. Technical feasibility of IPM is judged on two criteria: change in the pesticide use, and yield change over the conventional chemical control. As far as change in pesticide use is concerned, it is the basic goal of IPM to reduce pesticide use, and this evidence is well established under experimental as well as field conditions. Its effect on yield could be either way. Nevertheless, evidences presented in this study suggest substantial yield saving advantage of IPM over chemical control in food as well as non-food crops.

Economic Feasibility

Technical feasibility is a necessary but not a sufficient condition for commercialization and adoption of a technology. The necessary condition is the net benefits it entails to the producers over the conventional technology. Net benefits can be measured in terms of the difference in per hectare net revenue due to application of new technology and/or changes in unit cost of production. Studies included in this volume suggest IPM as a cost-effective technology. The magnitude of net benefits however would depend on the type of input used in IPM package, its application rate and price. Evidences show that even under experimental conditions some technically feasible IPM packages turn out to be economically infeasible because of higher prices of some of its constituents.

The inference is 'IPM has the potential to substitute chemical pesticides without demanding any additional resources and without having any adverse effects on agricultural productivity. Nevertheless, inputs prices are an important determinant of the economic feasibility of IPM, and any increase in prices of critical inputs may upset its economics'.

Socio-economic and Policy Issues

Despite its techno-economic superiority over conventional chemical control, adoption of IPM remains restricted to hardly 2 percent of the area treated with plant protection inputs. This estimate is based on the informed opinions of the researchers, extension personnel and policy makers. The structure of agrochemical market also suggests a similar level of adoption; biopesticides share only 2 percent of the agrochemical market in India (Saxena, 2001). There could be a number of technological, social, economic, institutional and policy factors restricting large scale adoption of IPM.

Technology characteristics are important determinants of adoption

The characteristics of technology have an important role in farmers' adoption decisions (Adesina and Zinnah, 1993; Lapar and Pandey, 1999). IPM draws heavily on complementarities and interactions of different methods of pest control (chemical, biological, cultural and mechanical), and each of the components has its own specific characteristics and requirements for application. This makes IPM a complex technology. Generally, the farmers adopt those components that show immediate effect, and are easily available. Biopesticides comprise a major component of IPM. Most of the biopesticides are host-specific, slow in action and have short shelf-life. Besides, application of some of the components is labour intensive compared to conventional chemical control (Birthal *et al.*, 2000). In other words, farmers are risk averse and such technological characteristics create an apprehension among the farming about their efficacy to control pests. The complexity of IPM necessitates active involvement of stakeholders (researchers, extension workers and farmers) to alleviate apprehensions through participatory/ adaptive research trials.

The major issues that the researchers would be confronting in the decades to come include basic research for development of broad-spectrum biological pesticides and improvements in their efficacy and shelf-life. At present, problems of insecticide resistance, resurgence and secondary pest outbreak are not reported against biological substitutes. Maintenance of this property would require sustained research efforts. Biopesticides based on predators, parasites, viruses, fungi, etc. are sensitive to chemical pesticides. This warrants research emphasis on development of bio-pesticides having better compatibility with chemical pesticides. Genetic engineering for resistance breeding will remain a gray area for long. Biotechnology has got tremendous potentialities for developing biopesticides.

Role of extension system goes beyond technology dissemination

Unlike many other technologies that require only limited information and delivery for adoption, IPM is akin to a new technology and knowledge intensive. Its effective implementation requires extension workers to have a sound understanding of the characteristics of the technology, its target host and relationship with natural enemies, and its method of application before the technology is delivered to the farmers. Lack of understanding of any of these would adversely affect its adoption. The extension workers should act more as a collaborator, consultant, and facilitator in dissemination of the knowledge, with the farmer playing a more active role.

In order to achieve this both the central and state governments have made considerable efforts to impart training to the extension workers. During 1995 and 2000, on an average an extension worker has been trained thrice in IPM methodologies. To transfer the skills to the farmers, more than 6200 farmers' field schools were established. These efforts however have not trickled down much, as only 0.2 percent of the farmers were trained during this period.

Extension system needs to overhauled in knowledge about IPM inputs, methodology of IPM and timely delivery of services to the farmers to accelerate the adoption of IPM.

Community participation is key to success of IPM

Pest has the characteristics of a detrimental common property resource. It does not recognize spatial boundaries. In other words, successful pest control demands collective efforts. Yet, most of the times pest control efforts are individualistic, giving rise to a number of pest control related problems, such as pest resistance, resurgence and secondary outbreak, destruction of natural enemies of insect pests and other beneficial insects. Collective pest management assumes greater significance in the context of IPM. There are a number of management practices such as observance of synchronicity in sowing dates, use of resistant varieties, crop rotations, etc. that require close cooperation among farmers to achieve maximum pest control efficiency. Further, IPM relies on inputs derived from living organisms, and the application of different control methods in a locality, in particular chemical pesticides, would adversely affect the activities of the biological inputs.

Though, a majority of the farmers could be aware of the benefits of collective action, a number of socio-economic factors act as a disincentive to participate in it. Birthal (2003) empirically examined the factors constraining community participation and found that social heterogeneity (caste differences) was the main hindrance. Further, the farmers applying IPM technologies were more willing to participate. The need therefore is to evolve institutional mechanisms that promote group action. The current concept of Farmers' Field School though is based on the principles of collective action; it is often observed that either the groups are not formed, or even if the groups are formed, they disappear once the program is withdrawn.

Community participation is key to successful adoption of IPM, and needs to be sustained by devising an appropriate exit policy. Local bodies, such as Panchayats, Non-Governmental Organisations, Self Help Groups, etc. should be encouraged to shoulder this responsibility. Incentives and awards should be given to those farmers/groups who are following IPM approach.

Supply of biopesticides is critical to sustainability of IPM

As noticed earlier, biopesticides capture only 2 percent of the agrochemical market, although the mass production standards and techniques have been developed for a number of biopesticides. Further, most of the production takes place in public sector units. So is their distribution. Of over 400 biocontrol laboratories in India, 70 percent are in the domain of public sector. Most of the laboratories are small and cater to the location-specific needs only of a small area. The average gross cropped area per biocontrol laboratory is large. This shows that production of biopesticides is thinly spread.

Nevertheless, the continental dimensions of the agricultural sector offer vast scope for expansion of biopesticide industry. Some inherent technical characteristics of bio-pesticides however act as disincentive to the entry of private sector. Unlike chemical pesticides, most of the bio-pesticides are not broad spectrum and are slow in action. Many of these like *Trichogramma* and *Crysoperla* have a short shelf-life, ranging from a few weeks to few months. Thus, production of biopesticides is fraught with risk. Other constraints in expansion of biopesticide industry are uncertain demand, and lack of appropriate infrastructure for transportation, storage and marketing.

Rural unemployed and educated youths should be encouraged to establish small-scale biopesticide production units at village or block level. Measures, such as training to the potential entrepreneurs, provision of institutional credit, subsidies, insurance against low offtake of inputs due to low pest infestation, and exemption from taxes and duties would stimulate production of bio-pesticides.

Further, bio-pesticide manufacturing units are under strict registration and quality control requirements. The process of registration is cumbersome and costly, which discourages potential entrepreneurs.

Considering the role of biopesticides in ecological conservation and human health safety, registration requirements should be relaxed, though without reconciliation with quality standards.

Enforcement of pesticide regulations will help improve adoption of IPM

In recent years, the central government has banned a number of pesticides for use in agriculture in consideration of their adverse effects on environment and human health. Despite this, many of these are available in the market. For example, DDT and BHC, which are permitted for use for malaria control, are widely used in agriculture. Further, many pesticides that have been banned elsewhere in the world are available to Indian farmers. Lower prices of such pesticides induce farmers to use them. A number of spurious pesticides are available in the market because of lack of strict enforcement of regulations and/or regulatory loopholes.

Strict enforcement of the regulations governing production, use, distribution and quality of pesticides would help weed out spurious elements from the industry and would benefit the farmers.

Economic incentives will encourage farmers switching over to IPM

Price of a technology is an important determinant in farmers' decision for its adoption. At present, bulk of the supply of biopesticides comes from public sector, often provided at subsidized prices under IPM programmes. The evidences show that benefits of adoption of IPM are marginally higher than the conventional chemical pest control (Birthal, 2003). An increase in the price of biopesticides due to cost considerations or withdrawal of subsidies would upset the economics of IPM. Since biopesticides generate considerable social and environmental benefits, the government should think of classifying them into 'green box' for provision of subsidies. Simultaneously, the incentives/subsidies, if any, on synthetic pesticides be withdrawn and the resultant savings be diverted towards promotion of IPM. Linking of agricultural credit and insurance to IPM can also facilitate its faster diffusion.

Another alternative is to make production and use of chemical pesticides unattractive through fiscal instruments of taxes, excise duties, sales taxes, etc. on intermediary inputs and final output. The decline in pesticide use during the early 1990s was on account of imposition of heavy taxes on pesticide industry. The pesticide industry, which has established strong market over the last three decades, may resist it, but it may be pursued to switch over to production of safer pesticides and biopesticides.

Withdrawal of subsidies on chemical pesticides and diversion of the same towards production and use of biopesticides, and linking institutional credit and insurance with IPM adoption would induce farmers switching over to IPM.

Development of market for pesticide-free products is a necessary

Economic incentives may not be sustained for a long. An alternative is to develop markets for pesticide-free or low-pesticide residue produce by creating consumer awareness about health benefits of such produce. At present, there are no premium markets and standards for organic food in India. Since in the short-run there is a possibility of shortfall in yield on switching over to IPM, farmers even if they are willing to adopt IPM may not do so. In developed countries market for pesticide free products is developing and these products fetch premium prices. This however is lacking in India. This would require not only development of certification procedures and labeling system to gain confidence of the consumers. The cost of certification is high for an individual farmer. The cost can be brought down considerably if a group approach is followed.

Evolving simple and cost-effective certification and labeling systems to enable farmers to produce pesticide-free products and to gain confidence of the consumers will boost adoption of IPM.

Conclusions

India has successfully reduced pesticide consumption without adversely affecting the agricultural productivity. This was facilitated by appropriate policies that discouraged pesticide use, and favoured IPM application. Despite it, adoption of IPM is low owing to a number of socio-economic, institutional and policy constraints. On the supply side, lack of commercial availability of biopesticides and inappropriate institutional technology transfer mechanisms are the critical impediments to increased application of IPM. The presence of private sector in biopesticide production and marketing is marginal, and needs to be improved through economic incentives. On the demand side, farmers though are aware of technological failure of pesticides to control pests, and their negative externalities to environment and human health, pest risk is too high to experiment with newer approaches to pest management. IPM is a complex process and farmers lack understanding of biological processes of pests and their predators and methods of application of new technology components. The socio-economic environment of farming is also an important factor in adoption of IPM. There are a number of IPM practices that work best when applied by the entire community and in a synchronized mode. This is unlikely to happen without demonstrating benefits of group approach, and external motivation and support to the farmers. Though many technology programs are based on community approach, they do not have any proper exit policy to sustain the group approach. The IPM policy should also provide incentives to farmers to adopt IPM as a cardinal principle of plant protection.

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Integrated Pest Management for Sustainable Agriculture

Amerika Singh and O.P. Sharma[1]

Introduction

India's population has been growing at an annual rate of 1.8 percent, and is expected to touch 1.3 billion mark by 2020. At this rate of population growth, the country would require an additional foodgrain of about 2 million tonnes a year (Paroda, 1999). Although in the recent decades, India has achieved self-sufficiency in foodgrain production, concerns of food security will remain as ever, as the scope to bring additional land under cultivation is limited and the agricultural production technology has started showing signs of fatigue, and has been accompanied by the degradation of natural production resource base. Notwithstanding these facts, the incremental production has to come from productivity increases without damaging the ecological foundations of agriculture. This underlies the need for generation and diffusion of new technologies that produce sufficient food and protect the environment and human health. According to the noted agricultural scientist, M.S. Swaminathan (1999), agriculture production systems in the 21st century need to be based on the appropriate use of biotechnology, information technology and ecotechnology. Integrated Pest Management (IPM) is such a technology. This paper takes a stock of research and development in IPM in India and provides a perspective for the future.

Losses due to Pests

Insect pests, diseases and weeds are the major constraints limiting agricultural productivity growth. It is estimated that herbivorous insects eat about 26 percent of the potential food production. Emerging problems of insecticide resistance, secondary pest outbreak and resurgence further add to the cost

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of plant protection. Annual crop losses due to insect pests and diseases in India are estimated to be 18 percent of the agricultural output. Losses caused by specific pests may be higher. *Helicoverpa* spp. in cotton causes losses up to 50 percent. According to Raheja and Tewari (1996), *H. armigera* (American bollworm) alone causes an annual loss of about Rs1000 crores. The production losses have shown an increasing trend over the years. In 1983, the losses due to insect pests were estimated worth Rs 6,000 crores (Krishnamurthy Rao and Murthy, 1983), which increased to Rs 20,000 crores in 1993 (Jayaraj,1993) and to 29,000 crores in 1996 (Dhaliwal and Arora, 1996). New pests have appeared due to the changes in the cropping patterns and the intensive agricultural practices.

Evolutionary Trends in Chemical-based Pest Management

Until the beginning of 20th century, farmers relied exclusively on cultural practices such as crop rotation, healthy crop variety, manipulations in sowing dates, etc. to manage the pests. Use of pesticides, although began in 1870s with the development of arsenical and copper-based insecticides, discovery of pesticidal properties of DDT during the World War II revolutionized the pest control. DDT was effective against almost all-insect species and was relatively harmless to the humans, animals, and plants. It was effective at low application rates, and was also less expensive, hence the Indian industries too joined the race. Farmers were amazed with its effectiveness and started to use it increasingly particularly during the green revolution era. As a result of rising demand, the pesticide industry rapidly expanded its research on synthetic organic insecticides as well as on other chemicals controlling the pests. The negative externalities of chemical pesticides, however, started emerging soon after the introduction of DDT. Producers then turned to the more recently developed, and much more toxic, organophosphates (OP) and pyretheroid insecticides, which resulted in development of resistant strains. Most of the pesticides were originally based on the toxic heavy metals such as arsenic, mercury, lead and copper.

Pesticides often kill the natural enemies along with the pests. With natural enemies eliminated, it is difficult to prevent recovered pest populations from exploding to higher and more damaging levels, and often developing resistance to chemical pesticides. Repeated applications of chemical pesticide only repeat this cycle. At low yields, benefits from pest control were not huge. However, as yields started increasing, pesticide use started becoming widespread. Their adverse effects on the environment and human health also soon became apparent. During the early 1960s, the public concerns about these effects were galvanized by Rachel Carson in her classic 'Silent Spring', published in 1962.

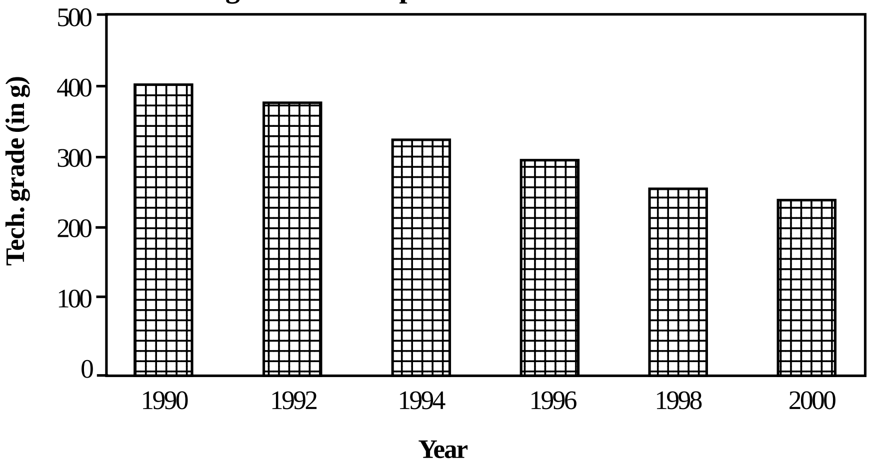
Indiscriminate, excessive and continuous use of pesticides acted as a powerful selection pressure for altering the genetic make-up of the pests. Naturally resistant individuals in a pest population were able to survive onslaughts of the pesticides, and the survivors could pass on the resistance traits to their generations. This resulted in a much higher percentage pest population being resistant to pesticides. At present, the number of weed species resistant to herbicides are estimated to be 270, and plant pathogens resistant to fungicides are 150. Resistance to insecticides is common and more than 500 insect species have acquired resistance to the pesticides.

Intensive Agriculture and Pesticide Use in India

In India, pesticide use has been increasing at an annual rate of 2.5 percent since early 1970s. About 96,000 tonnes of technical grade pesticides are currently produced in the country (Anonymous, 1997), of which two-thirds are used in agriculture (Khader Khan, 1996). The adoption of the high yielding cereal varieties led to manifold increase in the crop yields. Maintaining higher yields also led to a dramatic increase in the pesticide use; from 5,700 tonnes in 1960 to 46,195 tonnes in 2000. Although per hectare pesticide use in India is about 250g, pesticides are used indiscriminately (Dhaliwal and Arora, 1996). About half of the total pesticides used in agriculture goes towards controlling insect pests and diseases of cotton, which occupies only 5 percent of the total cultivated area. Cotton receives as many as 15-20 rounds of insecticide sprays right from the vegetative stage till its maturity. According to the estimates by Birthal and Jha (1997), one hectare of cotton receives 3.75kg of pesticides. Rice with an area share of 24 percent accounts for 17 percent of the total pesticide use.

Indian 'Green Revolution', one of the greatest success stories in the world, with dramatic impact on the food security, was based on principles of intensive agriculture. However, the intensive agriculture has led to the newer problems such as excessive and untimely use of irrigation water, erosion of genetic resources caused by the replacement of rich diversity of the traditional crop varieties with a few high yielding varieties, and inappropriate use of critical inputs such as chemical fertilizers and pesticides (Paroda, 1999). Thus, with intensification of agriculture and consequent increase in genetic uniformity of crops, the incidence of insect-pests, diseases, nematodes and weeds has also increased. The pests that hitherto were of novelty have become the key pests affecting a number of crops.

Fig. 1 : Per ha pesticide use in India



One notable feature of intensive agriculture was increased use of pesticides, particularly during the green revolution years (Fig.1). Until 1995-96, the major group of chemical pesticides used in agriculture was that of insecticides (80%), followed by fungicides (10%) and herbicides (7%). Thereafter, the share of insecticides declined with simultaneous increase in the shares of herbicides and fungicides. The share of insecticides in 1999-2000 was 60 percent, of fungicides, 21 percent, and of herbicides, 14 percent. Although the consumption of pesticides per hectare has remarkably come down (Fig. 1), the use of pesticides on different crops varies remarkably (Table 1). Per hectare consumption of pesticides started declining since early 1990s. This is obviously due to increasing awareness of ecological concerns and IPM initiatives taken up by different state governments (Table 2).

There are substantial regional variations in pesticides consumption and its trend. Earlier, Andhra Pradesh, Karnataka and Gujarat used to account for

Table 1. Pesticide consumption by major crops, 1993-94

Crop	Cropped area (%)	Pesticide use (%)
Cotton	5	54
Rice	24	17
Vegetables & fruits	3	13
Plantation crops	2	8
Sugarcane	2	3
Others	64	5

Source: Anonymous, 1997

Table 2. Total pesticide consumption by states, 2000

	Consumption	
State	Total (tonnes)	Percent
Uttar Pradesh	7459	16.15
Punjab	6972	15.10
Haryana	5025	10.88
Andhra Pradesh	4054	8.78
Gujarat	3646	7.90
Maharashtra	3614	7.83
West Bengal	3370	7.30
Karnataka	2484	5.38
Tamil Nadu	1685	3.65

Source: Directorate of Plant Protection Quarantine & Storage, 2001

bulk of the total pesticide consumption, but this has come down substantially due to initiatives taken up state governments. Current statistics show Uttar Pradesh, Punjab and Haryana as the major consumers.

Sustainable Agriculture and Integrated Pest Management

The solution to the pesticide externalities lies in the implementation of Integrated Pest Management (IPM), which combines the use of different pest control strategies (cultural, resistant varieties, biological and chemical control). IPM is thus more complex for the producer to implement, as it requires skills in pest monitoring and understanding of the pest dynamics, besides the cooperation among the producers *en mass* for effective implementation. During 1960s when the IPM began to be promoted as a pest control strategy, there were fewer IPM technologies available for field application. During 1970s, research generated some novel products and knowledge for successful implementation of IPM in crops like rice, cotton, sugarcane and vegetables. However, the exaggerated expectations about the possibility that dramatic reduction in pesticide use could be achieved without significant decline in crop yields as a result of adoption of IPM could not be realized.

Integrated Pest Management (IPM) is an ecologically based strategy that focuses on long-term solution of the pests through a combination of techniques such as biological control, habitat manipulation, modification of agronomic practices, and use of resistant varieties. Embracing a single tactic to control a specific organism does not constitute IPM, even if the tactic is an essential element of the IPM system. Integration of multiple pest suppression techniques has the highest probability of sustaining long-term crop protection. Pesticides may be used to remove/prevent the target organism, but only when assessment with the help of monitoring and scouting indicates that they are needed to prevent economic damage. Pest control tactics, including pesticides, are carefully selected and applied to minimize risks to the human health, beneficial and non-target organisms, and environment.

In the context of crop protection, sustainability refers to the substitution of chemicals and capital with farm grown biological inputs and knowledge, aimed at reduction in the cost of production without lowering the yields (Swaminathan, 1995). Sustainability builds on the current agricultural achievements, adopting a sophisticated approach that can maintain high yields and farm profits without degrading the resources. Sustainable agriculture is a reality based on the human goals and on the understanding of the long-term impact of human activities on the environment and on other species. This philosophy combines the application of prior experience and the latest scientific advancements to create integrated, resource-conserving, equitable farming systems. The systems approach minimizes environmental degradation, sustains agricultural productivity, promotes economic viability in both the short and long run, and maintains quality of the life (Charles and Youngberg, 1990). Sustainable farming practices commonly include:

- Crop rotations that mitigate weeds, disease, insect and other pest problems; provide alternative sources of soil nitrogen; reduce soil erosion; and reduce risk of water contamination by agricultural chemicals
- Pest control strategies include integrated pest management techniques that reduce the need for pesticides by practices such as scouting/ monitoring, use of resistant cultivars, timing of planting, and biological pest controls
- Increased mechanical/biological weed control; more soil and water conservation practices; and strategic use of green manures
- Use of natural or synthetic inputs in a way that poses no significant hazard to humans or the environment.

Tools of IPM

Monitoring: Crop monitoring, that keeps track of the pests and their potential damage, is the foundation of IPM. This provides knowledge about the current pests and crop situation and is helpful in selecting the best possible combinations of the pest management methods. Pheromone traps have got advantage over other monitoring tools such as light and sticky traps. Being selective to specific pest, they have proven their usefulness in large scale IPM validations in cotton, basmati rice, chickpea and pigeonpea.

Pest resistant varieties: Breeding for pest resistance is a continuous process. At the same time the pests also, particularly the plant pathogens, co-evolve with their hosts. Thus, gene transfer technology is useful in developing cultivars resistant to insects, plant pathogens and herbicides. An example of this is the incorporation of genetic material from *Bacillus thuringiensis* (Bt), a naturally occurring bacterium, in cotton, corn, and potatoes, which makes the plant tissues toxic to the insect pests. Scientific community is impressed by its huge potential in managing the pests, but is also concerned about the possibility of increased selection pressure for resistance against it and its effects on non-target natural fauna. However, due to ethical, scientific and social considerations, this potential technology has been surrounded by controversies.

Cultural pest control: It includes crop production practices that make crop environment less susceptible to pests. Crop rotation, fallowing, manipulation of planting and harvesting dates, manipulation of plant and row spacing, and destruction of old crop debris are a few examples of cultural methods that are used to manage the pests. Planting of cover crops, nectar-producing plants and inter-planting of different crops to provide habitat diversity to beneficial insects are important management techniques. Cover crops, often legume or grass species, prevent soil erosion and suppress weeds. A cover crop can also be used as a green manure, which is incorporated in the soil to provide nitrogen and organic matter to the subsequent crop. When incorporated in the soil, some cover crops of the *Brassica* family have the ability to suppress nematode pests and wilt diseases. Left in the field as residues, rye and wheat provide more than 90 percent weed suppression. Cultural controls are selected based on knowledge of pest biology and development.

Physical or mechanical controls: These are based on the knowledge of pest behaviour. Placing plastic-lined trenches in potato fields to trap migrating Colorado potato beetles is one example of the physical control. Shaking of the pigeonpea plant to remove *Helicoverpa* larvae is a common practice in pigeonpea growing areas. Hand picking of insect pests is perhaps the simplest pest control method. Installation of dead as well as live bird perches in cotton and chickpea fields has proved effective in checking the bollworm infestation. Using mulches to smother weeds and providing row covers to protect plants from insects are other examples.

Biological controls: These include augmentation and conservation of natural enemies of pests such as insect predators, parasitoids, parasitic nematodes, fungi and bacteria. In IPM programmes, native natural enemy populations are conserved, and non-native agents may be released with utmost caution. *Trichogramma* spp. are the most popular parasitoids being applied on a number of host crops. A number of microorganisms such as *Trichoderma* spp., *Verticillium* spp., *Aspergillus* spp., *Bacillus* spp. and *Pseudomonas* spp. that attack and suppress the plant pathogens have been exploited as biological control agents.

Chemical controls: Pesticides are used to keep the pest populations below economically damaging levels when the pests cannot be controlled by other means. Pesticides include both the synthetic pesticides and plant-derived pesticides. Synthetic pesticides include a wide range of man-made chemicals. These are easy to use, fast-acting and relatively inexpensive. Ideally, pesticides should be used as a last resort in IPM programmes because of their potential negative effect on the environment. Pesticides with the least negative impacts on non-target organisms and the environment are most useful. Fortunately, new generation pesticides with novel modes of action and low environmental effects are being developed and registered for use. Pesticides that are short-lived or act on one or a few specific organisms fall in this class.

Economic threshold assessment is based on the concept that most plants can tolerate at least some pest damage. Much research has been done to determine the damage thresholds for a variety of crops and pest situations, yet the studies are inconclusive. In an IPM programme where the economic threshold is known, chemical controls are applied only when the pest's damaging capacity is nearing to the threshold, despite application of other alternative management practices.

Botanical pesticides can be prepared in various ways. They can be as simple as raw crushed plant leaves, extracts of plant parts, and chemicals purified from the plants. Pyrethrum, neem, tobbaco, garlic, and pongamia formulations are some examples of botanicals. Some botanicals are broad-spectrum pesticides. Botanicals are generally less harmful to the environment, because of their quick degrading property. They are less hazardous to transport. The major advantage is that these can be formulated on-farm by the farmers themselves.

Strategies for IPM Implementation

The IPM packages tested at several research centres vis-a-vis the farmers' practices indicate superiority of the former. IPM practices enabled reduction in the number of chemical sprays. IPM system also resulted in increase of natural enemies by three-fold, reduced the insecticide and environmental pollution (Dhaliwal and Arora, 1996).

An integrated strategy for the management of major pests and diseases is possible by (i) breeding new varieties with built-in resistance, (ii) evolving efficient methods of pest control through pest surveys and monitoring, and (iii) biological control of pests with the help of conservation and augmentation of natural enemies like parasites, predators and insect pathogens. Economically viable integrated pest management strategies have been developed for the control of major pests in rice, cotton, pulses, sugarcane, etc. Control of Pyrilla and top borer of sugarcane, mealy bug of coffee, lepidopterous pests affecting cotton, tobacco, coconut, sugarcane, etc. are a few examples where success has been achieved through the release of biocontrol agents. A major achievement has been the development of mass rearing technology for biocontrol agents such as *Trichogramma* spp., *Chrysoperla* spp. and nuclear polyhedrosis viruses (NPV) of *Heliothis* and *Spodoptera*.

Indian scientists and extension workers are aware of negative externalities of the pesticides, and the concept of economic thresholds. The Department of Biotechnology, Government of India, provides financial assistance to the State Agricultural Universities and other research organizations for developing and producing biopesticides and biocontrol agents. A number of biopesticide production units and plant protection clinical centres have been established and strengthened in recent years. As a result, the use of biopesticides and biocontrol agents in India is rising, but it has not reached the desired level. The biopesticides are cheaper than the chemical pesticides. Besides being eco-friendly, they do not pose risk of resistance development. A rough estimate of demands for different biopesticides proposed in the IXth Five Year Plan is given in Table 3. The estimates look to be difficult to meet unless a mission-oriented approach is followed. It appears that the concept of using biopesticides and biocontrol agents among the farmers is still in infancy. Only 1 percent of 143 million hectares cropped area confined to only about 2500 villages of the 6 lakh villages in the country has been covered under IPM. Thus, there is a need to synthesize, validate and promote appropriate location-specific IPM modules.

Table 3. Estimated demand of different biopesticides to cover major crops

Bio-agents/Pheromones	Demand to cover 50% of area
Trichoderma preparation	5000 tonnes
Trichogramma	4000 lakh cc
Helicoverpa NPV	4200 lakhs LE
Spodoptera NPV	19000 lakh LE
Helicoverpa pheromone trap	350 lakhs
Spodoptera pheromone trap	350 lakhs

Major Obstacles

Although, IPM has been accepted as the most attractive option for protection of crops from the ravages of pests, implementation at the farmers level has been limited. Pesticides continue to dominate and their injudicious use represents the greatest threat to IPM. For an effective implementation strategy, it is necessary to identify the obstacles to its dissemination, some of which are:

- Low awareness and innovativeness of extension personnel and target groups
- Inadequate interaction between research and extension agencies
- Problem of timely and adequate supply of quality inputs, including biocontrol agents and biopesticides
- Complexity of IPM vs simplicity of chemical pesticides
- The dominant influence of pesticide industry
- Non-availability of location-specific IPM modules for many crops

Essentials for implementation

- Availability of location-specific IPM modules, which are ecologically sound, economically viable and socially acceptable
- High level of target group participation
- Area-wide dissemination strategy
- Removal of obstacles in dissemination of IPM
- Measuring, evaluating and publicizing the impacts of IPM.

Conservation of natural enemies of pests and their augmentation is of prime importance. Besides, the intrinsic property of renewability, reversibility and resilience of botanicals and biopesticides make them most dependable tools for sustainable IPM. Hence, to maintain ecological balance and to manage the pests, the use of bio-agents and biopesticides/botanicals must receive priority attention.

Conclusions

There is an emerging consensus that modern petrochemical-based farming is unsustainable and there is a need to develop and promote ecological approaches to food production. Biotechnology offers a great scope to do this. The most obvious and apparently environment-friendly alternative to pesticides is to follow the naturally occurring biological approaches. Many plant species have been reported to possess pesticidal and pest growth inhibiting properties, but their potential remains untapped by the industry.

Holistic planning provides farmers with the management tools they need to manage biological complex farming systems in a profitable manner. A successful IPM programme requires time, money, patience, short- and long-term planning, flexibility and commitment. The research managers must spend time on self-education and making contacts with extension and research personnel to discuss farming operations, which vary widely. This would aid in developing integrated plans. The government could create policy environment for promotion of IPM. The central and state governments must take lead in changing the pest control picture through measures that would make chemical control less attractive through legislation, regulatory and fiscal measures.

The Indian Council of Agricultural Research (ICAR) and the Department of Agricultural Research and Education of the Ministry of Agriculture, Government of India, are committed to the development and promotion of IPM in the country. It is the top priority of the ICAR and the Government of India to provide safe and effective technologies to protect against unacceptable losses due to insect pests, weeds and diseases.

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3

Integrated Pest Management in Rice in India: Status and Prospects

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Introduction

Prior to the introduction of the modern varieties during the 1960s, the rice crop survived for centuries with traditional varieties with robust plant type but low yield. Farmers used to grow varieties with different genetic backgrounds in a mosaic fashion, meaning existence of several varieties in the field during the crop season. This together with low or no fertilizer use probably was the major reason for the maintenance of pest populations at low level. These varieties could cope up with a range of biotic and abiotic stresses. However, during the mid 1960s modern high yielding varieties (HYVs) were developed and introduced. Single or a couple of such varieties with a narrow genetic base started occupying vast stretches of lands. Further, these varieties were photo-insensitive and could be cultivated in non-traditional areas. These were fertilizer responsive and, therefore, farmers started applying higher doses of fertilizers in general, and nitrogen in particular. These changes in rice cultivation resulted in an altered microclimate, which led to the accentuation of the insect pest and disease problems.

Leafhoppers, planthoppers and leaf folder, which were of minor importance, have assumed the status of major pests. Gall midge has become a serious problem in many areas and has also extended its activity to dry season, particularly in the coastal areas. Stem borer, which was not known in states like Punjab and Haryana, has become a deadly pest there. Sporadic pests like rice hispa, ear cutting caterpillar and gundhi bug have been causing serious damage to rice, intermittently (Table 1). Among diseases, recurrent epidemics of bacterial leaf blight and rice tungro disease is often observed

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Table 1. Intensity of insect pest problems on rice in different states

State	Stem borer	Gall midge	Brown plant hopper (BPH)	Green leaf hopper (GLH)	Leaf folder (LF)	White backed plant hopper (WBPH)	Cut worms	Hispa	Gundhi bug
Andhra Pradesh	S	M	S	S	S	M	M	M	L
Assam	M	-	L	L	M	-	M	M	M
Bihar	M	M	-	M	L	L	-	L	L
Gujarat	M	-	-	M	M	L	L	L	L
Haryana	VS	-	-	L	S	S	L	L	L
Himachal Pradesh	M	-	-	L	M	M	-	L	-
Jammu & Kashmir	L	-	-	M	M	L	-	-	L
Karnataka	M	M	M	L	M	M	-	L	L
Kerala	S	S	S	M	M	L	L	L	L
Madhya Pradesh	M	S	M	S	M	M	L	L	L
Maharashtra	S	S	M	L	M	L	L	L	L
Manipur	L	S	-	L	M	-	-	-	L
Meghalaya	L	L	L	L	L	-	-	L	L
Nagaland	L	-	-	L	L	L	-	L	-
Orissa	S	S	M	S	M	L	M	L	L
Pondicherry	S	M	S	M	S	M	L	L	L
Punjab	VS	-	-	L	M	M	-	M	-
Rajasthan	L	-	-	L	L	L	L	-	-
Tamil Nadu	S	M	M	M	S	M	L	M	L
Tripura	L	L	-	L	L	L	L	L	L
Uttar Pradesh	M	L	M	M	M	M	M	L	M
West Bengal	S	M	S	M	M	M	-	M	M

L – Low, M – Moderate, S – Severe, VS – Very Severe in the coastal regions and the Indo-Gangetic plains. Blast has emerged as a major production constraint in irrigated ecosystem. Many diseases such as sheath blight, sheath rot, false smut and leaf scald have become severe in several parts of the country.

India has a history of pest outbreaks resulting in extensive losses in rice production systems (Atwal *et al.,* 1967; Israel and Rao, 1968; Khaire and Bhapakar, 1971; Katiyar *et al.,* 1972; Kulshreshtha *et al.,* 1974; Rao and Muralidharan, 1977; Chelliah *et al.,* 1989). Damage due to gall midge outbreak in Kuttanad area of Kerala during the *Rabi* season in 1996 is estimated worth Rs 6 crores (Devi *et al.,* 1998). A number of factors have contributed to pest outbreaks, of which major ones are: cultivation of modern varieties over vast stretches, cultivation of varieties that do not possess resistance to major pests, cultivating rice throughout the year, providing permanent food source to the pests, use of high levels of nitrogen, and increased emphasis on insecticides (Chelliah *et al.,* 1989).

Yield losses ranging from 21 to 51 percent have been estimated due to moderate to serious incidence of stem borer, gall midge, planthoppers and other sporadic pests in the rice growing areas of the country. The development of suitable Integrated Pest Management (IPM) strategies is essential to overcome the above biotic constraints mainly, pests and diseases for realising yield potential of rice. In view of the fact that farmers have been mostly relying on chemical control for managing the pests, it has become imperative to develop a holistic system of tackling pests, which is environment-friendly, economically viable and socially acceptable.

Status of IPM Research in Rice

Host plant resistance

Host plant resistance is the most effective, economical, practical and easiest means of controlling the pests. Further, it is compatible with other methods of pest control. Most of the modern varieties grown widely in the pest/ disease prone areas possess resistance to at least one insect pest or disease. Of the total 570 commercial varieties released in India, 51 varieties are resistant to gall midge, 25 to brown planthopper, 3 each to stem borer and green leafhopper and two to whitebacked planthopper (Table 2). Amongst gall midge resistant varieties, all are resistant Gm biotype 1; 24 are resistant

Table 2. Sources of resistance and released varieties against important insect pests of rice

	Insect pest	Donors	Released varieties
1.	Gall midge	CR143, Eswarakore, Leuang 152, Ob 677, Ptb 10, Ptb 18, Ptb 21, Siam 29.	Sneha, Pothana, Kakatiya Erramallelu, Kavya, Rajendradhan 202, Karna, Ruchi, Samridhi, Usha, Asha, MDU 3, Bhuban, Samalei, Orugallu, Abhaya, Shakti, Suraksha, Daya, pratap, Udaya, IR 36, Shaktiman, Tara, Kshira, Sarasa, Neela, Lalat, Phalguna, Mahaveer, Vibhava, Divya, Dhanya Lakshmi, Surekha, Vikram, Kunti.
2.	Brown planthopper	ARC 5984, ARC 6650, Karivennel, Leb Mue Nhang, Manoharsali, Oorapandy, Ptb 10, Ptb 18, Ptb 21, Ptb 33, Triveni.	Chaitanya, Krishnaveni, Vajram, Pratibha, Makom, Pavizham, Manasarovar, Co-42, Chandana, Nagarjuna, Sonasali, Rasmi, Jyothi, Bhandra, Neela Annanga, Daya, Aruna, Kanaka, Remya, Bharatidasan, Karthika.
3.	White backed planthopper	Ptb 33	HKR 120
4.	Green leaf hopper	Ptb 2, W 1263	Vikramaraya, Lalat, Khaira, Nidhi
5.	Stem borer	TKM 6	Ratna, Sasysree, Vikas

against biotype 2; 11 are against biotype 4; and 6 are against biotype 5. The brown planthopper resistant varieties have been developed utilizing 11 resistant donors. Many of these resistant varieties possess high yield and other desirable agronomic characters, and are being extensively cultivated in the pest endemic areas (Kalode and Krishnaiah, 1991).

To cope up with the genetic diversity in host plant, insect/pathogens also display a wide range of genetic variability, resulting in variable reaction to certain cultivars in different areas. In gall midge, three biotypes were characterized after extensive testing of differentials over a period of 13 years at 11 field locations in 7 states (Kalode and Bentur, 1989). The fourth biotype appeared in 1986 in north-eastern parts of Andhra Pradesh where gall midge resistant varieties like *Phalguna* and *Surekha* succumbed to the attack of the pest, though these varieties were being extensively cultivated for more than 10 years in this region. In 1990, a similar report was received from the Vidarbha region of Maharashtra where a population akin to biotype 4 was found to have developed due to cultivation of resistant varieties like *Phalguna*. Recent testing of the standard set of differentials in Kerala has brought out the existence of another biotype (biotype 5). The continued testing of host plant differentials led to the identification of yet another biotype 6 in Manipur during the late 1990s. The gall midge biotype so far identified can be very well distinguished by the reaction pattern displayed by the differentials (Table 3).

Table 3. Reaction of differentials against Indian biotypes of gall midge

Group	Differentials	Reactions against biotype*				
		1	2	3	4	5
I	Eswarakora/W 1263	R	S	R	S	R
II	Siam 29/ARC 5984	R	R	S	S	R
III	Velluthacheera/Aganni	R	R	R	R	S
IV	TN 1	S	S	S	S	S

* Distribution : Biotype 1 = A.P., M.P.; Biotype 2 = Orissa; Biotype 3 = Bihar, Manipur; Biotype 4 = North Coastal A.P. and Coastal Maharashtra; Biotype 5 = Kerala.
R = resistant, S = susceptible

Cultural control

Cultural practices are normal agronomic practices that are followed to increase crop productivity, and at the same time are useful in pest suppression (Table 4). Sometimes these work wonders in containing the multiplication of insect pests and spread of diseases. These include:

- Early and synchronous planting often controls insect pests like yellow stem borer, gall midge, BPH, WBPH and GLH as well as blast disease particularly in *kharif*. However, this needs community action and often depends on availability of water in command areas.

- Application of optimum dosage of nitrogen in 2-3 splits avoids build up of insects such as gall midge, leaf folder, BPH and WBPH and diseases like blast and bacterial leaf blight. In case of bacterial leaf blight, higher levels of N fertilizer (> 100 kg/ha) increase disease severity and reduce yield in susceptible, but not in resistant varieties (Reddy, *et al.,* 1979).

Table 4. Various cultural practices useful in insect pest management of rice

Practice	YSB	GM	BPH	LF	BHP	GLH	CW
Synchronous planting	*	*	*	-	*	*	-
Synchronous harvesting	*	-	*	-	-	-	*
Harvesting at lower part of the plant	*	-	-	-	-	-	-
Mixed varieties	-	-	*	-	-	-	-
Short duration varieties	-	-	*	-	-	-	-
Time of transplanting							
Early	*	*	*	-	*	-	-
Delay	*	*	-	-	-	-	-
Formation of alleyways	-	-	*	-	*	-	-
Sanitation	-	-	-	*	-	*	*
Fertilizer management							
Judicious 'N' inputs	-	*	*	*	*	*	-
Water management							
Draining off	-	*	*	-	*	-	-
Flooding	-	-	-	-	-	-	*
Flooding to crop height followed by spreading of kerosene-sawdust mixture to trap and poison the pests	-	-	*	-	*	-	-
Early irrigation/flooding stubble	*	-	-	-	-	-	-
Stubble management by burning/ ploughing	*	-	-	-	-	-	-

*Utilized effectively

- Crop rotation is important to break continuity in insect pest build up or in disease cycle.
- Provision of alleyways of 30 cm width after every 2-3 metres, particularly in BPH/WBPH endemic areas, helps reduce their infestation.
- Stubble destruction soon after harvesting to prevent the carryover of the stem borer and gall midge.
- Water management including draining of water from the fields when abundant planthopper population is contemplated (Krishnaiah, 1995).

The cultural practices are simple and offer great scope for effective pest management in future, particularly in rainfed rice where scope for application of insecticides and fungicides is less due to greater risk and uncertainty.

Chemical control

Chemical control is one of the effective and quickest methods of reducing insect pest population. Often it is the only solution to a sudden appearance of the insect pests in the initial or later stages of the crop growth. Appropriate chemical control strategy involves the right choice of active ingredient, suitable formulation and application techniques on the basis of pest biology and crop phenology. The knowledge regarding the most susceptible stage of the pest, quantitative data on pest incidence and significance of particular pest populations on yield loss is also crucial for economic and successful pest control. Further, understanding of the potential hazards of pesticides to the users, consumers and environment is essential.

Several insecticides, both granules and spray formulations, were evaluated for their effectiveness against specific pests to determine their dosage and spectrum of toxicity under the coordinated and lead research programmes of the Directorate of Rice Research (DRR), Hyderabad (Tables 5 and 6).

Table 5. Spectrum of toxicity of spray formulations against insect pests of rice

Insecticide	Rate g a.i./ ha	Stem borer	Leaf folder	Hispa	Brown plant hopper	White backed plant hopper	Cut worms	Green leaf hopper
Quinaphos	500	**	***	**	-	**	-	-
Phosalone	500	***	**	***	**	-	-	**
Monocrotophos	400	***	***	**	***	***	**	***
Chlorpyriphos	500	***	***	**	-	**	**	-
Carbaryl	750	*	**	**	***	***		**
Fenitrothion	500	*	**	-	-	-	*	-
Phosphamidon	500	**	***	**	***	***	-	**
Fenthion	500	*	-	***	-	***	-	*
Dichlorvos	500	-	**	-	**	-	***	-
Endosulfan	600	***	**	-	-	-	***	-
Ethofenprox	75	*	-	-	***	***	-	***
Cartap	300	***	***	-	-	-	**	**
Fepronil	50	***	***	**	***	***	**	***

* Moderately effective ** Effective *** Highly effective

Table 6. Spectrum of toxicity of granular formulations against insect pests of rice

Insecticide	Rate g a.i./ ha	Stem borer	Gall midge	Whorl maggot	Leaf folder	Hispa	Brown plant hopper	Green leaf hopper
Carbofuran	750	***	**	***		**	***	**
Phorate	1250	***	***				**	**
Quinalphos	1000	***	***					
Fenthion	1000	***	**	**	***			
Sevidol	1000	***						
Cartap	750	***			***			
Isazophos	600	***	***	**	***		***	***
Fipronil	75	***	***	**	**	**	***	**

* Moderately effective ** Effective *** Highly effective

In the wet nursery, general practice is to broadcast carbofuran or phorate granules 10 days after sowing to control stem borer and gall midge infestations. As an alternative, soaking of sprouted seed in 0.2% chloropyriphos for 3 hours prior to sowing has been found effective against gall midge.

To manage insects pests like stem borer and gal midge in the early stages of crop growth, soaking of roots of the seedlings in 0.2% chlorpyriphos for 12 hours has been recommended. However, farmers experienced difficulties in implementing seeding root dip in large areas. An alternative technology involving application of granular insecticides like carbonfuran or quinalphos or isazophos @1.5 kg a.i./ha of nursery 5 days before pulling seedlings has been evolved (DRR, 1993-94).

Use of botanical pesticides

Utilization of botanical pesticides, mainly neem formulations is a novel approach as these are safe to the humans and environment. Unlike traditional insecticides, neem formulations do not outrightly kill the insect pests but incapacitate them through repellency, feeding deterrency, reproductive inhibition and oviposition deterrence. The greenhouse and field studies have revealed that neem formulations are moderately effective against BPH, WBPH, GLH and leaf folder (Table 7).

Biological control

Use of biological agents to manage crop pests is a key component of IPM. The successful use of several entomophages and

Table 7. Effect of selected neem formulations on leaf folder, WBPH and GLH under field conditions, *kharif* 1994

Neem formulation	Azadirachtin in the formulation (ppm)	Concentration of the formulation (%)	LF (ADL/10h) Kaul	WBPH (AN/10h) Kanpur	BPH+ WBPH (AN/10h) Sambalpur	GLH (AN/10h) Kanpur
Achook	300	2.0	9.7	5.0	18	8
Neemax	300	2.0	11.4	3.0	22	9
Neemgold	300	2.0	12.2	3.3	22	9
Rakshak	1500	0.5	13.1	5.5	24	10
FortineAza	20000	0.1	10.7	3.3	20	6
Chlorpyriphos		0.05*	2.1	2.3	38	4
Untreated control			33.0	33.0	40	50

*Based on a.i.

entomopathogens has projected biological control as a promising alternative to the chemical control. However, it provides adequate solution for only one or a few pest species like yellow stem borer and leaf folder, and have considerable effect on other important pests like gall midge and planthoppers. They are little effective against sporadic pests like rice hispa, gundhi bug and cutworm. Also unlike in other crops, use of biocontrol agents through inundative or inoculative releases in rice ecosystem has provided sporadic success (Pathak *et al.*, 1996). Hence, maximizing the impact of *in situ* natural enemies as an essential part of IPM program needs emphasis.

About 60 percent of natural control of insects in many crops including rice is due to the biological control agents, which have to be protected and conserved by avoiding unnecessary use of chemical pesticides. The amount of damage caused by the major pests of rice is governed largely by the activity of natural enemies (Rao *et al.*, 1983). Biocontrol agents fit in very well with most of the other components of IPM (Srivastava, 1992).

Augmentative in rice IPM by inundative releases

In India, inundative releases of natural enemies have been restricted to only egg parasitoids, particularly *T. japonicum* and *T. chilonis*, mainly because they are amenable for mass multiplication. In paddy, release of *Trichogramma* spp. (paddy ecosystem adapted strain) may be useful against the stem borer, *S. incertulas* and rice leaf folder complex, *C. medinalis* and *Marasmia.*

Inundative release of *Trichogramma* spp. to control stem borers and leaf folders in rice fields is being practised by the Central Biological Control Stations, located across the country, under the Directorate of Plant Protection, Quarantine and Storage, Government of India. Egg parasitoids like *T. japonicum, T. brasiliensis; T. chilonis* and *T. exigua* being mass multiplied and released in farmer's fields have been reported to be successful against stem borers, (Mathur, 1983). The inundative release of exotic parasite *T. japonicum* @ 20,000 per acre was effective in reducing stem borer infestation (Gupta et al., 1987). Four to nine releases of *T. japonicum* @ 1,00,000 adults/ha starting from 20 to 38 days after transplanting with an interval of 7-10 days resulted in 3.7 to 59.0% decrease in leaf damage due to leaf folder. Leaf damage was found to have negative correlation with the number of parasitoid releases (Bentur *et al.,* 1994).

