12. Integrated Pest Management Options for Better Crop Production.

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Abstract

Every one is greedy and wants to produce more and more at the cost of the nature and the natural resources. The present day natural resource management is a perfect example of how Indian agriculture is affecting the eco-systems. The excessive dependence on chemical pesticides led to the development of resistance in pests to pesticides, out breaks of secondary pests and pathogens/biotypes, and occurrence of residues in food chain. To overcome such situations and minimize damage to human-and animal-health, several organizations have started advocating the concept of IPM with better profits. This chapter is aimed to discuss the importance of various insect pests and diseases of economic importance of major crops in India and their eco-friendly management strategies in watershed perspective.

Keywords: Crop production, IPM, bio-control, watersheds, bio-safety.

Introduction

Agricultural sector in India has long been recognized for its dependence on chemical control for the management of biotic stresses (insect, diseases, and weeds). The increasing population often demands more and more food grain production. The crop yields in farms are generally low and there are wide gaps between the farmers' yields and the potential yields of several crops. Though reliable estimates on crop losses are limited, Oerke et al. (1995) brought out about 42 % loss in global output due to insect pests, diseases and weeds despite the use of plant protection options. The loss could have been up to 70% in the absence of plant protection. In India, the pre-harvest loss was up to 30% in cereals and pulses and it can be up to 50% in cotton and oil seeds crops (Dhaliwal and Arora, 1993). Annual Economic loss due to *Helicoverpa* alone was estimated at Rs. 2,000 crores despite the use of pesticides worth Rs. 500 crores (Pawar, 1998). Kishor (1997) indicated about 15% gross agricultural loss in Andhra Pradesh due to *Helicoverpa* epidemic in cotton growing areas during 1988. In India, the losses due to a 5% increase in neck blast caused loss of grain yield of about 6% (Kapoor and Singh, 1983) whereas bacterial blight can cause grain losses ranged from 60-70% in rice Raina et al. 1981). Stripe disease of barley caused 70-72% yield loss (Pant and Bisht, 1983). Yellow mosaic virus caused yield losses in greengram and blackgram by 67% (Jain et al. 1995). In groundnut, collar rot caused losses ranging from 28-47%. In the past five decades there was a steady increase in the chemical utilization from 2.2 gm ha^{-1} of active ingredient (ai) in 1950 to the current level of 650 gm ha^{-1} which is a 300 fold increase (David, 1995). In recent years farmers' incomes are declining particularly due to increased cost of plant protection in puts. Among various pesticides, the use of insecticides was much in India compared to the global scenario (Verma, 1998).

The excessive dependence on chemical pesticides led to the development of resistance in pests to pesticides, out breaks of secondary pests and pathogens/ biotypes, and occurrence of residues in food chain. To overcome such situations and minimize damage to human - and animal-health, several organizations have started advocating the concept of IPM with better profits. Besides damage to human health, total dependence on chemical pesticides has eliminated bio-diversity, resulting in the reduction of natural enemies. Though Indian plant protection in the modern age is making larger strides of progress, it is necessary to consider the treasure of ancient knowledge, particularly the use of safer pesticides for the development of integrated water shed development. In fact this is not new, and there was ample evidence that our ancestors had the knowledge and experience and lived under healthier environments than the present generations. It is envisaged that an innovative integrated plant protection can change the fortunes of the farming communities.

Integrated watershed Management with IPM as one of the components has been considered in all watershed programs in India with the primary goal as:

- To increase the productivity with reduced pesticide risk to the producers, consumers and the environment.
- Conserve the biodiversity through augmenting natural enemies of biotic stresses.
- Encourage eco-friendly approach of pest management
- Ensure farm productivity and profitability with reduced inputs on plant protection.
- Empower farmers through periodic training and exposure visits to improve their decision making process.

Integrated Pest Management

Integrated pest management can be defined as `One or more management options adopted by farmers to maintain the density of potential pest populations below threshold levels for enhanced productivity and profitability of the farming system as a whole, the health of the farm family and its livestock, and the quality of immediate and downstream environments'.