Studies conducted in India and abroad indicate that native natural enemies can be used profitably in pest management (Ridgeway and Vinson, 1976). Increased attention is now being given towards conservation of natural enemies. Though not estimated, the biological control in paddy appears mainly through natural control and some of the natural enemies provide good pest control when their populations are conserved. Several natural enemies have been identified from different rice growing areas of the country (Table 8). The abundance and relative occurrence of natural enemies with that of the phytophages in different rice ecosystems have been studied in Kerala (Beevi *et al.,* 2000).

Studies on the impact of natural enemies carried out through multi-location trials under the All India Coordinated Rice Improvement Programme have revealed that egg parasites of stem borer, *Tetrastichus, Telenomus* and *Trichogramma* spp. seem to thrive in the natural biocontrol plots (NBC) with higher parasitism, compared to that in the need-based protection (NBP) and schedule-based protection (SBP). In the case of gall midge, the parasitism due to the major parasite, *Platygaster oryzae* does not seem to have much impact on gall midge in the field. In the case of leaf folder, schedule-based protection (SBP) not only resulted in increased pest infestation but also had adverse effect on larval parasitism sometimes.

Table 8. Important natural enemies of rice pests

Insect	Natural enemies	Stage parasitised	Potential mortality
Stem borer	*Telenomus* spp. *Tetrastichus* spp. *Trichogramma* spp.	Egg	30-50% eggs; up to 100% egg masses
Gall midge	*Platygaster orzae*	Larva/pupa	80-90% at peak
Planthoppers	*Anagrus* spp. Oligostia spp. Gonatopus spp. Cyrtorhinus lividipennis *Lycosa* spp and other *Spiders*	Egg Nymph EGG/Nymph Nymph/adults	10-15% 20% egg predation
Leaf folder	*Trichogramma* spp. Apanteles spp. *Tetrastocjis* spp.	Egg Larva Pupa	
Hispa	*Apanteles* spp. *Bracon* spp.	Egg Larva	

Among the predators, spiders, mirid bugs and coccinellids have been observed to be more common and dominant, while dragon flies, damsel flies, ground beetles, staphylinids, and ear wigs were also observed at low to moderate levels. The studies have clearly revealed that the predator populations were at higher level the in natural biocontrol and need-based application situations and were relatively undisturbed due to less pesticide use, compared to that in SBP.

Nevertheless, these studies have shown that SBP resulted in higher yields. But in terms of net returns, need-based application of insecticides resulted in higher profits. The need-based application of insecticides is thus an economical and practical way to ensure higher yields (Katti *et al.,* 2000, Katti and Pasalu, 2001). It also results in maintenance of a pest population at very low level, which helps build up of natural enemy populations. Thus, quantifying natural biocontrol in different agro-ecosystems of rice and demonstrating the effectiveness of natural enemies would help in curbing insecticide use.

Conventional practices has resulted in the destruction of certain predatory fauna when used indiscriminately and has often caused outbreaks of pests that used to be controlled by the natural enemies previously. Nevertheless, multi-location testing under All India Coordinated Rice Improvement Programme (AICRIP) has revealed that some insecticides like carbofuran and phorate as well as new granular insecticides like cartap and isazophos are safer to natural enemies compared to spray formulations of recommended insecticides like monocrotophos, chlorpyriphos, etc. Recent studies also suggest that even the spray formulations of triazophos and acephate are relatively safer to egg parasites of stem borer and predatory mirids and spiders. Among the neem formulations, neemax, rakshak, econeem, neemazal and neem gold are safe to major natural enemies like water bug *(Microvelia douglasi atrolineata*), egg parasitoids of stem borer (*T. japonicum*) and mirid bug *(C. lividipennis*), etc. (Jhansilakshmi *et al.,* 1997a; 1997 b; Jhansilakshmi *et al.,* 1998).

Use of biopesticides

Use of microbial pesticides like *Bt (Bacillus thuringiensis)* formulations with endotoxins is another useful approach. They are specific to insect pests and safe to the humans, natural enemies of insect pests and other non-target organisms. Evaluation of some of these formulations has revealed that they are effective against leaf folder and moderately effective against stem borer. Some of the fungal pathogens such as *Beauveria bassiana* against rice hispa (Hazarika and Puzari, 1997), *Pandora delphacis* against BPH (Narayanasamy, 1995), etc. have also been found promising.

Insect sex pheromones

Sex pheromones have been found effective in the management of yellow stem borer. They control the insect through capture and annihilation by either mass trapping or disrupting mating communication. In monitoring, efforts are made to work out 'trap capture thresholds' for utilizing as decision tools in the use of insecticides for stem borer control.

Mass trapping by installing 20 sleeve traps/ha each with 5 mg pheromone impregnated lures reduced the stem borer infestation under moderate pest load. Mating disruption by a single application of slow release formulation of pheromones @ 40g a.i./ha within a fortnight after planting through multipoint sources could result in season-long control of stem borer and produce grain yields similar to plots receiving two sprays of conventional insecticides (Hall *et al.,* 1998).

The pheromones are likely to play an important role in rice IPM strategies in future (Krishnaiah *et al.*, 1998). However, sex pheromones are species-specific and are not useful in situations where two or three insect pests occur simultaneously. Under such situations use of cultural practices coupled with appropriate and safe insecticides appears to be unavoidable.

Pest Surveillance

Pest surveillance is the most important and integral part of IPM technology. It involves direct measurement of pest or disease occurrence, development of population and damage at regular intervals. Usually, sampling 25 plants in 5 clusters on a diagonal line of the plot at 7-10 days interval is suitable for ascertaining insect pest levels, natural enemy populations and damage due to diseases. These form the base for arriving at control decisions by taking economic thresholds as guidelines. The tentative economic thresholds are presented in Table 9. Traditionally, light traps are used for indirect assessment for the presence/development of insect pest populations. However, pheromones baited traps have been successfully utilized for monitoring stem borer and leaf folder (Krishnaiah, 1995).

On-Farm Implementation of IPM

Large-scale implementation of IPM needs coordination of the government agencies, NGOs, industry and farmers. Since IPM requires a collective action, cluster approach of selecting villages and farmers in contiguous areas needs to be followed. The Indian Council of Agricultural Research (ICAR) initiated 6 Operational Research Projects (ORPs) on IPM for rice in 1975 under the supervision of the Directorate of Rice Research (DRR), Hyderabad, Kerala Agricultural University and Department of Agriculture, West Bengal. The components of IPM included monitoring of the pest, parasite and predator populations, minimal use of pesticides at selected times to encourage natural enemies build up, ploughing of rice stubble and the use of early maturing short duration resistant varieties of rice. Adoption of IPM practices resulted in increase in the rice yield from 3488 to 4983 kg/ha in Andhra Pradesh during 1981-86 (Krishnaiah and Reddy, 1989). In Kerala, the number of insecticide sprays were cut down from 4-6 to an average of 2 (Sankaran, 1987). There are also other examples of successful implementation of IPM in rice in selected districts

Table 9. Damage, economic thresholds and suggested control measures for common pests in rice

Pest	Characteristic damage	Economic thresholds	Control measures
Stem borer	Death of central shoot-Dead heart (DH) white ear (WE), Loss of tillers	10% DH or 1 egg mass 1moth/m^2	Stubble destruction Resistant varieties like Vikas Sasyasre, Ratna. *Chemical control
Gall midge	Central leaf sheath modified to a Silver shoot (SS), Loss of tillers	5% (at active tillering stage)	Early planting, Resistant varieties Phalguna, Surekha, Suraksha, *Chemical control
Brown plant hopper Whitebacked plant hopper	Plants wilt and dry- Hopper burn	10 insects per hill at veg. 20 insects/ hill at later stage	Resistant varieties, Alleyways formation, Draining the fileds, Judicious 'N' use, Chemical Control
Green leaf hopper	Vector of tungro disease, Plants wilt and dry in severe cases	2 insects/hill in tungro endemic areas. 20-30 insects/hill in other areas	Resistant varieties, Chemical control
Leaf folder	Leaf damage, ill filled grain	3 damaged leaves/ hill post active tillering stage	Judicious 'N' use, Chemical control
Cutworm	Defoliation and damage to rachillae	1 leaf/hill stray incidence prior to harvesting	Flooding, Chemical control
Gundhi bug	Partial chaffy grains	1 nymph/adult per hill	Removal of alternate host plants, Chemical control

* need-based

of the states like Haryana, Tamil Nadu, Andhra Pradesh, Uttar Pradesh, Kerala and Madhya Pradesh (Razak, 1986).

The above concept follows a 'prescriptive approach' wherein technologies appropriate to farmers' conditions are developed in the research institutes and transferred to the farmers for implementation. But, many technologies developed by the researchers are irrelevant to the farmers' conditions and are finally abandoned. For instance, seedling root dip technique of insecticide application for controlling early season pests after transplanting could never found place among the farmers' practices. This is mainly due to the fact that the procedure of seedling root dip is considered cumbersome, and carrying the treated seedlings on heads is detrimental to human health. Similarly, many of the varieties developed with BPH resistance could not find their due place in farmers' fields due to poor threshability and grain quality.

The latest trend in IPM is 'bottom-up' or 'participatory approach'. Therefore, IPM can be described as the best mix of control tactics resulting into better yield and profit, and safety to the humans and environment. The focus is on to maximize the use of biological and cultural components, including host plant resistance and biological control agents. In situations where pesticides have been in use for a long time, the aim shall be to minimize their use as much as feasible. In situations where pesticides have never been used, IPM programmes can still be developed using other appropriate control technologies.

IPM involves managing the pest in the context of farming system with clear reference to social, economic and environmental factors. This clearly shows the necessity of understanding the farmers' perceptions, knowledge and conditions in the context of farming systems and not just the rice crop alone. Therefore, IPM involves working with the farmers in their fields and devising technologies suitable to their conditions. Farmers can understand and identify the differences between different crop growth stages and insect pests, which are external and cause alarm. However, they generally fail to differentiate between the damages caused by internal feeders. Many farmers rarely differentiate between the disease symptoms and the nutritional disorders. They also often fail to recognize the damage by stem borer at the vegetative and heading stages and the moths as well as the egg masses on plants. Very few farmers really understand the role played by the general predators like spiders, mirid bugs, etc. Therefore, the IPM approach for the future should be bottom-up in character evolved under farmers' conditions.

Trials conducted under the coordinated programmes following the above approach had shown that in areas where gall midge and stem borer or brown planthopper and stem borer were the major problems, selection of either gall midge or brown planthopper resistant variety followed by need-based application of insecticides against other pests was observed to be a useful strategy (Tables 10 and 11). Higher net profit could be obtained (DRR, 1985) with minimum insecticide use in the resistant varieties. IPM verification trials conducted under farmers' conditions under the coordinated programmes (DRR, 1995) as well as large scale implementation of IPM through farmers' participatory approach carried out by DRR in two villages, Mandapaka and Suryaopalem (Table 12) in the rice bowl district of West Godavari in the state of Andhra Pradesh also confirmed this.

Table 10. Influence of varietal resistance and need-based insecticide application on incidence of insects pests and grain yield in BPH endemic areas

Variety	Treat-ment	BPH (No./10 hills)			SB (%WE)			Yield (t/ha)		
Resistant	PM	102	87	94	3.6	5.6	4.6	3.14	3.87	3.51
(IET 7575	NM	116	197	156	8.4	25.0	16.7	2.89	2.02	2.46
Susceptible	PM	782	483	632	9.5	15.4	12.5	3.08	1.42	2.25
	NM	1011	1103	1057	7.6	53.3	30.5	2.47	0.44	1.46

Table 11. Efficacy and economics of integrated pest management in gall midge endemic areas

Variety	Treat-ment	Gall midge (%SS)	WBPH (AN/10 hills)	Yield (kg/ha)	Cost of plant protection (Rs/ha)	Net profit (Rs/ha)	Benefit cost ratio
Resistant Variety (IET 8865)	PM	0.0	14	3095	78	1254	16.1
	NM	0.0	473	2429			
Susceptible Variety (Sona)	PM	15.0	16	2486	925	727	0.8
	NM	31.1	379	1660			

PM = Pest Management; NM = No Pest Management

Table 12. Economics of grain yield in on-farm IPM trial

Treatment	Total cost (Rs/ha)	Cost of Insecticides (Rs/ha)	Yield (kg/ha)	Net profit (Rs/ha)
IPM	12920	1156	6880	15521
FP	13025	1706	5320	11834

Prospects of Rice IPM

Resistant varieties

Utilization of host plant resistance would continue to be the major thrust in future IPM programmes. However, in view of the changing pest scenario and occurrence of two or three pests simultaneously, emphasis should be on multiple resistant varieties. A number of donors with multiple resistance like Velluthacheera, ADR52, Pandi and Chennellu that have proven resistance to gall midge, BPH and WBPH have already been identified. Utilizing these donors, a number of varieties such as Suraksha, Vikramarya, Shaktiman, Rasmi and Daya with resistance to major insect pests and diseases have been released for cultivation in Andhra Pradesh, Orissa, West Bengal, Kerala and Madhya Pradesh (Table 13). Greater emphasis should be laid on development of such varieties in the future research programmes.

One major strategy that needs careful consideration is 'situation-based host plant resistance deployment'. A variety to be considered for release in a state or region should possess at least moderate resistance to the major insect pests and diseases prevalent in the area. For instance, a variety/ hybrid to be released in coastal Andhra Pradesh should possess resistance to BPH as well as bacterial blight, the two major menaces that are difficult to contain. Similarly, in Punjab and Haryana, tolerance/resistance to stem borer, WBPH and BLB should be possible even with the existing sources of resistance. For Assam, stem borer tolerance and resistance to BLB are

Table 13. Varieties with multiple resistance to more than one pests or diseases

Variety	States where released	Resistant
Suraksha	Andhra Pradesh, Orissa, West Bengal	GM, BPH, WBPH, BL
Vikramarya	Andhra Pradesh	GM, GLH, RTD
Shaktiman	Orissa, West Bengal	GM, BPH, WBPH, BL
Rasmi	Kerala	GM, BPH, BL
Daya	Orissa	GM, BPH, GLH, BLB
Samalei	Orissa, Madhya Pradesh	GM, BPH, GLH, BL
Bhuban	Orissa	GM, BLB
Kunti	West Bengal	GM, BL
Lalat	Orissa	GM, BPH, GLH, BL

GM = Gall midge, BPH = Brown plant hopper, WBPH = White backed plant hopper, GLH = Green leaf hopper, BL = Blast, RTD = Rice turgro disease, BLB = Bacterial leaf blight must in a variety to be considered for release. In addition, locally acceptable grain quality and agronomic traits should be taken into account.

Genetic engineering

Genetic engineering has the potential to overcome some of the problems in resistance breeding through conventional means. For instance, presently donors with only low level of resistance/tolerance against stem borer and leaf folder are available. Hence, efforts must be focused on evaluation of wild accessions followed by their utilization. Availability of biotechnological tools like embryo rescue techniques can come handy in this process. Deployment of novel genes like Cry IA (b) and Cry IA (c) from suitable strains is another approach. Efforts in this direction would hopefully result in the development of transgenic rice in India.

Another area in which genetic engineering can help IPM is the confirmation of insect biotypes or pathotypes of pathogens. Although differentials can help in identifying biotypes in the case of insect pests, some discrepancies still exist in the reactions of differentials over time. Attempts are currently underway to utilize genetic tools in clearing such discrepancies in case of gall midge and brown planthopper. Utilization of genetic markers and marker-aided selections has not been exploited so far for the development of pest/ disease resistant varieties. These techniques can hasten the development of resistant varieties against insect pests and diseases.

Natural biological control

Natural biological control is considered to be the foundation of IPM. Efforts have been initiated at DRR as well as in AICRPs to demonstrate and quantify the impact of natural biological control in rice ecosystem. The results have revealed that in case of low to moderate pest damage, need-based application of insecticides was enough to maintain a favourable balance between pest and natural enemy populations, and maintain yield levels similar to the schedule-based protection as practiced by farmers. Similar studies should be carried out in different rice-based cropping systems.

Avoidance of resurgence of pests

In pest endemic areas where insecticide application is unavoidable, care should be taken to overcome the problem of resurgence, particularly of BPH and leaf folder. In the case of BPH, synthetic pyrethoroids, like deltamethrin and cypermethrin and some of the organophosphates such as quinalphos have been observed to be responsible for causing resurgence. Hence, avoiding these insecticides is the best solution for resurgence. Nevertheless, chemical control should be integrated with proper mix of cultural practices such as draining of water and formation of alleyways.

Similarly, application of granular insecticides such as phorate or carbofuran in early stages of crop growth can lead to resurgence of leaf folder in the later stages. It is usually not possible to totally avoid these formulations in rice ecosystem, since these are effective against stem borer and gall midge. Hence, to nullify their resurgence causing effect, they could be followed by application of newer chemicals such as cartap, spray or granules.

Plant products and biopesticides

These non-traditional pesticides are likely to play a major role in rice IPM. Therefore, fine-tuning of application technologies, such as method and time of their utilization along with safer insecticides should form a component of IPM. Neem is abundantly available in India, and exploitation of neem formulations in pest management has tremendous export potential.

Pheromones

Insect sex pheromones are useful for monitoring of insect pest populations. These have been attempted for monitoring of yellow stem borer and leaf folder populations as alternatives to light traps. Pheromones have also shown potential for direct control of yellow stem borer through annihilation by mass trapping and disrupting mating communication. Mass trapping by installing 20 sleeve traps per hectare each with 5 mg pheromone impregnated lures could reduce damage due to stem borer by about 70 percent.

Strategic integration of two non-insecticidal components, viz. pheromone-mediated mass trapping and biocontrol through inundative release of *T. chilonis* to chek both yellow stem borer and leaf folder pests can be an efficient and cost effective alternative to conventional insecticide application, particularly in areas where YSB and LF cause economic damage and limit yields (Katti *et al.*, 1999).

As sex pheromones have been detected in the case of gall midge and rice hispa, and efforts are underway for refinement of pheromone utilization technology, which is likely to play an important role in pest monitoring and surveillance (Krishnaiah, 1995). The utilization of pheromones may revolutionize the rice pest management.

Agro-ecosystem analysis

Rice crop is a definitive agro-ecosystem in which the primary producer of photosynthate is rice plant itself. It has many herbivorous organisms like insect pests feeding on different plant parts, from sowing to harvesting. A number of fungi, bacteria and viral organisms also cause detrimental effect on the rice plant. However, the composition of pests and diseases infesting rice crop may vary in different regions. For instance, in the north-western states (Punjab and Haryana), stem borer, leaf folder and whitebacked planthopper among insect pests, and bacterial leaf blight among diseases are the important pests. While in the coastal Andhra Pradesh, stem borer, gall midge and brown planthopper are major insect pests besides leaf folder, whitebacked planthopper, though they are relatively less important. In Assam, stem borer among insect pests and bacterial leaf blight and blast among diseases are of major concern. In upland and rainfed rice areas, some other insect problems like termites, root aphid and gundhi bug are of major concern in addition to stem borer and leaf folder. Blast is a major disease problem in upland and hilly areas. This pest identification is a first step in developing location-specific IPM programmes. Once the pest has been identified, the immediate step is the selection of a variety with desired traits such as resistance, grain quality, etc. This should be followed by sowing and planting at an appropriate time.

After the crop establishment, due importance should be given to the role of natural enemy fauna including general predators like spiders as well as pest specific parasites like *Trichogramma* against stem borer and leaf folder or *Platygaster* against gall midge. The role of spiders should be looked into critically as these feed not only on BPH, WBPH and GLH but also on mirid bugs which predate on leafhopper and planthopper. Also, the crop should be carefully monitored throughout the crop season.

Dissemination of information and human resource development

Farmers adopt new techniques only if there is a clearly felt need for effective pest management, and yield significant financial gains. Farmers' interest would be sustained only if the IPM technologies are practical under local agronomic and socio-economic conditions. If labour is a constraint, labour intensive IPM practices should be given secondary importance.

The approach should be participatory involving different stakeholders like government agencies, researchers, extension workers, non-governmental organizations (NGOs), farmers, etc. While seeking participation of the NGOs, their strengths and weaknesses should be taken into account. Many NGOs are small and inexperienced and lack expertise in project and financial management. Many times they fail even to validate new IPM modules under local conditions. Local leaders like progressive farmers and school teachers are often looked upon as guides by the general farming community, particularly resource poor farmers. Their advice is given considerable weightage in adopting the new IPM technologies.

The central and state governments must give a clear commitment to IPM as a national policy. If the state/country is planning an agricultural programme that involves substantial intensification of the production, pesticide use should be restricted.

Pesticide industry is a major stakeholder in the IPM programmes. Often it is the word of the pesticide dealer that carries weight with the farmers. It is, therefore, imperative for the pesticide industry to contribute towards strengthening of the IPM programmes.

IPM must involve the process of human resource development with emphasis on ecological studies by the researchers. It should be viewed not merely as a programme but a process of sustainable crop production. Courses on applied ecology (with emphasis on IPM) should be introduced at the undergraduate and postgraduate levels. Curriculum should also be developed for vocational institutes.

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4

Integrated Pest Management Techniques for Rainfed Rice Ecologies

B.N. Singh and S. Sasmal[1]

Introduction

Rainfed rice occupies 55 percent of the total area under rice in India and contributes 30 percent to the total rice output. Rice tungro disease (RTD), blast, sheath blight, brown plant hopper (BPH), white backed plant hopper (WBPH), green leaf hopper (GLH) and other biotic factors constraint rice yield in rainfed rice ecologies.

Different insect pests and diseases cause damage to the rice crop at different stages of its growth, resulting in an annual loss of about 10 percent in rice output worth Rs 5,000 crores. In some years, the loss increases to as high as 20 percent. In 1943, outbreak of brown spot disease in Bengal led to the Great Bengal Famine, which resulted in starvation deaths of about 3 million people. Leaf and panicle blast has been a major disease in the hilly areas and in upland rice in both pre- and post-semi-dwarf HYV era. Bacterial leaf blight (BLB) and RTD became major problems after introduction of HYV during the late 1960s. There has also been a major change in the status of several rice pests in the recent past. This is due to cultivation of semi-dwarf varieties and intensive agriculture. Many minor pests have now assumed the status of major pests. Some of the major diseases now are: blast, BLB, RTD, sheath blight, false smut, brown spot and sheath rot, and insects are yellow stem borer (YSB), BPH, GLH, gall midge, hispa, leaf folder and gundhi bug. Even after introduction of resistant cultivars, evolution of new pathotypes and biotypes has become a regular phenomenon. A further challenge is the development of resistance to insecticides by many insect pests. Mites and nematodes, which were insignificant in rainfed ecologies have become a threat in recent years.

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For different rainfed rice growing ecologies and production systems of India, 10 IPM modules have been developed (Table 1), of which 4 are for the irrigated rice, and 6 for the rainfed rice (Singh and Gangopadhyay, 2000). The pest problem and its management vary in each module as per the location. The major rice varieties in each state are given in Table 2.

Table 1. IPM modules for irrigated and rainfed rice ecologies and production systems in India

Modules	Ecologies and production system	Area (m ha)	Region*
1.	Irrigated rice, wet season	14.0	H, NW, NE, E, C, S
2.	Irrigated rice, dry season	4.0	E, NE, S
3.	Hybrid rice	0.5	E,S,N
4.	Scented rice	2.0	NW
5.	Upland rice	6.0	H, E, NE, C, W
6.	Rainfed lowland, shallow drought prone	4.0	C, E, NW
7.	Rainfed lowland, shallow favourable	4.0	E, NE, C
8.	Medium-deep waterlogged and flood prone	5.0	E, NE
9.	Deep-water rice	4.0	E, NE
10.	Coastal wetlands	1.0	E, W
	Total	**44.5**	

* H= Hills; NW= North West; E= Eastern; NE= North East; C= Central; S= Southern; W= Western

Rainfed Upland Rice Ecology

Upland rice covers about 6 million hectares. Its productivity is low (0.6 to 1.0 t/ha) owing to biotic constraints like root knot nematode, termite, weeds, leaf and panicle blasts, brown spot, gundhi bug and grain discolouration. Abiotic stresses like drought, poor soil type and acidic upland soils also aggravate the pest problems. However, by effectively controlling these, the productivity of upland rice can be improved to 3.0 t/ha.

A holistic IPM package for upland rice should focus on weed control through cost effective methods. Proper weed control effectively reduces the incidence

Table 2. Major varieties in different rice ecologies of India

States	Rice area (lakh ha)	Upland	Rice varieties rainfed lowland	Deep-water
Andhra Pradesh	39	Aditya, Tulsi	Swarna, Sambha Mahsuri, Vijetha	Badava, Mahsuri
Arunachal Pradesh	1	Ngoba, VL Dhan 81	-	-
Assam	26	Kalinga III, Heera, Annada, Luit	Ranjit, Bahadur, Ketakijoha, Mahsuri, Manoharsali	Panikekwa, Padmanath
Bihar	30	Prabhat	Rajshree, Radha, Sugandha, Mahsuri, Kamini	Janaki, Vaidehi, Sudha
Chattisgarh	37	Kalinga III	Safri 17, Mahamaya, Kranti	-
Goa	0.2	Goa1	CSR 10, CSR 27	-
Gujrat	6	Kalinga III, GR 3, GR 5	Mahsuri, CSR 27	-
Haryana	11	Govind	Taraori Basmati	
Himachal Pradesh	1	PNR 519	China 988, Himalaya 741	-
Jammu and Kashmir	3	-	Ranbir basmati	-
Jharkhand	20	Kalinga III, Birsa 101, Vandana	Mahsuri, Jayshree	-
Karnataka	14	Amruit	Intan, Annapurna	Hemavati
Kerala	4	Suvarnamodan	Neeraja, Neela	-
Madhya Pradesh	18	JR 75, Poorva	Safri 17, Mahamaya, Shyamala	-
Maharashtra	15	Ambemohar	Mahsuri, Ratnagiri 2	-
Manipur	2	Lemaphou	Punshi, Mahsuri, KD 5-3-14, Taothabi	Eriemaphou
Meghalaya	1	Ngoba, Megha rice 2	Mahsuri	-
Mizoram	0.5	Ngoba	-	-
Nagaland	1	Khonorullo, Nagobario, Ruluo	-	-
Orissa	45	Kalinga III,	Mahanadi, Pooja,	Durga, Sarla

Contd...

Table 2. (Concld.)

States	Rice area (lakh ha)	Upland	Rice varieties rainfed lowland	Deep-water
		Heera, Khandagiri	Savitri, Gayatri, Radhi, Lunishree, Sonamani, Utkalprabha, Padmini	
Pondichery	0.5	-	Ponmani (CR1009), Bharathidasna	-
Punjab	26	-	Basmati 385, Punjab Basmati 1	-
Rajasthan	2	Kalinga III, Vagaddhan	Mahisugandha	-
Tamil Nadu	23	MDU1, Paramakudi 1	ADT 32, Ponmani (CR 1009), Ponni, ADT 44, Co-43, ADT 40	-
Tripura	3	Vandana	Mahsuri	-
Uttar Pradesh	46	Narandra 118, Govind	Mahsuri, Swarna, Vijetha	Jal Lahri, Jalmagna, Jalpriya, Madhukar, Chakia 59
Uttaranchal	3	Majhera 3, VL Dhan 206	-	-
West Bengal	61	Kalinga III, Vandana	Mahsuri, Swarna, IET 5656, Savitri, SR 26B	Jogen, Sabita
Total	**445**			

of insects and diseases also, as the weeds act as alternate hosts for many pests. Such an IPM strategy should have a necessary understanding of the interrelationships among the nematodes, weeds, diseases, and insects control practices (Rajamani *et al.,* 2001). The IPM practice developed for this ecosystem is given in Table 3.

The appropriate variety of rice that can be grown in drought prone red and lateritic uplands should have weed competitiveness and tolerance to diseases and insects. The variety Kalinga III and Vandana have traits of weed competitiveness and tolerance to blast and brown spot diseases. These varieties have been doing well in different upland regions of eastern India. Controlling weeds, by various methods like off-season tillage, proper land

Table 3. IPM module for rainfed upland rice

Sl No.	Pest	Name	Control measures
1.	Nematode	Root-knot	· Use of neem cake · Soil incorporation of carbofuran @ 1.0 kg a.i./ha at the time of sowing
2.	Insects	Termite	Seed dressing with chlorpyriphos @ 0.75 kg a.i./100 kg seed
3.	Weeds	*Echinocloa*, *Digitaria*, *Sanguinalis* & *Cyperus* etc.	· Practice of summer season ploughing and line sowing · Apply moderate levels of N40 kg/ha, avoid basal apply on N, apply N after weeding in two splits · Use finger weeder, and wheel hoes, etc. · Spray pre-emergence herbicide butachlor @1.5-2.0 kg a.i./ha, and one hand-weeding at 40 DAS · Anilfos as post emergence is also effective
4.	Diseases	Brown spot	Apply potash @ 20 kg/ha, spray Dithane-M 45 @ 2 mL/litre
		Leaf and panicle blast	Prophylactic treatment with Bavistin @ 2 g/kg of seed or if it is above ETL, spray Bavistin 2 g/litre or Hinosan 1.5 mL/litre or Beam 75 @ 0.6 g/litre
		Sheath rot	Spray sheathmar/Validamycin @ 2mL/litre for sheath rot control
5.	Insect	Gundhi bug	Apply Chlorpyriphos/Follidol or Malathion dust @ 25 kg/ha or spray Monocrotophos @ 0.5 kg a.i./ha
6.	Storage pest	Rats grain moth and rice weevil	Zinc phosphide 1% (W/W) as bait Treat jute bags with malathion 50 EC @ 5 mL in 20 litres of water and also spray the storage godowns with Melathion or Fenitrothion or Deltamethrin

preparation, optimum seed rates, row seeding, application of moderate levels of nitrogen in splits, and balanced fertilization increase yield substantially. Herbicide application like butachlor, thiobencarb, pendimethalin and butanil, supplemented by hand weeding helps in cost-effective weed control.

Deficient soil moisture in the field encourages appearance of termites and diseases like blast and brown spot. Hence *in situ* moisture conservation measures like bunding of plots and summer ploughing are useful. Termite infestation, which reduces plant stand considerably in lateritic soils, can be controlled effectively by seed treatment with chlorpyrifos (0.02%). To control gundhi bug, need-based applications of dust formulations like chlorpyrifos or monocrotophos 36EC has been found to be useful.

The blast disease can be controlled by prophylactic seed treatment with bavistin. If it is above economic threshold level (ETL), spray application of bavistin or hinosan or beam 75 is recommended. Use of ecofriendly botanicals like aqueous extract of bael leaves (*Aegle marmelas*) and Tulsi leaves (*Ocimum sanctum*) has been found effective to control blast. Interactive effects of seed treatment and chlorpyrifos and bavistin(or other chemicals) are not yet known and need detailed study.

In root knot nematode infested areas, seed treatment with chlorpyrifos is effective. Similarly, growing pulses like blackgram (urdbean), greengram (mungbean), pigeonpea or sesamum in rotation reduces infestation of nematodes. Use of neem cake and carbofuran also reduces nematode populations. These practices may be adopted based upon the site-specific needs, historical background and cost effectiveness. While developing holistic package, research should identify common practices with multiple benefits.

Rainfed Low Land – Shallow Drought Prone Rice Ecology

Rainfed lowland rice is grown in an area of 13 million hectares in India, where adoption of high yielding varieties is limited. This ecology can be further divided into three major categories: shallow drought prone, shallow favourable, and medium-deep waterlogged depending on the moisture stress and water depth. In 4 million hectares shallow rainfed lowland drought prone areas, root knot nematode, weeds, brown spot, leaf and panicle blasts, sheath rot, and stem borer are the major problems. Mostly land races are grown in this ecology. But, many improved cultivars like Safri 17, T141, BR 8, BR 34, Sudha, Janaki, Vaidehi, which are selection from land races, are also popular.

Weed management forms a major component in the pest management in this ecology. Though in lowland rice, weed is not a major problem compared to upland rice, hand weeding and weedicide use for weed control should be rationally combined to achieve economical weed control. The IPM package developed is given in Table 4.

Table 4. IPM module for rainfed lowland, drought prone ecology

Sl No.	Pest	Name	Control measures
1.	Nematode	Root-knot	· Use of neem cake · Soil incorporation of carbofuran @ 1.0 kg a.i./ha at the time of sowing
2.	Weeds	*Chara, Nifella, Monocoria, Ludvigia, Cyperus,* wild rices	· Practice summer ploughing · Hand weeding · Herbicide use. Butachlor or Anilfos
3.	Insects	Yellow stem borer	· During tillering period: apply carbofuran @ 1.0 kg a.i./ha if standing water is available otherwise spray monocrotophos @ 0.5 kg a.i./ha · During heading stage: monitor YSB using pheromone traps @ 5 traps/ha. If it is above ETL, apply monocropophos @ 0.5 kg a.i./ha
4.	Diseases	Brown spot	Apply potash @ 30 kg/ha and apply Dithane-M-45 @ 2 mL/litre
		Sheath rot	Apply sheathmar/validamycin @ 2 mL/litre spray Dithane-M-45 @ 2 mL/litre
		Leaf and panicle blast	Prophylactic treatment with Bavistin @ 2 g/kg of seed or if it is above ETL, spray Bavistin 2g/litre or Hinosan 1.5 mL/litre or Beam 75 @ 0.6 g/litre
5.	Storage pests	Rats, grain moth and rice weevil	Treat jute bags with malathion 50 EC @ 5 mL in 20 litres of water and also spray the storage godowns with Melathion or Fenitrothion or Deltamethrin

Rainfed Lowland-Shallow Favourable Ecology

This ecology is similar to the irrigated ecology. The warm and humid climate is conducive for the growth of many pests, which are the major constraints to increasing rice production. It is therefore essential to evolve suitable location-specific, pest management strategies, which are economically viable and environmentally safe. In the recent past, there has been a change in the status of several rice pests. Though stem borer remains as the major insect pest, several minor pests and weeds have gained greater importance. Improved varieties like Mashuri, Pankaj, Savitri, Gayatri, Moti, Pooja, Monoharsali, Rajshree, Ranjit, Swarna and Sambha Mahsuri are grown in this ecology. This area is about 4.0 million ha. Gall midge, false smut, leaf folder, hispa, mites, BPH and WBPH and panicle blasts are the major pests. Varietal development for resistance to pests like stem borer, bacterial blight, RTD and sheath blight has achieved limited success and their management is mainly by chemical control. Use of biocontrol agents, a key component of IPM, through inundative or inoculative releases has provided limited success (Pathak *et al.*, 1998). Thus, there is a need to conserve natural biocontrol agents in this ecosystem. Recently, pest monitoring as well as mass trapping of yellow stem borer using pheromone traps have been found promising. A number of cultural practices like ploughing after paddy harvest and burning of stubbles in extreme cases have been advocated for management of stem borers. Need-based use of chemicals and botanicals for management of different pests, in the absence of other management practices, is important and therefore many chemicals and their methods of application have been identified. The IPM package developed is given in Table 5.

Medium-Deep Waterlogged and Flood-Prone Ecology

This ecosystem lies in the eastern India and occupies an area of 5.0 million ha. Aquatic weeds, stem borer, case worm, ufra nematode, RTD, and false smut are major pests. The IPM technology developed is given in Table 6.

Deep Water Rice Ecology

Deep water rice (DWR) occupies around 4.0 m ha, about 9% of the total rice area in the country. In the eastern India, DWR area is concentrated in

Table 5. IPM module for rainfed lowland, shallow favourable ecologies

Sl No.	Pest	Name	Control measures
1.	Weeds	*Chara, Monocoria, Vaginalis, Cyperus difformis,* Wild rices	Summer ploughing, purple leaf base varieties, hand weeding. Butachlor @ 1.5 kg a.i./ha as pre-emergence, Anilophos as post-emergence
2.	Insects	Gall midge	· Seedling root dip with chlorpyriphos @ 0.02% for 12 hours · Nursery treatment with Carbofuran @ 1.5 kg a.i./ha one week before uprooting · Apply phorate @1.0 kg a.i./ha
		Stem borer	· During tillering period: apply carbofuran @ 1.0 kg a.i./ha if standing water is available otherwise spray monocrotophos @ 0.5 kg a.i./ha · During heading stage: monitor YSB using pheromone traps @ 5 traps/ha. If it is above ETL, apply monocropophos @ 0.5 kg a.i./ha
		BPH	Spray at the base, imidacloprid @ 0.2 kg a.i./ha
		WBPH	Apply choropyriphos/monocroptophos @ 0.5 kg a.i./ha
		Case worm	Apply monocrotophos @ 0.5 kg a.i./ha.
		Leaf folder	Apply quinalphos or monocrotophos @ 0.5 kg a.i./ha
		Hispa	Apply phosphamidon @ 0.5 kg a.i./ha
		Mites	Apply kelthane (Dicotol) @ 0.5 kg a.i./ha
3.	Diseases	RTD	Apply carbofuran @ 1.0 kg a.i./ha or spray imidacloprid @ 0.2 kg a.i./ha
		Sheath blight	Apply sheathmar/validamycin @ 2mL/litre
		BLB	Apply mixture of Streptocycline 50g/litre and copper oxychloride 500 mg/litre
		Brown spot	Apply Dithane-M-45 @ 2 mL/litre
		False smut	Kalisena foliar spray @ 2g/litre or foliar spray of Dithane-M-45 (1%) at the time of grain discolouration
		Grain discolouration	Foliar spray of Dithane-M-45 (1%) at the beginning of grain discolouration
4.	Storage pests	Rats, grain moth and rice weevil	Treat jute bags with malathion 50 EC @ 5 mL in 20 litres of water and also spray the storage godowns with Melathion or Fenitrothion or Deltamethrin

Table 6. IPM module for rainfed lowland, medium-deep waterlogged and flood-prone ecology

Sl No.	Pest	Name	Control measures
1.	Weed	*Chara*	Mechanical weeding
2.	Insect	Yellow stem borer	· Monitoring of YSB @ 5 traps for ha. If it is above ETL, use 20 traps/ha for mass trapping and use Trichocards; T. *japonicum* @ 50000/ha 3 times at 10 days interval · Summer ploughing
		Caseworm	Apply monocrotophos @ 0.5 kg a.i./ha
		Hispa	Apply phosphomidan @ 0.5 kg a.i./ha
3.	Disease	RTD	Apply carbofuran @ 1.0 kg a.i./ha as granules or spray imidacloprid @ 0.2 kg a.i./ha
		False smut	Kalisena foliar spray @ 2g/litre or foliar spray of dithane M-45 (1%) at the time of grain discolouration
4.	Nematode	Ufra	Hot water treatment of seeds before sowing. Apply carbosulfan spray 0.04% once at PI stage and other at heading stage
5.	Storage pest	Rats, grain moth and rice weevil	Treat jute bags with malathion 50 EC @ 5 mL in 20 litres of water and also spray the storage godowns with Melathion or Fenitrothion or Deltamethrin

Assam, north Bihar, coastal Orissa, eastern Uttar Pradesh and West Bengal. The yield of DWR is comparatively low, ranging between 0.5-1.5 t/ha. Among the diseases, the most serious one is bacterial blight, causing 60% leaf infection at flag leaf stage. Other important diseases are: brown spot, RTD, sheath rot, and false smut. The yield loss due to disease (s) ranges from 7 to 42 percent in case of bacterial blight, and upto 22.2 percent in case of false smut. The RTD causes severe yield losses upto 90 percent (Chakrabarti, 2001).

Ufra nematode occurs in severe form in certain parts of Assam. The major insect pests of DWR are: yellow stem borer causing more than 50 percent of stem damage. Other insect pests of importance are hispa, mealy bug,

Table 7. IPM module for deepwater

Sl No.	Pest	Name	Control measures
1.	Insects	Yellow stem borer (YSB)	Ploughing of field after harvest of deep-water crop in December-January
			Monitoring of YSB @ 5 pheromone traps/ha and of above ETL use 20 traps/ha for mass trapping
			Release T. japonium @ 50000/ha 3 times during Egg lying period
		Mealybug	Phorate spot application @ 1.0 kg a.i./ha
		Hispa	Apply phosphamidon @ 0.5 kg a.i./ha
2.	Disease	Bacterial leaf blight	Apply cow dung slurry @ 2 kg/litre as foliar spray before water accumulation in the field
		False smut	Kalisena foliar spray @ 2 g/litre or foliar spray of dithane M-45 (1%) at the time of grain discolouration
		RTD	Grow resistant varieties like Durga (Orissa), Sabita (West Bengal)
3.	Nematode	Ufra	· Hot water treatment of seeds before sowing · Apply carbosulfan spray 0.04% once at PI stage and other at heading stage
4.	Rodents	Rats	Zinc phosphide 1% (W/W) as bait

leaf folder and whorl maggot. The IPM technology for this ecosystem is given in Table 7.

Deep water rice environments of eastern Uttar Pradesh and Bihar are complex and risk-prone where rice is grown as rainfed crop under shallow flooding for first three months. Deep water rice (DWR) overlaps with the rainfed lowlands, and in most cases shares a common pest complex, especially in the years of low rainfall.

Coastal Wetland Ecology

Rice is an important crop in the coastal districts during the monsoon season. Farmers grow old traditional rice varieties. Soil salinity is a problem in these areas. At some places, groundwater is also saline, which causes accumulation of the salts on the soil surface during the dry season. The occurrence of insect pests like stem borer, gall midge and leaf folder, and diseases like sheath rot and bacterial leaf blight, and weeds like wild rice, *Echinocloa* spp., *Cyperus* spp. and *Schenoplectus* spp. are common. As a result, the yield in the coastal areas is low, the average being around 1.5 t/ha, which is below the national average (1.9 t/ha). To overcome these problems in coastal saline situations, a need-based integrated pest management is needed for economic and sustainable yield (Table 8).

Plant protection measures such as nursery treatment (carbofuran or phorate @ 1.0 kg a.i./ha), seedling root dip (0.02% chlorpyrifos), monitoring and controlling of YSB through sex pheromone traps and tricho-cards, seed treatment (bavistin @ 2g/kg seed) for sheath rot, control of vector for RTD and need-based fungicide application are essential. In addition, integrated weed management practices like summer ploughing, application of pre-emergence herbicide (butachlor @ 1.5-2 kg a.i./ha followed) and hand weeding 34-40 days after sowing help to reduce weed growth. Since the field situation is not conducive for top dressing of fertilizers, use of

Table 8. IPM module for coastal wet land

Sl No.	Pest	Name	Control measures
1.	Weeds	*Chara*	Summer ploughing
		Typha and water hyacinth	Remove mannually
2.	Arthropods	Crabs	Bunds can be treated with Thimet @ 5 g/hole
3.	Insects	Stem borer	As in deepwater (Table 7)
		Leaf folder and Case worm	Spray with monocroptophos @ 0.5 kg a.i./ha
4.	Diseases	RTD	Grow resistant varieties like Durga, Sabita, Lunishree
		BLB	Apply cow dung slurry @ 2kg/litre as foliar spray before water accumulation in the field
		Sheath rot	Spray sheathmar/validamycin @ 2 mL/litre
5.	Rodents	Rats	Zinc phosphide 1% (W/W) as bait

inorganic nitrogen fertilizers is low. Suitable nutrient management practice such as basal application of a combination of organic and inorganic nitrogen together with potash and phosphatic fertilizers is beneficial. Integrated pest management, nutrient management and use of salinty resistant varieties would definitely help in improving rice productivity in the coastal ecology.

Conclusions

Since 1965, about 630 rice varieties have been released in different states of India. Yet, in rainfed ecosystem a majority of the farmers grow land races or selections from the land races. Judicious application of fertilizers and sowing and planting time play an important role in pest incidence and its management.

Use of need-based and schedule-based pesticides is essential to avoid the pest resurgence. It has to be integrated in each module recommended for different ecologies. Nitrogenous fertilizer, plant spacing, plot-to-plot irrigation influence the incidence of diseases like BLB. There is also a need to protect the natural parasite and predator populations, and spraying should be avoided in such cases.

Economic analysis suggests host plant resistance to be the most rewarding tool of IPM. Susceptible varieties get eliminated after the outbreak of a disease or insect. Multiple host plant resistant varieties having resistance to nematodes, diseases and insects need to developed. But due to changing selection pressure of the pest, need-based application of biopesticides supplemented with biocontrol agents, cultural practices, and cow dung and urine, etc. is also important.

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5

Integrated Pest Management in Basmati Rice

D.K. Garg and R.N. Singh[1]

Introduction

Basmati or scented rice is mainly grown in the northern states of Uttar Pradesh, Haryana, Punjab, Uttaranchal, Rajasthan and Jammu & Kashmir. India exports huge quantities of scented rice, and thus, it has gained the status of a commercial crop, fetching high prices in both the domestic and export markets. The traditional tall Basmati cultivars are lodged under high doses of nitrogenous fertilizers and yield less grains. Research efforts over the last two decades have resulted in development of varieties like Pusa Basmati-1, Kasturi and Haryana Basmati, which are high yielding and semi-dwarfs. However, none of these varieties has resistance to insect pests and diseases. Leaf folder (LF) *Cnaphalocrocis medinalis*, yellow stem borer (YSB) *Scirpophaga incertulas*, gundhi bug *Leptocorisa* spp. and whiteback plant hopper (WBPH) *Sogatella furcifera* are the major insect pests affecting the yield of these varieties (Garg and Baranwal, 1998; Kushwaha, 1990). Besides, diseases like sheath blight *Rhizoctonia solani*, bacterial leaf blight (BLB) *Xanthomonas campestris pv oryzae*, blast and brown spot also reduce their yield potential substantially (Garg and Baranwal, 1998; Kushwaha, 1990). To control these pests, farmers follow pesticidal approach, which is expensive and many a times leads to pesticide residue problems. Being an export-oriented crop, the presence of pesticide residues often hampers its export potential. To overcome these problems, integrated pest management (IPM) is considered to be a viable option. Nevertheless, limited efforts have been made to transfer IPM technologies to Basmati producers. This paper examines the technical and economic feasibility of IPM in Basmati rice under field conditions.

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Evaluation of IPM Module

An IPM module, synthesized by the National Centre for Integrated Pest Management (NClPM), New Delhi, was initially evaluated at the Rice Research Station, Kaul (Haryana) of the CCS Haryana Agricultural University, Hisar, during 1994 and 1996. The module comprised mainly of (i) release of parasitoid, *Trichogramma japonicum* against major insect pests, LF and YSB, (ii) neem-based pesticide and insecticide as a last resort, (iii) rice husk that contains silicon to control blast disease (Hooda and Srivastava, 1996), and (iv) need-based application of fungicides. This module was compared against chemical control. The trials were laid out with improved Basmati rice variety, Taraori local.

Incidence of the insect pests and diseases was regularly monitored for pest control interventions. The pest data was recorded using standard procedures. From the data gathered during the three years on the infestation of LF and YSB, it was observed that IPM as well as chemical control were equally effective in suppressing LF and YSB. Amongst diseases, Iowest incidence of blast was recorded in IPM plots. This indicates the effectiveness of silicon in suppressing the blast incidence.

The grain yield under both IPM and chemical control treatments was higher compared to untreated control. It was marginally higher in chemical control, but the benefit cost ratio was slightly higher in the case of IPM due to lower costs (Garg and Baranwal, 1998).

Validation of IPM Module in Farmers' Fields

The western Uttar Pradesh, traditionally a sugarcane growing area is gradually diversifying towards paddy. The main reasons for this are: low prices of sugarcane and waterlogging in low-lying areas adjoining the Yamuna canal. These conditions make it ideal for growing paddy, especially the more remunerative Basmati type. The change is more visible in and around Baghpat, Baraut and Shamli regions of western U.P. In the quest of realizing better yields, farmers make substantial investments in plant protection measures, mainly chemical control. With this in view, the NCIPM conducted on-farm trials of IPM in one of the progressive farmers' fields in Shikohapur village near Baraut in 1997 with Pusa Basmati variety in seven acres, adopting the same agronomical practices that farmers of the region generally follow, except that in IPM plot, application of balanced fertilizers and irrigation schedules were advised. There were three treatments: (i) IPM based on the surveillance and monitoring, release of parasitoid, *T. japonicum* and insecticide application as a last resort against major insect pests (LF, YSB); and need-based fungicide application against major diseases (blast, sheath blight), (ii) chemical control, and (iii) farmers' practices (FP) comprising mainly the use of pesticides. In 1998, the trial was repeated with the same three treatments at 7 farms with Pusa Basmati variety taking about one acre area under each treatment. Details of interventions in the treatments during both the years are given in Table 1.

Table 1. Details of interventions in IPM validation trials in farmers' fields, 1997-98

Treatment	Intervention
Kharif 1997	
· IPM	4 Releases of *T. japonicum* @ 100,000 eggs/ha
· Chemical	2 Applications of insecticide (monocrotophos @ 0.05% a.i.) + 1 application of fungcide (carbendazim @ 0.05% a.i.)
· Farmers' practices (FP)	1 Application of insecticide (monocrotophos)
Kharif 1998	
· IPM	Release of *T. japonicum* 4 times on all the farms, spray of fungcide (carbendazim) on farm 4, 5, 6, and 7
· Chemical	Spray of insecticide 2 times and single spray of fungicide
· Farmers' practices (FP)	One spray of different insecticides on farm 1 (chlorpyriphos @ 0.05% a.i., 3 (endosulfan @ 0.07% a.i.), 6 and 7 monocrotophos @ 0.05% a.i.)

Pest incidence

Leaf folder (LF) and yellow stem borer (YSB) are the major insect pests of the area. In 1997, LF infestation at 50 days after transplanting (DAT) was the highest under farmers' practices (I7.68%), followed by in chemical treatment (12.58%). Release of *T. japonicum* in IPM fields suppressed the infestation considerably (4.61%). The final observation at 80 DAT showed highest infestation of LF in FP plots, followed by IPM and chemical control plots. YSB incidence remained low during the entire crop season, and only stray incidences were recorded at vegetative stage in all the treatments. At pre-harvest stage also, the infestation was low. It was the lowest in IPM fields, indicating substantial effect of *T. japonicum* on YSB (Table 2).

Table 2. Percent incidence of leaf folder, stem borer and brown spot alongwith yield (q/ha) of Basmati rice at farmer's field, Baraut 1997

Treatment	Leaf folder		Stem borer	Brown spot	Yield (q/ha)
	50 DAT	80 DAT			
IPM	4.61	7.78	2.21	2.56	58.38
Chemical control	12.58	6.56	3.20	4.86	47.75
FP	17.68	10.10	4.32	5.63	43.68

In 1998, moderate incidence of YSB was recorded. The incidence of DH (dead heart) was the highest in FP, followed by in chemical control and IPM. Similarly, at pre-harvest, the infestation was almost at par in chemical control and FP, while in IPM the incidence was substantially low. Data on LF infestation also indicated a similar pattern (Table 3).

Table 3. Percent infestation of stem borer and leaf folder at farmers' fields, Baraut, *Kharif* 1998 (mean of 7 farms)

Treatment	Stem borer		Leaf folder	
	Dead Heart	White Head	40 DAT	75 DAT
IPM	4.81	6.80	8.88	6.57
Chemical control	8.35	14.47	17.86	10.68
FP	9.67	14.36	17.34	12.08

Observations on diseases revealed that in 1997 symptoms of brown spot disease started appearing in the first week of September. The third application of nitrogenous fertilizer was of 12 kg/ha in IPM fields, while in FP and chemical control, a higher dose of nitrogenous fertilizer was used (140 kg/ ha). Sheath blight, sometimes a devastating disease of rice, was also noticed at mid tillering stage of the crop in IPM as well as in FP and chemical control. The disease was noticed in a small patch of 2m^2 in IPM in which 67percent tillers were found affected. The disease was monitored daily and it did not spread further. However, in chemical control treatment, a spray of carbendazim was applied to control the disease. The major diseases like blast and bacterial leaf blight (BLB) were not noticed in any of the field, except the traces of leaf blast on few plants.

In 1998, sheath blight was the main disease, however, its incidence remained low. In chemical control, spray of carbendazim suppressed its incidence. In IPM, it warranted no fungicidal spray. Similar was the case in farmers' practices. Some farmers, however, sprayed the fungicide for its control.

Grain yield and economics

In 1997, highest yield of 58.38 q/ha was obtained with IPM, followed by chemical control (47.75 q/ha). The lowest yield (43.68 q/ha) was obtained in FP. The economic analysis resulted in the highest cost benefit ratio with IPM, followed by chemical control (Table 4). Although with IPM, pest incidence was suppressed effectively, the yield difference was quite high which might be attributed to some other factors like late transplanting in FP and chemical control fields, which was about one week later to IPM fields. Yield data of 1998 showed that all the farmers secured higher yields with IPM treatment as compared to chemical control or their own control tactics (Table 5). However, there was marked superiority of yield on farms 1, 2, 5 and 6 with highest yield of 65.97 q/ha at farm 1, followed by 58.69 q/ha at farm 6. It seems that proper crop management practices like judicious application of nitrogenous fertilizer and proper water management had helped in improving the yield. Almost all the fields suffered low to severe lodging due to unusual heavy rains with high velocity winds in the first week of

Table 4. Economics of IPM in Pusa Basmati rice on farmers' fields 1997 and 1998

Treatment	Year	Cost of plant protection (Rs)	Yield (q/ha)	Monetary gain over FP (Rs)	Cost benefit ratio (CBR)
IPM	1997	1020	58.38	14332.00	1:14.05
	1998	1445	47.71	11716.00	1:8.11
Chemical control	1997	1260	47.75	3968.00	1:-0.19
	1998	1705	35.96	-328.00	1:0.19
Farmers' Practices (FP)	1997	420	43.68	-	-
	1998	445	36.28	-	-

Note : Price of paddy was Rs 975/q in 1997 and Rs 1025/q in 1998.

Table 5. Yield (q/ha) of Basmati rice in IPM trials at different farms, Baraut, 1998

Farm No.	IPM	Chemical control	Farmers' practices
1.	65.97	32.76*	49.02
2.	47.05	36.06	34.61
3.	39.45	38.07	39.02
4.	34.11*	31.08*	30.19
5.	41.40	28.23*	21.62*
6.	58.69	34.88*	35.46*
7.	47.31	50.66	44.05
Mean	47.71	35.96	36.28

* Indicates reduction in yield due to lodging

October but the loss was quite visible in some of the fields, as shown in Table 5.

Proper water management and fertilizer usage in IPM fields reduced the lodging, as none of these fields suffered the severe lodging. Thus, it can be concluded from the yield data that IPM with some improved crop management practices is a better approach in comparison to chemical control or farmers' practices, although the lodging in these treatments further widened the yield levels.

Implementation of IPM in Shikohpur Village

In 1999, a village Shikohpur in the same district was selected for large-scale validation of IPM. This village was selected on the basis of a survey, which revealed that the farmers of this village had been using pesticides indiscriminately for pest suppression and some farmers even were applying 10-12 sprays of pesticides. Even then they were unable to mitigate the pest menace. The non-judicious use of pesticides in all probability had drastically reduced the beneficial natural fauna in the environment, which might have led to the unusual incidence of insect pests.

In 1999, 100 acres of land belonging to 23 farmers was covered under IPM programme, and another 30 acres was earmarked for non-IPM in which farmers allowed to use chemical pesticide at their own discretion. In 2000, a majority of the farmers in the village showed keen interest in adoption of IPM, and thus, the area under the programme was increased to 300 acres. A nearby village Sarurnpur was taken as non-IPM village. In this village also the farmers grow mostly Pusa Basmati and rely on pesticides to overcome pest problems.

Pest incidence

LF and YSB were found as the major insect pests, followed by gundhi bug. In 1999, YSB incidence remained low in general both at vegetative and panicle development stages. The records on LF infestation in 1999 showed that at 50 DAT, it was much less in IPM (8.75%), compared to non-IPM (15.03%). Evidently, the release of T. *japonicum* substantially suppressed the infestation level of LF. At 75 DAT, incidence was further reduced to 3.90 percent in IPM, while in non-IPM a higher level (14.45%) of incidence was noticed. Sheath blight was found to be the major disease. Its incidence was much less in IPM due to timely intervention in the infected fields in 1999 while it reached up to 13.02 percent in non-IPM at 55 DAT.

Regular monitoring of the insect pests and diseases in the year 2000 revealed LF and YSB as the major insect pests, followed by sporadic and low incidence of gundhi bug and hispa. Among diseases, sheath blight was the major disease, followed by bacterial blight. YSB incidence in IPM reached up to 5.98 percent at vegetative stage, while not much infestation was observed at flowering stage onward. In non-IPM village, moderate incidence of YSB was recorded at vegetative stage, and maximum 'dead hearts' were 8 percent in the last week of August. However, at post-flowering stage, the incidence reached up to 20 percent. Data on the incidence of LF indicated that in IPM at one stage the incidence reached at a quite high level (29.12 percent) but declined substantially. The release of *T. japonicum* in the third week of August brought down its incidence substantially. Another release during first week of September further suppressed the incidence of both LF and YSB. In non-IPM, the incidence was comparatively much higher with a peak of 38.12 percent during the last week of August. Although, there was a declining trend afterwards, the incidence remained high, compared to IPM village. It seems that the use of insecticides like phorate had very little effect on the incidence of LF. Another insect gundhi bug assumed the status of a pest in few fields under IPM but was suppressed

Table 6. Details of plant protection and non-plant protection inputs in IPM and non-IPM fields at Shikohpur

Treatment	Main interventions
Kharif 1999	
▪ IPM (100 acres)	i) Seed treatment with carbendazim @ 2g/kg seed. Two releases of *T. japonicum*
	ii) One application of methyl parathion dust @ 25 kg/ha in gundhi bug infested zone (5 acre area)
	iii) Spray of carbendazim for sheath blight in infected patches
▪ Non-IPM (30 acres)	i) Two applications of phorate @ 25kg/ha
	ii) One application each of carbendazim and streptocycline
Kharif 2000	
▪ IPM (300 acres)	i) Seed treatment with carbendazim
	ii) Two releases of *T. japonicum* (need-based)
	iii) Application of methyl parathion for gundhi bug in 10 acre fields
	iv) Spray of strepcycline in about 30 acres for BLB
	v) Spray of carbendazim (1-2) in about 29 acre
▪ Non-IPM	i) Phorate application (1-2)
	ii) Dimecron spray (1)
	iii) Copper oxychloride (0-1) application
	iv) Streptocycline (1-2 sprays)
	v) Carbendazim spray (1)
▪ Non-Plant Protection inputs	
(i) Fertilizer application	
IPM	N:P:K: 110:60:40 kg/ha, ZnSO4 25 kg/ha
Non-IPM	N:P:K: 140:70:0 kg/ha
(ii) Number of irrigation	
IPM	8 irrigations
Non-IPM	10 irrigations

N = Nitrogen, P = Phosphorus, K = Potassium effectively by dusting of methyl parathion @ 10 kg/acre. Not much damage due to this insect was reported in non-IPM.

Among diseases, the incidence of sheath blight was observed high during the first two weeks of August in few fields of IPM village. Its spread was checked by timely spraying of carbendazim. In non-IPM, it reached up to 31.0 percent, causing considerable damage to the crop. Overall, the incidence of sheath blight was higher in non-IPM fields. Another disease, bacterial blight was also noticed in one or two fields, but its spread was checked by spraying streptocycline. Brown spot infection also occurred in some fields, but did not require any intervention.

Natural enemy complex

In IPM fields, population of natural enemies was more compared to that in non-IPM fields. The common predators like grass hopper, *Conocephalus longipennis*, crickets and spider fauna were noticed in considerable numbers in IPM fields. Other predators like carabids and lady beetles were also found. Parasitism of major insect pests was noticed to be quite high in IPM fields. On the other hand, the population of all these natural enemies was almost negligible in non-IPM fields.

Grain yield and economics

The mean yield in IPM fields was 56.92 q/ha in 1999, compared to 50.33 q/ha in non-IPM fields. In 2000, the mean yield in IPM fields was 58.04 q/ha, while the farmers of Sarurpur village could obtain an average yield of 48.21 q/ha in spite of pesticidal interventions (Table 7). Costs and returns with and without IPM are presented in Table 7. Application of IPM resulted in higher economic returns in both the years. Further, the possibility of pesticide residues is completely ruled out.

Inspite of more number of pesticide applications, non-IPM farmers could not get higher yield. Although there was higher incidence of insect pests and diseases in non-IPM fields, there were certain other crop management aspects, which might be responsible for low yield.

- Time of planting plays a crucial role in obtaining higher yield. The optimum planting time (seeding) for Pusa Basmati-1 is between 20 and 30 May and transplanting between 20 and 30 June. Delayed planting results in decrease in yield. IPM farmers were advised to

Table 7. Economics of production of Basmati rice in IPM and Non-IPM at Shikohpur, in 1999-2000

(Rs/ha)

Expenditure/Returns	IPM		Non-IPM	
	1999	**2000**	**1999**	**2000**
Total cost (all inputs)[1]	17792	17781	19459	20553
Yield	56.92	58.04	50.33	48.21
Total returns	42690*	56589**	37747	47005
Net returns	24897	38807	18287	26451
Cost benefit ratio	1:2.40	1:3.18	1:1.94	1:2.28

* Price of paddy: Rs 750/1 ** Price of paddy: Rs 975/q

[1] Includes inputs like labour charges for land preparation, nursery sowing, pudding, transplanting, fertilizer application, hand weeding, pesticidal application, etc. and material costs like seed, fertilizer, pesticides, biocontrol agents, etc.

follow these dates, while in non-IPM, except a few cases, transplanting was delayed.

- Farmers of this region have a practice of planting a single seedling/hill. IPM farmers were advised to plant 2-3 seedlings/hill. This helped in improving the crop yield.

- Farmers used comparatively higher doses of nitrogenous fertilizer, which led to more vigorous growth of plants and foliage, thus the stem became succulent and prone to lodging. Moreover, the susceptibility to diseases like sheath blight and bacterial blight also increases by both these factors. Higher dose of nitrogenous fertilizer is also known to help the buildup of some insect pests. Garg *et al.* (1999) reported the role of proper water management and judicious fertilizer use for reduced lodging in IPM fields.

- Farmers either used no seed dressers or wrong seed dressers. Further, the wrong pesticidal interventions by farmers resulted in resurgence and population build up of many minor insect pests and diseases. Farmers used pesticides like phorate granules, which sometimes helped in resurgence of leaf feeders like LF. Moreover, it had deleterious effect on many natural enemies.

Conclusions

Sustainability of the rice production system is under threat due to increasing use of chemical fertilizers and pesticides. The IPM if adopted, can help improve sustainability of the system.

At present, IPM covers only about one percent of the total 143 million hectares of cultivated area in the country. A little efforts have been made to synthesize the location-specific IPM modules to take care of insect pests, diseases and weeds, and other crop damaging organisms together (Mathur *et al.*, 1999; Pathak *et al.*, 1998). Validation of IPM in rice suggests that such efforts could help in reducing pesticide use and improve crop yield (Garg *et al.*, 2000; Katti, 2000).

Application of IPM in Basmati rice is crucial to minimize pesticide residue problem, as well to reduce its cost of production. Large export consignments of Basmati rice are rejected due to high pesticide residues (The Economic Times, Feb. 15, 2001). The solution to this lies in the development and implementation of area-specific, cost effective and environmental-friendly IPM strategies.

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6

Integrated Management of Groundnut Diseases in India

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Introduction

Groundnut (*Arachis hypogaea* L) is the most important oilseed crop in India. It occupies 35 percent of the total area under oilseeds and contributes more than 40 percent to total oilseeds output (Prasad, 1994). Groundnut crop is prone to attack by many diseases and to a much larger extent than many other crops. More than 100 pathogens, including viruses, have been reported to affect groundnut but only a few are economically important in India such as leaf-spots [('*Tikka*'), early leaf-spot *(Cercospora arachidicola)*, late leaf-spot *(Puccina personate = C. personatum)*], rust *(P. arachidis)]*, and aflatoxin contamination *(Aspergillus flavus* and *A. parasiticus)*. The other diseases such as collar rot *(A. niger)*, stem-rot *(S. rolfsii)*, root-rot *(M. phaseolina = R. bataticola)*, bud necrosis (tomato spotted wilt virus), clump and peanut (groundnut) mottle disease are localized. Some of the diseases, which were of minor importance in the past, have become major today. Rust and bud necrosis which were not known two decades ago, have turned out to be of economic significance now. Recently, a new disease named as peanut stem necrosis disease [PSND], caused by tobacco streak virus (TSV), has become a potential threat to groundnut production in southern India.

Groundnut is largely cultivated by small farmers. And since diseases are the major constraint to sustainable groundnut production, it is necessary to develop disease management strategy that would be within the reach of small farmers. Crop management practices for groundnut vary from no-input but labour-intensive practices in many states of India to partial mechanization in some states like Gujarat and Punjab; accordingly the disease

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management practices vary widely. There may be minimal disease management, some or indiscriminate use of fungicides or total reliance on host plant resistance (HPR).

Madden (1987) defined integrated pest management (IPM) as “a holistic, multidisciplinary management system that integrates control methods on the basis of ecological and economic principles for pests that co-exist in an agro-ecosystem”. This notion certainly encompasses disease management within the groundnut production systems in India. Two major treatises on the diseases of groundnut and their management (Middleton *et al.,* 1994 and Pande *et al.,* 1996) provide an excellent background to the nature of the diseases, the pathogens that cause them, and an insight into the ongoing problems. In this paper, emphasis has been laid mainly on an integrated disease management. Cultural practices, HPR, and judicious usage of fungicides can be integrated into location- and problem-specific management plans designed to minimize initial levels of disease, and/or obstruct the progress of disease to keep it below economical loss-causing levels. The distribution and changing scenario of diseases and losses caused by them are also discussed.

Distribution of Diseases in India

Early leaf-spots (ELS) and late leaf-spot (LLS) are mainly prevalent during the *kharif* than the *rabi* season or in summer in almost all groundnut growing areas in the country and become endemic frequently. The LLS is usually more severe than ELS, but, recently severe outbreaks of ELS have been observed in the states of Andhra Pradesh, Karnataka and Tamil Nadu (Pande and Narayana Rao, 2000).

After the initial report of groundnut rust *(P. arachidis)* from Punjab (Chahal and Chohan 1971), it was recorded in different groundnut production systems of India. Subrahmanyam *et al.* (1979) reported rust from the southern states of India. Surveys conducted by National Research Centre for Groundnut (NRCG) during *kharif*, 1980-81, 1981-82 and 1982-93, revealed moderate to heavy incidence of rust in all groundnut growing districts of Saurashtra region. Its occurrence was also reported on *rabi*/summer crop during April, 1981 in Orissa near Cuttack and in Saurashtra near Junagadh (1981 and 1982) (Ghewande and Misra, 1983). In general, rust on groundnut crop now seems to be prevalent throughout India (Pande and Narayana Rao, 2000).

Collar-rot *(A. niger)* is prevalent in almost all groundnut growing areas of the country. It is a serious disease in the sandy loam and medium black soils of Punjab, Andhra Pradesh, Tamil Nadu, Uttar Pradesh, Rajasthan, Orissa, Madhya Pradesh, Karnataka, Maharashtra, Gujarat and Haryana. This disease is more destructive in the *kharif* than in the *rabi* and/or summer seasons. Stem-rot caused by *S. rolfsii* is sporadic in most of the groundnut growing areas of the country and is assuming importance in Tamil Nadu, Andhra Pradesh, Karnataka (Pande and Narayana Rao, 2000. The disease epidemics have also been reported from Madhya Pradesh and Gujarat. Similarly, root-rot *(M. phaseolina)* which was sporadic all over the country in light soils, is particularly serious in Tamil Nadu, Andhra Pradesh, Maharashtra, Uttar Pradesh and Rajasthan (Ghewande and Mishra, 1983; Pande and Narayana Rao, 2000).

Yellow mold and the related aflatoxin contamination of groundnut seed occur throughout the world; however, they are more severe in subtropical and tropical regions. In India, it has been reported from all the groundnut producing regions. Aflatoxins produced by the fungi *A. flavus* and *A. parasiticus* are the most potent of known carcinogens (Mehan *et al.*, 1991). Aflatoxin contamination can occur in the stems of peanut seedlings or in pods or seeds when the tissues are invaded by the causal agent of yellow mold. The combination of yellow mold and aflatoxin contamination can be grouped into pre-harvest and post-harvest contaminations. The factors that affect pre-harvest contamination are: drought, poor calcium nutrition, damage by soil insects, high soil temperatures, biological damage, mechanical damage, susceptible cultivars, improper use of nematicides and fungicides. The post-harvest contamination is affected by: inadequate artificial drying, high moisture content, moisture leaks during storage, higher temperature during storage, damage by storage insect pests and rodents, and microbial deterioration.

Bud necrosis (tomato spotted wilt virus) of groundnut is wide-spread with a broad host range. It is a serious disease in Andhra Pradesh (Pande and Narayana Rao, 2000) and Madhya Pradesh. It has also started assuming importance in Haryana in the recent years. Clump disease (virus), first reported from the former Madras State by Sundara Raman (1926) was later observed during 1977 in crops grown in the sandy soils of Punjab and Gujarat and was also reported from Uttar Pradesh and Andhra Pradesh. The occurrence of peanut (groundnut) mottle disease (virus) was first reported in Andhra Pradesh by Reddy *et al.* (1978). It has also been observed in farmers' fields in Maharasthra and Andhra Pradesh. A higher incidence of about 40 percent plants infected with this disease in *rabi*/summer crop in Saurashtra was observed by Ghewande (1984). During the 2000 *kharif* season, an outbreak of a new disease identified as "peanut stem necrosis disease" (PSND) resembling bud necrosis and caused by an isolate of tobacco streak virus (TSV), was recorded from Andhra Pradesh (Reddy, D.V.R., personal communication).

Losses

Yield losses caused by leaf-spots and rust ranged from 15 to 80 percent. Losses in pod yield (up to 29%) due to rust at Dharwad were reported by Siddaramaiah *et al.* (1977). Similarly, Ghuge *et al.* (1981) reported that rust alone reduced 50 percent pod yield. Subrahmanyam *et al.* (1980) reported that the losses in the susceptible genotypes were to the extent of 70 percent due to combined attack of rust and leaf-spots, while rust alone was responsible for 52 percent reductions in pod yields. Recently, in an on-farm participatory research on the management of foliar diseases, mainly late leaf-spot and rust of groundnut, Pande *et al.* (2001a) reported an increase in haulm yield up to 80 percent and pod yield up to 60 percent in the fungicide-protected plots than in unprotected plots.

The seed and seedling diseases (collar-rot, stem-rot, root-rot) of groundnut cause severe seedling mortality, resulting in patchy crop stand and have a devastating effect on the prospects of a successful groundnut crop. Collar-rot is reported to cause 40 percent loss in the crop establishment and yield in Punjab (Chohan, 1973). Recently, Pande and Narayana Rao (2000) have observed up to 30 percent reductions in plant stand due to collar-rot and estimated 20 percent pod yield reduction in the farmers' fields in the states of Andhra Pradesh, Karnataka and Tamil Nadu. Stem-rot caused up to 27 percent loss in Uttar Pradesh and in the Deccan Plateau (Singh and Mathur, 1953, Pande and Narayana Rao, 2000). Approximately 5-15 percent loss in the initial crop stand is due to seed-rot and seedling collapse (Pande and

Narayana Rao, 2000). Additionally, pod deterioration caused by the soil-borne pathogenic fungi has been reported to be potentially serious in several farmers' fields in Andhra Pradesh, Tamil Nadu and Karnataka (Pande and Narayana Rao, 2000).

In India, bud necrosis disease caused yield losses up to 50 percent (Chohan, 1978). In the case of late infection caused by clump disease, losses up to 60 percent have been recorded (Ghanekar, 1980). Recently, a new virus disease – peanut stem necrosis (PSND) – caused crop loss of nearly Rs 300 crores in groundnut in Andhra radesh during the *kharif*, 2000 season (Reddy, D.V.R., personal communication).

Integrated Management of Diseases

Considering the extent of prevalence and magnitude of losses, it appears that diseases are the major constraint to groundnut production in India. To achieve sustainable pod and haulm yields, their management is necessary. Components of disease management and their integration are as follows:

Host resistance

Host-plant resistance to foliar diseases is not available in the high-yielding groundnut varieties. A large collection of the world germplasm has been screened against leaf-spots and rust under laboratory and field conditions at ICRISAT, and the lines showing resistance have been identified (Mehan *et al.*, 1996, Subrahmanyam *et al.*, 1980). Similar attempts have also been made at National Research Centre for Groundnut (NRCG), Junagadh, Gujarat, for evaluating germplasm for resistance to many diseases and varying levels of resistance to several diseases have been identified (Singh and Ghewande, 1980). Sources of moderate levels of multiple resistance to leaf-spots and rust are available. For example, groundnut line NcAc 17090 possesses high levels of resistance to both these diseases. Efforts have been made to involve several resistant lines in disease resistance breeding programmes at ICRISAT and NRCG and its centres in India. A few wild *Arachis* species have also been reported to be highly resistant and immune to rust and leafspots in India (Subrahmanyam *et al.*, 1980 and Pande and Rao, 2001a). Attempts have been made to transfer and quantify resistance to leaf-spots and rust from several wild species into the cultivated groundnut at ICRISAT (Mehan et al., 1994) and elsewhere (Chiteka *et al.*, 1988a and

1988b). Several of wild *Arachis* species derivatives though resistant to foliar diseases, have long-duration and thus are not suitable to the rainfed conditions in India.

Certain genotypes (NC-2 and NCAc 18016 and T-17, T-11-11, EC 1682, RB-4, T-25, T-9 and Mainpuri local) have been reported to be resistant to *S. rolfsii* in either greenhouse tests or field screenings (Mathur and Kureel, 1965). Stable resistant to stem-rot across locations and environment has not been found. Groundnut genotypes showed variations in susceptibility to stem-rot depending on temperature. Some genotypes that were susceptible at 23 ^{o}C (min) to 36 ^{o}C(max) showed resistance at 16 ^{o}C(min) to 31 ^{o}C(max), indicating the possible temperature sensitivity of stem-rot resistance gene in groundnuts (Pande *et al.,* 1994). In general, resistant to stem-rot is not available in the agronomically acceptable cultivars.

Reliable and stable sources of resistance for viral diseases have not been reported so far in the country.

Cultural control

This aspect of crop health management was neglected and/or overlooked specifically in groundnut crop. Some of the cultural practices which can be adopted easily by farmers are:

- Adjustment of the date of sowing if possible so that the susceptible stage of the crop growth does not coincide with the highly congenial weather for pathogens to establish and cause greater damage to groundnut crop.
- Close or wider planting is essential, as spacing influences the microclimate which in turn along with virulent form of pathogen dictates disease development. Generally wider spacing though helps in minimizing the foliar disease development, but thin plant stands result in poor yields (Pande and Narayana Rao, 2001b).
- Limited research has been conducted to understand disease development in sole groundnut crop vis-a-vis combination of other crops with groundnut in the same season (Pande *et al.*, 1993). Leaf-spots and rust being airborne diseases, spread quickly where there is continuity of host plants over large areas. It is worthwhile knowing the various

economically profitable combinations which may act as barriers for spores and check the spread of the disease to some extent. Effect of fertilizer on the disease development has not been established in groundnut. In general, very little has been documented on the effect of crop rotation in the groundnut disease management. It is known that crop rotation with non-host crops can reduce the incidence of soil-borne diseases, but it is not a practical proposition under rainfed cultivation of groundnut in India.

Attempts have been made to establish suitable cultural practices to manage leaf-spots and rust diseases (Ghewande *et al.*, 1985 and Pande and Narayana Rao, 2001b). Removal of infected debris from field and burning it are recommended for the control of foliar diseases. Application of phosphorus to soil prior to sowing reduced rust incidence and intensity. In general, strict plant quarantine regulations should be enforced to avoid the spread of rust on pods or seeds to disease-free areas.

The incidence of collar-rot disease may be minimized by avoiding mechanical damage, destroying plant debris, deep ploughing and crop rotations. The lower incidence of collar-rot, stem-rot and bud necrosis in early sown (June) crop and close plant spacing (22.5 × 7.5/10 cm) has been reported (Ghewande, 1983).

Biological control

It would be worthwhile exploring the possibilities in managing the diseases using biological control agents. Several bacterial and mycoparasites like V*erticillium lacani, Penicilliura islandicum, Eudarluca caricis, Acremonium persicium, Darluca filum, Tuberculina costaricana, Hansfordia pulvinata* and *Euphysothrips minozzii* on uredia of groundnut rust *(P. arachidis)* pathogen have been reported (Siddaramaiah *et al.*, 1981; Shokes and Taber, 1983; and Pande *et al.*, 2001a). Additionally, P. *lacani* has been observed to parasitise on leaf-spot pathogens of groundnut. There is a need to further develop/explore their use efficiently under field conditions. Biological control of soil-borne pathogens such as *M. phaseolina* and *S. rolfsii* can be achieved by resident antagonists or through introduction of antagonists in the soil. Both *T. viride* and *T. harzianum* were found to be capable of reducing the sclerotial population of *M. phaseolina* (Sharma, 1982). Seed treatment with spores and mycelium of *T. polysporum* protects the seeds from invasion of *M. phaseolina*. Several *Trichoderma* species have also been applied to seeds to control stem-rot in groundnut. Among them *T. harzianum* grown on celaton-molasses medium has been used successfully at field scale (Backman and Rodriguez-Kabana, 1975).

Chemical control

There have been continuous efforts in evolving suitable fungicidal schedules for the control of groundnut diseases. Recently, a combination of minimal use of fungicides with moderate levels of HPR in the management of foliar diseases has been found economical and acceptable by the small and marginal farmers (Pande *et al.*, 2001b). Further, for an effective management of foliar diseases, weather-based disease forecasting systems have been developed (Butler *et al.*, 1994), and their use at field scale is under evaluation.

Leaf-spots and rust are controlled by spraying carbendazim (Bavistin) @ 0.05 percent plus Mancozeb (Dithane M-45) @ 0.2 percent at intervals of 2 to 3 weeks, 2 or 3 times, starting from 4-5 weeks after planting. In the all India trials, this combination controlled both diseases effectively and gave the highest yields (Reddy, 1982). Application of Tridemorph (Calixin) as spray @ 0.07 percent gave complete control of rust (Ghuge *et al.*, 1980). Natarajan *et al.* (1983) have recommended two sprayings of Triadimefon (Bayleton) @ 100 g $acre^{-1}$ as 200 L spray solution to control rust. Recently, in the farmers' participatory evaluation of a combination of moderate levels of HPR with judicious use of fungicides, Pande *et al.* (2001a) effectively controlled LLS and rust in groundnut cultivars ICGV 89109 and ICGV 91114 with one spray of chlorothalonil @ 2 g L^{-1} water and 800 L solution ha^{-1}.

The incidence of collar-rot can be minimized by treating the seeds with Thiram 75 WP @ 3.5 g kg^{-1} kernel. In places where Thiram is not available, Carbendazim/ Mancozeb/Captafol @ 2.0-2.5 g kg^{-1} kernel may be used (Singh and Ghewande, 1980). Good control of pre-emergence rot caused by *M. phaseolina* has been achieved by seed dressing with Captafol (Shanmugham and Govindaswamy, 1973). Brassicol 75 percent WP (0.5%) can also be applied @ 1 litre $metre^{-2}$ or in the form of soil dust 25 kg ha^{-1} in two split applications, 12.5 kg ha^{-1} before sowing and the other 12.5 kg ha^{-1} 15 days later (Shanmugham and Govindaswamy, 1973). A mixture of fungicides, viz. terrachlor + terrazole @ kg ha^{-1} + 40 kg ha^{-1} at pegging was found effective in controlling stem-rot disease (Chohan, 1978). Soil drenching with carboxin has been reported to be effective against *S. rolfsii* (Amma and Shanmugham, 1974). Although several chemicals have been found effective in controlling stem-rot, these are not practicable at smallholder level.

Control of yellow mold and management of aflatoxin contamination in groundnut can be achieved by preventing the *A. flavus* group from entering groundnut tissues by either destroying or diverting the contaminated seeds and adopting improved crop husbandry (Mehan *et al.*, 1991). These are:

- Avoid mechanical damage to the crop during cultivation, harvesting, and subsequent processing;
- Harvest at proper maturity;
- Dry the produce in the fields as rapidly as possible;
- Prevent rewetting during or after drying;
- Remove damaged or molded pods and seeds;
- Dry to safe moisture level (8%) before keeping in storage; and
- Store at low temperature and low humidity.

Most of these recommendations have been applied with considerable success by large farmers in the developing countries but are neglected in India because of several socio-economic constraints. The genetic resistance, identified by several workers, depends upon the presence of an undamaged seed testa and any damage to the testa greatly reduces the levels of resistance.

Controlling of vectors (Thrips) with systemic insecticides like Dimethoate @ 400 mL ha^{-1} or Methyldemeton @ 360 mL ha^{-1} might give protection against bud necrosis and stem necrosis diseases. Soil application of Nemagon and Temik, one week before planting, was found to be most effective in reducing the clump disease incidence and increasing the yield when compared with untreated plots (Ghanekar, 1980). In general, management of virus diseases is achieved by controlling the vector population wherever applicable.

Farmers' Participatory Integrated Management of Foliar Diseases On-farm

Identification of moderate levels of resistance to foliar diseases

Twenty-one high-yielding groundnut genotypes maturing in 95-120 days after sowing (DAS) and a susceptible cultivar, TMV 2, sown as a systematic control and indicator genotype were evaluated for their resistance to foliar diseases under artificial disease epidemic situations at ICRISAT farm (Table 1). Foliar diseases were scored on 1-9 rating scale where 1 was for no disease and 9 was for maximum disease severity from 35 DAS to harvest at 10-day intervals.

Significant differences were recorded in the progress of foliar diseases among the test genotypes up to 85 DAS. Thereafter, at 95 DAS and beyond, except in ICGV 86699, there were no significant differences in severity of foliar diseases between test genotypes and TMV 2. The genotype ICGV 86699 supported the slowest rate of epidemic development throughout the growth stages (Table 1). Pod and haulm yields were

Table 1. Foilar diseases progress of groundnut genotypes in screening nursery at ICRISAT-Patancheru

Genotype	Foliar disease score on 1-9 point rating scale[1] Days after sowing					
	45	55	65	75	85	95
ICGV 86699	1.0	1.0	1.5	2.0	2.0	2.5
ICGV 89104[2]	1.3	2.3	3.3	4.3	5.3	8.0
ICGV 91114[3]	1.3	2.3	3.7	4.7	5.7	7.7
ICGV 91116[4]	1.7	2.7	4.0	5.0	6.7	8.7
ICGV 91123[5]	1.7	2.7	3.7	4.7	6.3	8.3
ICGV 92269	1.5	2.7	4.0	5.3	7.0	8.7
TMV 2[6]	2.0	3.0	4.7	6.0	7.7	9.0
LSD (5%)	0.51	0.55	0.72	0.76	0.75	0.67

1 = No disease and 9 = > 80% maximum disease severity

2 = Similar foliar dieease reaction in ICGV 91117, 91278, 94360

3 = Similar foliar dieease reaction in ICGVs 91124, 91146,92268,94283

4 = Similar foliar dieease reaction in ICGVs 86168, 91109, 94319,

5 = Similar foliar dieease reaction in ICGVs 91112, 91151, 92209, 92234, 94278

6 = Susceptible control

LSD = Least significant difference

Table 2. Haulm and pod yields of groundnut genotypes in foliar diseases screening nursery at HCRIDAT-Patancheru

Genotype	Yield, t ha^{-1}	
	Haulm	Pod
ICGV 86699	3.26	1.89
ICGV 89104[2]	2.78	1.59
ICGV 91114[3]	2.67	1.66
ICGV 91116[4]	1.92	1.50
ICGV 91123[5]	1.74	1.56
ICGV 92269	1.66	1.45
TMV 2[6]	1.15	0.90
LSD (5%)	0.242	0.361

2 = Similar foliar dieease reaction in ICGV 91117, 91278, 94360
3 = Similar foliar dieease reaction in ICGVs 91124, 91146,92268,94283
4 = Similar foliar dieease reaction in ICGVs 86168, 91109, 94319,
5 = Similar foliar dieease reaction in ICGVs 91112, 91151, 92209, 92234, 94278
6 = Susceptible control
LSD = Least significant difference

significantly greater in all the genotypes than the susceptible control (Table 2). Three groundnut genotypes, ICGV 89104, ICGV 91114 and ICGV 86699, had lower severity of foliar diseases and greater pod and haulm yields and hence were selected for further detailed disease epidemic analysis and to identify the appropriate crop growth stage and level of disease epidemic to execute the economical fungicide spray schedule.

Integration of moderate levels of resistance and minimal use of fungicides

The selected genotypes (ICGV 89104, ICGV 91114 and ICGV 86699) along with a highly susceptible genotype TMV 2 were exposed to different fungicide spray schedules in a field experiment at the ICRISAT farm. Fungicide, Kavach (Chlorothalonil) @ 2g L^{-1} water and 800 L chemical solution ha^{-1} was sprayed. Four fungicide programs followed were: T_1 = No fungicide applied; T_2 = Fungicide, Kavach, applied as one spray schedule at 60 DAS. T_3 = Fungicide, Kavach, applied as two spray schedules, 60 and 75 DAS; T_4 = Fungicide, Kavach, applied as three spray schedules at 60, 75 and 90 DAS. Foliar diseases were scored as explained earlier.

The severity of foliar diseases was significantly low in fungicide-sprayed plots than in unsprayed plots. The plot which received one fungicide spray at 60 DAS was found more economical than the rest of the spray schedules. Therefore fungicide schedules T_3 and T_4 were not further evaluated. The progress of foliar diseases in both the early-maturing genotypes (ICGV 89104 and ICGV 91114) was slower up to 85 DAS in fungicide-sprayed (one spray) plots than in TMV 2 and thereafter, the diseases shot up and reached maximum at maturity. Groundnut genotype ICGV 86699 though supported the slowest rate of epidemic development and remained apparently healthy for longer time, was found to be unacceptable because of its kernel colour and unpredictable pod filling under SAT environment.

Thus, a combination of an effective and economical spray application that reduced the rate of epidemic growth of foliar diseases in improved genotypes was identified. These findings were further validated as an integrated disease management (IDM) package in on-farm with several farmers in Andhra Pradesh.

On-farm validation of Integrated Disease Management

One hundred and sixty farmers from the state of Andhra Pradesh participated in raising these on-farm trials using normal agronomic practices. Two early-maturing genotypes, ICGV 89014 and ICGV 91114, and a local cultivar were evaluated in these trials. Fungicide, Kavach, was sprayed once at 60 DAS. Foliar diseases were scored as in earlier experiments. Three randomly sampled plots (2 × 2 m) were harvested. Haulm and pod yields were calculated for one hectare after drying.

The rate of progress of severity of foliar diseases was significantly slower and less up to 85 days in ICGV 89104 and ICGV 91114 than in local cultivar with single spray, given at 60 DAS. The response to minimal fungicide application, and thereby substantial reduction in epidemic growth of foliar diseases as exhibited by HPR in these genotypes resulted in an increase in haulm yield by 87 percent and pod yield by 140 percent. Net profit of Rs 15,400 from these genotypes and Rs 3500 from local cultivar were obtained. Thus, a four-fold increase in net income in on- farm IDM trials was achieved at several locations .

These on-farm studies clearly suggested that when moderate level of resistance as quantified by slower disease development was combined with minimal use of fungicide, both haulm and pod yields and economic returns were higher than obtained with chemical control on susceptible cultivars.

In collaboration with non-governmental organizations (NGOs), National Agricultural Research Systems (NARS), and other developmental agencies, we are in a process of scaling up of the IDM technology in major groundnut-growing regions of India, particularly in the Deccan Plateau.

Concluding Remarks

Since we no longer aim to achieve absolute control, but rather an economic reduction in disease level, it is natural that integrated disease management approach, which calls for combining adequately all available control methods in increasing the groundnut production, is most desirable. However, the distance between a plant pathologist and farmer is large. There is also a need to bridge gaps between technologies generated in the field of disease management and their transfer and adoption, to achieve sustainable yields of groundnut by smallholders.

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7

Integrated Pest Management in Vegetable Crops

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Introduction

Tomato, brinjal, cabbage, cauliflower, okra, beans and cucurbits are important vegetables cultivated in India. Cultivation of hybrids or improved varieties of vegetables during off-season, intensive agronomic practices and indiscriminate use of insecticides have disrupted the delicate balance between the insect pests and their natural enemies. The development of insecticide resistance in tomato fruit borer (*Helicoverpa armigera*), brinjal fruit borer (*Leucinodes orbonalis*), serpentine leaf miner (*Liriomyza trifollii*), and diamond back moth (*Plutella xylostella*) in cabbage are a few examples. To combat these insecticide resistant insects, IPM techniques are being devised. Use of marigold as a trap crop for tomato fruit borer, *H. armigera*, mustard as a trap crop in cabbage and cauliflower, use of NPV and *Trichogramma* against tomato fruit borer, application of neem seed kernel extract against all the pests of crucifers are a few well-known IPM technologies. Use of neem and pongamia cakes in the pest management in brinjal, cucurbits and okra are the new strategies devised. The IPM is yet to make a large scale impact in farmers' fields. Therefore, there is an urgent need to popularize the new technologies after taking stock of the existing techniques and if necessary, modify them to suit different ecological needs. This paper presents a status report of the available IPM technologies for vegetable crops including their limitations and economic aspects.

IPM Technologies

Trap Crops

Use of mustard and marigold as trap crops in cabbage and tomato are the two important classical IPM technologies available to farmers.

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Mustard as trap crop and neem seed kernel extract (NSKE) for cabbage and cauliflower

The technology developed in 1989 (Srinivasan and Moorthy 1991; 1992) recommends two rows of bold-seeded Indian mustard after every 25 rows of cabbage. The first row of mustard is sown 15 days prior to the cabbage planting and second row is sown 25 days after planting. Mustard attracts more than 80 percent of the cabbage pests. However, the mustard foliage is to be sprayed with dichlorvos to kill pests in addition to 2-3 sprays of Neem Seed Kernel Extract (NSKE).

This package was evaluated under All India Coordinated Vegetable Improvement Project (AICVIP) and has been recommended to its Rahuri and Hyderabad centres. This technology was also demonstrated in Ooty along with the release of *Diadegma semiclausum* in Tamil Nadu under SAVERNET (South Asian Vegetable Research Network, funded by ADB and executed through Asian Vegetable and Research Centre, Taiwan).

The rate of adoption of this package is not known, though many farmers around Bangalore grow mustard around the cabbage crop and spray pesticides on mustard also when they spray on cabbage. This, however, is not desirable as the diamond back moth (DBM) may not lay eggs where insecticides are sprayed. The limitation of the technology is that the farmers have to sacrifice two rows of the main crop for the trap crop (Subramaniam 1997). There is also difficulty in raising the second row of mustard. These are in addition to the problem of wet grinding of NSKE every time for spraying.

Marigold as trap crop for management of tomato fruit borer

Use of tall African marigold as trap crop for the management of tomato fruit borer, *H. armigera,* was demonstrated in 1992 (Srinivasan *et al.,* 1994). Under this package, 45-day old marigold is planted for every 16 rows of tomato to synchronize flowering in both the crops. Most of the eggs of borer are laid in marigold flowers or flower buds, and only negligible eggs are laid in tomato. Whatsoever little incidence of the insect is controlled by spraying of endosulfan at 28 and 35 days after planting (DAP).

This package was also evaluated under All India Coordinated Vegetable Improvement Project (AICVIP) and has been recommended at Rahuri and

Hyderabad centres. Many tomato farmers grow marigold around the crop and also market the marigold flowers.

The limitations of this technology are that the flowering in marigold and tomato has to be synchronized and some tomato rows are to be sacrificed for marigold (Subramaniam, 1997).

Use of botanicals: Use of neem seed kernel extract sprays

NSKE sprays are recommended on a variety of crops such as cabbage, cauliflower, tomato and cucurbits against all pests, on tomato and cucurbits against serpentine leaf miner, and on beans against stem fly, *Ophiomyia phaseoli*.

In cabbage and cauliflower, NSKE sprays provided excellent control of all the pests and the crop could be raised without a single insecticide application. It was demonstrated in 1989 by Srinivasan and Moorthy (1992). Demonstration of NSKE sprays under mechanised cabbage farming was also done in a large area of Tamil Nadu by Moorthy *et al.* (1998).

Many farmers are aware of the usefulness of NSKE sprays, but they do not know the proper method of its preparation. Some also complain about non-availability neem seeds in the market during the summer when pest problems are more. Further, preparation of the extract is problematic as it involves grinding and filtering, which irritate eyes.

As an alternative to NSKE, neem seed kernel powder (NSKP) and neem seed powder (NSP) were used for extraction under the Institute Village Link Programme (IVLP) of IIHR during 1996 and both were found effective in controlling DBM. The storage studies on these powders undertaken at IIHR, revealed that NSP can be stored up to 5 months in ploythene bags without much loss of efficacy (Moorthy and Kumar, 2000). Hence, powders can be prepared, packed in ploythene bags and stored. This powder can be soaked overnight and used for extraction. Marketing of NSKP or NSP can be undertaken on a commercial scale by the private companies, specifically in and around cabbage growing areas. However, this is yet to be exploited commercially.

Many neem formulations are available in the market, but these are moderately effective compared to NSKE (Srinivasan and Moorthy, 1993). Perhaps, the only exception is a new powder formulation with 6% azadirachtin. It was found highly effective against DBM in cabbage (at the dose of 1g/L) and also in tomato against fruit borer. Many neem formulations have been found effective against serpentine leaf miner also.

The use of neem seed cakes is well known for controlling nematodes. These also reduce soil-borne insects like termites, grubs, etc. The use of cakes for the management of many insect pests of brinjal, okra, cucurbits, etc. was demonstrated recently at IIHR, Bangalore.

The mode of action of cakes seems to be ‘repellency’ through the volatiles present in the cakes. The effect was also found to be reduced with rise in temperature and high wind velocity during summer and pre-monsoon months. The utility of the cakes in IPM of different insect pests and crops is briefly described below.

Brinjal: The insecticide resistant brinjal shoot and fruit borer was effectively reduced to 6-10% by 2-3 soil applications of neem and pongamia cakes @ 250 kg/ha. This was found to reduce the incidence of ash weevil, gall midge and thrips successfully and with minimum insecticide use. However, the incidence of mite and aphid could not be reduced by the cakes.

Okra: The soil application of neem cake @ 250 kg/ha at sowing, and two repeated applications at 30-45 days interval was found to reduce the incidence of petiole maggot (*Melanogromyza hibisci*), fruit borer (*Erias vitella*) and hopper (*Amrasca biguttula biguttula*). The incidence of different pests under the IPM programmes during 2000-2001 is given in Table 1.

Neem cake virtually reduced all the insect pests as well as the virus diseases. Powdery mildew was also very low in the plots treated with neem cakes. Pongamia cake was also effective. Powders were less effective. Hence, neem cakes can be used as a component of IPM in okra and also in disease management.

Cucurbits: Studies conducted at IIHR revealed that application of neem cake or sprays of NSKE were very effective in controlling fruit fly in cucumber (Table 2). Soil application of neem cake reduced the incidence of fruit fly to 6 percent, whereas insecticide applied plots recorded its incidence at more than 15 percent.

Table 1. Incidence of major insect pests and virus disease in okra under different management programmes

Treatments[1]	Petioles affected by petiole maggot, %	Mean number of hoppers/3 leaves/plant	Cumulative fruit borer, %	Plants with virus disease, %
Neem seed powder	13.79	3.63	11.21	0.66
Pongamia seed powder	15.73	3.97	16.54	1.33
Neem cake	4.76	2.77	5.22	0
Pongamia cake	2.44	3.04	6.22	5
Untreated control	16.67	7.24	24.24	80.64

[1]All the cake and seed powder applications were given @ 250 kg/ha as soil application. First application was done at 10 days after sowing, and repeated 2 more times at 30 days interval.

Table 2. Incidence of fruit fly under different management programmes in cucumber

Treatments	Dose, %	Mean
NSKE	4	11.08
Carbaryl	0.15	15.17
Metasystox	0.05	22.77
Monocrotophos	0.05	20.84
Phosphomidon	0.05	22.36
Neem cake	100 g/pit	6.26
Pongamia cake	100 g/pit	21.45
Control		48.96

The soil application of cakes and foliar soap sprays were more effective in reducing thrips in water melon as compared to insecticide sprays.

Cabbage and cauliflower: The results in both cabbage and cauliflower indicated that neem cake application reduced DBM significantly. In these crops, foliage development takes a long time to cover the soil surface. Hence, the volatiles in the cakes may get evaporated fast. Therefore, effect may not be very significant when the crop canopy is poor, especially during the early growth stage of the crop. The study on cauliflower showed that it could be very effective during winter when temperature and wind velocity are low.

Tomato: The effect of different management practices on the incidence of tomato fruit borer, *Helicoverpa armigera,* recorded in Table 3, indicates that the neem cake was moderately effective on fruit borer while neem and pongamia soaps seemed to be more effective.