IPM Options Followed in Watersheds

Among various plant protection options, the watershed team has chosen to promote the following eco-friendly approaches for use by farming communities.

- Diagnostic surveys and farmers interactions for determining the economic importance of various pests.
- Training farmers in the diagnosis and management of pests.
- Periodic monitoring of biotic stresses.
- Incorporation of agronomically suitable resistant varieties into the system.
- Building knowledge on the role of cultural practices.
- Enhancing the role of natural enemies through augmentation.
- Encouraging the production and adoption of bio-pesticides at village level.
- Need based application of chemical pesticides.
- Adoption of bio-safety and protective clothing while using chemicals.
- Networking farmers across watersheds for sharing information inputs and market intelligence.

Diagnostic Surveys

Before initiating biotic stress management at watershed level, one should take up in-depth farmer participatory appraisal (PRA) for diagnosis and categorize various biotic stresses to design appropriate management strategies. To achieve this, general PRA needs to be organized at each location and the results should be discussed with the group. The whole farming community needs to be involved at every level of decision making. The biotic stress atlases should be developed and updated at regular intervals. These atlases should be in a language that could be easily communicated to the farmers.

Scouting squads should be constituted by drawing the educated rural youth for regular monitoring of the fields. The information from surveys should be consolidated to draw meaningful conclusions on the pest/disease scenario. The risk due to severity of the pests should be communicated to the farmers from time to time through various communication systems such as farmer field schools, radio, television and modern information and communication technology (ICT) tools.

Capacity Building

After PRAs and diagnostic surveys, an in-depth training in the diagnosis and management options to address the biotic constraints has to be taken up either at headquarters or at village level to cover maximum number of beneficiaries. To achieve maximum impact, audio visual aids such as videos, handouts in local languages would be of immense value. After this exercise, periodic crop monitoring from sowing to crop harvest and evaluation of various constraints has to be taken up with the help of trained resident guide involving key farmers of the village. Pest monitoring tools such as pheromone traps, light traps, sticky traps and weather monitoring apparatus need to be established at every watershed. This information would be of strategic value and acts as a historic database to assist farmers in decision making process.

Bio-Safety

The present day Indian agriculture totally ignored the bio-safety over the past five decades and majority of the farmers have not adopted even protective clothing to avoid the chemical toxicity, operational hazards and food safety. This area has been given high priority to avoid chemical induced accidents and to provide better health and environment.