Many farmers apply both neem and pongamia cakes at the time of planting potato, brinjal, cabbage, etc. believing that the ant and pest problems would get reduced. Most of the insect pests become active only after 30 days of planting or at flowering time. Hence, their effect on insect pests is not clearly demonstrated.

The main limitation of the cake is that its effect is lost at high temperatures and high wind velocities. Therefore, it can be better used only under moderate weather conditions. In Bangalore weather, it could be used for 8 months in the year (July-February) successfully. Farmers have readily accepted this package in brinjal. There is a great potential to extend this package for other crops like red gram and cotton.

Use of soaps

Sprays of neem and pongamia soaps were found to be highly effective in controlling insecticide resistant DBM in cabbage (Table 4). The studies conducted at IIHR have shown that soaps were also effective in reducing *Helicoverpa armigera* in tomato (Table 3) and to a limited extent shoot and fruit borer in brinjal.

While oil sprays could reduce the DBM incidence in cabbage, they were slightly phytotoxic and reduced head size as compared to soaps (Table 4).

Table 3. Incidence of tomato fruit borer under different treatments

Treatments	Dose, %	Mean fruits bored, %
Neem cake	250 kg/ha	13.21
NSKE	4	11.12
Neem oil	1	13.24
Pongamia oil	1	13.76
Soluneem	600 ppm	7.97
Neem soap	1	6.64
Pongamia soap	1	6.96
Control	-	33.23

Table 4. Efficacy of neem and pongamia soaps on DBM and yield in cabbage

Treatments	DBM incidence/plant	Yield (t/ha)
NSKE	3.00	109.60
Bt	3.00	92.67
Soluneem	3.33	99.60
Neem oil	9.00	66.53
Pongamia oil	7.67	73.33
Neem soap	2.33	111.33
Pongamia soap	4.67	116.67
Control	36.33	43.87

The efficacy of soaps in cabbage was successfully demonstrated under on-farm trials during the summer of 2000-2001 under IVLP programme. These can also be used as a component of IPM in other crops like tomato, cucurbits, and beans.

The advantage of soaps is that they have very low residual toxicity and are readily washed away with water. However, a thorough coverage of plant surface is necessary, because the insect may not die unless the soap droplet falls on it.

Sprays of soaps should be done judiciously, avoiding frequent sprays as they may inhibit vegetative growth. Further, these soaps are not yet commercially available and have potential in national and international markets.

Biocontrol

Release of Trichogramma: Inundative releases of the egg parasitoid, *Trichogramma brasilensis* @ 2,40,000/ha are also recommended for the control of fruit borer. Six releases at weekly intervals @ 40,000/ha with the first release coinciding with 50% flowering in tomato is recommended. This IPM along with nuclear polyhedrons virus (NPV) sprays on tomato was demonstrated. However, the release of parasitoid alone is not very effective (Moorthy *et al.*, 1992).

Sprays of NPV: The sprays of Ha NPV at 250 larval equivalents/ha, has been found to be effective in controlling fruit borer. Studies at IIHR have indicated that 3-4 applications at weekly intervals, the first spray coinciding with flowering, reduced pest incidence to minimum (> 5%). (Moorthy *et al.,* 1992 and Mohan *et al.,* 1996). The presence of *H. armigera* eggs was monitored by pheromone traps on the young leaves on the top of the plant.

The main limitation, however, was its availability and the quality of NPV supplied by the private companies.

Use of barriers: Use of nylon net as a barrier for control of brinjal shoot and fruit borer was studied at IIHR, Bangalore and Indian Institute for Vegetable Research (IIVR), Varanasi. This strategy along with shoot clipping could reduce the borer incidence by 16%. However, the cost of nylon net is high, and studies are, therefore, being conducted on the use of live barriers like maize. These barriers may also be effective in reducing the wind effect when cakes are applied.

Economics of IPM

Tomato: Tomato fruit borer, *H. armigera* is the major pest on tomato. The benefit cost ratio of marigold as trap crop for tomato fruit borer management was studied by Khaderkhan *et al.* (1998) and observed a benefit-cost (B:C) ratio of 1.53 compared to 1.08 from non-IPM technologies. The net return using IPM was Rs 60,168/ha as compared to Rs 47,359/ha in chemical control.

In addition to the fruit borer, an introduced insect pest serpentine leaf miner (SLM), *Liriomyza trifolii,* is also another important pest of tomato. Hence, the following IPM is suggested for tomato crop:

- Apply neem cake/pongamia cake @ 250 kg/ha while planting to reduce the leaf miner and fruit borer egg laying and spotted wilt disease

Table 5. Economics of IPM in tomato

(Rs/ha)

Technique	No. of sprays	Cost of spraying	Yield (kg)	Gross return	Cost of cultivation	Net return	B:C ratio
Non-IPM farms	17	11362	49400	91375	44016	47359	1.08
IPM farms	8	6628	62280	99450	39282	60168	1.53

Source: Khaderkhan *et al.* 1998

- Plant 45-day old marigold seedlings and 25-day old tomato seedlings simultaneously in a pattern of one row of marigold for every 16 rows of tomato (optional for tomato fruit borer management)
- Spray NSKE (4%) or neem seed powder (7%) at 15 and 25 DAP (for serpentine leaf miner control, if required)
- Repeat neem cake application at flowering to reduce incidence of fruit borer incidence
- Spray NPV 250 LE four times in the evening at intervals of 4-7 days for a pure tomato crop. If marigold is grown as a trap crop, spray it only twice at 28 and 35 DAP.

Brinjal: Shoot and fruit borer (*Leucinodes orbonalis*), ash weevil (*Myllocerus subfaciatus*), gall midge (*Asphondylia* sp.), leaf feeding beetle (*Henosepilachna vigintioctopunctata*), leaf hopper (*Amrasca bigutula biguttula*), aphids (*Aphis gossipii*) and red spider mite (*Tetranychus cinnabarinus*) are some important pests of brinjal. While fruit borer and hoppers are the major problems, mites, gall midge and ash weevil may also result in considerable yield loss in some regions.

Table 6. Cost of cultivation of brinjal under IPM using neem cake

Items	(Rs/ha)
Cost	
Neem cakes (1 tonne) applied three times	6000
Monocrotophos to control hopper, Dithane M 45 and chlorothalonil (all one time sprays)	3067
Fertilizer	5833
Seed	1400
Labour	22667
Total cost	38967
Yield and returns	
Marketable yield (t/ha)	18.33
Borer incidence (%)	8
Gross returns @ Rs 4.8/kg	87999
Net returns	47033

Neem cake has been found to be highly promising under moderate weather conditions. Its application was studied under IVLP programme at IIHR in farmers' fields during 1999-2000 and 2000-2001. The economics of the IPM during *kharif* 2000-2001 is given in Table 6. The cost and returns without IPM are provided in Table 7.

A comparison of net returns with and without IPM shows that integration of neem is cost-effective and results in higher yield and net higher returns. In view of this, the following IPM practices are suggested for brinjal:

- Apply neem /karanj (pongamia) cakes while planting @ 250 kg/ha in furrows to manage ash weevil
- Repeat cake application at 30-40 DAP to manage ash weevil and early incidence of shoot and fruit borer
- Repeat cake application at 90-100 DAP to manage fruit borer, midge, hoppers and thrips

Table 7. Cost of cultivation of brinjal under non-IPM plots

Items	(Rs/ha)
Cost	
Monocrotophos (1 spray)	1075
Cypermethrin (4 sprays)	7500
Endosulfan (1 spray)	800
Blitox (2 sprays)	4700
Dithane M 45 (1 spray)	630
FYM	3750
Fertilizers	6463
Seeds	875
Labour	27550
Total cost of cultivation	53343
Yield and returns	
Marketable yield (t/ha)	9.3
Borer incidence (%)	40.00
Gross returns @ Rs 4.8/kg	45000
Net returns	(-) 8343

- Spray NSKE/pongamia soap at 10-15 days of interval during summer and windy period (only if borer incidence is more than 10%)
- Spray dicofol (0.05%), if required to control mite.

Crucifers (cabbage and cauliflower): The cruciferous vegetables suffer from a number of insect pests. The important ones are: DBM (*Plutella xylostella* Linn.), leaf webber (*Crocidolomia binotalis* Zeller), stem borer (*Hellula undalis* Zeller), aphids, *(Brevicoryne brassicae* Linn, *Hyadaphis erysimi* Kaltenbach), stink bug (*Bagrada cruciferarum* Kirkaldy), striped flea beetle (*Phyllotreta striolata* Fabr.), and mustard saw fly (*Athalia lugens proxima* Klug). For these crops, planting Indian mustard as a trap crop and spraying NSKE take care of all the pests. NSKE sparys alone are also effective.

The economics of different packages (only NSKE, mustard as trap crop + NSKE sprays), including use of only insecticides were studied under IVLP programme (Srinivasamurthy *et al*., 1999). The results are given in Table 8.

A perusal of Table 12 shows that farmers' practices are not at all economical. Looking at the farmers' preference for readymade formulations, IIHR has prepared two alternatives: one, using neem seed powder and the other, spraying of neem and pongamia soaps. Neem seed powder can be soaked

Table 8. Economic assessment of IPM practices to manage DBM in summer cabbage 1996

Particulars	Farmers' practices (11 sprays)	NSKE (3 sprays)	Mustard as as trap crop + NSKE (3 sprays)
Cost of pesticides/NSKE (Rs/ha)	11500	1500	1625
Cost of cultivation (Rs/ha) (excluding pesticides)	24090	23590	23290
Marketable heads (%)	50	95	95
Yield (t/ha)	35	60	55
Cost of production (Rs/tonne)	860	410	453
Gross return (Rs/ha)	25000	60000	55000

Source: Srinivasmurthy *et al.* (1999)

overnight and filtered, and the extract can be sprayed. The powder can be stored in the polythene bags for 3 to 5 months, avoiding the drudgery of wet grinding of kernels every time.

The use of neem and pongamia soaps for the management of insect pests is a recent development. It was studied in four fields during summer 2001. The economics of this IPM is given in Table 9.

As the spraying with soap was done a little late in the above cabbage plot, aborted heads and multiple head formation was found in many plants (this was due to cabbage stem borer, *Hellula undalis*). To control this, spraying of contact insecticides was done within 10 days of planting, particularly in summer. Early spraying of NSKE and too much spraying are not recommended as these may reduce head size. NSKE sprays are to be given only after 20 DAP. In this particular farm, soap sprays though given late, had excellent control on DBM and the farmer received good returns. In neighbouring villages, the crop was devastated by DBM completely. The suggested IPM package is.

Table 9. Cost and returns from cultivation of cabbage using pongamia soap and neem soap IPM

Item	Rs/ha
Cost	
Dichlorvos (2 sprays)	1788
Neem soap (1.5 kg) (1 spray)	720
Pongamia soap (2 kg) (1 spray)	800
FYM	2000
Fertilizers	7616
Seeds (80 g)	2560
Labour	23360
Total cost of cultivation	38844
Yield and returns	Value
DBM incidence before soap spray	3.0/plant
DBM incidence after soap spray	0.38/plant
Yield (t/ha)	38.4
Gross returns	88000
Net returns	49192

- Sow one row of mustard for every 25 rows of cabbage (optional)
- Spray the seedlings with *Bt* just before transplanting
- Spray *Bt* between 10 and 15 DAP only if early incidence of DBM is noticed
- Spray NSKE/NSP/Soap/*Bt* from 20 DAP at intervals of 10-15 days, 3-4 times. Threshold of 1 larva/plant may be followed after the first spray given at 20 DAP. Maximum of 4 sprays are required for a crop of 70-80 days duration
- If mustard is taken as trap crop, then spray it with dichlorvos at intervals of 10-15 days.

Conclusions

Despite use of pesticides, insect pests and diseases cause considerable losses in vegetables. Moreover, many insect pests have developed resistance to insecticides used to control them, implying repeated applications of insecticides and increase in the cost of protection. The newer technologies and practices embedded in IPM provide better protection against insect pests, improve crop yields and net benefits to the farmers.

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8

Integrated Pest Management in Chickpea and Pigeonpea

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Introduction

Chickpea and pigeonpea are the major pulse crops grown in India. These occupy more than 50 percent of total area under pulses, and contribute 60 percent to total pulses production. The average productivity of chickpea and pigeonpea is about 800 kg/ha and 750 kg/ha, respectively, which is much lower than their potential yields. A number of factors limit achieving this potential, biotic constraints are the most important. Among the biotic stresses, diseases and insect pests are the major yield limiting factors causing a yield loss of about 30 percent. These can be reduced by effective pest management practices such as Integrated Pest Management (IPM).

The Pest Problem

Chickpea and pigeonpea are highly vulnerable to a number of pathogens, insect pests and nematodes (Nene and Sharma, 1996; Reed *et al.*, 1989; Chhabra *et. al*, 1992), and are damaged right from seedling to maturity and in storage. However, only few of these are of economic importance. Gram pod borer (*Helicoverpa armigera*) is the key pest of chickpea and pigeonpea, while pod fly (*Melanagromyza obtusa*) is the second major pest of pigeonpea. *H. armigera* is a wide spread pest. *M. obtusa* is a major pest in northern and central parts of India. Chickpea is attacked by wilt and root rot diseases (*Fusarium oxysporum* f. sp. *ciceri, Rhizoctonia solani, R. bataticola, F. solani*) in different areas while *Ascochyta* blight (*A. rabiei*) and grey mold (*Botrytis cinerea*) are restricted to northwestern plains and in the Tarai regions. The major diseases affecting pigeonpea are wilt (*Fusarium udum*), sterility mosaic (Pigeonpea sterility mosaic virus - PSMV)

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and *Phytophthora blight* (*P. drechsleri* f. sp. *cajani*). Under specific situations, *Alternaria* blight (*A. alternata*, *A. tenuissima*), *Cercospora* leaf sport (*Cercospora* spp.) also assume significant importance.

Losses

About 30 percent of the potential production of pulse crops is annually lost due to diseases and insect pests (Table 1). Losses due to wilt and sterility mosaic in pigeonpea have been estimated to be about 302 thousand tonnes, based on the prevalence status of these diseases during 1975 to 1980 (Kannaiyan *et al.*, 1984). Losses due to pod borer complex have been recorded as high as 668 thousand tonnes in chickpea, and 277 thousand tonnes in pigeonpea. The grain loss due to chickpea wilt and root rot has been estimated around 10 percent (Lal *et al.*, 1992; Singh and Dahiya, 1973), which amounts to approximately 520 thousand tonnes annually.

Chickpea and pigeonpea are predominantly grown on marginal or sub - marginal lands and by the resource poor farmers. Although protection packages have been developed for major pests and diseases, these have not been effectively employed to prevent losses due to poor economic status of the pulse growers. Even in situations where farmers are ready to use the management practices to get higher yields, they are not properly trained to use these inputs in the right manner and at the right time. The key management factors developed by the Indian Institute of Pulses Research, Kanpur, in coordination with centres of All India Coordinated Project on Improvement of Pulses are available for dissemination to farmers (Chhabra *et al.*, 1992; Lal and Katty, 1997; Srivastava and Sachan, 1998; Dhar and Gurha, 1998; Dhar and Chaudhary, 1998). For example, in the case of gram pod borer, effective chemical and biological control methods are available but the resistant varieties have not yet been developed. One tolerant variety, ICPL 332 (Abhaya), of pigeonpea has recently been released in Andhra Pradesh. Similarly, large number of natural

Table 1. Annual losses due to insect-pests and diseases in pulses

Biotic stress	Yield loss (%)	Value (Rs in crores)
Diseases	8-10	1500
Insect pests	18-20	3000
Total	26-30	4500

enemies of pests have been known to occur in pigeonpea (Romies and Shanover, 1997), but little is known to manipulate these as 'biological tools' to control insect pests of pigeonpea, especially against podfly. Crop rotations, intercropping, wider spacing, limited use of fungicides and occasional growing of tolerant varieties are among the traditional methods being used for management of diseases in chickpea and pigeonpea. In recent years, a good progress has been made in the development of wilt/ root rot resistant varieties in chickpea and pigeonpea (Dhar and Chaudhary, 2001). These have brought some stability in production in disease endemic areas. However, to further enhance the efficiency of these varieties, there is a need to provide other management options. Wilt resistant varieties of pigeonpea for northeastern plains (Uttar Pradesh, Bihar and West Bengal), which occupy a sizeable area under the crop, are not yet available. *Phytophthora* blight is another potential disease, especially in the short-duration pigeonpea varieties where biocontrol methods and resistant varieties are not available.

Integrated Pest Management

Use of chemicals, resistant/tolerant varieties, and biological agents alongwith modified cultural practices may help in controlling the diseases and pests to some extent (Dhar *et al.*, 2000). However, considering the diversity in pathogens and insect pests, the range of agroclimatic conditions and cropping situations influencing the pests and diseases, any individual practice may not be very effective. It is, therefore, worthwhile to integrate the available and compatible control measures to develop into economically viable integrated pest management (IPM) strategies.

The research on the Integrated Pest Management in pulses was initiated in 1979 with the establishment of the Project Directorate of Pulses at Kanpur. Initially, the impact of individual components of management was studied on the disease and insect pest incidence. Integration of management components was subsequently taken through the network of All India Coordinated Research Project (AICRP) on Pulses. Workable IPM packages were identified during the late 1980s and were recommended for field transfer in major pulse growing areas (Tables 2 and 3). Simultaneously, refinement in individual components was continued, major focus being on the host plant resistance.

A number of resistant sources against major diseases were identified, which have been employed to develop resistant lines to wilt in chickpea and pigeonpea, sterility mosaic in pigeonpea and *Ascochyta* blight tolerance in chickpea (Dhar, 2000; Dhar and Chaudhary, 2001). Although no true or high level of resistance against *Helicoverpa armigera* could be identified, a few lines with tolerance in both chickpea and pigeonpea have been isolated (Sachan and Lal, 1997). Lines with moderate resistance to pod fly have also been identified (Lal and Katty, 1997). These are being used as donors to develop tolerant varieties. Emphasis has also been laid on judicious use of pesticides, safer to natural enemies, pesticides with multiple action, biorationals, growth regulators, biopesticides, plant products and cultural practices (Sachan and Lal, 1997). The synthesized IPM packages (Tables

Table 2. Development of IPM package for chickpea

Components	1980s	1990s
Field	Deep ploughing	Deep summer ploughing
Resistant/ tolerant varieties	Very few against diseases	Varieties resistant to wilt/root rot and tolerant to *Ascochyta* blight. Donors for tolerance breeding are available for pod borer. Growing mixture of tolerant and susceptible genotypes is recommended for pod borer
Seed treatment	Cabendazim + Thiram (1:3 g/kg)	Antagonistic fungi at 2-4 g/ha seed and vitavax 1 g/kg seed
Intercropping & crop rotation	Linseed (4:1) and mustard (6:1 or 4:1)	Mustard 6:1
Sowing time	Timely sowing. Avoid delayed sowing	Timely sowing. Avoid delayed sowing
Foliar sprays	Endosulfan and *Ha*NPV	First spray with *Ha*NPV or NSKE or Bt, second spray with Bt or NSKE or endosulfan. Third spray (if needed) with Bt, NSKE or *Ha*NPV
Bird perches	No	30-40 perches/ha
Monitoring devices	No	Pheromone trap @ 5 traps/ha. A catch of 4-5 male moths/trap/night during post-winter months indicates that *H. armigera* will attain its ETL a fortnight later (NWPZ, NEPZ)

Table 3. Development of IPM packages for pigeonpea

Components	1980s	1990s
Field	Deep summer ploughing	Deep summer ploughing
Cultural practices	No	Ridge sowing + cover crops (cowpea, sorghum, soybean, mungbean)
Resistant/ tolerant varieties	Insect pests – Nil Diseases – Few	Very few, low to moderately resistant genotypes showing resistant against *H. armigera* and *M. obtusa* available Varieties resistant to wilt and sterility mosaic available for some areas
Seed treatment	Carbendazim + Thiram (1:3 g/kg)	Carbendazim + Thiram (1:3 g/kg)
Intercropping & crop rotation	With sorghum	With sorghum and harvesting only panicles. This results in lower incidence of wilt and stalks serve as perches for birds
Sowing time	Timely sowing	Timely sowing
Foliar sprays	2-3 sprays : Dimethoate – endosulfan/ Monocrotophos - *Ha*NPV	Dimethoate – *Ha*NPV – Bt/NSKE/ endosulfan
Bird perches	No	30-40 perches/ha
Monitoring	No	Pheromone trap @ 5 traps/ha. A catch of 4-5 male moths/trap night during post-winter months indicates that *H. armigera* will attain its ETL a fortnight later (NWPZ, NEPZ)

2 and 3) have been recommended for adoption through on-farm testing under various programmes like Front Line Demonstrations (FLD), Institute Village Linking Project (IVLP) and the AICRP on chickpea and pigeonpea.

Demonstrating Benefits of IPM

Between 1993 and 1998, 141 FLDs were conducted to disseminate IPM technology in chickpea at different locations in the country (Singh and

Asthana, 1998). The developed IPM package has been found effective in improving crop yield by 16 to 34 percent, with an average increase of 24.3 percent (Table 4). Although the yield improvement under IPM plots was significant, there is a need for refinement of the technology to obtain a better impact.

During this period, 176 IPM demonstrations were conducted in pigeonpea. The yield gain ranged between 5 and 40 percent with a mean of 28.2 percent (Table 5), indicating superiority of IPM over conventional chemical control.

Field demonstrations under AICRP during 1992 - 98 have also shown a better impact of IPM technology with yield increases of 33- 39 percent.

Constraints in Adoption of IPM

The demonstrations have proved IPM as an effective method of controlling pests. Yet, it is not being adopted by the farmers to the desired extent because of a number of constraints. Some important constraints are as follows:

On the supply side, supply of biopesticides and bioagents is a major problem in adoption of IPM in pulses. The technique for their mass multiplication in laboratory is cumbersome and difficult. Besides, there is a lack of trained personnel for mass multiplication of bioagents, their maintenance and

Table 4. Front line demonstrations (FLDs) on IPM (insect management) in chickpea (1993-1998)

AICRP centres	No. of demons-trations	Percent increase in grain yield under IPM over non-IPM					
		1993-94	1994-95	1995-96	1996-97	1997-98	Mean
MPKV, Rahuri	32	26.1	9.5	65.9	-	33.9	33.8
MAU, Badnapur	10	16.7	-	-	-	-	16.7
APAU, Lam	5	-	-	-	-	5.3	5.3
UAS, Bangalore	4	-	-	-	39.4	14.2	26.3
IGKVV, Raipur	15	-	24.7	19.3	-	42.1	28.7
JNKVV, Sehore	12	18.8	20.8	28.2	48.3	50.0	33.2
CSAUT, Kanpur	16	-	48.4	24.5	-	15.4	29.5
UAS, Gulbarga	47	14.3	-	10.1	29.7	28.9	20.7
Overall	141	19.0	25.8	29.6	39.1	27.1	24.3

Table 5. Frontline demonstrations (FLDs) on IPM (insect management) in pigeonpea during 1993-1998

AICRP centres	No. of FLDs	Grain yield (kg/ha)		Increase over non-IPM, %
		IPM	Non-IPM	
JNKVV, Sehore	10	836	780	7.18
MAU, Badnapur	5	880	577	52.50
MPKV, Rahuri	49	1826	1301	40.35
IGKVV, Raipur	8	1042	743	40.24
GAU, S.K. Nagar	23	1225	939	30.45
UAS, Gulbarga	36	987	768	28.50
APAU, Lam	8	1592	1514	5.15
TNAU, Pudukkottai	2	963	785	22.67
UAS, Bangalore	9	1133	863	31.28
IIPR, Kanpur	2	1272	1102	15.48
CSAUT, Bharari	8	1561	1308	13.30
BHU, Varanasi	17	1480	1279	15.70
Overall	176	1235	963	28.20

distribution at proper time. Also, there exist gaps in the present IPM packages. The major gaps are: lack of forewarning systems, inadequate pesticide application technology and non-availability of true resistant varieties. Besides, the linkages between the research and extension systems are weak. On the demand side, the main constraints are: farmers' lack of awareness about the IPM technology and the method of its application; and lack of cooperation among the producers.

Strategies for Effective Pest Management

To make IPM work, the constraints need to be addressed properly and the gaps in knowledge need to be bridged through R&D. Following strategies could help improve adoption of IPM:

- Training of the farmers and extension personnel in IPM methodology
- Aggressive demonstration campaigns by R&D institutions in collaboration with state functionaries and non-governmental organizations (NGOs)

- Improved availability of critical inputs biopesticides, bioagents and resistant varieties
- Development of monitoring tools and forewarning systems
- Advocate use of safer pesticides and appropriate application methods
- Research on multiple disease and pest resistant varieties, and
- Holistic integration of all informations to develop bio-intensive and cost-effective practices.

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9

Integrated Pest Management in Rainfed Cotton

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Introduction

Cotton, being a cash crop, is of great economic importance for the Indian farming community. Nevertheless, it is highly prone to a number of insect pests and diseases. A good crop with minimal pest attack brings prosperity, while a severe pest attack brings misery. This is more so in the rainfed areas where opportunities for growing alternative crops are limited due to marginality of the production environment. Thus, pest is an important determinant of the prosperity of the rainfed farmers. The pest problem though cannot be eliminated altogether, it can be minimized through application of appropriate pest management strategy, be it chemical pest control, biological control or integrated pest management (IPM). The chemical-based pest management, however, has been losing its efficiency mainly due to rising problem of insecticide resistance. The bollworm, *Helicoverpa armigera,* has developed manifold resistance to most of the insecticides intended to control it. In view of this, an IPM package comprised of cultural practices, resistant varieties, insect scouting, beneficial insects and the selective use of insecticides was developed and tested under field conditions. The effectiveness of IPM gets maximized when all growers use them on a community basis over area-wide. The goal of IPM does not aim for reduction of the insect population to zero but merely to a level below the economic damage.

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Pests of Cotton

Cotton is susceptible to a number of insect pests and diseases. These are briefly described below:

Aphids (*Aphis gossypii* Glover) : Aphids are usually found on the stems, terminals and underside of the leaves, resulting in upward curling and twisting of leaves. The pest is active during June-October. Aphids live in colonies and reproduce partheno-genitically. Adults live for 12-20 days and nymphal period lasts for 7-9 days. Thus, the pest has 12-14 generations a year. Both adults and nymphs suck sap from the tender leaves, twigs and buds, and weaken the plants. Each aphid makes several punctures and excretes honeydew, which encourages development of sooty mold on the twigs and leaves, and this makes plants look blackish. Honeydew attracts ants and sooty mold, aiding to the development of pathogenic bacteria.

Systemic insecticides (Imadacloprid @ 7g/kg or carbosulfan @ 4g/kg of seeds) applied as seed dresser or at planting time helps in controlling aphids early in the season. Application of other chemicals such as spray of 'Aphidin' also reduces its incidence.

Jassid (*Amrasca bigutulla bigutulla* Ishida) : The pest attacks crop during the first 50 days after sowing and is severe in early winter. Adults are about 3 mm long and greenish yellow during summer and have reddish tinge during winter. The hind portion of the forewings has two black spots on the vertex. Nymphs are greenish yellow and wedge-shaped. Nymphal and adult stages last for 7 -21 days and 35 - 50 days, respectively. Both adults and nymphs suck sap from underside of the leaves and devitalize the plants, turning them pale, red rust, dropping downwards, which later dry up.

Thrips *(Thrips tabaci* Lind.) : Thrips feed on the young leaves and the buds and stunt the crop growth. A common sign of a heavy thrips infestation is the distorted leaves that have turned brownish around the edges and cup upward. The pest is active during May- September. The nymphs and adults suck sap from the lower surface of the leaves lacerating the leaf tissues. Upper side of the older leaves turns brown and the lower side becomes silvery white. Leaves become curled, wrinkled and finally get dried. Control of thrips generally results in early crop maturity.

Whiteflies *(Bemisia tabaci* Genn.) : Whiteflies damage cotton by sucking sap from the plants and by secreting honeydew on which sooty mold grows and stains the lint. Heavy feeding reduces plant vigour, causes premature defoliation and reduces yield. The pest occurs throughout the year. Nymphs and adults are sluggish creatures, clustered together on the undersurface of the leaves. All whitefly stages are found on the undersurface of the cotton leaves. The nymphs and adults feed on the cell sap, reduce the vitality of the plant interfering with normal photosynthesis due to the excretion of honeydew and formation of sooty mold all over the surface of the leaf and lint of the opened bolls, resulting in process of blackening. Chlorotic spots develop on leaves and in severe cases, the veins become translucent. Sooty mold contaminates the lint. The insect helps in transmitting leaf curl virus (CLCV).

Bollworms : Cotton bollworm and tobacco budworm are devastating pests of cotton. Widespread problem of insecticide resistance, especially against pyrethroids, has occurred in all the cotton growing areas in the recent past. Using alternative insecticides is thus necessary to control high levels of bollworm infestation. During periods of moth activity, field monitoring twice a week is necessary. In the previously untreated fields, apply a recommended larvicide when infestation is low.

Spotted bollworm (*Earias insulana* Boisd. and or *Earias vitella*) : *E. vitella* is abundant in high rainfall areas and *E. insulana* in scanty rainfall areas. The pest attacks the crop from 35 to 110 days of the age. Moths lay eggs on flower buds, branches and twigs, pupation takes place inside flimsy cocoon in fallen buds, plant debris or soil. The development is completed in 17-29 days in summer and is greatly prolonged in winter (42-84 days). Caterpillars cause damage by boring into the growing shoots, buds, flowers and bolls. The attacked shoots wither, droop and ultimately die, and flowers and buds drop off. Infested bolls do not shed, open prematurely and the quality of the lint is spoiled. Pupation takes place in the bolls, impairing the development of bolls.

Pink bollworm (*Pectinophora gossypiella* Saunders) : Pink bollworm is one of the most destructive pests of cotton. The pest is active during July-November. Adults are dark moths with blackish spots on forewings. The caterpillars are creamy yellow when young and turn pink when grown. Eggs are laid on the underside of tender parts of the plant (shoots, flower buds, leaves and green bolls). The egg, larval and pupal periods last for 4-15, 8-42, 8-12 days, respectively. The life-cycle is completed in 3-6 weeks. The damage is caused by by feeding on the flower buds, panicles and bolls. The holes of entry close down by excreta of larvae feeding inside the seed kernels. They cut window holes in the two adjoining seeds thereby forming "double seeds" and finally damage them. The attacked buds and immature bolls drop off. Lint is destroyed, ginning percentage and oil content are impaired. The pest hibernates in "double seeds" and can be located in the cavities (hibernacula), impairing the development of the bolls.

American bollworm (*Helicoverpa armigera* Hubner) : The pest is polyphaghous, most severe in attack, and is active from July to October, and February to April. The adult moth is stout, yellowish brown with a dark speck and area on the forewings, which have greyish wavy lines and a black kidney shaped mark, whereas the hind wings are whitish with blackish patch along the outer margin. The larva is about 35 mm long, greenish brown with dark grey yellow stripes along the sides of the body. Eggs are deposited on tender parts of plant. The larvae feed on the leaves initially and then bore into the square/bolls and seeds with its head thrust into the boll, leaving the rest of the body outside. A single larva can damage 30-40 bolls. The entry holes are large and circular at the base of the boll.

Semi-looper (*Anomis flava* Fabricius.) : Loopers are small, greenish looping worms with small white stripes down their backs. These worms feed on leaves, causing a ragged appearance. Loopers that occur in late season in high numbers are most likely the soybean looper species. This species is very difficult to control with currently registered insecticides. Begin controls when worms are small and the top bolls expected for harvest are not mature. Late-season loopers are sporadic in their occurrence but may completely defoliate cotton the community when they occur. It is a sporadic pest and sometimes causes serious damage to the crop. The adult is reddish brown with forewings traversed by two dark zigzag bands, while the hind wings are pale brown. The larva of semilooper is 25-30 mm long, pale yellowish green with five white lines longitudinally on the dorsal surface and six pairs of black and yellow spots on the back. Eggs are laid singly on the upper surface of the leaf. Pupation takes place in plant debris or in the soil. The life-cycle is completed within 28-42 days. The young larvae congregate in groups and move actively, feed on the leaf lamina by making small punctures. The grown up larvae feed voraciously, leaving only the midrib and veins. They feed by chewing the leaves from margin towards the leaf veins. The caterpillars feed on tender shoots, buds and bolls.

Bacterial blight *(Xanthomonas axonopodis* p.v. *malvacearum* (Smith) Dye) : Cotton plant is affected by the bacterial blight at all stages of the crop development, starting from seedling stage. The pathogen is seed-borne and the disease is transmitted from the cotyledons to leaves, followed by the main stem and bolls. Symptoms, at each stage are of different descriptive nature, based on plant organ or the growth stage affected, viz. seedling blight, angular leaf spot, vein blight, blackarm and boll lesions. Foliar symptoms are known as angular leaf spot (ALS). Initially, the spots are water-soaked and more obvious on the dorsal surface of the leaf. Another common leaf symptom occurs when lesions extend along the sides of the main veins. This may be seen together with or in the absence of ALS and is referred to as 'vein blight'. In susceptible cultivars, infection spreads from the leaf lamina down the petiole to the stem. The resulting sooty black lesions give rise to the term 'black-arm' by which the disease is commonly called. The lesion may completely girdle the stem, causing it to break in high windy conditions or under the weight of developing bolls. In India, where the crop is grown under irrigation, losses of 5-20% are often experienced.

Grey mildew *(Ramularia areola* Atk) : The disease appears first on the lower canopy of older leaves when the plant attains maturity, usually after the first boll-set. It appears in the form of irregular angular, pale translucent spots with a definite or irregular margin formed by the veins of leaves. The dorsal surface of the leaves shows profuse sporulation (giving the lesions a white mildew-like appearance), causing light green to yellow green coloration on the ventral (upper) leaf surface which in due course becomes necrotic and dark brown in colour. At this stage, they can be easily mistaken from the angular leaf spot phase of bacterial blight. The severely affected leaves often defoliate and result in premature boll opening with immature lint.

Components of IPM

An IPM module has been developed for the key insect pests, pathogens, and weeds. Following are the chief components of IPM implemented under field conditions.

Cultural practices

Some cultural practices have a significant effect on crop management, and hence they need to be recommended after considering their overall effect on the crop yield. Acid de-linted seed provides a good insurance against seed-borne diseases. Any practice, which delays or extends fruiting is likely to invite greater attack by insects and diseases. High plant population, excessive nitrogen rates, late planting, and excessive irrigation and moisture can extend the fruiting period, apart from influencing pest populations directly, hence they need to be avoided. The attack of grey mildew at the time of harvesting need not be prevented. Early harvest with no ratooning and stalk destruction restricts food availability to key pests, and thereby helps in keeping the pest population below threshold level.

Predators and parasitoids

Parasites and predators are the first line of defence against sucking pests, bollworms, and tobacco budworms. Predators such as coccinellids, spiders, pirate bugs, larvae of green lacewings, and parasitic wasps (*Bracon* spp. and *Encarsia* spp. are important regulators, particularly in early and mid season. Some insecticides are more toxic to parasites and predators; consequently, they should be used to kill the target insects only when necessary and at minimum doses. In this study, *Helicoverpa* was the key pest and *Trichogramma chilonis* was released @ 1.5 lakh/ha to control this. Crop cafeteria concept needs to be encouraged to augment population of beneficial insects. Growing of tobacco, marigold, sorghum, maize and cowpea in cotton fields is helpful. Growing of maize interlaced with cowpea on the borders has proved highly effective in managing the population of sucking pests. Likewise, growing of *Setaria* as 10^{th} row attracts predatory birds for devouring bollworm larvae.

Selective and judicious use of insecticides

Selection of insecticides should be based on several factors. Effectiveness of the pesticide should not be the only consideration in pest management. Insects' development of resistance affects the beneficial insects and non-target organisms, human safety hazards. The economic considerations are also important and need equal attention. Insecticides should be applied only after the pest reaches economic threshold level, and is beyond control. This can be determined by scouting at least twice a week, and by fixing pheromone traps at random places in the fields to obtain population densities of both destructive and beneficial insects. Need-based use of pesticides to control cotton insects would not only reduce insecticide use, but also prevent development of pesticide resistance. It would bring down the application costs and lower the total amount of unnecessary insecticides in the environment.

Proper timing and coverage are also extremely important. Field scouting coupled with moth catch information (received from pheromone traps) enables timely application of pesticides. Ensure proper coverage using ground equipment by applying 500 to 600 litres of water per ha. Spray nozzles need to be kept clean for proper functioning. Adjust spray booms to keep nozzles form dragging through the foliage to cover lower surface, which harbors the future generations of majority of the pests.

IPM : A Case Study

The IPM package described above was tested on-farm during 1995-96 and 1996-97 at Cotton Research Station, Nanded; and simultaneously in Barad & Kinwat villages of Nanded district, Maharashta, through on-farm demonstrations. With use of IPM, pesticide applications could be reduced from an average 6 to 2 while sustaining the crop yield. The objective was to make farmers understand the relevance of pests and their naturally occurring enemies, and make them aware of the externalities of the excessive and indiscriminate use of chemical pesticides. Learning constitutes a key element which not only helps the farmer to deal with pest management but also provides them a new capacity to deal with physical, social and environmental factors with self-confidence. It also creates awareness and interest in alternative biological-based technology. The key status of the cotton IPM module lies in the seed treatment with systemic pesticides as they are less hazardous when compared with aerial applications, regular scouting and monitoring of pest incidence through installation of pheromone traps, augmentation of natural enemies (*Trichogramma chilonis* @ 1,50,000/ha at 10-15 days intervals), integrated with a range of cultural methods (an uniform plant stand) by means of using same genetic material, application of fertilizers as basal dose only, planting border row of maize intercepted with cowpea (Amoako-Atta, and Kidega, 1983) to encourage the activity of the natural enemies and serve as refuge and setaria as intercrop (as live perch for predatory birds), use of microbials such as *Bacillus thuringiensis* and HaNPV (Panchabhavi *et. al.,* 1995) and botanicals such as neem seed kernel extract (NSKE 5%) (Bhatnagar and Kandasamy, 1993). If the need be apply insecticide in the mid day to avoid foraging predators and pollinators.

Encouraged with the consistent success, the NCIPM implemented the IPM package on a larger area in the ensuing *kharif* season (1998) in Astha village of Nanded district. The village is located in the tribal belt, on the borders of Yavatmal district of Maharashtra and Adilabad district of Andhra Pradesh. The district Nanded represents the cotton growing environment of the cotton belt of Maharashtra as well as some of the adjoining districts of Andhra Pradesh and Madhya Pradesh.

The package was transferred on 127 hectares of land belonging to 76 cotton-growing farmers under the expert guidance. The farmers were taught about IPM practices by organising Farmers' Field Schools. Besides, the NCIPM provided critical biological inputs such as *Trichogramma chilonis* and HaNPV, free of cost. Farmers evinced keen interest in the new pest control method. One of the reasons for this was that in the preceding year, cotton had suffered heavy losses due to Helicoverpa. Their attempts to control Helicoverpa through chemical control had been futile. The repeated applications of pesticides resulted in cost escalation, squeeze in net returns and indebtedness of the farmers.

The innovative measures were implemented by convincing farmers about the advantages of the technology over their conventional practices and imparting training through regular farmers field schools. The socio-economic impact analysis was designed primarily to compare the IPM technology with the farmers' practices, evaluate the effectiveness and economic performance. The economic analysis presented in Table 1 is indicative of the success of IPM.

The success of the IPM implementation can be attributed to the following tactics:

- Clean-up campaign
- Sucking pest complex: Aphidin @ 4 mL/1 litre of water (Spraying as per ETL) or seed treatment with Imidachloprid 70 WS @ 5 g/kg seed

Table 1. Economics of IPM (1998-99 to 1999- 2000)

(Rs/ha)

Item	1998		1999		2000	
	IPM	Non-IPM	IPM	Non-IPM	IPM	Non-IPM
Paid out costs						
Hired labour						
Male	1368	1434	1350	1400	1375	1420
Female	1965	2211	1975	2200	2039	2207
Bullock labour	1174	1214	1180	1250	1225	1235
Seeds	563	714	563	720	687	687
Manures & fertilizers	1305	2054	1400	2050	1362	2082
Plant protection	1537	2280	1255	2156	1465	1908
Picking/harvesting	905	588	2150	1612	2000	1264
Interest on working capital for 7 months @ 10%	515	616	568	664	592	670
Total paid out costs	**9332**	**11111**	**10441**	**12052**	**10747**	**11473**
Imputed costs						
Family labour						
Male	0	0	0	0	0	0
Female	480	0	240	0	320	0
Supervision charges	933	1111	1044	1205	1075	1147
Total imputed costs	1413	1111	1384	1205	1395	1147
Total cost	**10745**	**12222**	**11725**	**13257**	**12142**	**12620**
Seed cotton yield kg/ha	963	593	1075	806	1002	632
Value of output	18970	11682	21500	16120	19739	12450

Note: IPM in Ashta village; Non-IPM farmers practices in Murli village.

- Bollworms management
- Intercropping with maize + cowpea and sateria
- Maize + cowpea as border crop and one row of sateria in between each 9^{th} and 10^{th} rows of cotton
- Installation of pheromone traps @ 5 traps / ha from 35 to 40 DAS
- Release of *Trichogramma chilonis* @ 1.5 lakh eggs /ha at 35 to 40 DAS

- Spraying of 5 % NSKE at 40 to 45 DAS
- Second release of *Trichogramma chilonis* @ 1.5 lakh eggs /ha at 50 to 55 DAS
- Second spraying of 5 % NSKE at 55 to 60 DAS
- Spraying of HaNPV @ 250 LE/ha at 65 to70 DAS
- Spraying of endosulfan 35 EC @ 0.07 % at 75 to 80 DAS, if required
- Hand collection of harmful larvae at weekly interval, starting from 40 DAS.

Conclusions

- IPM technology has got wide scope in agriculture
- It is a low cost technology
- It is free from spreading pollution in environment or in soil
- It can help in the maintaining the natural bio-agents
- Farmers can produce HaNPV at village level and can meet their own requirements
- There is no secondary outbreak of pest and diseases
- Generally, *Helicoverpa armigera* migrates from cotton to pigeon pea, chickpea and other *Rabi*/summer crops. Successful control of *H. armigera* at early stage in cotton crop, reduces the chances of migration considerably, and enables farmers reap a better harvest of *Rabi*/summer crops.

IPM needs to be promoted area-wise. This needs wide publicity and extension efforts. IPM technology should concentrate on pest instead of individual crop. Networking is essential from village to SAUs. Forecasting of pest / disease outbreak should be strengthened.

10

Economic Evaluation of Pest Management Technologies in Cotton

Pratap S. Birthal[1]

Introduction

Pesticides together with high yielding seeds and fertilizers have made significant contributions to the growth of global agriculture. Despite, pesticides have come under severe criticisms due to their potential hazards to environment and public health. The concerns are more in developed countries. In developing countries, more worrisome is the failure of pesticides in controlling the pests and rising cost of plant protection. This is often attributed to their excessive and indiscriminate use. In India, the usage of pesticides is low, i.e. 270 g/ha of the gross cropped area (Birthal, 2003). But, its distribution is uneven across crops. About half of the total pesticide use is on cotton, while area under its cultivation has never exceeded 5 percent of the total cropped area.

India has the largest area under cotton in the world, but the cotton yield is one of the lowests; 240 kg/ha as against the world average of about 600 kg/ha. Although over the last three decades, cotton yield has nearly doubled, it has almost been stagnating in recent years owing mainly to rising pest problem. *Helicoverpa armigera, Pectinophora gossypiella, Spodoptera litura, Bemisia tabaci* and *Empoasca devastans* are the major pests of cotton. *H. armigera* and *B. tabaci* have developed manifold resistance to almost all the insecticides intended to control them (Mehrotra, 1989; Kishor, 1997; Singh, 1997; Pawar, 1998; Saini and Jaglan, 1998; Alam, 2000). As a result, about half of the potential cotton production is lost due to insect pests (Dhaliwal and Arora, 1993). And, the loss has increased over time (Dhaliwal and Arora, 1993). It increased from about 18 percent during the early 1960s to over 50 percent during the early 1990s. Annual economic loss due to

[1] National Centre for Agricultural Economics and Policy Research, Library Avenue, New Delhi 110 012

Helicoverpa spp. alone is estimated at Rs. 200 millions, despite use of pesticides worth Rs 50 millions (Pawar, 1998). Kishor (1997) estimated the loss due to outbreak of *Helicoverpa* in 1988 in cotton growing regions of Andhra Pradesh state equivalent to 15 percent of the its agricultural gross domestic product.

In order to manage the pest problem effectively, R&D strategies emphasize non-chemical approaches such as biological control and Integrated Pest Management. And, the research has yielded new technologies using naturally occurring enemies of insect pests (parasitoids, predators and pathogens). More than 160 natural enemies have been studied for their utilization against insect pests (Singh, 1997), and some of these have even been standardized into technologies. Important ones are: *Trichogramma, Bracons, Crysoperla carnea, Crytaemus montrouzieri, Bacillus thureingiensis, Bacillus sphaericus*, Nuclear Polyhedrosis Viruses (NPV) and *Trichoderma*. In addition, a number of plant products, such as azadirachtin (neem), pyrethrum, nicotine, etc. are also available as biopesticides. These are claimed to be effective against pests, particularly when used in conjunction with other methods of pest control, including chemical pesticides, agronomic practices and mechanical control (Kishor, 1997; Chowdry and Seetharaman, 1997; Birthal *et al.,* 2000; Birthal, 2003). The field application of these technologies has, however, been limited and sporadic (Jayaraj 1989; Alam 1994; Saxena 2001). Hardly two percent of the total cropped area receives application of these technologies. There could be a number of factors constraining adoption of these technologies by the farmers. Nevertheless, their low adoption indicates that technical efficacy is the necessary, but not a sufficient condition for wider application of a technology. For wider acceptance, it has to meet other performance criteria such as practicability, economic efficacy and sustainability. The objective of this paper is to assess the technical and economic performance of biological pest management technology vis-à-vis the conventional chemical pest control technology.

Data

In this paper, experimental data was used to examine the technical and economic efficacy of different pest control strategies. Data on pest infestation, pest management inputs and crop output were compiled from the annual reports of the Project Directorate on Biological Control (PDBC), Bangalore – an organ of the Indian Council of Agricultural Research. The PDBC conducts multi-location pest management trials on a number of crops. Information on cotton pest management was collected for three locations, viz. Gujarat, Punjab and Tamil Nadu. Data for Gujarat pertained to the period 1991-1998, for Punjab 1990-1998 and for Tamil Nadu for 1992-1997. The data on pest populations and the inputs applied to contain these are in the form of averages for the crop period. The boll or bud damage was used as a proxy for level of pest infestation. Further, the data was not consistent over time in terms of inputs used and their quantities. The quantities were often changed every crop season, but not in a significant manner. Thus for analysis purpose we have grouped different trials into four categories: (i) natural control, (ii) chemical control, (iii) biological control, and (iv) IPM. Natural control refers to the situation of natural pest infestation without any pest control intervention. Chemical control involves application of pesticides, and biological control involves use of one or more biological pesticides (bioagents, biopesticides and herbal pesticides). Integrated pest management involves use of both chemical and biological technologies.

Trichogramma chilonis and *Crysoperla carnea* were two biological pesticides used in integrated pest management in Gujarat. The trials were conducted on two cotton varieties, viz. CH6 and CH8. The pest management trials in Punjab were conducted on four cotton varieties, viz. LH1134, F846, F414 and F1054. *T. chilonis*, *C. carnea*, NPV, and Bt were the inputs used in the biological control. IPM combined the use of *T. chilonis*, *C. carnea* and chemical pesticides. Trials in Tamil Nadu included bio-intensive IPM proposed by PDBC, moderately chemical-intensive IPM developed by Tamil Nadu Agricultural University (TNAU), Coimbatore, and the chemical-intensive IPM practised by the farmers in the state. Bio-intensive IPM included application of *T. chilonis*, NPV, *C. carnea*, neem oil and need-based application of chemical pesticides. TNAU method included all inputs as in bio-intensive IPM module, but with quantitative variations. Farmers' practices included chemical pesticides, NPV and neem oil. Trials were conducted on two varieties, LRA5166 and MCU5.

Analytical Tools

Estimation of yield loss

'Yield loss avoided' is the most important indicator of the performance of a pest management technology. Yield loss is generally estimated taking the difference between the yield of the best-protected plot and the yield under natural infestation. Lower the loss, better is the performance of technology. The yield comparison with and without protection often leads to underestimation of yield loss, because a considerable proportion of yield is lost even after protecting the crop with the best available technology. This suggests estimation of potential yield – the yield that can be achieved in the absence of pest infestation. The actual yield obtained with application of different pest management technologies/methods is then compared to estimate the yield loss.

In recent years, the econometric approach has been used to estimate the potential yield. It presupposes the existence of a functional relationship between yield or yield loss and level of pest infestation (Waibel, 1986; Lichtenberg and Zilberman,1986). Regression method is then used to establish the relationship between yield or yield loss and pest infestation, and the potential yield or yield loss is estimated by extending the regression line up to the coordinate. The point of intersection corresponds to the potential yield or yield loss. In other words, the intercept term in the regression equation provides estimate of the potential yield or yield loss. The approach can be used for single as well as several cultivation periods and has the advantage of incorporation of different technological options in the model.

The potential yield is obtained by regressing the actual yield (Y_i) on the level of pest infestation (I_i). The relationship can be written as:

$$Y_i = f\ (I_i) \qquad ...(1)$$

Equation 1 is appropriate when there is a single technology/method of pest management. When a comparison of technologies/methods is involved, Eq.(1) is estimated simultaneously with Eq.(2) that represents the relationship between pest infestation and the technology (T_i). Technologies are represented by dummies; a technology takes the values 1 if used, zero otherwise. As the level of pest control effort varies across technologies/methods, it is desirable to include this as a variable on the right hand side of Eq.(2). This can be represented by the cost of controlling the pest (C_i), i.e.

$$I_i = f\ (T_i, C_i) \qquad ...(2)$$

These relationships were established using time series averages of trial data, and to neutralize the time effect on the level pest infestation, a time variable was added to the right hand side of Eq.(2). In experiments, crop varieties were also changed over time, and since varieties differ in their potential yield, variety dummies (D_v) were incorporated on the right hand side of Eq.(1) as to estimate the potential yield of different varieties. Finally, we estimated the following equations using SURE technique:

$$Y_i = f\ (I_i, D_v) \qquad ...(3)$$

$$I_i = f\ (T_i, C_i\ t) \qquad ...(4)$$

Different functional forms were tried to estimate these equations. The linear form gave the best fit in terms of signs of the coefficient and their level of significance. The intercept term in Eq.(3) provides of potential yield of the variety taking value 1 in the Eq.(3). Addition of the value of the coefficient of variety dummy to the intercept term provides its potential yield. Actual yield (Y_i) of a variety is then compared against its potential yield (Y_p) to arrive at the yield loss (Y_l). Equation (5) provides the yield loss in percent:

$$Y_l = (Y_p - Y_i) / Y_p * 100 \qquad ...(5)$$

Estimation of net benefits

A technology finds acceptance with the potential users if it yields net benefits equivalent to its competing alternatives. Thus, a cost-benefit analysis was undertaken to examine the relative profitability of pest management method. Changes in the costs and the returns for each pest management method were calculated over the costs and returns from no-crop protection. The change in net revenue due to application of a method was calculated by Eq. (6):

$$D X = X_1 - X_2 \qquad ...(6)$$

where, X_1 is the net revenue/ha from the application of the pest management technology, and X_2 is the net revenue/ha from unprotected field.

Net benefits (NB) estimated by using Eq. (7):

$$NB = D X - D C \qquad ...(7)$$

where, $DC = C_1 - C_2$ is the net cost change due to technology; C_1 is per hectare cost on application of technology, and C_2 is per hectare cost with no-protection.

Estimates of Yield Loss

Results of the regression Eq.(3) (infestation-technology equation) and Eq.(4) (yield-infestation equation) are presented in Tables 1 to 3. In Gujarat, the relationship between pest infestation and different pest management methods in equation (3) is negative (Table 1). Coefficients on IPM and biological control are highly significant, suggesting their higher potential as compared to that of chemical control. Relationship between cost of protection and level of infestation is positive and significant at 10 percent level, implying need for greater pest control efforts with increase in level of pest infestation. Relationship between yield and boll damage is negative and significant. Intercept term that provided estimate of potential yield of variety CH6 is positive and significant. Coefficient on CH8 variety is positive and highly

Table 1. Regression estimates of the relationship between yield, pest infestation and pest management technology : Gujarat

Explanatory variables	Dependent variable	
	Yield (kg/ha)	Boll damage (%)
Intercept	1791.967(10.993) ***	29.704(10.297) ***
Boll damage, %	-33.083 (5.283) ***	
Variety dummy		
CH6 = 0		
CH8= 1	1547.458 (11.765) ***	
Cost of protection (Rs./ha)		0.000178(1.662) *
Dummy for method		
Natural infestation = 0		
Chemical control = 1		-4.698 (1.748)*
Biological control = 1		-17.882(5.389)***
Integrated Pest Management = 1		-22.581(5.800)***
Time trend		0.474 (1.088)
log-likelihood function	-206.391	-85.567
No. of observations	29	

Figures within parentheses are t-values.
***, ** and * significant at 1, 5 and 10 percent levels, respectively.

significant, indicating its higher yield potential, compared to CH6 variety. The potential of yield of CH6 and CH8 is thus 1792 and 3339 kg/ha, respectively.

In Punjab, the relationship between level of pest infestation and different pest management methods is negative (Table 2). Chemical control emerges as the best protection method, compared to the other two methods. As expected, yield is a declining function of infestation, and the relationship is significant. Intercept term is positive and significant providing a potential yield of 1979 kg/ha for variety LH1134. The potential yield of F846 and F414 is not significantly different from this. Potential yield of F1054 (2286 kg/ha) however is significantly higher than that of LH1134.

In Tamil Nadu, the bio-ntensive and moderately chemical-intensive IPM (TNAU) provide control over the farmers' practices (Table 3). Yield has a negative and significant association with the pest infestation. Intercept term is positive and significant and provides a potential yield of1931 kg/ha for variety LRA5166. Coefficient on variety MCU5 is positive and significant. The yield of potential of MCU5 variety is 723 kg more than that of LRA5166.

Table 2. Regression estimates of the relationship between yield, pest infestation and pest management technology: Punjab.

Explanatory variables	Dependent variable	
	Yield (kg/ha)	**Bud damage (%)**
Intercept	1978.651(17.923) ***	28.324(6.942) ***
Bud damage, %	-29.442 (16.569) ***	
Variety dummy		
LH1134 = 0		
F846 = 1	-66.043 (0.512)	
F414 = 1	-30.168(0.252)	
F1054 = 1	306.764 (2.112) **	
Cost of protection (Rs./ha)		-0.000384 (0.542)
Dummy for method		
Natural control = 0		
Chemical control = 1	-12.319(2.992) ***	
Biological control = 1	-1.049(0.275)	
IPM = 1	-4.915(0.955)	
Time trend		1.994 (1.423)
log-likelihood function	-350.405	-201.409
No. of observations	47	

***, ** and * indicate significance at 1, 5 and 10 percent levels, respectively.

Table 3. Regression estimates of the relationship between yield, pest infestation and pest management technology: Tamil Nadu

Explanatory variables	Dependent variable	
	Yield (kg/ha)	Bud damage (%)
Intercept	1930.889(14.928) ***	6.133(3.632) ***
Boll damage, %	-113.654 (7.646) ***	
Variety dummy		
LRA 5166=0,		
MCU5= 1	723.233 (6.001) ***	
Cost of protection (Rs./ha)	-	0.0000726(0.934)
Dummy for method:	-	
Farmers' practices=0		
Bio-intensive IPM (PDBC)		-4.124 (1.836) *
IPM (TNAU)		-3.083 (2.728) ***
Time trend	-	0.701 (20.021) **
log-likelihood	-109.275	-39.44
No. of observations	15	

***, ** and * indicate significance at 1, 5 and 10 percent levels, respectively.

Estimates of yield loss[1] corresponding to different pest management methods are presented through Tables 4 to 6. Biological control and IPM have been further categorized as with and without integration of *Crysoperla* because it is a costly input and its integration increases the cost of protection manifold. The method without *Crysoperla* has been represented by suffix I, and the one with *Crysoperla* by suffix II. In Gujarat, biological control and IPM were more effective in avoiding the yield loss in the case of both CH6 and CH8 varieties (Table 4). With chemical control, more than half of the output of CH6 was lost due to insect pests. With biological control-I (without *Crysoperla*), the loss was 31 percent, and with biological control-II (with *Crysoperla*), it could be reduced to 6 percent. Application of IPM with and without *Crysoperla* resulted into a yield loss of 23 percent and 43 percent, respectively. The loss could have been increased to 58 percent on leaving the crop unprotected. Yield loss of CH8 variety under natural infestation conditions was estimated at 37 percent. Chemical control reduced it to 27 percent and biological control and IPM to about 10-11 percent.

In Punjab, the loss in potential yield of the variety F846 was estimated at 43 percent with chemical pest control, 58 percent with biological control and 53 percent with IPM. The loss without protection was almost equal to that

[1] Yield loss is the average for the years under consideration

Table 4. Estimates of yield loss with different pest management technologies: Gujarat

Pest control strategy	Realized yield (kg/ha)	Potential yield (kg/ha)	Yield loss (kg/ha)	Yield loss (%)
Variety: CH6				
Chemical control	885	1792	907	50.61
Biological control –I	1241	1792	551	30.77
Biological control –II	1683	1792	109	6.08
IPM-I	1026	1792	766	42.75
IPM-II	1372	1792	420	23.44
Natural infestation	750	1792	1042	58.14
Variety : CH8				
Chemical control	2424	3339	915	27.43
Biological control –I	-	-	-	-
Biological control –II	2965	3339	374	11.21
IPM-I	-	-	-	-
IPM-II	2997	3339	342	10.25
Natural infestation	2100	3339	1239	37.13

Note: I: without *Crysoperla*; II: with *Crysoperla*

with application of IPM. For F414, the loss without protection was 44 percent, and this could be reduced to 16 percent with chemical control. Biological control reduced it to 39 percent, while the loss with application of IPM was slightly higher than that without protection. More than half of the potential output of the variety F1054 was lost in the absence of pest management measures. Chemical control could bring it down to 34 percent and IPM without *Crysoperla* to 36 percent. Unlike in Gujarat, integration of *Crysoperla* was not effective. For the variety LH1134, more than two-thirds of its potential output could have been lost under natural infestation. Protection with chemical pesticides brought it down to 11 percent. IPM and biological control were not as effective.

The estimates of yield loss in Tamil Nadu suggest maximum protection against insect pests with application of moderately chemical-intensive IPM in the case of variety LRA5166; the yield loss was about 21 percent. Bio-intensive IPM was the next best option (32%). Highest yield loss was estimated under biological control[2] . On the variety MCU5, bio-intensive IPM was found to be the best method of control with yield loss of about 25

[2] In the PDBC method, the trials without use of chemicals were considered as biological control trials

Table 5. Estimates of yield loss with different pest management technologies: Punjab

Pest control strategy	Actual yield (kg/ha)	Potential yield (kg/ha)	Yield loss (kg/ha)	Yield loss (%)
Variety: F846				
Chemical	1099	1933	834	42.55
Biological control –I	805	1933	1128	57.91
Biological control –II	-			
IPM-I	897	1933	1036	53.07
IPM-II	897	1933	1036	53.07
Natural infestation	880	1933	1053	53.98
Variety : F414				
Chemical control	1633	1948	315	16.19
Biological control –I	-			
Biological control –II	1189	1948	759	38.98
IPM-I	1061	1948	887	45.55
IPM-II	-			
Natural infestation	1094	1948	854	43.84
Variety : LH 1134				
Chemical control	1770	1979	209	10.56
Biological control –I	1200	1979	779	39.36
Biological control –II				
IPM-I	1403	1979	576	29.11
IPM-II				
Natural infestation	650	1979	1329	67.16
Variety : F1054				
Chemical control	1514	2285	771	33.74
Biological control –I	1129	2285	1156	50.59
Biological control –II	1303	2285	982	42.98
IPM-I	1453	2285	832	36.41
IPM-II	1339	2285	946	41.40
Natural infestation	1122	2285	1163	50.90

Note: I: without *Crysoperla*; II: with *Crysoperla*

percent, followed by the moderately chemical-intensive IPM (29%). Yield loss was the highest under farmers' practices.

Economic Feasibility

A yield saving technology need not necessarily rank higher in profitability than its competing alternatives. Given the crop output and its price, cost of

Table 6. Estimates of yield loss with different pest management technologies : Tamil Nadu

Pest control strategy	Actual yield (kg/ha)	Potential yield (kg/ha)	Yield loss (kg/ha)	Yield loss (%)
Variety: LRA5166				
Bio-intensive IPM	1319	1931	612	31.67
Moderately Chemical-intensive IPM	1523	1931	408	21.10
Biological control	810	1931	1121	58.01
Chemical-intensive IPM	1045	1931	886	45.86
Variety : MCU5				
Bio-intensive IPM	1977	2654	677	25.51
Moderately Chemical-intensive IPM	1879	2654	775	29.20
Biological control	-	-	-	-
Chemical-intensive IPM	1475	2654	1179	44.42

technology application (type of inputs, their application rates and prices) determines the profitability of technology. An inter-technology comparison of cost and returns[3] associated with the pest management methods is presented below.

In Gujarat, the costs of biological control and IPM were higher than that of chemical control, irrespective of the crop varieties (Table 7). The cost of protection with biological control and IPM increased manifold on integration of *Crysoperla* in these. Net returns from variety CH6 under natural infestation were estimated at Rs 11132/ha. These were no different from the application of chemical control and IPM-I. Integration of *Crysoperla* in biological control and in IPM resulted in negative net returns. Net benefits (added returns – added costs) over natural control were positive with application of biological control and IPM without *Crysoperla*. Application of biological control and IPM on CH8 was profitable despite use of *Crysoperla*. What this implies is that (i) application of costly inputs such as *Crysoperla* should be restricted only to high yielding varieties, and (ii) the research should aim at reducing cost of *Crysoperla* production.

[3] The estimates of costs and returns are the averages for the period under consideration and were computed at triennium ending 1997-98 average prices prevalent in the state

Table 7. Relative profitability of different pest management technologies: Gujarat

Rs/ha

Inputs	Chemical control	Biological control-I	Biological control–II	IPM-I	IPM-II	Natural infestation
Variety: CH6						
Gross returns	13276	18608	25245	15390	20580	11253
Cost of protection	2522	2782	35381	4181	36742	121
Net returns	10754	15866	-10136	11209	-16162	11132
Added cost	2401	2661	35260	4060	36621	-
Added returns	2023	7355	13992	4137	9327	-
Net benefits	-378	4694	-21268	77	-27294	-
Variety : CH8						
Gross returns	36353	-	44475	-	44955	31493
Cost of protection	2658	-	9240		9656	-
Net returns	33695		35235		35299	31493
Added cost	2658	-	9240	-	9656	-
Added returns	4860	-	12982	-	13460	-
Net benefits	2202		3742		3804	-

Chemical control appears to be the best option in Punjab, irrespective of the varieties on which it had been applied (Table 8). On F846, the cost of chemical control was higher than that of biological control, but was less compared to that of IPM. The gross returns were also higher from chemical control, resulting into higher net returns. Net benefits were negative at the margin with application of chemical control, and highly negative with the application of biological control and IPM. The cost of chemical control on F414 was less than those with other two methods. Net returns from the application of chemical control were almost twice than those from the biological control and IPM. Even the returns from no-protection were higher than those from biological control and IPM. The application of these methods was not profitable. Chemical control on LH1134 was cost-effective and also yielded higher net returns in comparison to those from biological control and IPM. Net benefits were positive under all situations, but the highest net benefits were realized with chemical control. In the case of F1054, the cost of biological control was the least, and was followed by chemical control. Highest net returns were realized with application of chemical control. Net benefits from biological control and IPM were negative.

In Tamil Nadu, the cost of protecting the variety LRA5166 with biological control and bio-intensive IPM was five to six times higher, compared to

Table 8. Relative profitability of different pest management technologies: Punjab

Rs/ha

Inputs	Chemical control	Biological control-I	Biological control–II	IPM-I	IPM-II	Natural infestation
Variety: F846						
Gross returns	15932	11673		13007	13007	12754
Cost of protection	3217	1653		3763	5818	0
Net returns	12715	10020		9244	7189	12754
Added cost	3217	1653		3763	5818	
Added returns	3178	-1081		253	253	
Net benefits	-39	-1734		-3510	-5565	
Variety: F414						
Gross returns	23679	-	17241	15385		15863
Cost of protection	2090		4840	2294		0
Net returns	25589		12401	13091		15863
Added cost	2090		4840	2294		
Added returns	7816		1378	-478		
Net benefits	5726		-3462	-2772		
Variety: LH1134						
Gross returns	25665	17400		20348		9424
Cost of protection	1822	2490		3091		35
Net returns	23843	14910		17257		9389
Added cost	1787	2455		3056		0
Added returns	16241	7976		10924		
Net benefits	14454	5521		7868		
Variety: F1054						
Gross returns	21953	16367	18894	21061	19416	16273
Cost of protection	4725	2615	7389	5462	11008	304
Net returns	17228	13742	11505	15599	8408	15969
Added cost	4421	2311	7085	5158	10704	
Added returns	5680	94	2621	4788	3143	
Net benefits	1439	-2217	-4464	-370	-7561	

those of moderately chemical-intensive and chemical-intensive IPM (Table 9). The higher cost was due to the inclusion of *Crysoperla* in these methods. This resulted into negative net returns. Net benefits over chemical-intensive IPM were negative for all technologies, except the moderately chemical-intensive IPM. In the case of MCU5, the bio-intensive IPM yielded higher gross returns, compared to those from moderately chemical-intensive IPM, yet higher cost of protection (due to *Crysoperla*) rendered its application unprofitable.

Conclusions

The findings indicate a variation in the technical and economic performance of biological control and IPM across regions/locations. This is perhaps due to the differences in agroclimatic conditions of the selected locations that exert considerable influence on pest populations. Crop variety too is an important factor in pest management, as varieties vary in their yield potential and resistance to pests. The yield saving potential of biological and IPM is better than that of the chemical control in Gujarat and Tamil Nadu. Application of these technologies has also resulted in higher net economic benefits particularly in Gujarat. On the other hand, in Punjab the chemical control has resulted in better protection as well as economics. The profitability of different methods is influenced by the inputs used. For instance, integration of *C. carnea* into biological control and IPM though provides effective protection against insect pests, the benefits are not utilizable due to higher cost of application. This implies the need for standardization of application

Table 9. Relative profitability of different pest management technologies: Tamil Nadu

Rs/ha

Inputs	Bio-intensive IPM	Moderately chemical-intensive IPM	Biological control	Chemical-intensive IPM
Variety: LRA5166				
Gross returns	19355	22350	11883	15335
Cost of protection	28777	4960	24670	4977
Net returns	-9422	17390	-12787	10358
Added cost	23800	-17	19693	0
Added returns	4020	7015	-3452	0
Net benefits	-19780	7032	-23145	0
Variety : MCU5				
Gross returns	28995	27565	-	21368
Cost of protection	31772	5891		5930
Net returns	-2777	21674	-	15438
Added cost	25842	-39		0
Added returns	7627	6197		0
Net benefits	-18125	6236		0

rates of such inputs and reduction in their cost of production. The cost-benefit analysis has considered only the tangible costs and benefits of these technologies. Inclusion of intangible costs and benefits to environment and public health would reduce the perceived net benefits of chemical control, and improve the net benefits of biological control and IPM.

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Economics of Integrated Pest Management in Rice and Cotton in Punjab

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Introduction

Punjab is one of the highest pesticide consuming states in India. With more than 50 percent of the gross cropped area allocated to rice and cotton, agriculture in the state encounters varied insect pest problems. Insect/pests such as plant hoppers, leaf folders, rice stem borer, etc. and diseases such as bacterial leaf blight, blast, sheath blight, etc. are the major pest problems of rice in Punjab. In the case of cotton, the most important insect pests are bollworms, besides jassids and whitefly. The important diseases of cotton are bacterial blight, leaf blight, wilt, etc.

To protect the crop from the attack of insect pest, farmers in Punjab rely mainly on chemical control besides using cultural and mechanical control practices. Recently, pest control practices based on Integrated Pest Management (IPM) have also been introduced in selected districts of Punjab. The paper attempts an evaluation of the IPM program in Punjab. The specific objectives of the present study were:

- To assess the impact of IPM program with special reference to adoption of improved agro-economic practices, use of biocontrol methods and reduction in the use of pesticides, and
- To study the cost-effectiveness of IPM program from farmers' perspective.

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Methodology and Data

The study is based on the primary data collected from a sample of 60 farmers trained in Farmers' Field Schools (FFS) and 60 non-FFS-farmers from rice and cotton growing areas of Punjab. Jalandhar district was selected for the study of IPM-program on rice, while Bathinda district was selected for the study on cotton. The data on pesticide-use at the farm level, adoption of IPM practices, constraints in adoption of IPM, effects of pesticide-use on environment, etc. were obtained for an in-depth analysis.

Although IPM has been in existence for quite some time, in large parts of the study region, it is of a fairly recent origin. Most of the FFS-farmers had only little experience with the lPM, usually of less than two years. Strictly speaking, enough time had not elapsed to enable one to undertake a comprehensive impact evaluation of the program and to assess its long-term effect. This aspect of the impact evaluation presented in this study has to be kept in view while generalising the conclusions and drawing inferences about the robustness of the results.

The impact of the program was evaluated by comparing certain identified parameters of FFS and non-FFS-farmers; views, experiences and perceptions of the FFS-farmers; and the extent to which the program was able to generate awareness amongst the non- FFS-farmers. The important impact parameters included: continuity in use of IPM after its initial adoption, general experience with the use of technology, impact on cropping pattern, crop yields, reduction in pesticide consumption, impact on cost of production, perceived impact on soil, environment and human beings, and skill development. The sustainability of the IPM technology was evaluated on the basis of perceptions of the user farmers.

Experiences of FFS-farmers with IPM

To evaluate the impact of the program it was necessary to know about the experiences farmers had with the IPM in managing pests, and it was ascertained from the sampled FFS-farmers. The results suggest that the adoption of IPM is a relatively recent phenomenon in Punjab (Table 1). While more than two-thirds of rice farmers reported having switched over to IPM about a year ago, about one-fifth of them had been using it for more

Table 1. Experience with IPM of FFS-farmers (No. reporting)

Size groups (acres)	Number of farmers	Year started using IPM				Total
		Up to 1995-96	1996-97	1997-98	1998-99	
Rice						
Up to 5.0	9	1	-	-	8	9
5.1-10.0	9	1	-	1	7	9
10.1 +	12	4	2	-	6	12
Total	30	6	2	1	21	30
Cotton						
Up to 5.0	5	2	1	2	-	5
5.1-10.0	2	1	-	1	-	2
10.1 +	23	6	4	3	10	23
Total	30	9	5	6	10	30

than four years. In the case of cotton, on the other hand, one-third of the farmers had switched over to IPM only about a year ago, while the others had been using it for two to four years. The results show that a large number of the FFS-farmers had switched over to IPM only recently. The cotton farmers, however, had relatively more experience in use of IPM than rice farmers.

A study by farm size provided some interesting results on IPM adoption rates in different years. In the case of rice, the larger farmers were the first to adopt the IPM technology, and more than 50 percent of them had been using it for over three years. In contrast, almost all the farmers belonging to the small and medium size groups of farms reported having switched over to IPM only a year ago. This pattern of adoption indicated that the demonstration of positive effects of IPM adoption by large farmers might have encouraged small and medium farmers also to adopt IPM technology.

In the case of cotton, although the sample size in the first two size groups of farms (small and medium) is very small to draw some concrete generalizations from the findings, they have not lagged behind the large farmers in switching over to IPM.

The difference in pattern of IPM adoption by different size groups of farms between rice and cotton farmers could possibly be due to the difference in intensity of the pest problems between rice and cotton areas. In cotton growing areas, the acuteness of the pest problem, huge expenditure on pesticides, increasing resistance of pests to pesticides, etc. might have encouraged the adoption of IPM program, irrespective of farm size. On the other hand, not so acute pest situation in rice could have encouraged only larger farmers to try out the IPM technology first and the success of its demonstration on the larger farms might have encouraged smaller farmers also to switch over to IPM.

The initial switching over to IPM by the user farmers might have been influenced by a number of factors such as desire to reduce expenditure on pesticides, ineffectiveness of the available pesticides to control certain pests, farmers' participation in the IPM training program, persuasion by the extension staff, or simply the desire to give a try to the new approach. This one-time switching over to IPM does not, however, necessarily imply that the user farmers have been using IPM continuously thereafter also. It is quite possible that after using IPM for one or more seasons, some of the user farmers might have switched back to the traditional methods of pest control. Drawing any firm conclusion regarding the extent of adoption and acceptance of the technology by the farmers on the basis of one-time adoption can give a misleading picture.

To ascertain whether the farmers, after having once switched over to IPM, have been using it continuously ever since, we collected the required information from the sampled farmers. Almost 83 percent of the rice farmers and 93 percent of the cotton farmers reported using IPM continuously ever since they had switched over to this method of pest management (Table 2). These results, however, need to be interpreted somewhat cautiously, since, a large number of farmers, especially rice farmers, have switched over to IPM only recently. Thus, while the available results do point towards encouraging signs of sustainability of IPM technology, this would have to be assessed afresh, say after two-three years.

We also attempted to ascertain the broad perception of the FFS-farmers towards the use of IPM technology. About 77 percent of the rice FFS-farmers and 90 percent of the cotton FFS-farmers reported their experience with IPM as "good" (Table 2). In the case of rice farmers, the majority of the farmers whose experience with the use of IPM has not been "good", belonged to the small size group of farms. The specific reasons for their not-so-good experience with IPM need to be probed further.

Table 2. Continuity in use of IPM technology by FFS-farmers and their perception about it (No. reporting)

Size groups (acres)	Number of farmers	Using IPM continuously		Experience with IPM	
		Yes	No	Good	Otherwise
Rice					
Up to 5.0	9	6	3	5	4
5.1-10.0	9	9	-	9	-
10.1 +	12	10	2	9	3
Total	30	25	5	23	7
Cotton					
Up to 5.0	5	5	-	4	1
5.1-10.0	2	2	-	2	-
10.1 +	23	21	2	21	2
Total	30	28	2	27	3

Components of IPM Technology

The study compared various parameters of the FFS and non-FFS-farmers to assess the impact of the lPM programme. The FFS-farmers by definition are those farmers who have attended the Farmers' Field Schools. Participation in the training school, however, does not necessarily ensure the adoption of the technology by farmers or adoption of all the components of the IPM technology by those farmers. As discussed earlier, IPM technology for pest management is a multi-pronged approach, which encompasses a compatible use of the available methods and techniques of pest control based on cultural, mechanical, biological and chemical methods. Deriving full benefits of the IPM approach requires adoption of different components/ practices of the strategy. The FFS-farmers may not be employing all of these practices and/or the different components of these practices. The efficacy of IPM would thus vary, depending upon which components/ practices the farmers actually employ.

To ascertain the extent of adoption of IPM technology by the FFS-farmers, we collected the information on the IPM practices being used by them. The results suggest that while various cultural practices and mechanical practices had widespread adoption by these farmers, the adoption of biological practices was almost totally absent (Table 3).

In the cultural practices almost all the FFS-farmers were undertaking timely sowing of crops. More than 77 percent of the rice farmers and 53 percent

Table 3. Components of IPM technology used by FFS-farmers (No. reporting)

Particulars	Rice	Cotton
Total number of FFS-farmers	30	30
Cultural practices		
Deep ploughing	23	16
Use of resistant/tolerant varieties	-	8
Crop rotaion		
Timely sowing	29	27
Optimum fertilizer use	10	13
Mechanical process		
Hand picking and destruction of insects	17	10
Trapping through pheromone traps	13	22
Using rope method	16	4
Biological practices		
Conservation of parasites predators	-	-
Control through biocontrol fauna	-	-
Placing egg masses in perforated cages	-	1
Installing bird perches in the field	4	1
Release of *Trichogramma*/NPV*	1	1
Release of eggs and larvae	1	1
Chemical control		
Use of pesticide on the basis of ETL	10	8
Using neem-based pesticides	-	-

*Used only in cotton

of the cotton farmers were also practising deep ploughing. The mechanical processes comprising the three important components – hand picking and destruction of insects, trapping through use of pheromone traps and use of rope – were being used by the FFS-farmers though the intensity of their use differed. Thus, while 73 percent of the cotton FFS-farmers used pheromone traps, only 43 percent of the rice farmers used these traps. Similarly, while 57 percent of the rice farmers reported hand picking and destruction of insects, it was practised by 33 percent of the cotton farmers. Use of biological practices was almost absent, barring a few exceptions. Almost one-third of the FFS-farmers reported using pesticides on the basis of economic threshold level of pest population. Not even a single farmer reported use of neem-based pesticides, mainly due to their non-availability in the market.

As a result of partial adoption pattern, the impact of difference components of the impact of the IPM adoption would differ, depending upon which components of the technology the farmers have employed. Due to small size of the sample, we did not classify the farmers on the basis of the different components of IPM technology used to assess its impact. We, however, would like to underline the fact that this important finding of partial adoption of the IPM technology by the FFS-farmers had to be kept in view while drawing conclusions and interpretations about the efficacy of IPM technology *per se*.

Impact of IPM on Use of Pesticide: FFS-Farmers

One of the important indicators of the success of IPM is its impact on the use of pesticides. We asked the IPM practising farmers as to whether the shift towards IPM had led to any change in the pesticides consumption. Almost 75 percent of the farmers in both the rice and cotton areas reported a decline in pesticide-use after having shifted to IPM (Table 4). Eight out of thirty FFS-respondents in rice, and seven in cotton reported no reduction in pesticide usage after switching over to IPM. One cotton farmer even reported increase in pesticide-use. An important feature of this pattern of reduction in pesticide-use was that it had occurred across all the size groups of farmers.

The pesticide consumption varied from year to year, depending on weather conditions, nature and intensity of pest attack, etc. Therefore, ascertaining the extent of decline in pesticide consumption by a comparison of 'before' and 'after' situation could, apart from possible distortions resulting from memory bias, give a somewhat misleading picture. In a given year, however, both the users as well as the non-users of IPM faced a similar pest scenario and as such a comparison of their pesticide consumption could possibly give a better picture of the extent to which pesticide reduction was effected.

Table 4. Impact of IPM on use of pesticides by FFS-farmers (No. reporting)

Size groups (acres)	Rice				Cotton			
	No. of farmers	Decline in pesticide usage			No. of farmers	Decline in pesticide usage		
		Yes	No change	Increased		Yes	No change	Increased
Up to 5.0	9	7	2	0	5	2	2	1
5.1-10.0	9	8	1	0	2	2	-	-
10.1 +	12	7	5	0	23	18	5	-
Total	30	22	8	0	30	22	7	1

The information on the average number of pesticide sprays by FFS and non-FFS-farmers and cost incurred per acre by different size groups of farmers on pesticide is presented in Table 5. The results suggest that both in terms of number of sprays and the value of pesticides, their usage is less in FFS-farms compared to in non-FFS farms. The reduction in pesticide-use by FFS-farmers was reported by all the size groups of farmers and for both the studied crops, though the extent of decline amongst farms as also amongst crops varied. In terms of percent decline, the average decline in pesticide consumption in rice (about 15 percent) was relatively higher than that in cotton (about 10 percent).

Given that most of the farmers have shifted to IPM during the last one or two years only, a 10 to 15 percent reduction in pesticide consumption is not a small amount. Once the full package of IPM technology is adopted and availability of biopesticides is ensured, the confidence of the farmers in the technology is bound to increase. This is likely to result in the greater reduction in pesticide consumption.

Impact on Cropping Pattern and Cropping Intensity

The results on cropping pattern and cropping intensity for FFS and non-FFS farmers provided no significant difference between these two groups. The

Table 5. Pesticide consumption of FFS and non-FFS-farmers

Size group (acres)	FFS-farmers			Non-FFS farmers		
	Number of farmers	Average number of pesticide sprays	Value of pesticides (Rs/acre)	Number of farmers	Average number of pesticide sprays	Value of pesticide (Rs/acre)
Paddy						
Up to 5.0	9	0.9	129	11	2.1	274
5.1-10.0	9	1.6	354	8	3.0	364
10.1 +	12	1.8	218	11	2.1	241
Total	30	1.7	230	30	2.3	268
Cotton						
Up to 5.0	5	5.7	1088	4	7.4	1561
5.1-10.0	2	4.6	845	5	14.6	2309
10.1- +	23	7.1	1154	21	10.2	1196
Total	30	7.0	1145	30	10.3	1249

switching over to IPM for pest management had not therefore led so far to any significant change in these two variables.

Impact on Cost of Cultivation

The cost of production and the net returns from cultivation of paddy and cotton by FFS and non-FFS farmers are given in Table 6 in terms of per acre gross value of output, cost of cultivation and the net returns on different size groups of farms. As pointed out in the discussion on the differences in their crop yields, it is difficult to attribute the resultant differences in gross value of output and cost of production to the adoption of IPM.

Impact of IPM on Other Variables

To assess the impact of IPM, information on the following variables was collected: crop yield[1], crop quality, soil quality and human health. The results are presented in Table 7.

Table 6. Cost of production and value of output in FFS and non-FFS farms for paddy and cotton

(Rs/acre)

Size groups (acre)	Paddy						Cotton					
	FFS-farmers			Non-FFS farmers			FFS-farmers			Non-FFS farmers		
	GVO	Cost	NVO	GVO	Cost	NVO	GVO	Cost	NVO	GVO	Cost	NVO
Up to 5.0	10841	4878	5963	10506	4885	5621	9880	4150	5730	4230	2157	2073
5.1-10.0	11086	5321	5765	11599	5568	6031	9234	3963	5361	9542	3960	5582
10.1	10299	4789	5510	10586	5028	5558	8276	3145	5131	7082	2975	4107
Total	10458	4873	5585	10753	5118	5635	8324	3179	5945	7122	3046	4076

Note: GVO-Gross Value of Output; Cost-Operating Cost, NVO-Net Value of Output (Returns Over Operating Cost)

[1] One may argue that crop yield is a non-quantifiable variable and as such should not be clubbed with the other three qualitative variables. While it is true that crop yields on FFS and non-FFS farms is quantifiable, it would not however be correct to attribute the observed differences in crop yields between the two categories of farms to IPM alone. One would need to account for differences in other inputs and cultural practices affecting crop yields and the possible interaction effect of IPM with some of these variables. The qualitative information presented here represents the perception of the user farmers; though the quantitative information on differences in crop yields between FFS and non-FFS farmers have also been given elsewhere in the report.

Table 7. Impact of IPM on some important variables (No. reporting)

Variables	Rice	Cotton
Crop Yield		
Increased	18	9
Declined	-	-
No change	12	15
Do not know	0	6
Crop Quality		
Improved	22	7
Deteriorated	0	0
No change	8	13
Do not know	0	10
Soil Quality		
Improved	22	9
Deteriorated	0	0
No change	8	10
Do not know	0	13
Human Health		
Positive	25	17
Negative	0	0
No change	5	5
Do not know	0	7

In the case of rice, 60 percent of the user farmers reported that their crop yield has increased after having shifted to IPM while the remaining 40 percent reported no change in their crop yield. In the case of cotton, about 30 percent of the farmers reported some increase in their crop yield after switching over to IPM, a large number of them (50 percent) reported 'no effect ' of IPM.

On the quality front, about 75 percent of the rice farmers reported improvement in quality of the crop after switching over to IPM. This view was, however, shared by only about 25 percent of the cotton farmers. In the case of cotton, about 40 percent farmers reported 'no significant change' in crop quality as a result of adoption of IPM.

Regarding crop quality, and also the perceived impact on soil quality, 75 percent of rice farmers reported improvement in soil quality after adopting IPM. In cotton, only 30 percent of the respondents, perceived a positive change in soil quality, while about 45 percent replied that they ‘do not know’ if the soil quality had undergone any change.

As regards the perceived impact of using IPM on human health, more than 80 percent of the rice farmers and about 57 percent of the cotton farmers reported a positive impact on human health after shifting to IPM. However, about 16 percent of both rice and cotton farmers did not observe any change in terms of impact on human health.

Farmers as Trainers of IPM

Another important indicator, not necessarily of IPM program per se but of the process of dissemination of knowledge about IPM, is the ability of lesser farmers to impart the acquired training to his fellow farmers. More than 90 percent of the both rice and cotton FFS-farmers expressed their willingness to impart the required training (Table 8). The result has an important implication on future extension strategy for IPM program. So far, only a small number of farmers has been trained in the Farmers’ Field Schools. For an expeditious propagation of the IPM, the government and other agencies can bank upon some of these farmers to for training of the fellow farmers.

Table. 8 FFS-farmers as trainers of IPM (Nos.)

Particulars	Rice	Cotton
Total number of FFS-farmers	30	30
Can impart training	28	28
Cannot impart training	2	2

Extent of Awareness about IPM amongst Non-FFS-farmers

Since not much time has elapsed for the launch of the IPM program, one would not expect a large multiplier effect in terms of its widespread adoption by the non-FFS-farmers. One would, however, expect creation of some awareness about the program.

The extent of awareness about the IPM program amongst the non-FFS-farmers was studied through some of the awareness parameters and the results are presented in Table 9. The findings demonstrate that the efforts made so far had generated enough awareness about the IPM program amongst the non-FFS-farmers. About two-thirds of the farmers in both the rice and cotton regions were aware about the IPM program. Of the remaining, who were not aware about the program, almost all expressed their willingness to know about it.

It was also found that between 70 to 80 percent of these farmers had acquired this information from fellow farmers and not through any official agency or print/electronic media. Fellow farmers were reported to be the most important source of information for all the size classes of farmers in both the crop study regions.

Table 9. Awareness about IPM program amongst non-FFS-farmers (Nos.)

Size groups (acre)	Total number of farmers	Awareness about IPM		Source of information		Interested to know about IPM	
		Yes	No	Fellow farmers	Others	Yes	No
Rice							
Up to 5.0	11	8	3	5	3	3	
5.1-10.0	8	6	2	5	1	1	1
10.1 +	11	5	6	4	1	6	
Total	30	19	11	14	5	10	1
Cotton							
Up to 5.0	4	1	3	1		2	1
5.1-10.0	5	4	1	4		1	
10.1 +	21	15	6	11	4	6	
Total	30	20	10	16	4	9	1

Constraints in Application of IPM

The FFS-farmers after undergoing formal training in the use of IPM are expected to apply it in their fields. No follow-up training programs are organised. Most of the farmers, however, had undergone this training only recently and it is likely that they would face some problems in its application on their farms.

The results present a somewhat different picture. About 63 percent of the rice FFS-farmers, 87 percent of the cotton FFS-farmers did not face any problem in using IPM (Table 10). Of the remaining farmers who faced problems in the use of IPM, approached the extension agencies for solution of their problems. The problems in the application of IPM were not restricted to any specific group of farmers – in the case of rice, a few farmers from all the size groups had some difficulties while in the case of cotton, it were the farmers belonging to the largest size group who reported some problems.

Table 10. Number of FFS-farmers reporting problems in use of IPM

Size group (acres)	IPM in rice			IPM in cotton		
	No. of farmers	Problem		No. of farmers	Problem	
		Yes	No		Yes	No
Up to 5.0	9	4	5	5		5
5.1-10.0	9	2	7	2		2
10.1 +	12	5	7	23	4	19
Total	30	11	19	30	2	26

Sustainability of IPM

Since the IPM technology has been introduced only a few years ago, we had indicated that drawing any firm inference about the long-term sustainability of the technology on the basis of such an indicator be made with caution. To assess the long-term sustainability of the IPM technology, we collected the needed information from the FFS-farmers. It was found that more than 93 percent of both rice and cotton FFS-farmers viewed that the IPM had the potential of sustainability in the long-run (Table 11). This

Table 11. Sustainability of IPM technology: FFS-farmers opinion (No. reporting)

Size groups (acres)	IPM in rice			IPM in cotton		
	Total no. of farmer	Yes	No/DNK*	Total no. of farmers	Yes	No/DNK*
Up to 5.0	9	9	0	5	5	0
5.1-10.0	9	9	0	2	2	
10.1 +	12	10	2	23	21	2
Total	30	28	2	30	28	2

DNK = Dot not know

view was not only shared by all the farmers, but the small and medium farmers were more emphatic about its sustainability.

Advantages IPM over Pesticides for Pest Management: FFS-farmers

A farmer would switch over to a new approach only if the advantages of using it outweigh the disadvantages of the old one. These advantages could be in terms of either quantifiable parameters (reduction in costs or increase in crop yields) or perceived advantages (improvement in soil quality, less harmful for human health, etc.) or a combination of quantitative and qualitative parameters. We asked the FFS-farmers as to what comparative advantage they had observed in adopting IPM vis-a-vis relying on pesticides alone. The results are presented in Table 12.

In the case of rice, the user farmers (> 60%) opined that the method of pest control in IPM was less harmful to soil, environment and human beings. Another important consideration favouring IPM (50 %) was that it cuts down the cost of pest control.

Table 12. Perceived advantages of using IPM method vs pesticide usage by FFS-farmers (Nos.)

Size groups (acres)	Number of farmers	Perceived advantages of IPM over pesticides				
		Less harmful for soil/ environn/ humans	Less expenses	Protects friendly insects	Reduces sprays	Specifics not aware/ DNK
Rice						
Up to 5.0	9	4	5	0	0	3
5.1-10.0	9	7	4	1	0	0
10.1 +	12	7	6	1	1	0
Total	30	18	15	2	1	3
Cotton						
Up to 5.0	5	2	1	2	0	1
5.1-10.0	2	1	1	9	0	0
10.1 +	23	8	6	18	5	6
Total	30	11	8	20	5	7

Note: Sum of cell frequency may not tally due to multiple answers by respondents

In the case of cotton crop, where the pest problem is much more acute and the farmers use pesticides very intensively, the most important reason for using IPM, cited by two-thirds of the farmers, was that it protected the friendly insects in the environment and thereby reduced the need for pesticide applications. As in the case of rice farmers, the other two reasons cited by cotton farmers for favouring IPM were its less harmfulness to soil, environment and human beings and also saving on input costs.

Conclusions

The study suggests that IPM programme, though introduced not long ago in Punjab, has found acceptance with the farmers, and their experience with it has been ”good”. The IPM as being used currently actually involves application of only a few components of the technology and full package of practices is not being used by a majority of the farmers. Use of the technology even at the current level has led to a decline of 10 to 15 percent in use of pesticides by the farmers. Once the farmers start using full package of practices of IPM technology, the pesticide consumption may go down still further. The results, however, do not provide conclusive evidence of the financial superiority of IPM technology over the traditional methods of pest control. The farmers also, perceive an improvement in quality of crop, soil and human health as a result of use of IPM technology.

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Adoption and Impact of Integrated Pest Management in Important Crops in Haryana

A.K. Dixit and K.N. Rai[1]

Introduction

Haryana is one of the most progressive states of India with rice and wheat as dominant crops in the irrigated areas. In the less irrigated areas, cropping pattern is diversified; besides wheat and rice, a number other crops such as pulses, oilseeds, coarse cereals, cotton and sugarcane are also of considerable importance. However, over the time, a tendency towards monoculture of wheat and rice has been developing in some parts of the state. This coupled with indiscriminate and excessive use of irrigation, fertilizers and pesticides has been causing a considerable damage to the natural resources. As a result, the growth in agricultural productivity has started tapering off with diminishing returns to additional input usage.

During the last quarter of the twentieth century, the pesticide consumption has increased considerably in Haryana. Its share in the total pesticide consumption of the country increased from 3 percent in 1975-76 to 9 percent in 1997-98, and the per hectare consumption increased from 278 to 828 g. During the 1990s, when per hectare consumption of pesticides in most of the other states was declining, it remained almost stagnant in Haryana. The slowing down of growth in agricultural productivity in the face of high pesticide consumption indicates the initiation of the process of diminishing returns to additional input usage. With this in view, the state government, in recent years, has started promoting use of alternative pest control technologies such as bio-agents, biopesticides and plant-based pesticides in an IPM mode to control the pest menace effectively. But, the adoption of new technologies is extremely low. The purpose of this paper is to examine

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the economic feasibility of the emerging technologies, and constraints in their adoption.

Data and Methodology

On the basis of agro-climatic conditions and pesticide-use intensity, Haryana can be divided into three regions. Region I consists of Yamuna Nagar, Kurukshetra and Sonepat districts with high pesticide-use. The region is well endowed with irrigation facilities and is the most advanced. On the other hand, districts of Bhiwani, Mahendragarh, Rohtak, Gurgaon, Hisar, Jind and Rewari have less irrigation facilities, and use the least pesticides. In between these two fall the medium pesticide using districts of Sirsa, Karnal, Kaithal, Ambala and Panipat.

For the purpose of this study, one district from each region was selected keeping in view the area under those crops that demand higher plant protection. The selected districts were: Sonepat, Hisar and Karnal. Moreover, these districts had a diversified cropping pattern. From each district, four villages were identified randomly, and from each village, 15 farmers were selected. Data were collected from these selected farmers as per pre-tested schedules through interview mode for the agricultural years 1997-98 and 1998-99.

Data pertaining to the cropping pattern, input-output details by crops, and other information were collected from the selected farmers. Besides, the experimental data on different methods of pest control in paddy and cotton were collected from the Regional Research Station, Uchani (Karnal) of the CCSHAU, Hisar. The data on cotton pest control were collected from the village Parbhuwala in Hisar district adopted under the project 'Development of Integrated Pest Management (IPM) packages under selected crop conditions'.

Adoption of IPM

Paddy

To promote use of biopesticides and other environmentally-safe methods of pest control, farmers of village Baraunda (Karnal) were trained by the experts to manage the pests rather than eradicate them. The adoption of different

IPM practices is given in Table 1. Before adoption of IPM, farmers were ignorant about the use of cultural practices such as deep summer ploughing, resistant varieties, balanced fertilization and bund raising to restrict and minimize the occurrence of various insect-pests. However, a good percentage of IPM-trained farmers adopted these cultural practices during the second year of IPM programme. Among the trained farmers, 15 percent adopted the rope method of suppressing leaf folder infestation during the first year itself. But, in the subsequent years, only 30 percent adopted this practice. The low adoption was because of the labour-intensive nature of this practice. Light traps were adopted by 40 percent of the farmers, while the sex pheromone traps were installed by all of them. These practices helped in detecting and keeping the yellow stem borer below the threshold level. None

Table 1. Adoption of integrated pest management practices in paddy by farmers in Haryana

(in percent)

Practice	Before adoption of IPM	1996-97	1997-98
Cultural Practices			
Deep summer ploughing	10	60	80
Use of resistant variety	-	30	50
Balanced fertilization	-	80	100
Bund raising	-	20	50
Mechanical Control			
Use of sex pheromone traps	-	100	100
Use of light traps	-	10	40
Rope shaking	3	15	30
Chemical Control			
Area cover (%)			
Use of Themet/Furadon against root weevil	95	20	3
Use of *Endosulfan* against leaf folder, WBPH	90	15	7
Biological Control			
Use of *Bacillus thuringiensis* (Bt) against leaf folder	-	15	50
Neem product (Repellant)	-	-	100
Yield (q/ha)			
Common varieties	56	58	66
Basmati	22	25	25

of the farmers adopted mechanical practices such as clipping/pruning of seedling and rouging out the infested plants, etc.

Farmers were advised to use environmentally-safe pesticides and biopesticides. About half of the farmers used Bt, and practically all applied neem products (Table 1). About 95 percent of the total area was covered under chemical control and a majority of farmers used to apply pesticides without observing pest population before the adoption of IPM programme. However, only 35 and 10 percent of the area was covered under chemical control during first and second years of IPM adoption, respectively. It was interesting to find that a majority of the farmers did not apply pesticides in 1996-97 and 1997-98 and this did not affect the yield.

Sugarcane

Thirty farmers of the village Sankehera (Yamuna Nagar) were trained by the experts of the University in collaboration with Indian Farmers' Fertiliser Cooperative (IFFCO) during 1996-97 and 1997-98. Adoption level of different pest management practices is recorded in Table 2. The results showed that urea solution (2%) and neemax substituted the pesticide endosulfan in 30 percent of the area in the first year and 80 percent in the second year. The adoption of cultural and mechanical pest control practices was quite satisfactory in the second year of the programme. However, use of light trap was not that high.

The biological control covered 10 percent of the area, and replaced the chemical pesticides to a great extent. And, the yield of sugarcane increased from 50 to 57 t/ha with the introduction of IPM programme.

Cotton

Thirty-five farmers of the village Parbhuwala (Hisar) were trained by the experts of CCSHAU through the Farmers' Field School. The aim of the programme was to persuade the farmers for a need-based chemical application in combination with other methods of control. The data on the extent of adoption of IPM measures by the selected cotton growers during 1996-97 and 1997-98 are presented in Table 3.