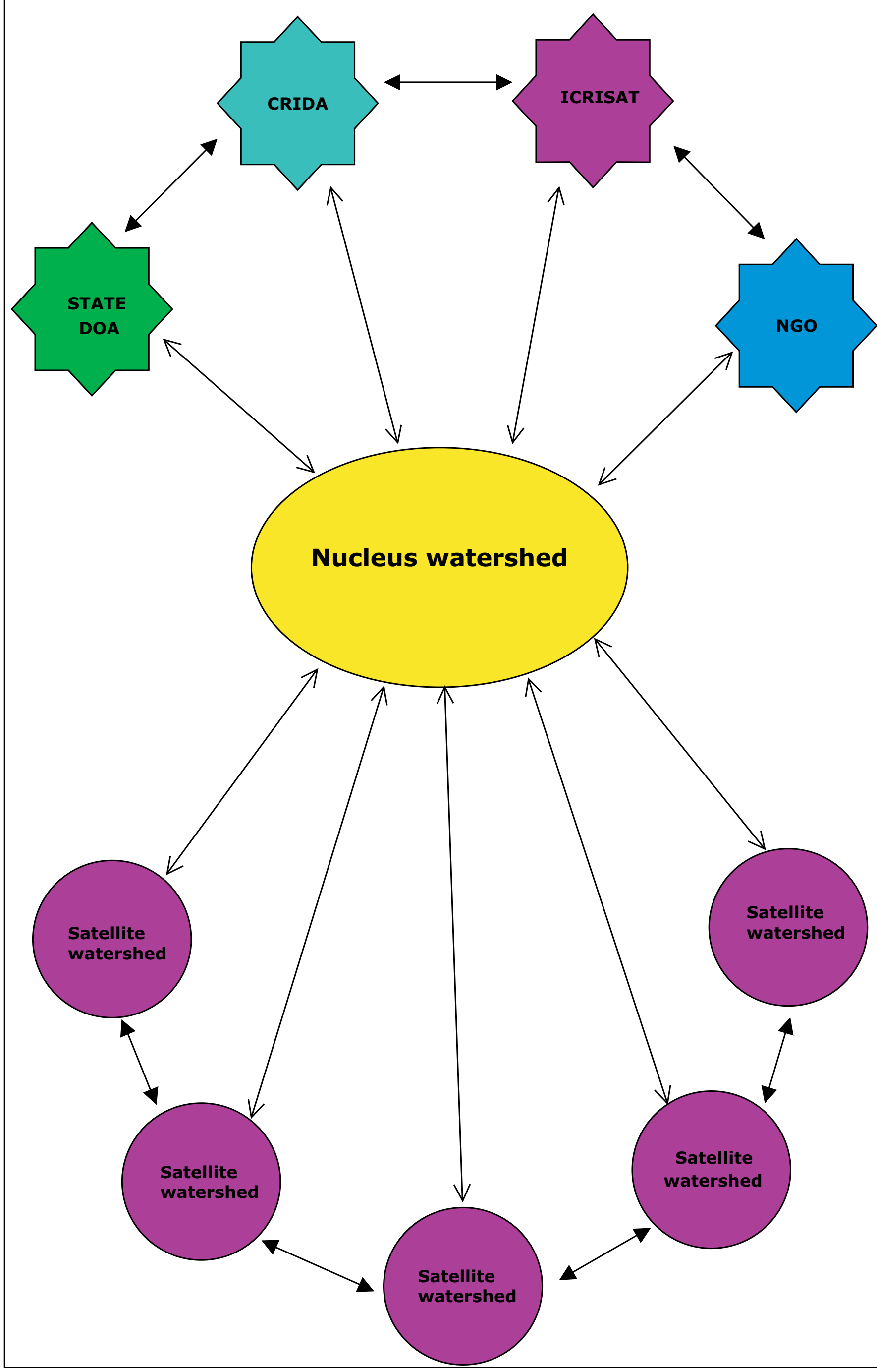
Networks

Though importance of farmers' networks is known for a decade in Indian agriculture, the implementation is far away from the reality. In developing integrated watersheds, in a systems approach, initiation of networks across watersheds in the district, state and nation wide is of immense value to update and create information flow across the farming community.

The Process

The proposed integrated watershed management has been taken up in a consortium approach involving government, non-governmental and international organizations with farmer participatory approach. This multidisciplinary, multi-organizational approach provides a platform between different organizations and farmers. Various developmental activities have been taken up with farmer initially in nucleus watersheds in the first year. After strengthening these nucleus watersheds, in terms of technology exchange and capacity building, the activities were scaled up to satellite watershed with the active involvement of trained farmers from nucleus watersheds. The impact of this approach was studied by comparing various outputs including enhanced productivity, increased profits, and reduced inputs on pesticides and

Organizational Structure of Integrated Watershed Management



minimum disturbance to the environment in contact and non-contract watersheds groups.

Monitoring Insect Pests

The insect pest population can be monitored following either direct or indirect techniques. The technique selected mostly depends on the type of insect being studied and its behavior. In case of direct sampling, insect pests are monitored by counting insects through direct observation. This can be either absolute or relative estimates.