Results showed that the adoption of economic threshold level (ETL) as a criterion for pest control was nil before the introduction of IPM programme, but after its implementation, 20 percent of the farmers in the first year and

Table 2. Adoption level of integrated pest management in sugarcane crop in Haryana

Practice	Before adoption of IPM	First year of IPM, 1996-97	Second year of IPM, 1997-98
Use of Chemical			
Against black bug	Endosulfan 95% farmers	Substituted by 2% urea solution spray or neemax in 30% area	Substituted by 2% urea solution spray or neemax in 80% area
Against termite and shoot borer	Chlorophyriphos (90%)	80%	90%
Against top borer	Carbofuran (95%)	*Trichgramma* spp. 100% in area	*Trichgramma* spp. 100% in area
Cultural Control			
Use of resistant varieties	-	Used a resistant variety against red rot	Used a resistant variety against red rot
Balanced fertilizers	- N:P:K: (135:48:0)	1005 ha area N:P:K: (6:2:1:)	1005 ha area N:P:K: (6:2:1:)
Heavy irrigation to control shoot borer	-	3%	45%
Mechanical Practice			
Removal of dead hearts and shoot	-	20% area	50% area
Eradication of infested shoots	-	22% area	60% area
Use of light traps against all adults of borer	-	20% area	30% area
Biological Control			
Application of *Trichgramma* spp.	-	100% area	100% area
Neem-based product	-	10%	305
Yield	50 t/ha	52.5 t/ha	57 t/ha

49 percent in the second year became conversant with the concept of ETL. Sixty-three percent of the farmers became capable of identifying the major insect-pests of cotton.

A perusal of Table 3 reveals low adoption of mechanical practices. The use of biocontrol (57%) and sex pheromone (40%) was adopted by only

Table 3. Adoption level of integrated pest management in cotton in Haryana

(in percent)

Practice	Before adoption of IPM	First year of IPM, 1996-97	Second year of IPM, 1997-98
Pest Surveillance			
Identification of pest	20.0	40.0	62.8
ETL adoption	-	20.0	48.6
Mechanical Control			
Use of sex pheromone	-	40.0	40.0
Manual killing of *Heliothis*	14.38	22.8	22.8
Chemical Control			
Use of synthetic insecticide	100.0	100.0	100.0
Use of contact insecticide	60.0	71.4	80.0
Use of organophosphate	-	65.7	65.7
Lower doses of insecticide	37.1	5.7	-
Over doses of synthetic parathmode	80.0	25.7	14.2
Proper doses, depending upon ETL	-	51.4	82.4
Biological Control			
Application of *Trichogramma*	-	57.1	57.1
Yield (kg/ha)	900	1,200	1350

those to whom these were provided under the programme. The pest-defender ratio of 2:1 was found useful to avoid the application of pesticides. However, none of the trained farmers had determined the pest-defender ratio due to lack of skill.

Economics of IPM

Paddy

The costs and returns associated with IPM and farmers' practices are shown in Table 4. Biopesticides, as well as mechanical and cultural controls, were effective against the major insect-pests of paddy crop. As per farmers' observation, chemical control measures had little effect on leaf-folder, while rope shaking and simultaneous use of biopesticide could check the attack of leaf folder. Though this practice is slightly costly than the chemical application alone, it has the advantage of minimizing health regards and the adverse effect of residues on micro-organisms.

Table 4. Comparative economics of integrated pest management and farmers' practices in paddy crop in Haryana

(Rs/ha)

Item	**IPM practice**	**Farmers' practice**
Field preparation	1150	1150
Seed	450	450
Seed treatment	100	-
Nursery raising and seedling transplanting	1150	1150
Fertilizer	2005	2338
Irrigation	4000	4550
Plant protection		
Weed management	500	463
Insect-pest Management		
Cultural		
Bund raising	120	60
Mechanical		
Use of sex pheromone traps	500	-
Light traps	180	-
Rope shaking	300	-
Chemical Pesticide		
Biopesticide		
B.T.K & neem product (300 ppm)	950	-
Harvesting, threshing & winnowing	2500	2500
Miscellaneous	250	250
Interest on working capital @ 12%	849	838
Total cost of production	15004	14816
Yield (tonne)	6.64	4.96
Value of the product	32536	29204
Net returns	17532	14388
Increase in yield over traditional; %	10.24	-
Cost of production per tonne	2250	248.59

The unit cost of production using IPM technique was Rs 2260/t, compared to Rs 2499/t without IPM. The increase in yield due to IPM being 10.24%, the net returns were Rs 17,532/ha, whereas in the case of farmers' practices (non-IPM), it was Rs 14,388/ha. Thus, IPM in paddy appeared to be an economically profitable proposition.

Sugarcane

The economics of IPM (demonstration trial conducted at farmers' fields in village Dhalawala Rodan (Karnal) and the existing farmers' practices are shown in Table 5. The results showed that IPM the technique could make use of chemical pesticides redundant. The incidence of borer was reduced through timely removal of dead hearts and eradication of infested shoots. However, requirement of human labour was higher in the case of IPM (145 mandays), compared to the non-IPM practices (134 mandays).

The cost of production per unit (Rs 358/t) was less in the case of IPM practices than in non-IPM practices (Rs 429/t). This was due to the higher yields resulting from the adoption of IPM practices. The increase in sugarcane yield was 15.78 percent. The net returns on IPM demonstration field were Rs 37384/ha as compared to Rs 26928/ha. in farmers' practices. Thus, the adoption of IPM in sugarcane cultivation entailed significant benefits to the farmers.

Cotton

Based on the occurrence of pest, particularly of *Helicoverpa armigera* on cotton crop during earlier years, two modules were finalized for its effective

Table 5. A comparison of economics of integrated pest management and farmers' practices in sugarcane in Haryana

(Rs/ha)

Item	IPM practice	Farmers' practice
Human labour (man days)	145 (Rs 8700)	134 (Rs 8700)
Bullock and tractor	3300	3300
Seed	7500	7500
Manure	500	-
Fertilizer	2000	2400
Plant Protection		
Seed treatment	050	-
Biocontrol (*Trichogramma* spp.) 3 times @ 50,000/ha	750	-
Weedicide	-	384
Insecticide	-	1630
Irrigation	1500	1275
Interest on working capital @ 12% per annum	2916	2943
Total cost	27,216	27,472
Yield (qt)	76	64
Value of product	64,600	54,400
Net return	37,384	26,928
Cost of production/ tonne	358	429
Increase in yield over traditional,%	15.78	-

management. The total cost for pest management with bio-intensive module (M-1) was Rs 5780/ha and with IPM (M-2) was Rs 6130/ha, whereas the cost of pest management in IPM adopted village was Rs 4880/ha (Table 6). It is clear that amongst different approaches, the cost of pest control was less in the case of farmers' practices based on chemical control. In bio-

Table 6. Cost of different pest management practices in cotton crop in Haryana

Module I			Module II		
Treatment	**Dose/ha (Ml)**	**Cost (Rs)**	**Treatment**	**Dose/ha (Ml)**	**Cost (Rs)**
Seed treatment (Imidacloprid 70 WS)	75g	760	Seed treatment (Imidacloprid 70 WS)	75g	760
Neem 9300 ppm	2500	600	Neem 9300 ppm	2500	600
Trichogramma spp	2 lakh	850	Endosulfan	2000	500
Trichogramma spp	2 lakh	850	*Trichogramma* spp	2 lakh	850
Endosulfan	2000	500	*Trichogramma* spp	2 lakh	850
HaNPV	450LE	870	Btk	1000g	950
Quinalphos 20 AF	2000	750	HaNPV	450 LE	870
Neem (300 ppm)	2500	600	Quinalphos 20 AF	2000	750
Total cost		5780			6130
IPM at Farmers' Field			Farmers' Practice (Non-IPM)		
Dimethoate/ Metasystox 25 EC	750	300	Monocrotophos 36 WSC	1250	500
Monocrotophos 36	1000	430	Endosulfan 35 EC	2500	650
Endosulfan 35 EC	2000	550	Monocrotophos	1250	525
Diathane M-45	1000	400	Fenvalerate 20 EC	625	388
Chlorpyriphos	2000	650	Quinalphos 20 AF	2500	775
Endosulfan 35 EC or Methylparathion/ Carbaryl, Sevin	1250				
Fenvalerate 20 EC or Cypermethrin 25 EC	500/625	300	Cypermethrin 25 EC	2000	750
Mechanical Control					
Manual labour	10	600			
Use of sex pheromone trap	800*				
Biocontrol *Trichogramma* spp.	850				
Total cost	4880				3588

* Sex pheromone traps and *Trichogramma* spp. were provided by the Department of Agriculture, Haryana at free of cost but here cost has been included as per market price.

intensive and IPM module, the emphasis is on use of bio-agents, biopesticides in combination with safer chemical pesticides based on economic threshold level. Whereas, in IPM at farmers' field, maximum emphasis is on chemical control based on ETL in combination with little use of bio-agents and mechanical control.

The comparison dearly indicates that IPM is costly in cotton because bio-agents and bio-pesticide are volatile in nature and require repeated use. To find the economical approach, the net returns were compared (Table 7). The expenditure on pesticides and their application was estimated at the prevailing market prices and total returns were calculated @ Rs 18.55/q. The data on yields (Table 7) indicated that IPM (M-II) recorded a higher yield (1.42 t/ha) than M-I and IPM at farmers' field (1.35 t/ha) each. The yield was minimum (0.62 t/ha) from the unsprayed crop. However, the cost of pest control under IPM (M-I) and bio-intensive (M-II) was much higher. The cost-benefit ratio of IPM in the adopted village has been found higher than all approaches (Table 7).

Costs of Externalities of Pesticides

Pesticides, besides polluting the environment, also impair human immune system – kidney, liver, nervous system and induce tumours, loss of memory, skin and allergic reactions, behavioural changes and several other known and unknown

Table 7. Cost and returns of different practices for management of insect-pest on cotton in Haryana

Treatment/ Module	Yield of seed cotton (kg/ha)	Increase in yield over control (kg/ha)	Return (Rs)	Total cost of pest control including labour (Rs)	Cost-Benefit ratio
Module I (Biointensive)	1350	730	13542	5780	1:2.34
Module II (IPM)	1420	800	14840	6130	1:2.42
IPM at farmers' field	1350	730	13542	4880	1:2.77
Farmers' practice (Non-IPM)	920	300	5565	3588	1:1.55
Module III Control (unsprayed)	620	-	-	-	-

Note: The selling price of the seed cotton = Rs 18,550/t.

diseases to human, livestock and other living organisms. The social cost of pesticide-use was worked out and is shown in Table 8. The results show that on an overall basis the total cost involved was Rs 73,885 for human treatment and Rs 22,350 for animal treatment. In Karnal district, among the selected farmers, two persons died due to inhalation of extremely toxic pesticides. In Sonepat district, it was reported that three animals worth Rs 52,500 died due to feeding on pesticide-sprayed fodder. Hence, the social cost involved to externalize pesticides externalities was Rs 170,235 in the study area.

Table 8. Cost on externalization the hazardous effect of pesticide in Haryana (1997-99)

Hazards effect	Cost (medicine + doctor's fees)						
	Number of cases	Cost of treatment (Rs)	Number of cases	Cost of treatment (Rs)	Number of cases	Cost of treatment (Rs)	Total cost (Rs)
Human- beings	8	3600	12	22,800	16	15,085	73,885
Animals	9	7,200	8	5,250	22	9,900	22,350
Human deaths	2	-	-	-	-	-	-
Animal Deaths	-	-	3	21,500	7	52,500	74,000
Total		43,200		49,550		77,485	170,235

Farmers' Perception regarding Impact of Pesticides on Environment

The farmers' perceptions regarding the impact of pesticides on environment is presented in Table 9. The indicators included the impact on human labour, animals, edible agriculture products, air, water, and soil. The frequencies of the response indicated that the labour involved in spraying was significantly affected by the pesticides. The impact on soil and water, as perceived through the crops grown in nearby fields or the next crop in the same field, was found to be relatively low. However, their impact on air was perceived to be quite high. Farmers were of the view that pesticides polluted the environment surrounding the sprayed area. Some of them reported that pesticides such as furadan, thimet, carbofuran, etc. emit fumes. The farmers also perceived that pesticides reduce soil fertility and add to water pollution. Impact of pesticides on edible products was perceived to be low in Sonepat district, but significantly higher in Hisar district.

Table 9. Farmers' perceptions about the impact of pesticides on environment

Impact of pesticide on	Karnal	Sonepat	Hisar	Overall
Labour	56 (93.33)	58 (96.66)	60 (100.00)	174 (96.66)
Human-beings, in general	51 (85.00)	45 (75.00)	42 (70.00)	138 (76.66)
Animals	38 (63.33)	34 (56.66)	39 (65.00)	111 (61.66)
Edible agricultural produce	18 (30.00)	10 (16.66)	20 (33.33)	48 (26.66)
Air	37 (61.66)	29 (48.33)	35 (58.33)	103 (57.22)
Water	28 (46.66)	17 (28.33)	15 (25.00)	60 (33.33)
Soil	8 (13.33)	4 (6.66)	3 (5.00)	15 (8.33)
Crops	19 (31.66)	5 (8.33)	18 (30.00)	42 (23.33)

Note : 1. Results based on farmers response from a sample of 180, spread equally across the three districts of Haryana

2. Figures within parentheses denote percentages.

Farmers' Response to IPM

The findings on the awareness, use and opinion on the effectiveness of different methods of pest control are given in Table 10. Awareness about the cultural method of weed control and insect control was low in Sonepat district. The use of cultural practices against insect control was also low in all the districts. However, a few farmers in Hisar district adopted cultural practices such as deep ploughing, burning of stubbles, etc. Awareness about manual control of weed was quite high; 61 percent farmers reported effectiveness of this method. The adoption level of manual weed control was also high because weeds are used as animal fodder and some weeds such as *bathu, cholai,* etc. are used for table purposes. Farmers were of the view that removal of dead heart and infected shoot of paddy significantly reduces the damage due to insect-pest and diseases. Awareness about role of crop rotation was very high, but its adoption was very low. Its effectiveness was realized by 60, 25 and 20 per cent of selected farmers in Karnal, Hisar and Sonepat districts, respectively. Awareness about seed treatment was also high, but its use was low.

On the other hand, awareness about chemical control was quite high. The effectiveness of insecticides, fungicides and weedicides was reported by 52, 13 and 49 per cent of farmers, respectively in three districts. The findings revealed that chemical control was the dominant method of pest control, probably because of its instant observable results.

table 10: Farmers response on awareness, adoption and effectiveness of different pest control measures

(in percent)

Control methods		**Awareness/ adoption/ effectiveness**	**Karnal**	**Sonepat**	**Hisar**	**Overall**
Cultural Methods	Insect	Aware	21.67	6.67	18.33	15.56
		Adoption	8.33	-	3.30	3.88
		Effectiveness	8.33	-	3.30	3.88
	Weed	Aware	6.67	5.00	20.00	10.50
		Adoption	-	-	16.67	5.56
		Effectiveness	-	-	16.67	5.56
Manual Control	Insect	Aware	40.00	30.00	16.67	28.88
		Adoption	3.33	11.67	3.33	6.11
		Effectiveness	3.33	16.67	3.33	7.77
	Disease	Aware	6.67	20.00	-	8.89
		Adoption	-	6.67	-	2.23
		Effectiveness	-	16.67	-	5.56
	Weed	Aware	100.00	100.00	100.00	100.00
		Adoption	50.00	75.00	93.00	72.78
		Effectiveness	45.00	60.00	93.33	66.11
Biological Control		Aware	10.00	26.67	3.33	13.33
		Adoption	-	-	-	-
		Effectiveness	-	5.00	-	1.67
Crop Rotation		Aware	98.33	96.67	95.00	96.67
		Adoption	8.33	16.67	11.67	12.22
		Effectiveness	60.00	20.00	25.00	35.00
Use of Sex Pheromones		Aware	6.67	3.33	6.67	5.56
		Adoption	-	-	-	-
		Effectiveness	-	-	-	-
Seed Treatment		Aware	86.67	83.33	95.00	83.33
		Adoption	35.00	6.67	18.33	20.00
		Effectiveness	25.00	6.67	8.33	13.33
Chemical Control	Insect	Aware	100.00	100.00	100.00	100.00
		Adoption	90.00	93.33	100.00	94.44
		Effectiveness	46.67	70.00	40.00	52.22
	Disease	Aware	53.33	10.00	66.67	43.33
		Adoption	20.00	-	30.00	16.67
		Effectiveness	11.67	-	26.67	12.77
	Weed	Aware	90.00	83.33	40.00	65.00
		Adoption	86.67	66.67	16.67	34.67
		Effectiveness	61.67	68.33	16.67	48.99

Conclusions

It has been found that in sugarcane and paddy crops, IPM is effective against major insect pests of these crops. In cotton crop need-based pesticide applications alongwith other alternatives such as mechanical and bioagents has been found economical. With IPM, sugarcane yield is higher by 16 percent over the traditional method, and without any additional cost. Higher cost benefit ratio is observed under IPM practice in both cotton and paddy. Social cost of negative externalities pesticides on human and animal health is estimated as Rs 945 household/annum. The awareness among farmers regarding ill effects of pesticides on human and animal health is also high. However, they are not much aware of their effects on natural resources like soil and water.

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Economics of Integrated Pest Management in Major Crops of Andhra Pradesh

K.R. Choudhary[1]

Introduction

The state of Andhra Pradesh is one of the top five consumers of pesticides in India, much of which is used in crops like cotton, rice and chillies. Indiscriminate use of hazardous pesticides has resulted in the reduction of bio-diversity and natural enemies of pest, outbreak of secondary pests, development of resistance to pesticides, and contamination of food and ecosystem. The worst examples in the state during the recent past were the outbreaks of white fly in cotton during the mid 1980s and *Helicoverpa armigera* in cotton in 1987 and 1997. The presence of pesticide residues in agri-products renders them unsuitable for export. The preference world-wide today is for pesticide-free and organic foods produced using eco-friendly approaches like host plant resistance and cultural, mechanical, physical and biological controls. Thus, the objectives of IPM are to improve the quality of produce, sustain crop productivity, minimize health hazards, prevent environmental pollution, conserve bio-diversity and minimize cost of production. This paper examines the economics of IPM vis-a-vis chemical control in major crops of Andhra Pradesh.

Methodology

Both primary and secondary data were used in the study. Secondary data were obtained from the research stations of the Acharya N.G. Ranga Agricultural University (ANGRAU), and the Centre for World Solidarity (CSW) – a non-governmental organization (NGO). The data on paddy

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were taken from Agricultural Research Station, Maruteru in West Godavari district, and on cotton from the Regional Agricultural Station, Lam, in Guntur district.

Components of IPM

Paddy

- Growing of pest-resistant paddy varieties and use of disease-free seeds
- Application of FYM
- Nursery protection with carbofuran granules only in the endemic areas of gallmidge and stem borer
- Transplanting at appropriate stage after removal of 2-4 terminal parts of seedlings to reduce the chances of carrying and migration of pests like stem borer and leaf folders
- Use of rope running and other mechanical practices to expose case worm and leaf folder larvae
- Application of nitrogen with potash- and neem-coated materials
- Application of recommended insecticides
- Harvesting of crop to the ground level to reduce the chances of yellow stem borer and gallmidge buildup, and
- Control of rodents.

Cotton

- Growing of cotton as a rotation crop rather than as a continuous monocrop
- Application of FYM and chemical fertilizers in an integrated manner
- Growing inter-crops/strip-crops/barrier-crops
- Use of delinted seeds for effective seed dressing with carborfuran, etc.
- Use of pest resistance varieties, seed treatment or stem application technique

- Use of sticky pheromones and light traps
- Building up of broad spectrum of predators spiders
- Lopping of cotton plants when maximum egg-laying of *Helicoverpa armigera* is noticed
- Using chemical insecticides judiciously
- Removal of cotton stubbles after last picking to break the cycles of pests
- Avoiding ratooning of cotton, and
- Keeping the field free from weeds.

Economics of IPM

Paddy

The details of costs and returns in paddy cultivation, under IPM and non-IPM experimental conditions are given in Table 1. The plant protection measures undertaken in IPM included use of controls like cultural, mechanical, biological and chemical in an integrated manner.

Table 1. Costs and returns from paddy cultivation using IPM and non-IPM technologies under experimental conditions

(Rs/ha)

Particulars	IPM	Non-IPM
Operational costs		
Seeds	650 (4.20)	725 (4.38)
Farm yard manure	3525 (22.78)	2120 (12.80)
Fertilizers	1020 (6.59)	1736 (10.49)
Plant protection chemicals/agents	600 (3.87)	1460 (8.82)
Irrigation costs	500 (3.23)	500 (3.02)
Labour costs	4530 (29.28)	5645 (34.09)
Interest on working capital @12.5% annui	282 (1.82)	317 (1.92)
Total	11107 (71.79)	12504 (75.52)
Fixed costs		
Rental value of owned land	4365 (28.21)	4053.60 (24.48)
Total costs	15472 (100)	16557 (100)
Returns		
Gross returns	26187	24322
Net returns	10716	7764

Note: Figures within parentheses indicate percent to total.

It was found that the cost of cultivation was higher in non-IPM fields as compared to IPM fields; it being Rs 15471/ha in IPM and Rs 16557/ ha in non-IPM fields. The operational cost including material and labour was Rs 11107/ha in IPM and Rs 12503/ha in non-IPM fields. The higher operational cost in non-IPM fields was mainly due to more expenditure on plant protection chemicals and fertilizers. The gross returns as well as net returns were higher from IPM farms.

Data from farmers' fields (Tables 2 and 3) showed a total cost of paddy cultivation as Rs 17056/ha with IPM and Rs 17282/ha without IPM technology. The cost of labour was slightly more in IPM than in non-IPM fields. It was

Table 2. Cost of cultivation of paddy using IPM and non-IPM technologies in farmers' fields

(Rs/ha)

Particulars	Non-IPM	IPM
Operational costs		
Human labour	5069 (29.33)	5103 (29.52)
Hired	3873 (22.41)	3200 (18.51)
Owned	1196 (6.92)	1903 (11.01)
Bullock labour	759 (4.40)	913 (5.36)
Hired	493 (2.86)	424 (2.49)
Owned	266 (1.54)	488 (2.87)
Machine labour	178 (1.03)	31 (0.18)
Hired	22 (0.13)	31 (0.18)
Owned	156 (0.90)	-
Manures	729 (4.22)	1100 (6.45)
Produced	365 (2.12)	458 (2.69)
Purchased	363 (2.10)	606 (3.55)
Seeds	673 (3.90)	646 (3.79)
Fertilizers	2038 (11.80)	1528 (8.96)
Plant protection chemicals/agents	1828 (10.58)	1461 (8.57)
Interest on working capital	293 (1.70)	280 (1.65)
Total	11572 (66.96)	11064 (64.87)
Fixed costs		
Land revenue	550 (3.18)	550 (3.22)
Depreciation	544 (3.15)	593 (3.48)
Interest on fixed capital	670(3.88)	609 (3.57)
Rental value of owned land	3945 (22.83)	4238 (24.85)
Total	5710 (33.04)	5991 (35.12)
Total costs	17282 (100)	17056 (100)

Note: Figures within parentheses indicate percentage to total.

Table 3. Returns from paddy cultivation with IPM and non-IPM technologies under farmers' conditions

(Rs/ha)

Particulars	IPM	Non-IPM
Productivity (q/ha)	53.91	51.03
Gross income (Rs/ha)	25431	23672
Net income (Rs/ha)	8375	7580

due to cultural and mechanical measures adopted in IPM fields. The manure was given high importance in IPM; its cost being Rs 1100/ha in IPM, compared to Rs 729/ha in non-IPM fields. Manuring included vermi-culture in some cases, while green manuring was practised in some other cases. Fertilizer cost was more in non-IPM (Rs 2039/ha) than in IPM (Rs 1528). Similarly, the cost of plant protection chemicals was higher (Rs 1829/ha) in non-IPM, compared to (Rs 1461/ha) in IPM fields. Use of resistant varieties, seed treatment, timely and judicious application of pesticides together with other recommended practices brought down the cost of plant protection in IPM. Both gross returns and net returns were more in IPM than in non-IPM fields. The results from both the research farms and farmer's fields indicated economic profitability of IPM technology in paddy cultivation.

Cotton

At the Regional Agricultural Research Station, Lam, the total cost of cultivation of cotton was Rs 31768/ha in IPM and Rs 33606/ha in non-IPM (Table 4); and the net returns were Rs 7732/ha and Rs 2394/ha, respectively.

The cost of manuring was higher in IPM (Rs 3755/ha) than in non-IPM (Rs 2050/ha). The cost of labour was also higher in IPM technology. Use of cultural and mechanical practices, such as clean cultivation, removal of cotton stubbles after last picking, topping of cotton plants when maximum egg laying of *Helicoverpa armigera* was noticed, etc. increased the cost of labour. A huge expenditure was incurred on pesticides on non-IPM fields. It was found that IPM technology helped in reducing the cost of cultivation of cotton under experimental conditions.

The cost of plant protection chemicals was higher (Rs 9688/ha) in non-IPM farms than in IPM farms (Rs 5676/ha). It was observed that farmers were highly irrational in using pesticides. They used costly synthetic pyrothroids

Table 4. Costs and returns of cotton production with IPM and non-IPM technologies under experimental conditions

(Rs/ha)

Particulars	IPM	Non-IPM
Operational costs		
Seeds	625 (1.97)	725 (2.15)
Manure (FYM)	3755 (11.82)	2050 (6.10)
Plant protection inputs	2950 (9.28)	5900 (17.56)
Fertilizers	1500 (4.72)	4093 (12.17)
Irrigation charges	250 (0.79)	-
Total cash costs	9080 (28.58)	12768 (37.99)
Labour costs	12150(38.25)	11092(33.01)
Interest on working capital @ 12.5% for half of the crop growth period	663 (2.09)	746 (2.22)
Total operational costs	21893 (68.92)	24606 (73.22)
Fixed costs		
Rental value of owned land	9875 (31.08)	9000 (26.78)
Total costs	31768 (100)	33606 (100)
Returns		
Gross returns – main crop	34000	36000
Intercrops	5500	-
Gross returns	39500	36000
Net returns	7731	2394

Note: Figures within parentheses indicate percent to total.

and also mixed some of the pesticides and sprayed the mixture. They used pesticides even against diseases. Farmers sprayed these chemicals 15 to 18 times on the crop, as against the recommendations of 5-6 sprayings only. It was learnt that the extension system was highly unsuccessful in educating cotton farmers in Andhra Pradesh. The farmers had to suffer huge losses due to pests.

The total cost of cultivation of cotton worked out to be Rs 33050/ha in IPM and Rs 37244/ha in non-IPM, and the net returns were Rs 4,984/ha and Rs 2,085/ha in IPM and non-IPM, respectively.

Non-Pesticide Management (NPM)

NPM is a systems approach that combines a wide array of crop production and protection technologies with a careful monitoring of pests and

Table 5. Cost of cultivation of cotton under farmers' condition: IPM technology vs non-IPM technology

(Rs/ha)

Particulars	IPM	Non-IPM
Operational costs		
Human labour	8504 (22.83)	9045 (27.36)
Hired	5268 (14.12)	5851 (17.80)
Family	3246 (8.71)	3194 (9.66)
Bullock labour	1822 (4.89)	1934 (5.85)
Hired	1083 (2.90)	857 (2.59)
Owned	738 (1.98)	1077 (3.26)
Machine labour	1203 (3.23)	1266 (3.83)
Hired	1020 (2.74)	1266 (3.83)
Owned	183 (0.49)	-
Manures	563 (1.51)	1462 (4.34)
Produced	325 (0.87)	824 (2.49)
Purchased	238 (0.64)	609 (1.84)
Seeds	2273 (6.10)	2122 (6.42)
Fertilizers	4069 (10.92)	3148 (9.52)
Plant protection inputs	9688 (26.01)	5676 (17.17)
Interest on working capital	879 (2.35)	768 (2.32)
Total	29000 (77.86)	25335 (76.65)
Fixed costs		
Land revenue	18 (0.05)	18 (0.05)
Depreciation	906 (2.43)	698 (2.11)
Interest on fixed capital	790 (2.12)	660 (1.20)
Rental value of owned land	6555 (17.53)	6339 (19.18)
Total	8245 (22.13)	7715 (23.34)
Total costs	37244 (100)	33050 (100)

Note: Figures within parentheses indicate percentage of total.

conservation of natural enemies in the eco-system. The NPM is basically a bottom up approach emphasizing empowerment of farmers. It is a decision-making support system which is economically viable, environmentally sustainable and socially acceptable. The Centre for World Solidarity in association with 12 NGOs has demonstrated the economic feasibility and sustainability of this approach in 810 ha area in Andhra Pradesh. The crops covered were pigeonpea and groundnut. The NPM incorporates the use of a combination of two or more of the following practices: deep summer ploughing, tolerant varieties, random planting, intercropping, trap cropping,

Table 6. Returns from paddy cultivation with IPM and non-IPM technologies under farmers' conditions

(Rs/ha)

Returns	IPM	Non-IPM
Productivity main crop (q/ha)	17.25	18.87
Intercrop (q/ha)	3.21	-
Gross income	38034	39330
Net income	4984	2085

neem seed kernel extract (NSKE) (5%), neem oil (3%), tobacco decoction, chilli garlic extract, cattle dung and urine, pheromone traps @ 5/ha, release of *Trichogramma*, light traps, bird perches @ 25/ha, yellow sticky plates @ 5/ha, white sticky plates @ 5/ha, yellow rice to attract birds, use of Nuclear Polyhedrosis Virus (NPV) 500 LE/ha (in case of pigeonpea), poison baits, and shaking of the plant.

The economics of NPM on cotton, pigeonpea and groundnut are provided in Tables 7, 8 and 9, respectively. The farmers could experience the benefits of NPM, viz. conservation of natural enemies of insects, higher yields and

Table 7. Economics of cotton production, 2000-2001

NGO	Yield (q/ha)		Cost of plant protection (Rs/ha)		Net income (Rs/ha)	
	NPM	Non-NPM	NPM	Non-NPM	NPM	Non-NPM
CROPS	10.98	8.90	950	7615	14112	770
MARI*	18.76	20.0	1178	4790	28115	19065
NAVAJYOTHI*	12.02	9014	1982	5322	13622	3952
SWARD	13.62	9.50	1826	9815	16056	1358

*****Under irrigated conditions

Table 8. Economics of NPM in pigeonpea cultivation, 2000-2001

NGO	Yield (q/ha)		Cost of plant protection (Rs/ha)		Net income (Rs/ha)	
	NPM	Non-NPM	NPM	Non-NPM	NPM	Non-NPM
CROPS	4.0	2.60	325	1235	6130	819
NAVAJYOTHI	20.0	22.0	641	2206	10192	5270
PEACE	3.0	3.6	192	452	3148	3332

**Net income includes income from intercrops

Table 9. Economics of NPM in *rabi* groundnut cultivation, 2000-2001

NGO	Yield (q/ha)		Cost of plant protection (Rs/ha)		Net income (Rs/ha)	
	NPM	Non-NPM	NPM	Non-NPM	NPM	Non-NPM
SPEAK INDIA	7.9	2.35	624	704	4195	-5332
CAFORD	14.6	9.78	283	985	8595	1062

**Net income includes income from intercrops

less cost of plant protection. More than 50% of the women farmers from the 'self-help groups' of the partner NGOs participated in the programme. *Dalit* (socially backward) farmers also participated in the programme.

Constraints in Adoption of IPM

- By offering seeds, fertilizers and pesticides on credit to the farmers, pesticide dealers pose a threat to IPM
- Pesticides companies use mass media like television and newspapers for poularizing their products through attractive advertisements
- Farmers are addicted to subsidy and they always look for some financial support for adopting NPM methods
- Bio-pesticides, biocontrol agents and other IPM components are not readily available
- There is no government machinery to monitor the quality of bio-pesticides; consequently, the desired results are not observed in many cases
- Large farmers discourage small farmers in adopting IPM methods by emphasizing more on their risky and unstable nature
- Scientific community is constrained in recommending use of IPM technology because farmers may ask for compensation in case of failures.

Recommendations

- Intensive research is needed to standardize the IPM packages for different crops

- Demonstration of socio-economic benefits of IPM on a large scale for its horizontal spread
- Bio-pesticides, biocontrol agents, etc. should be made available to farmers in adequate quantities
- Incentives may be provided to the farmers for adopting IPM.

14

Economics of Integrated Pest Management in Paddy in Bihar

Amalendu Kumar[1]

Introduction

Paddy is an important food crop in Bihar occupying more than 45 percent of the total cultivated area. The paddy yield, however, is low compared to that in many Indian states. It is because of low level of adoption of agricultural technologies. Besides, insect pests and diseases are important yield limiting factors in the state. Pesticide-use is low partly because farmers are poor and lack capacity to invest in cash inputs. On the other hand, emerging pest management technologies like integrated pest management (IPM) demand less of capital, and more of labour. Labour being abundantly available in Bihar, offers an opportunity to farmers in Bihar to switch over to IPM technology in a cost-effective manner. This paper assesses economic feasibility of IPM in paddy in Bihar.

Methodology

The study was conducted in two districts of Bihar, viz. East Champaran (Motihari) and West Champaran (Betiah). IPM demonstrations were conducted in these districts during 1994-95 to 1996-97. The demonstrations covered a total of 20 villages during this period, out of which 10 villages were selected for the present study. At the second stage of sampling, 50 IPM farmers proportionately distributed among the selected villages were selected from each district. Similarly, 50 non-IPM farmers were selected from each district for a comparison. IPM farmers were trained in Farmers' Field School (FFS).

Twenty-six percent FFS farmers were marginal farmers (< 1 ha), 27 percent small (1-2 ha), 28 percent medium (2-4 ha) and 19 percent were large

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farmers. Likewise, 21 percent non-FFS belonged to marginal, 31 percent to small, 29 percent to medium and 19 percent to the large category. The cropping pattern on both FFS and non-FFS farms was more or less the same; 56 percent of the gross cropped area was occupied with paddy, followed by wheat (27 percent). About 50 percent area had access to irrigation through canal, tank and tube-well.

Status of IPM in Bihar

The National Integrated Pest Management Programme is being organised in the state since 1994-95. During the last 5 years, 63 districts have been selected for demonstrations on crops like paddy, vegetables, pulses, oilseeds, etc. (Table 1).

Under the programme 248 FFS were organised, 1010 extension workers and 7220 farmers were trained. The total area covered under demonstration was 9920 hectares. Out of 63 demonstrations conducted, 57 were for paddy. Number of demonstrations however has been falling continuously.

Insect Pest Incidence

Paddy is attacked by a number of pests such as stem borer, gundhi bug, brown plant hopper, paddy skipper, green leaf hopper and army worms.

Table 1. Status of IPM in Bihar, 1994-95 to 1997-98

Year	Districts covered	Crops covered	No. of FFS organised	No. of extension personnel trained	No. of trained farmers	Area covered (ha)
1994-95	17	Paddy	68	333	2040	2720
1995-96	17	Paddy	68	272	2040	2720
1996-97	19	Paddy	76	304	2280	3040
1997-98	2	Vegetables	8	21	240	320
1997-98	4	Paddy	12	60	360	480
1997-98	2	Vegetables	8	20	240	320
1997-98	1	Pulses	4	—	—	160
1997-98	1	Mustard	4	—	—	160
Total	63		248	1010	7200	9920

Source: Office of the Joint Director Agriculture (PP) Bihar, Patna.

‘Saryug 52’ was the main rice variety grown by the respondents, covering nearly 70 percent of the total paddy area (Table 2). VIP Dhan and Sona Mansuri occupied rest of the area. On Saryug 52, stem borer incidence occurs every year in early stage of its growth; and remains active up to the harvesting stage. It causes damage to the extent of 20-30 percent. Some other insect pests also cause losses, but to a lesser extent.

Farmers’ Awareness about IPM

Farmers’ awareness about different components of IPM is presented in Table 3. Awareness about training was the highest among large farmers,

Table 2. Incidence of insect pests in paddy on sample farms

Variety	Pest	Stage of arrival	Percent damage	
			FFS	Non-FFS
Saryug 52	Stem borer	Tillering	20-25	20-30
	Gundhi bug	Flowering	10-15	15-20
	Brown plant hopper	Vegetative	10-15	15-20
VIP Dhan	Gundhi bug	Flowering	<10	<10
	Paddy skipper	Vegetative	15	20
Sona Mansuri	Army worm	Tillering	15	15
	Stem borer	Tillering	15-20	20-25
Local	Gundhi bug	Flowering	10-15	15-20
	Green leaf hopper	Tillering	upto 15	upto 15

Table 3. FFS farmers’ awareness about different component of IPM

Components	Awareness	Farm category					Chi-square
		Marginal	Small	Medium	Large	Overall	
Training	Aware	27	41	29	68	41	9.82*
	Not aware	73	59	71	32	59	
Mechanical control	Aware	19	30	68	53	42	15.7***
	Not aware	81	70	32	47	58	
Biological control	Aware	8	19	29	21	19	3.88**
	Not aware	92	81	71	79	81	
Reduced use of pesticides	Aware	31	41	54	26	38	4.55**
	Not aware	69	59	46	74	62	

*, ** and *** indicate level of significance at 1, 5 and 10%, respectively.

followed by small, medium, and marginal farmers. However, awareness about mechanical control, biological control and reduced use of pesticides was higher among medium farmers.

A comparison of awareness coefficients of non-FFS with FFS farmers indicated that non-FS farmers were less aware of IPM (Table 4). The reason being their non-acquaintance with IPM programme.

Cost Effectiveness of IPM

On an average FFS farmers incurred a cost of Rs 8542, which was about 6.5 percent higher than that of the non-FFS farmers (Table 5). Human and bullock labour together accounted for about 78 percent of this on both FFS and non-FFS farms. Further, a distinct positive relationship was observed between farm sized and cost of cultivation.

Pesticides shared 2.4 percent of the total cost on FFS farms and 3 percent on non-FFS farms. In absolute terms, pesticide cost was Rs 202/ha on FFS and Rs 241/ha on non-FFS farms. This indicated that application of IPM could reduce the pesticide-use, but marginally. Marginal and small farmers used less pesticide, compared to that by medium and large farmers.

There was little difference in mean yield of paddy between FFS and non-FFS farms; per ha yield being 2450 kg on FFS farms and 2402 kg on non-FFS farms. Unit cost of production was Rs 3.48/kg on FFS and Rs 3.36 on

Table 4. Non-FFS farmers' awareness about different component of IPM

Components	Status of Awareness	Farm category: Marginal	Small	Medium	Large	Overall	Chi-square
Training	Aware	19	19	19	11	17	0.77**
	Not aware	81	81	81	89	83	
Mechanical control	Aware	10	3	30	21	16	8.78*
	Not aware	90	97	70	79	84	
Biological control	Aware	0	0	7	5	3	3.67**
	Not aware	100	100	93	95	97	
Reduced use of pesticides	Aware	19	26	22	11	19	1.77**
	Not aware	81	74	78	89	81	

***, ** and * significance at 1, 5 and 10%, respectively.

Table 5. Farm size-wise cost of cultivation of paddy (Rs/ha)

Particulars	FFS farmers					Non-FFS farmers				
	Marginal	Small	Medium	Large	All	Marginal	Small	Medium	Large	All
Cost of labour	6347	6598	6739	6730	6684	5671	5961	6217	6339	6188
(human + bullock)	(83.1)	(81.2)	(17.7)	(76.4)	(78.1)	(81.8)	(80.7)	(75.7)	(75.3)	(77.7)
Seed	270	279	280	314	291	246	270	262	288	272
	(3.5)	(3.4)	(3.2)	(3.6)	(3.4)	(3.6)	(3.7)	(3.9)	(3.4)	(3.4)
Fertilizer	117	232	485	503	421	89	167	529	536	267
	(1.5)	(2.8)	(5.6)	(5.7)	(4.9)	(1.3)	(2.3)	(6.4)	(6.4)	(3.3)
Pesticide	0.0	84.9	206	294	202	64	98	266	311.9	241
	(0.0)	(1.0)	(2.4)	(3.3)	(2.4)	(0.9)	(1.3)	(3.2)	(3.7)	(3.0)
Other	904	931	963	970	956	864	890	936	948	1104
	(11.8)	(11.5)	(11.1)	(11.0)	(11.2)	(2.5)	(12.0)	(10.7)	(11.3)	(12.6)
Total	7639	8121	8672	8811	8554	6933	7386	8210	8423	8072
	(100.0)	(100.0)	(100.0)	(100.0)	(100.0)	(100.0)	(100.0)	(100.0)	(100.0)	(100.0)
Average yield (kg/ha)	2201	2155	2767	2681	2450	2138	2390	2519	2463	2402

non-FFS farms. This indicated that though IPM had the potential to reduce pesticide-use, but it did not appear to be as efficient as chemical control. It could be because of more use of labour in IPM applications.

Integrated Pest Management and the Environment

This section documents respondents' perceptions regarding impact of pesticides on environment. FFS farmers' awareness coefficient concerning adverse effect on human health ranged between 58 percent (marginal farmers) and 75 percent among medium farmers. On the whole 67 percent FFS farmers were aware of the hazards to human health due to pesticides.

These farmers were also aware about their adverse effect on animal health, environmental and beneficial insect, but awareness coefficient was low compared to that about human health. Awareness was found to be positively correlated with farm size. Compared to FFS farmers, the awareness about these effects was less among non-FFS farmers.

Farmers' Response to Pest Control Methods

A majority of the FFS farmers was aware of different methods (cultural, manual, crop rotation, and chemical pesticides) of pest control. Every farmer was aware of chemical control, but none of them was aware about biological control. About two-thirds of the FFS farmers used pesticides to limit pest

Table 6. FFS farmers' awareness of adverse effects of pesticides

(in percent)

Factor	Status of awareness	Marginal farmers	Small farmers	Medium farmers	Large farmers	All
Hazards to human health	Aware	58	67	75	68	67
	Not aware	42	33	25	32	33
Hazards to animal health	Aware	35	26	68	63	48
	Not aware	65	74	32	37	52
Environmental pollution	Aware	19	48	64	79	53
	Not aware	81	52	36	21	47
Harm to friendly insects	Aware	37	41	57	42	44
	Not aware	63	59	43	58	56

Table 7. Non-FFS farmers' awareness about adverse effects of pesticides

(in percent)

Factor	Status of awareness	Marginal farmers	Small farmers	Medium farmers	Large farmers	All
Hazards to human health	Aware	43	45	55	58	50
	Not aware	57	55	45	42	50
Hazards to animal health	Aware	19	26	41	37	31
	Not aware	81	74	59	63	69
Environmental pollution	Aware	5	10	21	21	14
	Not aware	95	90	79	79	86
Harm to friendly insects	Aware	00	6	24	16	12
	Not aware	100	94	76	84	88

infestation. Use of other methods was limited. Except on large farms, a positive relationship was observed between farm size and awareness and use of different components of IPM.

A comparison of these results with those of non-FFS farmers indicated that non-FFS farmers were less aware about the different components of IPM

Table 8. FFS farmers' response to awareness and use of different pest control methods

(in percent)

Pest control technology	Status of aware/Use	Farmers: Marginal	Small	Medium	Large	Overall
Cultural control	Aware	54	59	68	79	65
	Use	15	26	26	16	21
Crop rotation	Aware	81	89	79	100	87
	Use	8	33	47	26	28
Manual control	Aware	58	70	86	89	76
	Use	31	22	25	5	21
Biological control	Aware	65	52	61	95	68
	Use	0	0	0	0	0
Chemical pesticides	Aware	100	100	100	100	100
	Use	69	48	86	95	74
Seed treatment	Aware	19	41	75	84	55
	Use	0	7	25	26	15

(Table 9). This indicated that IPM programme had created less awareness about different components of IPM, and also helped promote their application only to some extent.

Constraints to Adoption of IPM

An attempt has been made to identify the field level constraints in adoption of IPM for paddy crop in Bihar. The results are presented in Tables 10 and 11.

The major constraints being faced by FFS farmers included unavailability of biocontrol agents, lack of extension backup, lack of involvement of IPM experts and lack of IPM inputs. For non-FFS farmers, these included unavailability of biocontrol agents, lack of IPM inputs, lack of extension support and lack of proper training.

The constraints faced by medium and large farmers are given in Table 10. Unavailability of biocontrol agents, lack of proper training involvement of

Table 9. Non-FFS farmers' response to awareness and use of different pest control methods

(in percent)

Pest control technology	Status of aware/Use	Farmers				
		Marginal	Small	Medium	Large	Overall
Cultural control	Aware	42	45	58	57	51
	Use	9	16	6	0	8
Crop rotation	Aware	61	61	89	78	75
	Use	19	16	27	10	18
Manual control	Aware	57	54	72	78	65
	Use	4	16	10	0	7
Biological control	Aware	19	22	91	31	28
	Use	0	0	0	0	0
Chemical pesticides	Aware	100	100	100	100	100
	Use	100	87	100	100	97
Seed treatment	Aware	19	41	75	84	55
	Use	0	0	7	11	6

Table 10. Ranking of constraints in adoption of IPM in paddy by marginal and small farmers

Constraints	FFS Farm		Non-FFS farm	
	Marginal rank	Small rank	Marginal rank	Small rank
Lack of proper training facilities	5	4.5	1.5	4
Lack of extension back up	6	2	3.5	3
Lack of IPM inputs	3	4.5	3.5	1.5
Lack of assured irrigation	4	6	5	5
Lack of involvement of IPM experts	1.5	3	6.5	7
Lack of confidence	8	8	6.5	9
Fragmented lands	9	9	8.5	8
Unavailability of bio-control agents	1.5	1	1.5	1.5
Unevenness of land	7	7	8.5	6

Table 11. Field level constraints on non-adoption of IPM as perceived by the marginal and small farmers

Constraints	FFS Farm		Non-FFS farm	
	Marginal rank	Small rank	Marginal rank	Small rank
Lack of proper training facilities	4.5	6.5	3	5.5
High wages of labour	10	3	7	3.5
Time taken initiatives	7	2	4	8
Lack of extension backup	2	5	9	9
Lack of involvement of IPM experts	4.5	4	8	1.5
Lack of confidence	8	10	5.5	7
Fragmented lands	9	9	10	10
Unavailability of bio-control agents	1	1	1.5	1.5
Unevenness of land	3	8	5.5	3.5
Lack of IPM inputs	6	6.5	1.5	5.5

IPM experts, lack of confidence in IPM and high wages of labour were the main constraints faced by these groups of farmers.

Conclusions

The study finds that paddy crop is attacked by a number of pests in both FFS and non-FFS farms. But the damage caused by stem borers has been heavy because it attacks at the tillering stage of the crop and remains active up to the harvesting stage. It causes about 30 per cent losses to the crop.

Cost of pesticides on paddy in both FFS and non-FFS farm does not differ significantly, the FFS farmers could reduce the use of pesticides marginally. There is a lack of awareness about IPM components both among FFS and non-FFS farmers. The non-FFS farmers, however, are less aware about IPM components. The use of these components is also less.

Both FFS and non-FFS farmers face a number of constraints, the prominent being lack of IPM inputs, lack of training and extension support.

15

Farmers' Perceptions, Knowledge and Practices Related to Rice IPM – A Case Study

Gururaj Katti[1], I.C. Pasalu[1], P.R.M. Rao[2], N.R.G. Varma[1] and K. Krishnaiah[1]

Introduction

The West Godavari district of Andhra Pradesh state in India is considered as a part of the 'rice bowl of India'. The rice-based cropping system is highly intensive, and a majority of the farmers harvest two crops of rice a year. More than 90 percent of the area is irrigated through canals. The average yield of rice is more than 5 t/ha. Farmers of this region practise intensive agriculture, using high-yielding rice varieties, adoption of improved agronomic practices like fertilizer application, water management, pest management, etc.

Research and development in pest management has not always resulted in adoption of improved practices due to a number of technological, social, economic and environmental constraints (Norton and Mumford, 1993). Further, the pest management practices followed by the farmers represent their decision-making ability, which is mainly influenced by their perceptions. The farmers choose such pest management options that appear to meet their objectives. The choice of technology is also influenced by their beliefs and attitudes towards the technology. Therefore, an understanding of the factors that affect their perceptions, knowledge and practices is critical in designing the effective management strategies (Litsinger *et al.*, 1980, Escalada 1985; Sivakumar *et al.*, 1997).

A farmers' survey is an important data-gathering process for assessing the needs of intended beneficiaries, to determine their level of knowledge

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and perceptions about the pest problems, and their attitudes towards pest management. If carefully designed and implemented, these surveys can guide both the research and extension workers to identify gaps in knowledge, misconceptions or inappropriate practices (Bentley and Andrews, 1996). Such findings related to the rice farmers of Asia have been documented by Heong and Escalada (1997). In India, Shivkumar *et al*. (1997) have reported the pest management practices of rice farmers in Tamil Nadu.

The present study is an effort to find the pest management perceptions, knowledge and practices of the farmers of the West Godavari region (AP). This study followed a preliminary survey carried out in 1998 (Katti *et al.,* 1999), which revealed that a majority of the farmers of this region had achieved high yields (> 5 t/ha) and they attributed it mainly to high pesticide-use. At the same time, some farmers were able to obtain high yields despite less use of pesticides. Keeping these contradictions in view, present study was undertaken to determine beliefs and pest management practices (pesticide-use, frequency, timings and targets) of the farmers, and to compare the differences in beliefs and pest management practices of high and low pesticide users.

Materials and Methods

Study area and data collection

The study was carried out in 21 villages of the West Godavari district. Double cropping of rice is practised throughout the region and the entire rice is transplanted. Data were collected using structured questionnaires by the trained enumerators. The questionnaire was pre-tested with a sample of 50 farmers and certain queries were modified to get more accurate information. A total of 512 randomly selected farmers were interviewed.

Measuring belief, attitudes and subjective norms

Attempts were made to measure the differences in the attitudes of the farmers after grouping them into high and low pesticide users, based on the number of pesticide applications. Twelve attributes related to the impact of pesticides on rice yields, and four attributes related to the cultural management practices were included to measure the differences using the pest belief model (Heong and Escalada, I999) and Fishbein and Ajszen's theory of reasoned action (TRA) (Normiyah *et al.*, 1995).

Each respondent was asked to assess individually the degree of belief (b_i) using descriptor phrases on a 5-point Likert Scale. The descriptors were: 'definitely not true', 'in most cases not true', 'may be true', 'in most cases true' and 'always true'. The farmers were asked to evaluate the importance of each of the beliefs (e_i) by using the following 5 descriptors: 'completely not important to me', 'not important to me', 'no opinion', 'important to me' and 'very important to me'.

Subjective norms (or peer pressure) were measured by assessing each respondent's perception of what specific reference groups expected him to do. The five reference groups were: neighbourers (other farmers), village leaders, spouses, plant protection technicians, and pesticide retailers. For the measure of normative belief (nb_i), each respondent was asked the following questions: 'what do you think each reference group expected you to do for pests observed in rice crop'. Responses were assigned scores as follows:

Never spray pesticides = 1
Spray pesticides once in more than 2 years = 2
Spray pesticides once every 2 seasons (occasionally) = 3
Spray pesticides at least once a season (frequently) = 4
Always spray pesticides every season = 5
No expectation = 6

The measure of motivation to comply (mc_i) was determined by another set of 5 questions for the reference group. How much do you care about what each reference group thinks you should do? Responses were assigned scores as follows:

I do not care at all = 1
What they think I should do is not so important = 2
What they think I should do will have no influence on what I do= 3
What they think I should do is important = 4
What they think I should do is very important= 5

Results and Discussion

Profile of farmers

Most of the farmers were aged around 40 years, and half of them had education up to matriculation while 38 percent were illiterate. Average farmholding was about 2 ha with an average yield of 7.48 t/ha (Table 1).

Pest management practices

A majority (> 70%) of the farmers felt that sheath blight was the most serious pest (rank 1) followed by planthopper (rank 2) and rats (rank 3). All the farmers applied pesticides to control the serious pests. The number of pesticide applications ranged from 1 to 12, a majority of them (75 %) gave

Table 1. Profile of farmers interviewed and pesticide-use timings, frequency, cost and yield

Attributes	Central tendency measures		
	Mean	Median	Mode
Age (years)	42.3	40	40
Area (farmholding in acres)	4.38	3.0	2.0
Experience in rice farming (years)	18.45	16.0	10.0
Timings of first insecticide application (DAT)	26.5	20.0	15.0
Timings of first fungicide application (DAT)	33.5	35.0	40.0
Number of pesticide applications			
Insecticides	3.19	2.0	3.0
Fungicides	1.99	2.0	2.0
Total	5.08	4.0	5.0
Amount spent (Rs/ha) on pesticide-use			
Insecticides	1105	1000	1750
	(1197)	(1200)	(494)
Fungicides	527	500	1000
	(976)	(775)	(775)
Pesticides	1632	1500	2750
	(2175)	(2132)	(1269)
Yield (kg/ha)	7484	7500	7500

Figures within the parentheses are the actual cost of pesticide-use calculated from the dose of pesticide applied.

3 to 6 applications in a season. On an average, five applications were given, which included three applications of insecticides and two of fungicides. The first insecticide application was given within 26 days after planting, while the fungicides were applied after 33 days of planting. The insecticides applied included a variety of chemicals; carbofuran, phorate and cartap among granular formulations and acephate, monocrotophos, chlorpyriphos and phosphamidon. Among fungicides, the use of hexaconazole, propiconazole, bavistin and dithane was common. No rodenticide was applied for rat control.

Pest management variables

Farmers spent on an average Rs 2175/ha towards pesticides (Table 1), Rs 1197 towards insecticides and Rs 976 towards fungicides. The average yield was 7484 kg/ha.

Estimates indicated that farmers would have incurred a loss in revenue up to Rs 9,728 ha (resulting from an average of 32.5% loss due to pests as mentioned by them) if no pesticides were applied to control them (Table 2).

Table 2. Comparison of attributes related to pesticide-use between low and high pesticide-users

Attributes	Pesticide users		
	Low (< = 4) n =223	High (> 4) n =289	Overall Mean
No. of pesticide applications	3.42	6.22	5.02
Amount spent			
Insecticides (Rs/ha)	897	1252	1105
Fungicides (Rs/ha)	615	465	527
Pesticides (Rs/ha)	1512	1717	1632
Estimated yield loss if pest control was not applied (%)	25.9	37.6	32.5
Yield (t/ha)	6.90	7.93	7.48

The number of pesticide applications was significantly correlated with the amount spent on pesticides (r = 0.57) and the expected loss prevented (r = 0.56).

Pest management practices and beliefs of high and low pesticide-users

Depending upon the number of pesticide applications, farmers were grouped into high and low pesticide-users for a comparison of their pest management practices and beliefs. The low pesticide-users included farmers adopting recommended practice of < 4 applications of pesticides for control of both insect pests and diseases. Farmers applying more than 4 applications constituted high pesticide-user group.

About 44% farmers were in the category of low pesticide-users, while 56% farmers applied pesticides more than 4 times. A comparison of the pesticide-use related attributes revealed that low users applied pesticides on an average 3.4 times during the season, compared to 6.2 times by the high users. The amount spent on insecticides was slightly higher in the high user-group (Rs 1252/ha), compared to Rs 897/ha by the low user-group. The high use group spent less on fungicides (Rs 465) than that by low user-group (Rs 615/ha). The perceived loss was also more in the high user-group (37.6%) than in the low user group (25.9%). Also, the average yield level was one tonne/ha less in the low user-group.

Beliefs and attitudes towards pest management and crop yield

The mean belief scores of 17 attributes related to the impact of pesticides and cultural management practices on rice yield are recorded in Tables 3 and 4. Mean scores were used for comparisons. A score of 3 suggeststed indifference, >3 implied strong beliefs and < 3 showed weak beliefs.

High users strongly felt that more sprays were needed to increase the yield, and pesticide mixtures were more effective. The low user-group also felt that more sprays were needed to increase the yield; however, they did not believe strongly that pesticide mixtures were effective. Both the groups did not feel that using high concentration of pesticides was more effective. The low-user group felt that calendar spraying was not essential, while higher user-group showed its willingness towards calendar application of pesticides.

Both the groups strongly felt that beneficial insects could limit pest population, applying more pesticides could be detrimental to human health and indiscriminate use of pesticides was harmful to non-target organisms. Both the groups also agreed that the information provided by the government/

Table 3. Farmers' attitude towards impact of pesticides on rice yields

	Attributes	Score					
		Low (< 4)		High (> 4)		Overall mean	
		(b_i)	(e_i)	(b_i)	(e_i)	(b_i)	(e_i)
(i)	If you aim to increase yields you need to use more sprays	3.07	3.31	3.61	4.25	3.37	3.84
(ii)	Pesticide mixtures are more effective if there is more than one pest in the field	2.72	2.83	3.76	3.88	3.31	3.42
(iii)	Using high concentrations of pesticides is more effective	2.16	2.12	2.45	2.17	2.32	2.14
(iv)	Calendar spraying is not essential to high production	3.00	3.20	2.32	2.53	2.61	2.82
(v)	Beneficial insects can limit pest populations	3.88	4.00	3.94	4.19	3.91	4.10
(vi)	To get high yield, all insect pests need to be killed	3.07	3.02	2.58	2.64	2.79	2.81
(vii)	Applying more pesticides can cause more pest problems	3.27	2.76	3.32	2.42	3.30	2.059
(viii)	Applying more pesticides can be detrimental to human health	4.04	4.12	4.25	4.32	4.16	4.23
(ix)	Indiscriminate use of pesticides is harmful to non-target organisms in the rice field/environment	3.98	3.82	3.96	3.90	3.97	3.87
(x)	Prophylactic pesticide application is better than control	3.15	3.17	2.87	3.06	2.99	3.11
(xi)	Pests reproduce so quickly that farmers do not have time to make spray decisions based on scouting	2.86	3.17	2.68	3.32	2.76	3.26
(xii)	Information provided by govt/extension workers is a good guideline for deciding when a farmer needs to spray	3.31	3.73	3.45	3.78	3.39	3.76

b_i = belief, e_i = evaluation

Table 4. Farmers' attitude towards cultural management practices and rice yields

	Attributes	Score					
		Low (< 4)		High (> 4)		Overall mean	
		(b_i)	(e_i)	(b_i)	(e_i)	(b_i)	(e_i)
(i)	High asynchrony of crops attracts more pests	2.75	2.46	3.31	2.38	3.07	2.42
(ii)	High nitrogen-use leads to more pests	3.92	3.68	4.14	3.32	4.04	3.36
(iii)	High cropping-intensity causes more pests	3.77	3.42	3.99	3.10	3.89	3.24
(iv)	Planting modern varieties reduce pest problems	3.79	3.81	3.97	4.03	3.89	3.93

b_i = belief, e_i = evaluation

extension agencies was a good guideline for the farmers to decide when to apply pesticide.

Scores on attitude towards cultural management practices and rice yield revealed that both the groups felt that high nitrogen-use and 'high cropping-intensity led to more pests, and planting modern varieties would reduce pest problems.

Beliefs and attitudes towards subjective norms

The impact of reference group (or peer groups) influencing farmers' pesticide-use decision was interpreted based on the mean scores of normative beliefs and motivation. Among the five groups, plant protection technicians (20.64) and neighbours (18.84) had the maximum influence followed by pesticide retailers (14.72) and village leader (14.40). The data revealed that spouses (12.61) had the least influence (Table 5).

Table 5. Farmers attitudes to the subjective norm in the behaviour: Sprarying pesticides for pest control

Reference group	Mean	Mode	Median
Neighbours (nb_1mc_1)	18.84	20.00	20.00
Village leader (nb_2mc_2)	14.40	18.0	18.0
Spouses (nb_3mc_3)	12.61	12.0	6.0
Plant protection technicians (nb_4mc_4)	20.64	20.0	20.0
Pesticide retailers (nb_5mc_5)	14.72	15.0	5.0

Discriminant Analysis

Discriminant analysis was carried out to account for the differences in perceptions and beliefs of the high and low user groups. The results indicated that the age and education of the farmers played a major role, while experience and size of farm holding did not have much effect (Table 6).

Data showed that all the farmers applied pesticides against diseases. A variety of chemicals, including the newly introduced, were used, particularly against diseases. This indicated that farmers were not only aware of the recently marketed chemicals but were also ready to use them if they were effective. This was particularly evident in the use of newer chemicals like hexaconazole and propicanozole against sheath blight and acephate, bipvin and cartap against insect pests like planthopper, stem borer and leaf folder. Interestingly, no rodenticide was found in use despite rats being considered by farmers as an important pest. Some farmers used phorate to combat rat population believing that the rats would run away due to the smell of this chemical, while others employed locally available rat traps.

The farmers belief scores and correlation between beliefs and decision actions suggested that farmers' pest management decision-making was based on their perceptions about the target pest, extent of perceived loss, pesticide use, timing and frequency of application, etc. High pesticide-users were more in numbers than the low pesticide-users. This indicated that farmers in this region believed that more pesticides were needed to increase the yields. There was also a tendency towards calendar-based applications rather than need-based sprays. Both these attributes indicated that the farmers were anxious to save the crop at any cost in their urge to achieve

Table 6. Results of the discriminant analysis

A. Standardized canonical discriminant function coefficients

Age	0.734
Study	0.811

B. Classification of Results

Actual group	No.	Predicted group membership	
Group 1	223	157(70.4%)	66(29.6)
Group 2	289	163(56.4%)	126(43.6%)

Grouped correctly classified: 55.27%

higher yields. Rajagopalan (1983) also reported that the plant protection measures used by farmers were generally based on their anxiety to save the crop.

Farmers rated sheath blight as their number one enemy; however, insect pests seemed to be their primary concern, as illustrated by the higher number of insecticide applications given in a season.

The strong influence of the neighbours (other farmers) on farmers' decisions seemed to suggest that pesticides application is a social norm. But, the stronger influence of plant protection technicians revealed the possibility of building a new belief and value system among the farmers by imparting information, knowledge and skill through suitable and regular training as well as awareness programmes.

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Promotion of IPM: Efforts and Experiences of Private Sector

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Introduction

Agro-industries are business enterprises having the aim of profit-making. Returns on investment made by any individual, family/group or the public at large is essential for the growth and survival of the business enterprises. This drive is stronger in industries in the private sector than that in the public sector. Industries always look for opportunities to enhance their turnovers and profits. The evaluation of Integrated Pest Management (IPM) has offered a good opportunity of growth and sustenance to those agro-industries that follow certain principles and believe in improving human-life.

IPM and Its Evolution

The conceptualization of IPM had started with the discovery of pest resistance to pesticides during the early 1950s. IPM was first referred to as an integrated control mechanism by Stern *et al.* (1959) – as applied pest control, which combined and integrated biological and chemical controls. Over the years, IPM has evolved to encompass every activity that influences not only the pests but all the living beings – man, animal, plant and environment.

Of late, the definition of IPM, as provided in the FAO International Code of Conduct on the Distribution and Use of Pesticides, has become most accepted. It reads as, 'Integrated Pest Management is a system that, in the

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context of the associated environment and the population dynamics of the pest species, utilizes all suitable techniques and methods in as compatible a manner as possible and maintains the pest populations at levels below those causing economically unacceptable damage or loss'.

In reality, IPM boils down to implementing whatever is conceptualized and thus the authors subscribe to call IPM 'a design and decision making process for structuring ecosystems to minimize pest damage and coping with unavoidable pest problems'. While IPM changes as the information, conditions and technologies change, the criteria for judging its effectiveness, productivity, stability, sustainability, and equity do not. People in the fields with sound knowledge of pests and diseases, crops and cropping systems, and environment are important for the implementation and success of IPM.

Contribution of Pesticide Industry to IPM

Pesticide industry has played an important role, directly or indirectly, in the evolution of IPM from the beginning (i.e. from the 1950s) when reports on pests developing resistance to pesticides and pesticide residues in food and feed, etc. had started appearing. The industry offered new chemicals to tackle pest resistance and also worked for addressing the problems of safety to non-targeted organisms and the environment. The industry has contributed much to the development of IPM through their technological innovations and by offering services to extension workers and farmers.

Technological innovations

The industry always looks for technological innovations as these empower them to compete and perform better in the market place. It is this drive, which makes industry to produce superior products to the satisfaction of consumers. Up-gradation of IPM that we have seen over the years has emerged largely from this consideration. Some important initiatives of the industry that have helped in shaping the IPM are given below:

Products with new chemistry

Pesticide industry has always looked for new chemistry to produce products with new promises of less persistence and high specificity to pests, low mammalian toxicity, safety to natural enemies, etc. From chlorinated hydrocarbons of the 1940s-50s, organophosphates and carbamates of the

1960s-80s, and pyrethroids of the 1970s-90s, the industry has moved to producing pesticides with newer chemicals including pyrroles, azoles, sulphonyl ureas, etc. Such products work with different modes of action and are effective at very low dosages (< 50 a.i./ha). The scenario of pest management is now changing worldwide to have the minimum possible pesticide load in the environment.

Production of safer pesticide formulations

Over the years, the pesticide industry has produced several new formulations, including replacement of the old ones, largely with the objectives of offering pesticides that provide greater safety to users with low risk of polluting the soil, water and air. Formulations such as Aqua Flow (AF), Suspension Concentrate (SC), Water Dispersible Granules, Concentrated Solution (CS), Microemulsions (ME), Suspension Emulsions (SE), etc. are also now available in the market.

Bioproducts and biopesticides

During the past decade, the industry has also ventured into the production of bio- pesticides and natural enemies of pests. Over a dozen of industrial units in India are now producing and marketing products based on botanicals (Azadirachtin), pathogens, parasites and predators *(Bacillus thuringiensis,* NPV, *Verticillium, Beauveria, Trichogramma, Bracon, Chrysopa, Coccinelid*, etc.) against insect pests, and *Trichoderma, Pseudomonas, Paecilomyces,* etc. against plant pathogens. Other biological products such as pheromones and mechanical devices such as light traps that help monitor and suppress pests are also now available in the market.

Genetically engineered plants

It is a great technological innovation based on large investments from the industry. It is going to revolutionize the agriculture world. The biotechnological mode of incorporating genes into plants to get the desired traits is going to make a big contribution to IPM. It enables plants to fight pests and diseases by making them produce toxins. Although there are apprehensions about the use of this technology, days are not far off when the use of pesticide would become minimum with the use of transgenic plants. *Bt* cotton against the lepidopteran pests, particularly the most dreaded *Helicoverpa*, has already made a dent in cotton production in several countries, including the USA, Australia, China. India has also made a modest beginning in this direction.

Pesticide application technology

During the past decade, a few industrial houses, including Monsanto and Excel, have started marketing selected pesticide appliances to improve the use and effectiveness of products. The manufacturers of pesticide appliances have innovated their appliances leading to improvement in pesticide application technology, which is an important component of IPM.

Services

Pesticide industry individually and through their associations offers plant protection services to its customers. In India, three such associations – the Indian Crop Protection Association (ICPA), Pesticide Association of India (PAl), Pesticide Manufacturers and Formulators Association of India (PAFAI) – are in operation. These associations liaise with the pesticide regulatory and law enforcing authorities and agencies and work for the advancement and improvement in plant protection. With the greater national and international thrusts and stringent policies, almost all have embraced working with IPM. For instance, the strategic objectives of ICPA are:

- Safe and judicious use of pesticides
- Incorporation of integrated pest management (IPM)
- Environmental protection
- Safeguarding of intellectual property rights (IPRs)
- Evolving common code of conduct for members
- Communications with stakeholders in plant protection

Activities are taken up as per the need of the farmers with support from the pesticide regulatory authorities. Some of the activities undertaken with a greater thrust during the past decade are described below:

Farmers' training and education programs

During the past five years, many training programs on topics such as safer and judicious use of pesticides, IPM and ICM (Integrated Crop Management), etc. were organized by ICPA and some industries for the benefit of extension workers and farmers. The staff of industry was also trained to disseminate knowledge through charts, posters, slides, video films, etc. Training programs were organized for local medical practitioners on proper treatment of patients affected by the pesticides. Safety kits to pesticide users and medical kits to medical practitioners for treating pesticide-affected patients have also been distributed in large numbers during the past 2-3 years. Quality posters and video films on natural enemies, natural control, pesticide applications, etc. produced by the companies have helped a lot in improving the knowledge of all the functionaries, including administrators and researchers in promoting and implementing IPM.

Field demonstrations and trials

To demonstrate the effectiveness of newer products, field trials and demonstrations are a regular activity of the industry. However, to respond to the problems of low crop productivity, increased cost of cultivation, sustainability, environmental pollution, etc. industry has started conducting demonstrations/trials with IPM/ICM packages in farmers' fIelds. During the past five years, thousands of such trials have been conducted by the industry with its own investment and without technical support and guidance from R&D institutions. Many of the educational programs, including 'field days', have been conducted for the benefit of the farmers. Specific mission programs like the 'Technology Mission on Cotton' launched by the Ministry of Agrlculture, Govt. of India in 2000, are being coordinated by the industry to meet their objectives.

The results of these demonstrations/trials have been very encouraging. For instance, the ICM trials conducted by M/s Excel Industries between 1998-99 and 2000-01 produced more than 15 percent increase in yield and about 5 percent decrease in cost of cultivation across many crops. In cotton, with 458 trials conducted across India during 1998-2001, yields averaged 650 kg/acre and cost of cultivation Rs 5762/acre in ICM plots as against the yield of 563 kg/acre and cost of cultivation Rs. 5930/acre in local plots (Table 1). The reduction in cost of pest control with ICM was 24 percent. The pesticide pollution with ICM package was estimated to have been reduced by 71 percent

Research and development

At times, industry has invested considerable resources in running special projects to improve plant protection. The best example is the contribution of ICPA on monitoring and management of insecticide resistance through a

Table 1. The average yields and costs of cultivation of cotton with ICM and local packages in different states of India, 1998-2001

States	No. of trials	Yield (kg/acre)		Cost of cultivation (Rs/acre)		Cost of pest control (Rs/acre)	
		ICM	Local	ICM	Local	ICM	Local
Punjab	59	566	488	5091	5128	2261	2576
Haryana	78	627	532	5215	5213	1478	1660
Rajasthan	81	683	527	4229	3892	1177	1168
Gujarat	86	1005	892	8716	9230	1858	2427
Maharashtra	63	544	458	2369	2279	928	1157
Orissa	12	874	787	7989	8376	1184	2297
Andhra Pradesh	67	643	504	5687	5977	1664	2516
Karnataka	8	794	700	10116	10707	4376	5715
Tamil Nadu	4	193	176	2450	2570	1300	1700
Total/Mean	458	659	563	5762	5930	1803	2357

Yield benefit with ICM over local package = 87kg/acre
Reduction in cost of cultivation with ICM = Rs 168/acre
Reduction in number of sprays with ICM = 3 sprays

specialized Committee – Insecticide Resistance Action Committee (IRAC) – during the last decade. lRAC not only disseminated information on insecticide resistance but also suggested ways to manage the pests. Their update indicates that 504 insect species have become resistant to at least one class of chemical insecticide; of these 283 are agricultural pests, 198 are medical and veterinary pests, and interestingly, 23 are beneficial insects.

Seminars, workshops, meetings, etc.

The industry organizes and provides support to research institutions and other agencies for organizing seminars, workshops, meetings on IPM and related topics, largely with a view to educate and disseminate the IPM concept and knowledge to people who matter in implementing the programme.

The outcome of these efforts made by the industry and R&D institutions has been positive. The consumption of pesticide has started declining (Table 2), with the new products slowly replacing the old ones for better effectiveness, economy and safety. Consumption of technical pesticides has declined from 80,000 tonnes in 1994-95 to 54,135 tonnes in1999-2000.

Table 2. Production and consumption of technical grade pesticides in agriculture in India: 1994-95 to 1999-2000

Years	Production (tonnes)	Consumption (tonnes)
1994-95	90758	80000
1995-96	96880	73652
1996-97	94350	66677
1997-98	84154	60143
1998-99	88751	57240
1999-2000	-	54135

Source: Directorate of Plant Protection, Quarantine and Storage, Department of Agriculture and Cooperation, Ministry of Agriculture, Govt. of India.

Farmers have started realizing the importance of IPM and ICM for sustaining and improving the crop production. They have started distinguishing between the quality products and spurious/contraband materials. They now understand the importance of services provided to them by the industry. The industry regards IPM and ICM as opportunities to try their latest technologies, serve farmers, farming communities and people at large, and weed out the unscrupulous elements from the industry.

What Needs to be Done?

Whatever said and done, we are all concerned for the stagnation in the crop productivity, increase in the cost of cultivation, degradation of natural resources, contamination of food and feed and environmental pollution. In this context, we need to make some strategic changes in the interest of sustainable and progressive agriculture, as this only can bring to the surface various anomalies resulting due to overuse and misuse of such chemicals and inappropriate farming practices.

Changing emphasis from plant protection to ICM

IPM by conception and design takes a limited view and approach towards increasing crop production and productivity by addressing the problem of pests. It often gets identified with a specific group of professionals – mostly entomologists, pathologists and those involved in plant protection. Often, it fails to excite others working on different modes of improving crop production. Even farmers, who are not well aware about IPM, have apprehensions about it and their interest is to get higher productivity, no matter whether it comes from an improved variety, irrigation or plant protection. This ideological and conceptual division that has unknowingly crept into the system has seemingly isolated people working in agriculture – with some talking on IPM, some on INM (Integrated Nutrient Management), some on LWM (Land and Water Management) and still others on some new concepts, thereby creating a lot of confusion. Thus, a broad and holistic approach of Integrated Crop Management (ICM) is essential.

Avoid relating pesticide usage with increased crop production

In many workshops, meetings, etc. references are often made to the amount of pesticide usage in Japan, the USA, Germany, etc. as against the usage in India to drive home the point that our crop productivity is low because of less usage of pesticides. This sends wrong messages and signals down the line as reference to other factors that largely determine the yields are not made.

Weeding out unscrupulous elements from trade

In the Indian pesticide market, about 30% products are known to be fake and contrabands. These need to be identified and all unscrupulous elements involved in this trade need to be seriously dealt with. This is essential for establishing a good business environment. These elements have been playing with the lives of many farmers who use pesticides with faith and hope.

Licensing only qualified people for distributorship and dealership

At many forums and meetings, scientists and extension workers have often voiced concerns about irresponsible attitude and behaviour of some of the pesticide distributors and dealers in guiding the farmers but hardly anything has been done so far in this regard. Minimum qualifications of a degree in agriculture or diploma in plant protection should be fixed for a person seeking issuance and renewal of license for the sale of pesticides and other agri-inputs. With the requisite qualifications, distributors and dealers are likely to have a better understanding of the subject and strong moral and ethical obligations to help and serve the farmers properly. This is very important for the success and spread of IPM and ICM technologies.

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Accelerating Adoption of IPM through Collective Action

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Introduction

Many promising technologies remain on the shelf due to lack of appropriate socio-cultural conditions at the grass-root level. Pest management technologies fall under this category because pest has the characteristics of a detrimental common property resource (Regev *et al.,* 1976). The pest does not recognize spatial boundaries (Ravnborg *et al.,* 2000). Effective pest control thus requires a collective action. Yet, most of the times, pest control efforts are individualistic, resulting into low pest control efficiency and higher cost of control.

Collective action assumes greater significance in the context of integrated pest management (IPM) technologies. These technologies are derivatives of the living organisms and are host-specific and slow in action. They lose their efficacy if chemical pesticides are applied in the vicinity of the farms receiving application of these technologies. Collective pest management internalizes externalities of chemical pesticides as well improves efficacy of pest management. It also generates economies of scale by lowering the transaction cost of information search and acquisition, and operational cost of control (Rook and Carlson, 1985; Collins *et a1.*, 1999). This paper analyzes farmers' subjective perceptions on the benefits of collective pest management, their willingness to participate in it and identifies factors influencing collective action.

Data

In this paper, primary data generated through household surveys in three districts of Tamil Nadu have been used. The districts were: Coimbatore,

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Tanjavur and Dharmpauri. Coimbatore was selected because cotton is an important crop there. Tanjavur is pre-dominantly rice dominant district and Dharampuri has considerable area under vegetables. A sample of 70 households with 50 percent IPM adopters was drawn from each of the district, and information was collected from the cotton, rice and cabbage farmers. The information includes farmers' perceptions on the benefits of collective action, their willingness to participate in it and the factors that influence this.

Perceptions on Benefits of Collective Action

To participate in any collective action is an individual's choice, but the sum of individual choices has collective consequences (White and Runge, 1994). Lack of participation could result in higher cost of protection and negative externalities, while participation could yield significant benefits. The necessary condition for voluntary participation is thus individual's expectations about the net benefits from participation. To elicit this information, farmers were asked to indicate the benefits they perceive to derive from this.

The respondents envisioned three main advantages of collective action: (i) better control of insect pests (saving in yield loss), (ii) reduction in pest control costs, and (iii) improved access to pest management information at reduced cost. Farmers appeared to possess good understanding about the benefits of collective pest management. The most commonly perceived benefit was the better pest control efficacy (Table 1). Reduction in pest

Table 1. Farmers' perceptions on benefits of collective pest management

(percent reporting)

Type of benefit	Cotton		Paddy		Cabbage	
	Adopters	Non-adopters	Adopters	Non-adopters	Adopters	Non-adopters
No. of farmers	43	36	40	41	35	35
Reduction in cost of control	48.8	41.7	47.5	39.0	62.9	60.0
Access to information at reduced cost	16.3	22.2	42.5	29.3	42.9	40.0
Low yield loss due to pests	47.2	48.8	40.0	29.3	48.6	45.7
Do not know	20.9	16.7	12.5	14.6	8.6	14.3

control cost was rated second, and enhanced access to pest management information at reduced costs was the next.

Willingness to Participate

Even the farmers are aware about the benefits of collective pest management it rarely exists in practice. A number of socio-economic, psychological, institutional and technological factors deter farmers to participate in collective action. Pest management encompasses a number of direct and indirect pest limiting interventions like crop rotation, use of resistant variety, plant spacing, intercropping, synchronicity in sowing operations, avoidance of indiscriminate use of pesticides, use of biopesticides, synchronicity in pest control operations, manual collection of insect larvae, etc. The collective action thus covers a wide range of activities. Besides, it requires financial commitments from the participants to meet the operational expenses of the group.

Whether a farmer participates in some or all the activities related to collective action would depend on the nature of the activity and its resource requirement. Table 2 documents farmers' willingness to participate in different activities.

In general, the willingness to participate was strong in case of indirect pest control activities. A majority of the cotton farmers was willing to avoid continuous cropping, follow appropriate crop rotations and intercrops, dry period ploughing, border or trap crops, field sanitation, recommended crop variety and synchronicity in sowing. There was marginal, if at all, difference in the responses of IPM and non-IPM farmers. Similarly, cabbage farmers' participation rate in most of these activities was quite high. However, adopters of IPM technologies exhibited higher willingness to participate. This was because many of the agronomic activities outlined above are followed by a majority of the farmers as routine farm management practices, and needed slight readjustments as per the requirements of collective action. In the paddy region, farmers' willingness to associate with the group for these activities was not as high as in the cotton and cabbage regions. This was because of differences in agroclimatic conditions and the nature of the crops. For instance, in paddy zone, two crops a year was a common practice, and this limited timely performance of various indirect activities as per the requirements of the group.

Table 2. Farmers willing to participate in collective pest management activity

(in percent)

Activity	Cotton		Paddy		Cabbage	
	Adopters	Non-adopters	Adopters	Non-adopters	Adopters	Non-adopters
Indirect						
Avoid continuous cropping	90.7	77.8	40.0	22.0	40.0	22.9
Follow crop rotation	95.3	88.9	60.0	61.0	74.3	54.3
Follow dry period ploughing	95.3	88.9	62.5	51.2	77.1	74.3
Synchronicity in sowing	79.1	75.0	40.0	61.0	85.7	74.3
Use resistant variety	67.4	80.6	62.5	56.1	51.4	22.9
Follow proper plant spacing	95.3	94.4	60.0	34.1	77.1	82.9
Grow inter/trap/border crops	95.3	88.9	12.5	17.1	48.6	40.0
Keep field clean	95.3	88.9	97.5	95.1	100.0	91.4
Direct						
Judicious use of pesticides	100.0	47.2	97.5	39.0	57.1	51.4
Use biologicals	100.0	61.1	100.0	34.1	100.0	51.4
Collect insect larvae	97.7	88.9	15.0	4.9	5.7	0.0
Expenditure sharing						
Transaction costs	76.7	77.8	92.5	61.0	60.0	42.9
Expert services	60.5	52.8	90.0	87.8	100.0	80.0

Farmers evinced considerable interest to participate in direct pest control activities. A majority of the cotton farmers was willing to avoid indiscriminate use of chemical pesticides and wanted to substitute these with biological products. They were also willing to practise manual insect control and observe synchronicity in pest management operations. So were the cabbage and paddy farmers. However, compared to IPM farmers, non-IPM farmers evinced less willingness to cooperate in these activities.

Another dimension was the monetary contribution by the participants towards costs of information search, its acquisition and dissemination, and expert services, if needed. Except in the cotton zone, a considerable proportion of the farmers was willing to contribute towards these costs.

Determinants of Participation in Collective Action

The above findings indicated that there existed latent potential for emergence of collective action for pest management. However, this could not be translated into reality because of a number of social, economic, psychological and institutional constraints. In order to identify the factors constraining emergence of collective action in pest management, ordered probit and OLS models were used with willingness to participate as a dependent variable.

Collective action encompasses a number of activities, and a composite index of willingness to participate can be constructed by summing up the number of activities in which a farmer is willing to participate. However, this attaches equal weights to all the activities, and does not reflect their relative importance. Thus, to consider the relative importance of pest management activities, a weighted index of willingness to participate was constructed, assigning suitable weight to each activity. The weights were devised on a scale of 1 to 4 after consultations with entomologists, agronomists and economists.

Monetary contributions towards information search, acquisition and dissemination, and cost hiring expert services were identified as the most important activities from the point of view of sustainability of the collective approach. Therefore, these were assigned a weight of 4. Direct pest management activities – avoidance of excessive and indiscriminate use of pesticides and use of biological pesticides ranked next in the consultation, and was assigned a weight of 3. The former reflect concerns of negative externalities of chemical pesticides, while the latter indicate farmer's willingness to adopt new technologies. Other direct pest control activities were assigned a weight of 2. Indirect activities were assigned a weight of 1. The weighted index of willingness to participate was obtained by using relationship (1):

$$I_j = (w_i A_{ij}) / \Sigma w_i \quad ...(1)$$

where, I_j is the index of willingness of participation of j^{th} respondent; A_{ij} is the i^{th} activity in which the j^{th} respondent is willing to participate, and w_i is the weight associated with i^{th} activity.

A number of factors were hypothesized to influence willingness of participation. These included decision-maker's personal and household characteristics, pest management technology in use, awareness about negative effects of pesticides, decision maker's perceptions regarding benefits of collective action and social impediments to collective action.

The success or failure of any cooperative venture, to a large extent, is determined by the degree of social cohesiveness. Greater the degree of cohesiveness, higher is the probability of success of a cooperative effort. Indian rural society is socially and economically much differentiated. Social differentiation is a result of different castes and religions of the potential participants, while economic differentiation results from inequities in distribution of resources. It is expected that a high degree of social and economic heterogeneity would have a dampening effect on farmers' willingness to participate in collective action. Farmers' subjective perception on social heterogeneity is defined as a dichotomous variable that takes on the value of 1 if the respondent considers lack of cooperation among the farmers as a deterrent to collective action, and a value of 0, otherwise.

Size of landholding is a proxy for economic heterogeneity. In the context of pest management, this also reflects differences in farmers' capacity to invest in pest management technologies and withstand pest risks. It was hypothesized that farmers with higher capacity to invest and withstand pest risks put higher value on long-term benefits of collective action, and therefore, would have a greater propensity to participate in it. The collective efforts may be adversely affected if the landholdings are highly fragmented. Non-participation by some tantamounts to reduced effectiveness of pest control measures. In other words, problem of free riding cannot be ruled out. Fragmentation may also encourage collective action because of latter's benefits of economies of scale. The effect of land fragmentation is thus indeterminate a *priori*.

To ensure synchronicity in pest control practices, collective action requires timely availability of labour. Pest control activities start from seedbed preparation and last beyond harvesting of the crop. For instance, in the case of cotton pest management, collection and destruction of stalks is an important activity, and non-performance by any one due to labour constraint may diminish the spirit of collective action. The probability of willingness to participate in collective action is expected to be higher among the households having higher labour endowment in relation to land.

Further, the technology of pest control might itself require collective action to realize its full potential (McCulloch *et al.*, 1998). Though collective action is a must for the success of any pest management technology, there are technologies that demand greater cooperation for realizing their full potential. For instance, most of the biological pesticides are sensitive to chemicals and their efficacy is adversely affected on application of chemical pesticides in the vicinity. The users of biological pesticides would, therefore, expect neighbours also to apply biological pesticides. The users of biopesticides were, thus, anticipated to exhibit higher willingness to participate in the collective action. A dichotomous variable with a value of 1 for users of biological pesticides, and a value of 0 for non-users is used in the model.

Personal characteristics of the decision makers such as age and education influence their attitudes towards collective action. A priori effect of age is indeterminate. Age of the decision makers may have both positive and negative impacts on their willingness to cooperate. Younger farmers have a long planning horizon and are expected to be more cooperative, while elder farmers may or may not be willing to participate in the collective action. Here, their past experience in such activities could be a guiding factor. Likewise, education can have both a positive as well as a negative influence on willingness to participate. A farmer with higher education (years of schooling) was anticipated to have a better understanding of pest and pest-related problems and, therefore, an inclination toward participation in collective pest management. At the same time, an educated farmer has better access to pest-related information and may prefer individual pest control over collective management if the social conditions for the latter are not conducive.

Farmers' subjective assessments of the economic and environmental benefits of collective action would also influence their willingness to participate. Two sets of explanatory variables were included in the model to capture these effects. The first set (i.e. direct economic benefits) included farmers' subjective assessment of reduction in cost of pest control inputs, saving in cost of information search and acquisition and yield advantage. It was hypothesized that these factors were positively related to participation decisions. Collective action reduces transactions and operational costs of pest management to the individuals (Rook and Carlson, 1985). Pest is a common problem, so are its solutions. In other words, there is a commonality in the pest-related information that farmers need. Thus, acquisition of the common information by the group entails significant reduction in search and acquisition cost of the information. Besides, synchronicity in pest control operations lowers operational cost by reducing problems of pesticide/ biopesticide drifts and inter-farm pest mobility. Reduction in inter-farm pest mobility implies better pest control and thereby higher crop yield. Farmers' subjective perceptions on these variables are defined as dichotomous that were given a value of 1 if the farmer considered these as benefits of collective action, and value of 0, otherwise.

Another set of variables relates to farmers' awareness of technological failure of chemical pesticides and their externalities to ecology and human health. Farmers' awareness about these was hypothesized to encourage collective action because of the latter's capacity to internalize such externalities through judicious applications of chemical pesticides and appropriate technologies. Four awareness variables, viz. technological failure of pesticides, externalities to ecology, externalities to human health to pesticide exposure and pesticide residues in food, were constructed to examine whether these influence farmers' the willingness to participate in collective action. Technological failure of pesticides included development of pest resistance, resurgence and secondary outbreak. Indiscriminate and excess use of chemicals reduces populations of natural enemies of insect pests, beneficial insects and soil micro-organisms. Human health externalities include effects on eye, skin, gastro-intenstinal system, cardiovascular system, muscular system and respiratory system. Indirect effect of pesticides on human health is through their entry into the food chain, i.e. residues of pesticides in food. Each of these variables was considered in the form of an additive awareness score, i.e. summation of a farmer's response to an externality.

Results of the probit and OLS models are presented in Table 3. The threshold coefficient for the probit model is positive and significant at less than one percent level, implying that there is no specification error in the model. The results show that, as expected, social heterogeneity (lack of cooperation) is negatively related to individual's willingness to participate in collective action and the effect is highly significant. Marginal effect of increase in social heterogeneity is also quite large for the farmers' towards higher end of

Table 3. Determinants of willingness to participate in collective pest management

Explanatory variables	Ordered probit estimates		OLS estimates
	Coefficient	Marginal effect (for index value of 2 or more)	
Personal characteristics			
Age (years)	-0.0032 (0.0119)	-0.0010	-0.0032 (0940)
Schooling (years)	0.0058 (0.239)	0.0018	0.0024 (0.303)
Farm characteristics			
Size of landholding (acres)	0.1860 (0.454)	-0.0059	-0.0008 (0.132)
No. of fragments	0.1864 (1.149)	0.0592	0.0352 (0.874)
No. of adult workers/acre	0.1210 (0.468)	0.0384	0.0038 (0.066)
Pest control method			
IPM=1, otherwise=0	1.2810 (3.509)***	0.4068	0.3756 (5.681)***
Lack of cooperation			
Yes=1, otherwise=0	-0.9242 (4.854)***	-0.2935	-0.2987 (5.396)***
Awareness of pesticide externalities (score)			
Technological failure	-0.3637 (3.933)***	-0.1155	-0.6405 (2.56)**
Ecological ill effects	-0.0445 (0.425)	-0.0141	-0.0444 (1.473)
Health impairments	0.1395 (1.661)*	0.0443	0.0306 (1.347)
Pesticide residues in food	0.0628 (1.134)	0.002	0.0043 (0.272)
Perceptions on benefits of collective action			
Reduction in cost of control			
Yes=1, otherwise=0	0.5484 (2.830)***	0.1741	0.1913 (3.393)***
Access to information at reduced cost			
Yes=1, otherwise=0	1.2403 (4.673)***	0.3939	0.3036 (4.955)***
Low yield loss due to pests			
Yes=1, otherwise=0	0.9742 (4.070)***	0.3094	0.2738 (4.366)***
Crop system			
Cotton=1, otherwise=0	2.9741 (9.436)***	0.9445	0.8599 (11.538)***
Cabbage=1, otherwise=0	0.5754 (1.7530)*	0.1827	0.1260 (1.457)
Threshold coefficient (MU)	2.8598 10.921)***		
Constant	0.1283 (0.162)	0.0407	1.2464 (6.055)***
log-likelihood function	-120.798		
Restricted log-likelihood	-223.482		
Chi-squared	205.368		
R-squared			0.6483
Adjusted R-squared			0.6219
F-value			24.54
No. of observations	230		230

***, ** and * are significant at 1, 5 and 10 percent levels, respectively
Figures within parentheses are t-values.

willingness index (29%). This indicates that farmers view social cohesion as a critical requirement for collective action. Coefficient on land holding size is positive, but insignificant. The marginal effect of this is also small. Thus, distribution of land (economic inequality) does not seem to constrain farmers' participation in collective action. The coefficient on land fragmentation is positive but insignificant. The probability of participation of those having higher willingness increases by 6 percent with one unit increase in land fragmentation. The inequality in the distribution of family labour too does not influence farmers' willingness to participate significantly.

Personal characteristics of the decision maker do not influence their participation decisions significantly. Marginal effects of these variables are also small. These imply that farmers irrespective of their personal traits realize the transboundary nature of pests and their damage potential.

Coefficients on variables reflecting economic benefits of collective action are positive and significant at less than one percent. These are not unexpected. Collective action reduces operational and transaction costs of pest control for individual farmers, as well as improves pest control efficiency. Amongst these, reduction in transaction costs of information appears to be the most important motivating factor for collective action. Reduction in crop damage is next important economic factor. Reduction in operational cost of pest control, however, is not as important. Marginal effects of changes in these variables are quite strong. The probability of participation increases by 17, 31 and 39 percent, respectively with one standard deviation increase in the value of these variables. The ranking of these effects is also not unexpected. Individuals lack information on pest management and incur considerable expenses towards information search and acquisition. Such costs get considerably reduced for the individuals if the information is obtained and used collectively. The technological failure of pesticides results in increased cost of pest control, but without corresponding reduction in crop damage. The farmers value collective pest management for its better pest control efficiency, even if there were not much savings in operational cost of pest control.

Effect of technology of pest management on the willingness to participate is fairly large. As expected, adopters of IPM exhibit significantly higher willingness to participate. The probability of participation is likely to increase by about 41 percent with one standard deviation increase in the number of adopters of IPM. This implies that efforts to accelerate adoption of IPM should focus on community as a whole rather than individuals.

Effects of pesticide externalities on farmers' willingness to participate in the collective action are mixed. Greater awareness about technological failure of chemical pesticides affects willingness to participate adversely. Similar results are observed for ecological indicators. These are unexpected and perhaps could be due to high degree of risk aversion among the farmers. On the other hand, likelihood of participation in collective action increases with greater concerns for food safety and human health.

Likelihood of participation in collective action varies across crop zones. Potential for collective action is significantly higher in the cotton as well as cabbage zones. This is because cotton and cabbage are susceptible to a number of insect pests and diseases, which cause considerable damage to the crop. Comparatively low potential of collective action in paddy zone is because of intensive paddy cropping and less pest menace.

Conclusions

An effective pest control requires community participation, and social cohesiveness is an important pre-requisite for it. Yet, farmers take independent pest control decisions. Lack of social cohesiveness is deterrent to an individual's participation in community pest management. However, farmers' rational economic self-interests are expected to motivate them to join together for pest management. In particular, the perceived cost economies and yield benefits have statistically significant influence on farmers' willingness to participate in this. The other economic and demographic factors do not appear constraining farmers to participate in collective action. Collective action is more important for technologies such as IPM that utilize biological inputs.

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Socio-Economic, Environmental and Institutional Aspects in IPM Adoption

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Introduction

The concept of Integrated Pest Management (IPM) was developed during 1960s and 1970s as an alternative to technological failure of chemical pesticides (insecticide resistance, secondary pest outbreak and pest resurgence) and their adverse effects on the human health and environment. Although pesticide-use was low in developing countries, these problems were becoming more severe there because of indiscriminate use of pesticides and their inappropriate methods of application.

In the early stages its development, IPM was a technical approach designed to reduce the number of pesticide applications. Subsequently, it developed into a methodology in which farmers were encouraged to develop IPM interventions themselves through a better understanding of the agro-ecosystems. Three stages can be distinguished in the development process of IPM. The first stage was the integration of different pest control methods. Technically, IPM consisted of a combination of control methods including biological control, host plant resistance, cultural control, and selective chemical control. In the second stage, crop protection was integrated with farm and natural resource management. It was realized that many agricultural practices also influence the pest development, and the crop intensification often leads to increased pest problems. Therefore, control measures were designed that fitted into the agro-ecosystems. In the third stage, the emphasis

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was on the integration of the natural and social sciences because by this time it had become evident that fixed prescriptions would not work in tropical agriculture characterized by significant variations in agro-ecological and socio-economic conditions. The extension systems, such as 'Training and Visit' did not provide sufficient flexibility because they were based on the concept of a 'top down approach' to transfer of technology. IPM projects were developed around a more dynamic extension model – the Farmer Fields School (FFS), which combined training with field-based location-specific research to provide farmers skills, knowledge and confidence to make ecologically sound and cost-effective decisions regarding the crop health.

India is the one of the seven countries involved in the FAO-initiated inter-country programme (1980) on IPM, but its adoption remains elusive. This paper examines the socio-economic, environmental and institutional issues in adoption of IPM.

Socio-economic Issues

IPM is considered to be the best option to internalize the externalities arising from the excessive and indiscriminate use of pesticides. Considerable evidences now exist to show that the chemical pest control is undesirable and uneconomical. Successful IPM implementation entails many benefits such as reduction in the pesticide-use and cost of plant protection and improvements in crop yields (van de Fliert, 1993; Peshin and Kalra, 1998). Fernandez (1998) has shown significantly positive impact of IPM crop yield and farm profits. At the national level, governments can save millions of dollars spent on pesticide subsidies (Kenmore, 1997). Further, many developing countries import huge quantities of pesticides, large savings in foreign exchange are expected on implementation of IPM.

Success of IPM is influenced by a number of variables, many of which can be controlled through programme planning and implementation processes like programme location and target audience (Orden and Buccola 1980). Farmers generally adopt technologies in a sequential manner, often accepting only a component of the available technology, and the adoption of technology increases over time. There are various socio-psychological characteristics, viz. age, education, farm size, mass media, extension participation, type of extension agency, risk orientation, scientific orientation and training programmes, etc. that exert considerable influence on the adoption of a system.

Adoption of a technology such as IPM is a dynamic process. Theories describing this dynamic technology adoption in agriculture have addressed constraints to adoption associated with profitability, risk and divisibility. These constraints generally deal with farm tenure, aversion to risks, inadequate farm size and lack of credit. Lack of technical guidance, non-availability of printed IPM materials, additional requirement of labour for IPM, non-availability of plant products, and quality of biocontrol agents like *Trichogramma*, Nuclear Polyhedrosis Viruses, and pheromone traps are other major constrains in adoption of IPM.

The success of IPM depends on the appropriateness of the IPM technologies. The technologies integrated into IPM are knowledge-intensive and require farmers to have an understanding of the pest, pest cycle and its natural enemies, as well of the technology, its target host and method and timing of its application. This hither to is one of the biggest barriers to adoption of IPM. Another major barrier to biological pest control and IPM is the existing well-established pesticide retail outlet. India has a large number of pesticide retailers, who often promote chemical pesticides. They lack knowledge about IPM inputs. Therefore, the biological inputs would have a direct competition with chemical pesticides. The relative prices of the two would also influence their use.