A selection of sampling techniques suitable for various types of pest are shown below

Insect	Sampling method
Whiteflies, midges, adult foliage beetles	Sweep net, direct observation and counting
Lepidopteran adults (*Spodoptera, Helicoverpa, Aproaerema* etc.,)	Light trap (night flying insects); pheromone trap; sweep net
Lepidopteran larvae	Direct observation and counting, beating/ shaking with ground cloth
Ground beetles (adult and larvae)	Pitfall trap soil sample
Thrips	Direct observation and counting
Leaf miner larvae	Direct observation and counting
Aphids	Colored sticky trap; direct counting of colonies.
Leaf hoppers	Colored sticky trap; sweep net
Beneficial insects	Sweep net, pitfall traps, insect rearing, de-vac

Disease Monitoring

Disease monitoring involves studying the disease progress curves based on the incidence and intensity of the diseases recorded at regular intervals. In case of multiple-cycled diseases, monitoring of the spore population in the near vicinity of the crop and microclimate of the crop helps in developing prediction models. For monitoring the spore fauna, spore-sampling devices such as spore collectors could be used.

The disease management system currently recommended in groundnut is in the form of a package and not precisely tailor-made based on actual information on host-pathogen dynamics in relation to weather and time. The Indian farmer is denied of a reliable as well as dependable disease prediction system (as against peanut farmers in the US), in absence of which the sudden outbreak of these diseases do not give enough time to take timely initiative to contain the rate of spread of the disease.

Recently, leaf wetness has been used as a parameter to forecast foliar disease incidence. Some efforts were made in the past, to work on the epidemiology of rust pathogen. Practically no concerted efforts have so far been made to develop the prediction systems for diseases either for a agro-climatic region or over regions. Very little efforts have been made to collect information on weather parameters influencing disease incidence and severity and develop forecasting models.

Pest and Disease Scenario in India

Among various pests, yellow stem borer, brown plant hopper, and gall midge on rice; *Pyrella* on sugarcane; *Helicoverpa* on legumes; white fly, boll worms on cotton; aphids on mustard; hoppers on mangoes; codling moth and mites on apples; scale insects and fruit flies on citrus; fruit and stem borer in brinjal; tobacco caterpillar on tobacco and vegetables; diamond back moth on crucifers continue to pose severe threat to the main field crops and became major yield reducing factor. In the storage, rice weevil, rice moth on cereals; bruchids on pulses and *Caryedon* on groundnut are of economic importance. The details are given in Table 1.

Table 1. Economically important pests of major crops in India

Crop	Common name	Scientific name	ETLs	Existing control methods
Cereals				
Rice	Stem borer	*Scirpophaga incertulus* Walker	5% white ears/ One egg mass sqm^{-1}	IPM
	Brown plant hopper	*Nilaparvata lugens stal.*	10 hoppers per clump.	IPM
	Gall Midge	Orseolia oryzae wood-mason	5-10% silver shoots	Host plant resistance(HPR)
	Leaf folder	*Cnaphalocrocis medinalis* guen	10-15% webbed foliage	HPR
Wheat	Aphid	*Schizaphis graminum* (rondani)	5-10% of plants with infestation	HPR
Maize	Stem borer	*Chilo partellus* (swinhoe)	5-10% infestation	Chemical
	Shoot fly	*Atherigona* spp.	5-10% dead hearts	Chemical
	Earworm	*Helicoverpa armigera* hubner	25-30% damage to cobs	Chemical

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Crop	Common name	Scientific name	ETLs	Existing control methods
Legumes				
Pigeonpea	Pod borer	*Helicoverpa armigera* (hubner)	5 eggs or 3 small larvae per plant	IPM
	Pod fly	*Melanagromyza obtusa* (malloach)	In all endemic locations	Chemical
	Leaf webber	*Maruca vitrata* (geyer)	5 webs per plant	Chemical
	Pod sucking bugs	*Clavigralla gibbosa spinola*	One egg mass per plant	Chemical
Chickpea	Pod borer	*Helicoverpa armigera* (hubner)	3 eggs or 2 small larvae per plant	IPM
	Cutworm	*Agrotis ipsilon* (hufnagel)	5% plant mortality	Chemical
Soybean	Stem fly	*Ophiomyia phasioli* (tryon)	5% plant infestation	Chemical
	Girdle beetle	*Obereopsis brevis* (swed)	5% incidence	Chemical
	Hairy caterpillar	*Spilosoma obliqua* (walker)	5 larvae meter row	Chemical
Oil Seeds				
Groundnut	Leaf miner	*Aproaerema midicella* deventer	5 mines per plant at 30 days of crop age	IPM
	Tobacco caterpillar	*Spodoptera litura* (fab)	20-25% defoliation at 40days	IPM
	Thrips	*Scirtothrips dorsalis* hood	5 thrips/terminal at seedling stage	Chemical
	Aphids	*Aphis craccivora* kouch	5-10 aphids per terminal at seedling stage stage in dry spells onlyin rainy season	IPM
Sunflower	Gram pod borer	*Helicoverpa armigera* hubner	One larva per head	Chemical
Sesame	Leaf webber	*Antigastra catalaunalis* dub	2-5 webbs per plant	Chemical
Rapeseed	Aphids	*Lipaphis erysimi* (Kalt)	5-10 aphids per plant	Chemical

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Crop	Common name	Scientific name	ETLs	Existing control methods
Vegetables				
Brinjal	Fruit and stem borer	*Leucinodes orbanalis*	1-5% shoot/ fruit infestation	IPM
Cabbage & Cauliflower	Dimond back moth	Plutella *xylostella* linn	1-5% incidence	IPM
	Tobacco caterpillar	*Spodoptera litura* (fab)	1-5% incidence	IPM
Tomato	Fruit worm	*Helicoverpa armigera* hubner	1-5% fruit damage	IPM
Fruits				
Apple	San Jose Scale	*Quadraspidiotus perniciosus* (comstock)	Appearance of pest in 5% trees	Chemical & miscible oils
	Codling moth	*Cydia pomonella* (L.)	1-2% incidence	IPM
	Phytophagous mites	*Panonychus ulmi (koch)*	5-10% foliage infestation	Miscible oil & IPM
Grapes	Flea beetle	*Scelodonta stricollis* (mots.)	20% foliar damage	Chemical
	Thrips	*Retithrips syriacus* (mayet)	5 thrips/young leaf	Chemical
	Mealy bugs	*Maconellicoccus hirstutus* green	1% bunch infestation	Chemical
Oranges	Fruit flies	*Carpomyia vesuviana* costa.	1-2% incidence	Chemical
	Defoliators	*Papilio demoleus L.*	20-30 % foliar damage	Chemical
Mango	Hopper	*Amritodes atkinsoni* leth.	2-5 hoppers per inflorescence	Chemical
	Leaf webber	*Orthaga exvinacea*	10% incidence	Chemical
	Stem borer	*Batocera rufomaculatus* deg	Appearance of the pest	Chemical
Cash Crops				
Cotton	American bollworm	*Helicoverpa armigera* hub.	5-10 % boll infestation	IPM
	Pink bollworm	*Pectinophora gossipiella* saund	5-10% boll infestation	IPM
	Whitefly	Bemisia tabaci genn.	8-10 adults/leaf	IPM
	Spoted bollworm	Earias insulana boisd.	5-10% boll infestation	IPM

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Crop	Common name	Scientific name	ETLs	Existing control methods
Sugarcane	Stem borer	*Chilo sacchariphagus indicus* (kapur).	10% shoot damage at tillering phase	IPM
	Scale insect	*Melanapsis glomerata* (green)	20-30% canes with scale incidence	IPM
Tobacco	Tobacco caterpillar	*Spodoptera litura* fab.	5-10% leaves with damage	IPM
	Whiteflies	*Bemisia tabaci* genn.	5-10 flies/leaf	IPM
Storage pests				
Cereals	Rice weevil	*Sytophilus* oryzae	Appearance of live insects	Chemical
	Paddy moth	*Sitotroga cerealella*	Appearance of adult moths	Chemical
	Rice moth	*Corcyra cephalonica*	Appearance of adult moths	Chemical
	Red flour beetle	*Tribolium castaneum*	Appearance of adult beetles	Chemical
Pulses	Bruchids	*Bruchus* sp.	Appearance of adult insects	Chemical
Oil seeds				
Groundnut	Groundnut bruchid	*Caryedon serratus*	Appearance of adult beetles	Chemical