Adoption of manual-mechanical agriculture practices, viz. clipping of seedlings before transplanting, rogueing out of infested plants and use of rope method for dislodging leaf feeders is negligible. Due to increasing mechanization of agricultural practices the possibility of adoption of such pest control practices in near future seems to be doubtful (Peshin and Karla, 1977).

Environmental Issues

The public concerns about the adverse effects of chemical pesticides on the environment and health have been the principal triggers of the development of IPM. The known effects of chemical pesticides include:

chronic and acute health problems in the humans; development of pesticide resistance in the pests; pest resurgence; deleterious effects on the livestock and non-target organisms (including beneficial insects); reduction in the biodiversity; and the contamination of agricultural products, soil and water. These problems are of immediate relevance to the farmers. Nevertheless, these problems may lead to broader environmental and associated issues that go beyond the limits of farmers' fields, influencing the overall public good or common property, public health, etc. Pesticide contamination of rivers, groundwater, and agricultural products leads to off-site impacts on the rural and urban communities and the non-target organisms. In the developing countries, it is, however, unreasonable to expect farmers to consider or be responsible for these broader consequences of pesticide use. However, these issues need to be taken into account to present a balanced view of the rationale for introducing IPM, and consider the broader public good rather than focus entirely on the local needs of farmers.

The potential that IPM offers for reducing pesticide-use is environmentally sound and significant in improving the quality of water, reducing risk of farmer and consumer from pesticide poisoning, and in contributing to ecological sustainability through conserving natural resource bases.

Technical potential of IPM can be measured in the framework of goals of IPM, that is, reduction in pesticide-use, efficacy of pest suppression and conservation of natural enemies of insect pests. IPM adopters applied significantly less pesticides (Birthal *et al*., 2000; Fernandez, 1998 and Razzak, 2001). Both the toxicity and environmental impact quotient (EIQ) have been found to decrease with the adoption of insect IPM (Fernandez, 1998). The presence of more number of natural enemies in the IPM-adopted fields (Birthal *et al*., 2000) has shown the contribution of IPM in conserving the biodiversity under farm situations. These evidences indicate that the IPM has the potential to reduce the adverse effects of pesticides in the environment.

Institutional Issues

Pest has the characteristics of common property resource and leaves no field unaffected whenever and wherever it occurs. The problem, thus, has to be tackled at the community level. This is important particularly in the application of IPM as it involves the use of bioagents and biopesticides, and the exclusive use of chemical pesticides in neighbourhood reduces their effectiveness (Birthal *et al*., 2000).

The success of IPM, thus, depends not only on the motivation, skills and knowledge of individual farmers, but on the participation of the entire community. Once farmers learn about the potential benefits of IPM (increased yields, reduced costs, etc.), they adopt it widely, triggering a transition away from conventional chemical control. What is required is the increased attention to community-based action through local institutions. Collective action succeeds where there are a small number of actors. This is, however, not realistic in India because of dominance of smallholders with considerable socio-economic heterogeneity. But still some components of IPM have been adopted with beneficial results (Kishor, 1997).

Thus, adoption of IPM cannot be forced on people. It needs external catalysts or facilitators, who can motivate farmers to develop local leadership. However, there are more intangible benefits of rediscovered social cohesion and solidarity. As confidence grows with success, groups evolve with new roles and responsibilities, often joining with other groups to achieve a wider impact (Pretty, 1996).

Policy Issues

A strong policy environment for IPM, that discourages use of pesticides, is important. Sometimes, this could be even a pre-requisite for implementation of IPM programmes. The highly acclaimed IPM training in Indonesia was preceded by a comprehensive reform of pesticide regulation and the removal of all subsides on insecticides (Rola and Pingali, 1993).

Of even greater importance is the firm support for IPM at the policy level. Policy makers and government officials can restructure the research and extension system to facilitate development and implementation of IPM. The institutional and economic structure in the rural sector of developing economies also requires some policy intervention to reconcile the long-term social goals with the short-term individual objectives. Promoting sustainable pest management within IPM framework requires improved research-extension linkage, effective training methodologies, community action and undistorted price structure (Pingali *et al*., 1997).

Government intervention in influencing farmer's choice of technology can be justified on the grounds of negative environmental and public health externalities of pesticides imposing costs on the society. These costs are rarely reflected in the prices that users pay. Often there is a divergence between the private costs and social costs. Thus, excessive and indiscriminate use of pesticides is not optimal from the society's perspective, and intervention by government is warranted.

A number of policy and regulatory instruments are available to encourage environmentally sound pest management practices. The important ones are:

- Development of a system that increases awareness among the policymakers, consumers, and producers of the hazards of pesticide-use
- Development of a regulatory framework to ensure appropriate and safe production, distribution, and use of pesticides
- Reorientation of agricultural and environmental policies to introduce appropriate economic incentives, including taxes and special levies on pesticides to account for the negative externalities, and short-term subsidies, for the positive externalities of IPM (Birthal *et al*., 2000)
- Orientation of research and technology policies to generate a steady supply of relevant pest management information and technologies, including adequate budget allocations for research, extension and training.

Strategies for Adoption

The two strategic elements in implementing IPM on a large scale are: (a) creation of a level playing field eliminating policies that promote environmentally unsustainable pest management techniques and strengthening regulatory institutions, and (b) implementation of positive measures to promote IPM through support for public awareness, research, extension and training, with an emphasis on decentralized, farmer-centred initiatives. The following points may be considered for increased adoption of IPM:

National policy

Establishment of a national IPM policy framework is the first step in area-wide adoption of IPM. Several countries have already moved in this direction, for example Cuba, the Netherlands and the United States. The advantages stem from overseeing the disparate package of measures needed to implement IPM, both upstream policy elements and on-farm implementation within a single coherent decision framework. This framework can also provide the basis for consultations with all the relevant stakeholders to secure broad institutional support for 'what may constitute a significant shift'.

Economic and regulatory measures

Many developing countries face constraints in implementing the economic and regulatory provisions required to support IPM. Several factors explain this. A comprehensive and rigorous network of registration, legislation, standards, training, monitoring, and information systems appear to be more expensive than alternate public sector programs with a short-term and more visible direct impact. These costs are raised further by limitations of infrastructure and communications. At the same time, the financial impact of IPM policies, such as lower subsidies, taxes and licensing and registration fees, falls most heavily on producers and marketeers of pesticides and initially on farmers engaged in the production of cash crops. Moreover, subsidies, tax exemptions on biocontrol inputs, etc. can have a significant impact on the adoption of IPM.

Development of markets

Products usually reach consumers through a series of informal channels: local village markets/collection points and weekly/bi-weekly village markets. Domestic markets are important in terms of consumer perceptions and preferences for high-value products. Consumers are becoming aware, better informed, and are even indicating preferences for low pesticide-residue products. The consumers' awareness need to backed up by dependable standards and labeling procedures.

The market for pesticide-free or organic food has been growing fast, particularly in the western countries. There could be good prospects for development of potentially lucrative export markets if India can establish and maintain quality. This would receive further impetus if ethical trade links were established. The possibilities for export would require a detailed market analysis. Attention should be paid to preferential treatments, long-term contracts, and quality preferences. In the long-run, export markets are expected to be more pesticide-sensitive.

Farmer-centered research, extension and training

Involvement of the farmers in generating site-specific techniques for specific farming systems is an important factor in determining the success of IPM. Its implementation requires that farmers, extension workers, and local crop protection technicians should have practical understanding of the ecology and life-cycle of major pests and their natural enemies and this knowledge be translated into appropriate decision making tools and practical control tactics.

A related feature of the successful initiatives is the role of pilot projects as the platform for demonstrating the benefits of IPM before launching a widespread extension and training programme. The training is to be backed by a continuous flow of information from pest scouts, farmers and others. This information could be transmitted on daily or weekly basis. Support for IPM implementation is inconsistent with a top-down technology- transfer approach. Farmer-to-farmer exchanges with success stories using biological controls and IPM would help in disseminating to other farmers. Some selected farmers could even be provided financial support to educate and train other farmers to strength implementation of IPM.

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Infrastructure Incentives and Progress of Integrated Pest Management In India

A.D. Pawar and M.P. Misra[1]

Introduction

The 'Green Revolution' technologies, viz. high yielding crop varieties, chemical fertilizers and pesticides coupled with assured irrigation and improved agronomic practices during the late 1960s and 1970s ushered India into an era of food self- sufficiency. However, this kind of intensive cropping was accompanied by the increasing problems of insect pests, disease and weeds. Farmers were motivated to adopt prophylactic control measures with emphasis on chemical pesticides. But the indiscriminate and injudicious use of pesticides resulted in several adverse effects, viz. development of resistance in pests to pesticides, resurgence in pests, pesticides residues in food, fodder, soil and water, pesticides poisoning, and health hazards to human beings, wild-life and livestock. These developments led to search for safer and cost-effective approaches to pest control. Integrated Pest Management is one such approach. The main objectives of IPM are to: keep pests below damaging levels, maximize crop yield, reduce cost of plant protection, and minimize environmental pollution and maintain ecological equilibrium. To realize the economic and environmental objectives of IPM, the Government of India has taken a number of measures for the promotion of IPM.

National Policy on IPM

The Government of India is signatory to the Agenda 21 of the United Nations Conference on Environment and Development (UNCED), 1972, which accepts IPM as an effective way to reduce the use of chemical pesticides. India, recognizing the global concerns of the adverse effects of chemical

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pesticides on environment and human health, adopted IPM as the main plank of plant protection strategy in 1985. Since then, a number of initiatives have been taken to promote IPM. These are discussed below:

Infrastructure development

- Setting up of 26 Central IPM Centres (CIPMC) for promotion of IPM approach in 22 States and 1 Union Territory (Annexure I). Four new CIPMCs in the north-eastern states of Arunachal Pradesh, Meghalaya, Manipur and Tripura are proposed to be set up.
- Assistance to state governments for setting up of 29 biocontrol laboratories and for production and release of biocontrol agents (Annexure II).
- Allocation of 50% state funds on plant protection to promote IPM.

Human resource development

- Organise season-long IPM training programmes for the training of trainers.
- Setting up of Farmers' Field Schools (FFS) to train Agricultural Extension Officers and farmers in IPM skills.
- Demonstration of field tested IPM practices.

Policy support

- Phasing out subsidies on pesticides and diverting the resultant savings for promotion of IPM.
- Phasing out/banning/restricting the use of hazardous pesticides.
- Liberalized criteria and procedures for the registration of biopesticides.
- Emphasis on production and use of biocontrol agents, biopesticides and pheromones.

IPM Centres, and the Facilities

For the promotion of IPM, the Government of India has established 26 Central Integrated Pest Management Centres (CIPMCs) under the Directorate of Plant Protection, Quarantine & Storage in 22 states and one union territory. Central government's efforts in promotion of IPM also include input from the Indian Council of Agricultural Research, State Agricultural Universities, and the Department of Biotechnology of the Govt. of India. The major activities of the CIPMCs are :

- To undertake pest surveillance and monitoring on major *Kharif* and *Rabi* crops to forewarn pest/disease situation with a view to supplementing the efforts of state governments for timely control measures.
- To issue pest and disease situation/forewarning bulletins to all the concerned authorities of state departments of agriculture and horticulture for need-based adoption of plant protection measures.
- To popularise biological control of pests by introducing exotic biocontrol agents, mass rearing and field releases, and conserving biocontrol agents against major pests and weeds.
- To extend technical help to state governments in establishing the biological control laboratories.
- To train extension workers, farmers, cooperatives, and other organizations in mass rearing/conservation of biocontrol agents.
- To organize Farmers' Field Schools (FFS) and demonstrations for popularising IPM among the state extension functionaries and farmers.

IPM Package of Practices

IPM package of practices for both *Kharif* and *Rabi* crops have been evolved and harmonized in consultation with IPM experts from the Indian Council of Agricultural Research, State Agricultural Universities, and the State Departments of Agriculture. The list of IPM package of practices is given at Annexure III.

Policy Developments

Apart from major policy enumerated in the previous paragraphs the central government from time to time convenes meetings of the senior executives of the state governments, and scientists of the Indian Council of Agricultural Research, and State Agricultural Universities for formulating policies for proper implementation of the IPM programmes. A National

Plan of Action on IPM has been evolved giving details of the priority areas for deriving full benefits of the IPM approach. The details of the Action Plan are as follows:

- Financial assistance from the central government should be channelised through plant protection division to facilitate effective implementation of IPM for achieving the desired results
- Every state government should identify a nodal officer of the rank of Joint Director Agriculture, for proper planning and implementation of IPM
- IPM packages developed at the national level should be fine-tuned to meet the local needs of a state
- Pest surveillance and monitoring should receive top priority at the state level for timely forewarning of pest and disease situations
- Biological control laboratories need further strengthening through joint ventures associating central/state governments and industry by way of signing MOU (Memorandum of Understanding) with condition of targeted reduction in pesticide-use
- Encouragement of production of sufficient quantity of biocontrol agents/ biopesticides as cottage industry should be given priority to facilitate equipping such laboratories with adequate facilities
- Incentives up to Rs 50 lakhs to private entrepreneurs may be provided as one time grant for the establishment of biopesticides and biocontrol units
- Financial assistance to the tune of 75 percent on the cost of biopesticides, biocontrol agents and pheromones should be provided by the Centre/States to promote IPM.
- Biocontrol agents/biopesticides, pheromones, etc. should be exempted from octroi, excise and custom duties, and sales taxe.
- Quality control standards for biopesticides already developed may be used for monitoring their quality.
- Registration requirement for biopesticides and pheromones need to be further simplified to facilitate bringing all biopesticides/biocontrol agents under the purview of Insecticides Act, 1968.

The Government of India also reviews the toxicity and residues of the pesticides registered under the Insecticides Act, 1968. Based on the expert opinion, the pesticides are being banned or recommended for restricted use. Biopesticides like neem-based formulations, *Bacillus thuringiensis*, *Trichoderma* have been registered for commercial use by the farmers to promote IPM. Also other biopesticides like NPV, GV, entomogenous fungi, etc. have been brought under the provision of Insecticides Act, 1968 so that farmers get quality biopesticides.

State Facilities

Most of the state governments have intensified their efforts to popularise IPM through demonstrations and trainings of the extension personnel and farmers. The Central Government, Indian Council of Agricultural Research and State Agricultural Universities are extending technical assistance for the training. The state governments are also strengthening their facilities for biocontrol production units. The State Departments of Agriculture, Horticulture, and Agricultural Universities have a strong network of extension set up at village, block and district levels with over one lakh extension personnel.

The state governments are providing 50 percent subsidy on the plant protection chemicals including biopesticides to the farmers. There are around 200 biocontrol laboratories functioning in the states to undertake bio-intensive pest management (Annexure IV).

Involvement of the Private Sector

A few private agencies have set up commercial insectaries for mass rearing and supply of biocontrol agents to the farmers. These efforts are, however, far from adequate. Now, a few NGOs have also started Krishi Vigyan Kendras (KVKs) with the assistance from the Indian Council of Agricultural Research, and a few biopesticides production units with the assistance of Department of Biotechnology, Government of India. The private plant clinic centres also help in promotion of IPM programmes in various states.

There are 130 biocontrol agents/biopesticides units in the private sector (Annexure IV)

Incentives

Under the centrally sponsored schemes of the Department of Agriculture and Cooperation, Ministry of Agriculture of the Government of India, the funds are being released by the Central Government on 75:25 sharing basis (Central:State) to the states for IPM programmes (Annexure V). The IPM demonstrations and trainings are being conducted in rice, cotton, pulses and oilseeds crops besides provision for IPM inputs, i.e. NPV, pheromones, biocontrol agents, etc. A sum of Rs 15,000 (pulses) to Rs 85,000 (cotton) is given for IPM training and demonstration. Also, a sum of Rs 9,025 is kept for conducting the Farmers' Field School through Central IPM Centres under Central Sector Schemes. Twenty-five biological control laboratories will be established in 25 cotton growing districts under Mini Mission II of the Technology Mission on Cotton. Financial grant of Rs 100 lakhs is given to set up the state biocontrol laboratories to produce biocontrol agents for use in cotton. Grants-in-aid of Rs 50 lakhs is being given to states for the establishment of 29 state biological control laboratories.

With a view to promote IPM, registration of biopesticides was allowed with relaxed data requirements, besides commercialization during temporary registration under section 9 (3B) of the Insecticides Act, 1968.

IPM posters and field guides on rice, cotton and IPM package of practices for 20 crops have been published and distributed to extension workers and farmers. IPM literatures in local languages are also distributed to farmers under the Farmers' Field School during field training in IPM. Some states also provide biopesticides on 50 percent subsidy to the farmers.

Progress of IPM

IPM training

A three-tier training programme namely season-long training courses, establishment of Farmers' Field Schools and IPM demonstrations has been designed to train farmers and extension functionaries. The resources for training courses in IPM have come from international organizations like FAO, ABD-CABI and UNDP. The IPM training-cum-demonstration commenced since 1981 by organizing demonstration in 40 ha farmers' rice fields for the entire crop season. During 1986-94, a total of 277 demonstrations were organized and 4,951 Subject Matter Specialists (SMS) and 64,580 farmers were trained (Annexure VI). The major emphasis in these trainings is on recognition of the friendly insects and spiders by the farmers and extension workers. While the IPM training-cum-demonstration programmes were in progress, the FAO Inter-Country Programme for the Integrated Pest Control in rice for the South and Southeast Asia has sponsored a number of field based short duration training courses on IPM in rice. The first training course was organised at Bangalore in 1980 to familiarise with biocontrol agents which are found in abundance in rice fields and play a major role in the natural suppression of pests. Thereafter, a series of short duration training courses on IPM in rice were organised with the technical and financial support of the FAO-IPC Regional Project in different parts of the country, viz. Cochin (Kerala), Adithurai and Kanchipuram (Tamil Nadu), Medichal (Ahdhra Pradesh), Bhubaneshwar (Orissa), Mandiya (Tamil Nadu,) and Jallandhar (Punjab), wherein 359 Subject Matter Specialists received practical field training in rice IPM (Annexure VII). These trained master trainers formed nucleus trainers on IPM in different states for imparting training to their fellow officials.

Besides, in 1994, FAO-IPC Regional Project organised a special orientation training programme of one month duration on IPM in rice to facilitate establishment of FFSs in the states. With the support of ADB-CABI project, 15 days short duration courses on IPM in cotton were also organised for the establishment of FFSs. A total of 642 officers were trained (Annexure VIII). Under the aegis of international organisations, FAO, ADB-CABI and UNDP, so far 33 IPM season-long training courses have been conducted in rice, cotton, vegetables, groundnut, mustard, gram, pigeonpea and chillies wherein 1072 master trainers from different states were trained (Annexure IX).

Farmers' Field Schools (FFSs) are conducted by 25 Central Integrated Pest Management Centres (CIPMCs). Five Agricultural Extension Officers and 30 farmers are imparted weekly training in IPM at each FFS for 10-12 weeks during the crop season. The agro-ecosystem analysis undertaken by trainee officers and farmers every week gives them opportunity to understand the built-in natural balance between the pests and friendly insects. At the end of the training, a Kissan Mela (farm fair) is organised at the site of the FFS to popularise the IPM concept with the neighbouring farmers. Total accomplishment under the FFS during 1994-2001 has been in the order of establishment of 6733 FFS in cotton, rice, pulses, oilseeds and vegetables and training to a strong core of 28,459 Agricultural Extension Officers and 2,03,032 farmers (Annexure X).

The major accomplishments of CIPMCs under the IPM from 1997-98 to 2000-2001 are given in Table 1.

Table 1. Major accomplishments of CIPMCs

S. No.	Activity	1997-98	1998-99	1999-2000	2000-2001	2001-2002
1.	Pest Monitoring lakh (ha)	7.15	8.30	8.40	8.59	8.00
2.	Biocontrol of pests					
	i) Field release of biocontrol agents (million Nos)	1803	2028	2149	2099	2000
	ii) Area coverage (lakh ha) (augmentation and conservation of biocontrol agents)	5.51	6.05	6.45	6.34	6.00
3.	IPM training-cum- demonstration					
	Farmers' Field School (Nos)	495	518	520	511	520
	AEOs trained (Nos)	2311	1776	1621	1690	2600
	Farmers trained (Nos)	14690	15564	15600	15749	15600

A total of 409 biocontrol laboratories have been established in the country to produce and use biocontrol agents under IPM programmes. Biocontrol agents/biopesticides are available for the control of insect pests of 26 important agricultural and horticultural crops besides antagonists for the control of diseases of 17 crops (Annexures X and XI). Biopesticides like *Bacillus thuringiensis, Trichoderma*, and neem-based pesticides have been registered and are now available commercially for use by the farmers. To supply quality biopesticides to farmers even NPV, GV antagonistic fungi and bacteria and entomogenous fungi have been brought under the purview of Insecticides Act 1968.

Reduction in pesticides consumption

Consequent upon the adoption of IPM as national policy on crop protection, the states have come forward to pursue IPM approach including use of biocontrol agents and biopesticides and need-based judicious use of pesticides. IPM has been successful in rice, cotton, pulses, oilseeds, sugarcane, vegetable and fruit crops. This has led to 24.71% reduction in pesticides consumption between 1994-95 and 1999-2000.

Conclusions

The concerted efforts made since 1990 have resulted in development of political will, bureaucratic commitment, research support and acceptability of IPM by the farmers. All these attempts have helped in vertical expansion of IPM to some extent. For reaching the masses, it is essential to promote lateral spread of IPM by associating farmers and Self Help Groups by organising community IPM programmes. In this connection IPM-trained farmers can be gainfully utilized.

Annexure I. Statewise location of central integrated pest management centres in the country

State/Union Territory	Location of C I P M C
Andhra Pradesh	Hyderabad, Vijaywada
Assam	Guwahati
Andman & Nicobar Islands	Portblair
Bihar	Patna
Chhattisgarh	Raipur
Goa	Maddgaon
Gujarat	Baroda
Haryana	Faridabad
Himachal Pradesh	Solan
Jammu & Kashmir	Jammu, Srinagar
Karnataka	Bangalore
Kerala	Ernakulam
Madhya Pradesh	Indore
Maharashtra	Nagpur
Mizoram	Aizwal
Nagaland	Dimapur
Orissa	Bhubaneswar
Punjab	Jalandhar
Rajasthan	Sriganganagar
Sikkim	Gangtok
Tamil Nadu	Trichy
Uttar Pradesh	Gorakhpur, Lucknow
West Bengal	Burdwan

Annexure II. State biocontrol laboratories in India financed by the Union Government

S. No.	Name of SBLC (Place)	District and State	Functional status as on Dec. 2002
1.	Nidadavole	West Godavari, Andhra Pradesh	Yes
2.	Dalgaon	Darrang, Assam	No
3.	Methapur	Patna, Bihar	No
4.	Gandhinagar	Gandhinagar, Gujarat	Yes (partially)
5.	Sirsa	Sirsa, Haryana	No
6.	Palampur	Kangara, Himachal Pradesh	Yes
7.	Srinagar	Srinagar, Jammu & Kashmir	No
8.	Gulbarga	Gulbarga, Karnataka	Yes
9.	Mannuthy	Trisssur, Kerala	Yes
10.	Bhopal	Bhopal, Madhya Pradesh	No
11.	Aurangabad	Aurangabad, Maharashtra	Yes
12.	Mantri Pukhari	Imphal, Manipur	No
13.	Upper Shillong	Upper Shillong, Meghalaya	No
14.	Medziphima	Kohima, Nagaland	Yes
15.	Bhubaneshwar	Bhubaneshwar, Orissa	Shortly
16.	Mansa	Mansa, Punjab	Yes (partially)
17.	Durgapur	Jaipur, Rajasthan	Yes
18.	Tadong	Gangtok, Sikkim	Yes
19.	Vinayapuram	Madurai, Tamil Nadu	Yes
20.	Arundhatinagar	Agartala, Tripura	Yes
21.	Moradabad	Moradabad, Uttar Pradesh	No
22.	Haldwani	Nainital, Uttaranchal	No
23	Tollyganj	Calcutta, West Bengal	No
24.	Naharlagun	Itanagar, Arunachal Pradesh	No
25.	Ela Farm	Old Goa, Goa	No
26.	Andrott Islands	Lakshasdweep	No
27.	Neihbawi Farm	Siphir Mizoram	Yes
28.	KVK Kurumbapett	Pondicherry	Yes
29.	Haddo Port	Port Blair, A&N Islands	Yes

Annexure III. IPM packages

Integrated Pest Management (IPM) Package for Cotton
Integrated Pest Management (IPM) Package for Groundnut
Integrated Pest Management (IPM) Package for Soybean
Integrated Pest Management (IPM) Package for Pigeonpea
Integrated Pest Management (IPM) Package for Blackgram/Green gram
Integrated Pest Management (IPM) Package for Wheat
Integrated Pest Management (IPM) Package for Gram
Integrated Pest Management (IPM) Package for Rapeseed/Mustard
Integrated Pest Management (IPM) Package for Sesame
Integrated Pest Management (IPM) Package for Sawflower
Integrated Pest Management (IPM) Package for Potato
Integrated Pest Management (IPM) Package for Onion
Integrated Pest Management (IPM) Package for Tomato
Integrated Pest Management (IPM) Package for Cruciferous Vegetables
Integrated Pest Management (IPM) Package for Cucurbitaceous Vegetables
Integrated Pest Management (IPM) Package for Legumineous Vegetables
Integrated Pest Management (IPM) Package for Brinjal
Integrated Pest Management (IPM) Package for Okra/Bhindi
Integrated Pest Management (IPM) Package for Chillies/Capsicum
Manual on Integrated Pest Management (IPM) in Rice
Manual on Integrated Pest Management (IPM) in Cotton
Farmers Field Guide on IPM for Rice
Farmers Field Guide on IPM for Cotton
Handbook on Diagnosis and Integrated Management of Cotton Pests
Extension Folder on IPM in Cotton

Annexure IV. Number of laboratories for production of biological agents/ biopesticides

S. No	Name of States/Uts	Central	ICAR/ SAUs	DBT	SBC Lab	State	Private	Total
1.	A&N Islands	1	1	1	1	1	-	5
2.	Andhra Pradesh	2	2	2	1	14	7	28
3.	Arunachal Pradesh	-	-	-	1	1	1	2
4.	Assam	1	1	1	1	1	1	6
5.	Bihar	1	-	-	1	-	4	6
6.	Chattisgarh	1	-	-	-	-	-	1
7.	Goa	1	-	-	1	1	-	3
8.	Gujarat	1	1	1	1	1	15	20
9.	Haryana	1	-	1	1	1	3	7
10.	Himachal Pradesh	1	1	-	1	1	-	4
11.	Jammu & Kashmir	2	-	1	1	1	-	5
12.	Lakshadweep	-	-	-	1	-	-	1
13.	Karnataka	1	7	1	1	10	10	30
14.	Kerala	1	2	1	1	9	1	15
15.	Madhya Pradesh	1	-	-	1	1	3	6
16.	Maharashtra	1	7	3	1	2	23	37
17.	Manipur	-	-	-	1	1	-	2
18.	Mizoram	1	-	-	1	1	-	3
19.	Nagaland	1	-	-	1	2	-	4
20.	Orissa	1	1	1	1	6	1	11
21.	Pondichrry	-	-	-	1	1	2	4
22.	Punjab	1	1	1	1	3	-	7
23.	Rajasthan	1		1	1	8	2	13
24.	Sikkim	1	-	-	1	-	-	2
25.	Tamil Nadu	1	3	4	1	76	38	123
26.	Uttar Pradesh	2	1	2	1	15	14	35
27	Uttaranchal	-	1	1	1	-	-	3
28.	West Bengal	1	-	-	1	13	3	18
29.	Delhi	-	2	-	-	-	3	5
30.	Meghalaya	-	-	-	1	-	-	1
31.	Tripura	-	-	-	1	1	-	2
	TOTAL	**26**	**31**	**22**	**29**	**171**	**130**	**409**

· One laboratory, out of these numericals, for each State, has been established through Grants-in-aid from the Department of Agriculture & Cooperation

Annexure V. Crops division schemes for promoting IPM

		(Rs in lakh)
¨	Mini Mission II of Technology Mission on Cotton (2001-2002)	2956.55
¨	Technology Mission on Oilseeds, Pulses & Maize	
	NRDP (2001-2002)	566.40
	OPP (2001-2002)	1644.90
¨	ICDP - Rice (2000-2001)	720.00
¨	ICDP – Wheat (2000-2001)	227.40
¨	Sustainable development of sugarcane-based cropping areas (2000-2001)	106.00

Annexure VI. IPM training and demonstrations period to launch of national IPM programmes, 1986-87 to 1993-94

Year	Training		Demonstrations
	Farmers	SMS	
1986-87	7100	200	12
1987-88	9200	205	14
1988-89	6800	208	18
1989-90	6700	204	18
1990-91	6000	300	24
1991-92	7000	826	24
1992-93	9900	785	66
1993-94	11880	2223	101
Total	**64580**	**4951**	**277**

Annexure VII. FAO-IPC sponsored field training on IPM in rice for Subject Matter Specialists (SMS)

S. No.	Place/State	Month	Year	No. of SMS trained
1.	Cochin (Kerala)	January	1987	47
2.	Aduthurai (T.N.)	September	1987	26
3.	Kanchipuram (T.N.)	August	1988	26
4.	Medchal (A.P.)	February	1989	30
5.	Bhubaneswar (Orissa)	September	1989	30
6.	Mandya (Karnataka)	November	1990	37
7.	Chinsurah (W.B.)	April	1991	35
8.	Gorakhpur (U.P.)	August	1991	43
9.	Raipur (M.P.)	September	1991	44
10.	Jalandhar (Punjab)	August	1992	41
	Total			**359**

Annexure VIII. Special orientation training on IPM during 1994

S.No.	Crop	Venue	Duration	No. of master trainers
1.	Rice	NPPTI Hyderabad	One month each (3 batches)	157
2.	Rice	Bhubaneswar	One week	30
3.	Rice	Saharsa (Bihar)	One week	53
4.	Rice	SCADA, Patna (Bihar)	One week	22
5.	Rice	Patna	One day	65
6.	Rice	Varanasi	One day	76
7.	Rice	Nainital	One day	78
8.	Rice	Sakotai (Tamil Nadu) (For women)	10 days each	71
9.	Cotton	Nagpur	15 days each (2 batches)	90
		Total		**642**

Annexure IX. Statewise training of master trainers through season long training

S. No.	States/Uts	Rice	Cotton	Vege-table	Ground-nut	Must-ard	Gram/ Tur	Chillies	Total
1.	A & N Islands	-	-	-	-	-	-	-	-
2.	Andhra Pradesh	39.	74	22	17	-	-	17	169
3.	Arunachal Pradesh	-	-	2	-	-	-	-	2
4.	Assam	3	-	3	-	-	-	-	6
5.	Bihar	28	-	35	-	4	-	-	67
6.	Bhutan	2	-	-	-	-	-	-	2
7.	Delhi	-	-	1	-	-	-	-	1
8.	Goa	2	-	-	-	-	-	-	2
9.	Gujarat	3	5	-	-	-	-	-	8
10.	Haryana	-	12	-	-	5	-	-	17
11.	Himachal Pradesh	-	-	2	-	-	-	-	2
12.	Jammu & Kashmir	3	-	6	-	2	-	-	11
13.	Karnataka	18	40	13	2	-	-	1	74
14.	Kerala	3	-	-	-	-	-	-	3
15.	Madhya Pradesh	9	4	4	-	1	14	-	32
16.	Maharashtra	10	44	-	4	-	2	-	60
17.	Manipur	2	-	-	-	-	-	-	2
18.	Meghalaya	-	-	2	-	-	-	-	2
19.	Mizoram	-	-	-	-	-	-	-	-
20.	Nagaland	8	-	2	-	-	-	-	10
21.	Orissa	1	-	5	-	-	-	-	6
22.	Pondicherry	-	2	-	1	-	-	-	3
23.	Punjab	16	38	6	-	4	-	-	64
24.	Rajasthan	-	4	-	-	10	-	-	14
25.	Sikkim	1	-	-	-	-	-	-	1
26.	Tamil Nadu	30	31	-	37	-	-	3	101
27.	Tripura	1	-	2	-	-	-	-	3
28.	Uttar Pradesh	59	1	40	-	28	4	-	132
29.	West Bengal	57	-	21	-	-	-	-	78
30	CIPMCs	32	39	67	2	12	10	5	167
31	Others	8	16	3	2	-	-	4	33
	TOTAL	**335**	**310**	**236**	**65**	**66**	**30**	**30**	**1072**

Annexure X. Human resource development in states during 1994-2001

S. No.	State/Uts	IPM Trained & Demonstrations		
		No. of FFSs	AEOs trained	Farmers trained
1.	A&N Islands	44	186	1380
2.	Andhra Pradesh	652	2092	19544
3.	Arunchal Pradesh	16	80	480
4.	Assam	342	1676	10270
5.	Bihar	329	1478	9897
6.	Chhattisgarh	52	260	1546
7.	Goa	60	168	1825
8.	Gujarat	321	1351	9650
9.	Haryana	304	1126	9021
10.	Himachal Pradesh	148	321	4080
11.	Jammu & Kashmir	188	853	5710
12.	Jharkhand	7	18	210
13.	Karnataka	416	1977	13850
14.	Kerala	156	617	5100
15.	Madhya Pradesh	415	1831	12869
16.	Maharashtra	768	3792	24240
17.	Manipur	32	160	960
18.	Mizoram	84	323	2537
19.	Nagaland	89	308	2650
20.	Orissa	252	1215	7580
21.	Pondicherry	40	200	1200
22.	Punjab	358	2020	12250
23.	Rajasthan	320	984	9607
24.	Sikkim	40	149	1210
25.	Tamil Nadu	248	1084	6640
26.	Uttar Pradesh	796	2861	20456
27.	Uttaranchal	20	100	600
28.	West Bengal	236	1229	7670
	Total (Achievement)	**6733**	**28459**	**203032**

Annexure XI. Biocontrol agents/biopesticides available for various pests species

Crop	Pest	Biocontrol agaent/ biopesticides	Dosage	Remarks
Sugarcane	Stalk borer, *Chilo auricilus;* Internode borer, *C.schhariphagus indicus* Shoot borer *C. infuscatellus* and Gurdaspur borer, *Acigona steniellus*	Egg parasitoid, *Trichogramma chilonis* (Sugarcane strain)	50,000/ha	
	Chilo spp	*Sturmiopsis inferens*	125 gravid female/ha	Sequential relese from 30th to 50th day of planting
		Allorphogas pyralophagus	-	-
	Top borer, *Scirpophaga excerptalis*	*T. japonicum* (Sugarcane strain)	50000/ha	-
		Isotima javensis	-	-
	Pyrilla *Pyrilla perpusilla*	*Epiricania melanoleuca*	2-3 egg masses or 5-7 cocoons in 40 selected spots/ha	Release should be made during the humid periods
		Metarhizium anisopliae	-	
	Scale insect *Melanaspis glomerata*	*Chilocorus nigrita* *Sticholotis madagassa* *Pharoscymnus horni*	1500 beetles/ha	Release at the first apperance of the pest
Cotton	Sucking pests: Aphids (*Aphis gossypii*, *Myzuz persisue*), white fly (*Bemisia tabaci*) and thirps (*Thrips tabaci*)	*Chrysoperla cornea*	2 larvae/plant in early stage of the plant and 4 larvae/ plant in later stage	
		Cheilomenes sexmaculata	1.5 lakh adults ha	Release at random on the crop canopy
		Neem 1500 ppm	-	-

continued....

Crop	Pest	Biocontrol agaent/ biopesticides	Dosage	Remarks
	Bolloworms *(Helicoverpa armigera, Pectinophora gossypiella* and *Earias* spp*)*	*Trichogramma chilonis*	150000/ha	
		Bacillus thuringiensis	1kg/ha	Apply during evening hours
	Helicoverpa armigera	*Helicoverpa armigera,* NPV	500 LE/ha is sprayed along with 0.5% jagerry and 0.1% ranipal	$6x10^9$ PIB/LE
		Cotesia marginiventris	3000 adults/ha	Release at random on the crop canopy
	Pectinophora gossypiella	*Bacon hebetor*	3000 adults/ha	Release at random on the crop canopy
		Bessa kirkpatricki	3000 adults/ha	-do-
	Earias spp.	Chlonus blackburni	3000 adults/ha	-do-
Rice	Stem borer, *Scripophaga incertulas*	*T.japonicum*	50,000/ha	
	Leaf folder, brown plant hopper *Naliparvata lugens*	*Cyrotorhinus lividipennis*	100 adults or 50-75 nymphs/m^2	If the predatorhost ratio reaches 1:4, no action is required
Tobaco	Ahpid *Myzuz nocotianae*	*Chrysoperla carnea* or *Apertochrysa* sp.	6 larvae/plant	
	Leaf caterpillar *Spodoptera litura*	*Spodoptera litura* NPV	250 LE/ha three times along with 0.25% boric acid	
		Telenomus remus *Steinernema* spp. *Beauveria* spp. *Nomouraea rileyi*		

continued....

Crop	Pest	Biocontrol agaent/ biopesticides	Dosage	Remarks
Maize	Stem borer *Chilo partellus*	*Trichogramma chilonis*	75000/ha	
Tomato	Tomato fruit borer, *Helicoverpa armigera*	*Trichogramma brasiliensis* or *Trichogramma pretiosum* or *Helicoverpa armigera* NPV	50000/ha or 250 LE/ha along with 0.25% boric acid	
Beans	Red spider mite *Tetranychus* spp.	*Phytoseilus permisilis*	10 adults/ plant	Release 30 days after germination or as and when infestation is noticed. The predator is also effective on tetranychid mites on brinjal and straberries
Cabbage/ Cauliflower	Diamond backmoth, *Plutella xylostella*	*Bacillus thuringiensis* (Several formu-lations including *B.t* oligosporogen mutant (300g) *Cotesia plutellae* *Diadegma semiclausam*	500g	Use permitted spreaders and organise spraying in the afternoon
Capcicum	*Heliothis armigera* *Spodoptera litura*	NPV (HA) NPV (SL) *B. thuringiensis* *Trichogramma*		
Brinjal/Bhindi	Fruit borer	*Trichogramma* *B. thuringiensis*		
Potato	Cutworm	*B. thuringiensis*		
Coconut	Leaf eating caterpillar, *Opisina arenosella*	*Gonizus nephantidis*, *Elasmus nephantidis* and *Brachymeria nosatoi*	Release in the ratio of 20, 50 and 30% of concerned stage	

continued....

Crop	Pest	Biocontrol agaent/ biopesticides	Dosage	Remarks
		Bracon brevicornis *Trichospilus pupivora* *Tetrastichus Israeli* *Brachymeria* spp.		
	Rhinoceros beetle *Oryctes rhinoceros*	Baculovirus	10 virus infected beetles	Area wise coverage gives best results
		Metarhizium anisopliae, Platymeris laevicollis		
	Cocunut mite *Aceria guerreronis*	*Hirsutella thompsonii, Neem*		
Chickpea and pigeonpea	*Helicoverpa armigera*	*Helicoverpa armigera,* NPV	250 LE/ha along with 0.25 boric acid	
Groundnut	Aphidis *Aphis craccivora*	*Cheilomenes sexmaculata* *Brumoides suturalis, Ischiodon scutellaris*		
Soybean	Caterpillars	*Trichogramma* *B. thuringiensis*		
Mustard	Aphids	*Chrysoperla* Neem 1500 ppm		
Citrus	Citrus mealy bug, *Planococcus citri*	*Cryptolaemus montrouzieri*	10 beetles per mealybug infested tree	
		Leptomastix dactylopii		
		Nephus regularis		
	Papilio demoleus	*Bacillus thuringiensis* var. *kurstaki*	0.5% a.i.	Use permitted spreaders organise spraying in the afternoon, ensure proper coverage. Also controls *H.armigera* in the nursery

continued....

Crop	Pest	Biocontrol agaent/ biopesticides	Dosage	Remarks
	Green scale, *Coccus viridis*	*Verticillium lecanii*	10^4 x 16 spores/m^2 + quinalphos 0.00 5%	Use permitted spreaders organise spraying in the afternoon ensure proper covarage
Grapes	Grape mealy bug, *Maconellicoccus hirsutus*	*Cryptolaemus montrouzieri* *Anagyrus dactylopii* *Verticillium*	10 beetles/ vine	
Apple	San Jose Scale *Quadraspidiotus perniciosus*	*Encarsia perniciosi*		
Mango	Mealy bugs, Hoppers	Neem 1500 ppm *Verticillium baeuvaria*		
Spices	Borers Thrips	*B. thuringiensis* Neem 1500 ppm		
Coffee	Pod borer	*Baeuvaria*		
Tea	Caterpillars Thrips Mites	*B. thuringiensis* Neem 1500 ppm		

Annexure XII. Biocontrol agents available for various crop diseases

Crop	Disease	Biocontrol agaent/ Biopesticides	Dosage	Remarks
Cotton, groundnut, chickpea, pigeonpea, sunflower, etc.	Seed borne and soil borne pathogens	*Trichoderma viride/ T.harzianum/ Pseudomonas flurescens*	Seed treat-ment @ 5 to 12 g/kg of seed	
Plantation and horticultural crops	Seed borne and soil borne pathogens	*Pseudomonas flurescens*	Soil application @ 2.5 to 5 kg in 100 kg FYM	
Rice	Sheath blight, leaf spots	*Trichoderma viride/ T. harzianum/ Pseudomonas flurescens*	Foliar application 5 g/litre	
Cotton	Wilt, rot, leaf, spot	*T. viride, T. harzianum Gliocladium virens*		
Pulses (gram, arhar, moong, urd)	Wilts	*Trichoderma*		
Sugarcane	Wilts, red rot, smut	*Trichoderma, Bacillus subtilis Pseudomonas* spp.		
Mustard	While rust & leaf spots	*Trichoderma*		
Wheat	Loose smut Spot blotch	*Trichoderma viride Chaetomium globosum Aspergillus niger*		
Vegetables	Wilts	*T. viride*		
Maize	Sheath blight	*T. viride*		
Potato	Early blight, late blight, black scurf	*Trichoderma*		

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The Future of Integrated Pest Management in India

O.P. Dubey[1] and O.P. Sharma[2]

Introduction

The contribution of agrochemicals in improving food security and human health cannot be undermined. They are, however, like a double-edged weapon; their indiscriminate use could result in a serious threat to the sustainability of the agricultural production system and human health. Though their long-term effects on environment and human health are yet to be fully understood, the short-term adverse effects of their indiscriminate use became apparent soon after their invention during the World War II. Many insect pests have developed resistance to chemical pesticides, and a number of beneficial insects that are natural enemies of the pests have disappeared. Realizing these threats, the scientific community has been proactive and developed safer alternatives using flora and fauna as substitutes for chemical pesticides. These alternatives are claimed to be as effective as chemical pesticides. Experimental evidences indicate that these provide effective protection against pests when used in conjunction with other methods of pest control, including chemical pesticides. The strategy is often referred to as Integrated Pest Management (IPM).

Since the adoption of IPM as a cardinal principle of plant protection in 1985, India has devised and implemented many IPM programmes encompassing research, extension and education with the objective to reduce the use of chemical pesticides, improve farm profitability, conserve environment and reduce adverse effect of pesticides on human health. Their effect is revealed in considerable reduction in pesticide-use, particularly during 1990s. The

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purpose of this paper is to provide a perspective on the IPM with emphasis on food security and safety.

IPM Research

The effectiveness of chemical pesticides in reducing the pest-induced losses has diminished in recent years. A number of insect pests have developed manifold resistance to the pesticides intended to control them. Further, with the destruction of natural enemies of insect pests, a number of new pests have emerged. These imply that intensive use of chemical pesticides is leading to increased cost of pest control and reduced farm profitability. Under such a situation, alternative technologies such as biopesticides could provide some solutions.

Research has generated a number of technologies using plants and pathogens. Many of these have, however, not been commercialized perhaps due to lack of their proven economic feasibility, short shelf-life, slow effect and incompatibility with chemical pesticides. Technologies such as, *Trichogramma chilonis* and *Crysoperla carnea* despite their proven effectiveness, do not find favour with industry as well as farmers because of their short shelf-life, sensitivity to chemical pesticides and higher cost of application. Plant-based pesticides are often slow in action. This suggests that the research should target overcoming these technological problems.

Genetic manipulation of seed varieties for pest resistance is an important constituent of plant protection strategy. Genetically modified varieties of some crops, such as cotton and rapeseed-mustard, have been developed but these are surrounded by controversies regarding their long-term effect on the environment and human beings. Nevertheless, genetic resistance could be an effective tool in pest management.

Public-Private Sector Interface

While most of the technologies have been developed by the public sector, private sector does not find investment in commercial production mainly because of their short shelf-life and stochastic pest behaviour. Most of the biopesticides are produced by the public sector firms. These hardly comprise 2 percent of the agrochemical market. Further, the pesticide has been biased towards chemicals, and views biopesticides as a threat to the existing chemical industry. Moreover, the firms engaged in production and promotion of biopesticides face stiff competition from the pesticide industry.

There is no denying the fact that transition from chemicals to biopesticides would be less remunerative in the short run. But, in view of global concerns of environmental conservation and rising consumer awareness about food quality, the industry has to switch over to biopesticides to harness the emerging opportunities. Nevertheless there is considerable scope to promote biopesticide industry as a small-scale industry with use of local resources, but with strict quality control.

Economic Feasibility

Scientists claim IPM to be an effective way of protecting the crops against insect pests. The claims are based on controlled experimental evidences and its wide scale testing under field conditions is yet to prove its economic feasibility. Its environmental and health benefits are well recognized. But farmers in the developing countries have a myopic view, and heavily discount the environmental and health benefits. They adopt a new technology only if it generates as much economic returns as the current technology. Evidences on economic feasibility are limited and scattered. Nevertheless, these indicate IPM as profitable as chemical control. Thus, in order to make IPM acceptable under field conditions, it is necessary to demonstrate its economic worth through large scale on-farm trials. In other words, there is a need for greater integration of biological and social science research.

Area-wide Adoption

There is hardly any information available on area protected with IPM. Estimates based on production statistics of biopesticides indicate that only about 1 per cent of the gross cropped area receives application of IPM inputs. One of the major impediments is the lack of availability of biopesticides and information thereon to the farmers. IPM is akin to a new technology and farmers often resist its adoption because of risk aversion. Further, as indicated above, many of the biopesticides are slow in action and are sensitive to chemicals. Since pest is a detrimental common property resource, it requires common action for its effective management. Application of chemicals in the neighbourhood of IPM farms reduces the effectiveness of IPM. But, the technological characteristics of biopesticides are such that demand greater involvement of community for realizing their full potential. The current efforts are largely individual-centered. The future of IPM would largely be determined by the community participation. There is a need to devise an 'incentive system' for the farmers who participate in community pest management. Involvement of local administrative units (*Panchayats*) and Non-Governmental Organizations (NGOs) could be of great help in pushing IPM forward.

Agricultural Extension

India has a well-developed agricultural extension system. It has, however, not been tuned to the emerging technological requirements of the farmers. Extension personnel often lack awareness on the IPM inputs in terms of their technological characteristics, application rates and method of application. In recent years though considerable efforts have been made to train extension personnel in IPM, the required skills have not percolated down to the farmers. A system of reward and punishment for extension personnel should be devised.

Funding

The current efforts to promote IPM are largely on account of the initiatives of the Government of India through its Central Integrated Pest Management Centres. Under the national programme for promotion of IPM, the state governments are required to allocate at least 50 per cent of the plant protection funds for promotion of IPM.

Regulations

The production of biopesticides is controlled by the same regulations as applicable to that of chemical pesticides. The process of registration is often cumbersome and costly. This encourages small entrepreneurs to undertake production of biopesticides. Moreover, there are more than 150 pesticides registered for use in agriculture. There are many pesticides that have been banned in the developed countries, but these are freely available in India. Biopesticides require entirely a different set of registration norms. It is, therefore advisable to relax registration norms for biopesticides considering their environmental and health benefits. Banning hazardous pesticides would help emergence of biopesticide industry.

Food Security and Quality

Until recently, food security has been an over-riding policy concern. Now with sufficient stocks of foodgrains, this has dissipated. A few years back it was apprehended that reduction in pesticide-use would adversely affect the production of food as well as non-food crops. And this might endanger the food security. Recent evidences, however, have indicated that gradual reduction in pesticide-use may not have much adverse effects on agricultural productivity. Further, there is a rising awareness about the food safety, particularly among the rich consumers. These concerns are going to be stronger in the future. Promotion IPM besides ensuring environmental protection would also ensure production of quality food.

At present, IPM is not very popular among the farmers. A number of technological, socio-economic, institutional and infrastructure related factors are responsible for this. The success of IPM would be determined by the extent to which these constraints are alleviated.

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