Several pathogens have been reported to cause serious diseases in many crops in India. Some of the economically important diseases of major crops in India are blast and blight in rice; rust and karnal bunt in wheat; leaf blight, rust, wilt and stem and cob rots in maize; wilt, root rots and blights in legumes; stem and pod rots and foliar diseases in groundnut; gray mold, A*lternaria* and bacterial blights, downy and powdery mildews in oil seeds; damping-off, wilt and powdery mildew in vegetables; downy and powdery mildews in mango, grapes and oranges; wilt and leaf spots in cotton; red rot and smut in sugarcane; damping-off and frog eye spot in tobacco. Fungi like *Alternaria, Aspergillus* and *Fusarium* species are also very important in storage and spoils quality and viability of grains, fruits and seeds. The details of economically important diseases and their causal agents and the available management strategies are furnished in Table 2.

Table 2. Economically important diseases of major crops in India

Crop	Disease name	Causal organism	Existing control methods
Cereals			
Rice	Blast	*Pyricularia oryzae*	IDM
	Sheath blight	*Rhizoctonia solani*	IDM
	Bacterial leaf blight	*Xanthomonas oryzae*	IDM
Wheat	Leaf or brown rust	*Puccinia recondite* f.sp. *tritici*	HPR & IDM
	Stem or black rust	*Puccinia graminis* f.sp. *tritici*	HPR & IDM
	Karnal bunt	*Neovossia indica*	HPR & IDM
	Loose smut	*Ustilago segetum*	IDM
Maize	Maydis leaf blight	*Cochliobolus heterostrophus*	HPR &chemical
	Common rust	*Puccinia sorghi*	HPR & chemical
	Downy mildew	*Peronosclerospora sp*	Chemical
	Fusarium wilt & stalk rot	*Fusarium moniliforme*	HPR
	Charcoal rot	*Macrophomina phaseolina*	HPR
Legumes			
Pigeonpea	Wilt	*Fusarium udum*	HPR
	Phytophthora blight	*Phytophthora drechsleri f.sp. cajani*	IDM
	Sterility mosaic	Sterility mosaic virus transmitted by *Aceria cajani*	HPR
Chickpea	Wilt	*Fusarium oxysporum f.sp. ciceri*	HPR
	Dry root rot	*Rhizoctinia bataticola*	HPR
	Collar rot	*Sclerotium rolfsii*	HPR
	Ascochyta blight	*Ascochyta rabiei*	IDM
	Botrytis gray mold	*Botrytis cinerea*	IDM
	Stunt	Bean leaf roll virus	HPR
Soybean	Pod blight	*Colletotrichum dematium* f. sp. *truncata*	Chemical & HPR
	Bacterial pustule	*Xanthomonas campestris*	HPR
	Bacterial Blight	*Pseudomonas sps*	Cultural & HPR
	Charcoal rot	*Macrophomina phaseolina*	Cultural & HPR
	Collar rot	Sclerotium rolfsii	HPR

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Crop	Disease name	Causal organism	Existing control methods
Oil Seeds			
Groundnut	Crown rot	*Aspergillus niger*	Chemical
	Stem & pod rots	*Sclerotium rolfsii*	HPR & cultural
	Aflatoxin	*Aspergillus flavus*	Integrated management
	Early leaf spot	*Cercospora arachidicola*	IDM
	Late leaf spot	*Phaeoisariopsis personata*	IDM
	Rust	*Puccinia arachidis*	HPR & IDM
Sunflowers	Gray mold	*Botrytis cinerea*	Chemical
	Alternaria blight	*Alternaria helianthi*	Chemical
	Wilt	*Verticillum dahliae*	HPR
	Scorch	*Maacrophomina phaseoli*	HPR
Sesame	Phytophthora blight	*Phytophthora parasitica*	Chemical
	Charcoal rot	*Macrophomina phaseolina*	HPR
	.Wilt	*Fusarium oxysporum* f. sp. *sesami*	HPR
	Cercospora leaf spot	*Cercospora sesami*	HPR
	Alternaria leaf spot	*Alternaria sesami*	HPR
	Bacterial blight	*Xanthomonas campestris*	HPR
Rapeseed	Alternaria blight	*Alternaria brassicae*	HPR
	Downy mildew	*Peronospora parasitica*	HPR
	Powdery mildew	*Erysiphe cruciferarum*	HPR
Vegetables			
Brinjal	Damping-off	*Phytophthora or Pythium sp*	Chemical
	Wilt	*Fusarium ozonium*	HPR
	Phomopsis blight	*Phomopsis vexans*	HPR
Cabbage	Downy mildew	*Perenospora parasitica*	Chemical
	Alternaria blight	*Alternaria solani*	Chemical
	Black rot	*Xanthomonas campestris*	Chemical
Cauliflower	Stalk rot	*Sclerotinia sclerotiorum*	Chemical
Tomato	Late blight	*Phytophthora infestans*	Chemical
	Leaf blight	*Septoria lycopersici*	Chemical
	Tomato spotted wilt	*Vial disease*	HPR + cultural
	Wilt	*Psuedomonas solanacearum*	HPR

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Crop	Disease name	Causal organism	Existing control methods
Fruits			
Apple	Scab	*Venturia inaequalis*	HPR + Chemical
Grapes	Anthracnose	*Gloeosporium ampelophagum*	Chemical
	Downy mildew	*Plasmopara viticola*	Chemical
	Powdery mildew	*Uncinula necator*	Chemical
Oranges	Canker	*Xanthomonas campestris* pr. *citri*	Chemical
	Gummosis	*Diaporthe citri*	Chemical
Mango	Powdery mildew	*Oidium mangiferae*	Chemical
	Anthracnose	*Colletitrichum gloeosporiodes*	Chemical
Cash Crops			
Cotton	Verticillium wilt	*Verticillium dahliae*	HPR
	Root rot	*Rhizoctonia sps*	HPR
	Alternaria leaf spot	*Alternaria macrospora*	IDM
	Anthracnose	*Colletotrichum gossypii*	Chemical
Sugarcane	Red rot	*Colletotrichum falcatum*	HPR
	Smut	*Ustilago scitaminea*	HPR
	Wilt	*Fusarium sacchari*	HPR
Tobacco	Damping-off	*Pythium aphanidermatum*	Chemical
	Frog-eye spot	*Cercospora nicotianae*	Chemical

Resurgence

As mentioned by Professor Matthews (2001), Imperial College of Science, UK. Three R's (resurgence, resistance and residues) are the main focus of the present day plant protection in all developing countries. In recent years wide spread resurgence of whitefly in cotton in the state of Andhra Pradesh, Gujarat, Karnataka, Tamil Nadu and Maharashtra have been reported, which was mainly due to the indiscriminate use of the insecticides (Rajak 1993). Of the several reasons for pest resurgence, misuse of pesticides, application of imbalanced micro-nutrients for plant nutrition, use of sub-lethal doses of insecticides, destruction of natural enemies, lack of bio- diversity due to changes in cropping systems and favorable environmental factors play critical role in outbreaks. This resulted in pesticide tread mill with increased investments on pesticides and eroded profits and severely impact on the environment.

Like insects, resurgence in pathogens also has become a normal phenomenon because of misuse and abuse of fungicides during last two decades. During the process of resurgence, the previously controlled diseases/pathogens remerge as a virulent and fungicide resistant strain, devastating the crops. The classical example of pathogen resurgence is the late blight of potato caused by *Phytophthora infestns*.

Development of Resistance to Pesticides

The abuse of pesticides on cotton over the past several years resulted in the development of resistance in *Helicoverpa* to a wide range of insecticides, 23-8022 fold resistance to cypermethrin, 10-17 fold resistance to cyclodiene (endosulfan), and 82 fold resistance to chlorpyriphos. In case of pink boll worm recent reports indicated 23-57 fold resistance to endosulfan. *Spodoptera litura* from southern part of India exhibited 45-129 fold resistance to chlorpyriphos. There are high levels of insecticidal resistance in *Bamisia tabaci* and cypermethrin than endosulfan and chlorpyriphos (Kranthi et al. 2001). Studies conducted on *Spodoptera* showed various levels of resistance to commonly used insecticides (Armes et al. 1997, Kranthi et al. 2001). Previous reports also suggested the occurrence of resistance in 14 pests of public health importance, 6 pests of stored grains and 7 pests of field crops (Rajak, 1993).

Similarly like insect pests, development of resistance against several systemic fungicides is observed in many pathogens. With the excessive and intensive use of a fungicide, the resistant strains may become a dominant part of population and result in the loss of fungicide effectiveness (Delp, 1990). Thus the resistance to fungicide is observed in pathogens like *Alternaria, Botrytis, Cercospora,* and *Phytophthora,* etc.

Pesticide Residues

The basic problem is the negligence of safety intervals after sprays and also the lack of residue monitoring in the products. There are many reports about the presence of insecticide and fungicides residues in the environment, food, fodder as well as in human bodies 86% contamination of DDT and 89% HCH in dairy milk from different states. The samples of mother's milk from eight districts of Tamil Nadu also revealed 87% contamination with HCH and 100% with DDT (Handa, 1995). Fungicide residues of benlate, captan, chlorothalonil and vinclozolin fall above admissible levels. To minimize the hazards due to pesticide residues strict regulatory measures need to be implemented at all levels of pesticide handling.

Development of ETLs for Major Pests

Under Indian conditions, most of the crops are grown in varied climatic conditions and hence there is a need for the development of appropriate ETLs to meet specific crop-pest-situation under different agro-climatic regions. A simple manipulations in ETLs to minimize the misuse of chemical pesticides need to be given high priority.

Development of Forewarning Systems for Insect-Pests and Diseases

In a watershed area, for the effective implementation of the IPM programs, forewarning systems for the pests would be handy as they not only help in deployment of timely pest management options but also reduce the cost of cultivation. Development of forewarning sytems needs information in threshold levels for pests and diseases, and conditions congenial for the development of epidemics.

Very few foliar/blight diseases of few crops have simulation models to predict or forecast the occurrence of diseases based on weather parameters and symptoms appearance to initiate or take up disease control measures. The best example of this prediction models is weather based advisory system (WBAS) using leaf wetness to predict onset of foliar diseases in groundnut.

Implications of Pesticides Usage in Plant Protection

Every one is greedy and wants to produce more and more at the cost of the nature and the natural resources. The present day natural resource management is a perfect example of how Indian agriculture is affecting the eco-systems. One must realize the responsibility in exploiting the natural resource beyond the optimum levels. If the present trend continues for some more years, one has to pay severe price and may ruin the natural balance to an irreparable level

During 1998, the Montreal, international delegation passed out the judgment to phase out the one dozen harmful compounds called "dirty dozen" including eight insecticides (Aldrin, DDT, chlordane, dieldrin, endrin, heptachlor, mirex and toxaphene). At this stage it is essential to emphasize that no chemical pesticide is safe to human health or environment. The word "safe" is a relative term. Some chemicals may harm us in short periods while others may affect in long-run. That is the only difference amongst them.

Adarsha Watershed, Kothapally: A Case Study

Adarsha watershed is located in Kothapally village (78° E and 17° N) in Ranga Reddy district of Andhra Pradesh, India and is 50 km northwest of Hyderabad. The total area under cultivation is about 430 ha, out of which 160 ha were irrigated. The farmers grow several crops including cotton, maize, sorghum , pigeonpea intercropped with maize, chickpea, vegetables, and paddy. Among various agricultural constraints insect pests were well recognized but the farmers were aware of only the chemical control. The farmers in this village were investing about US $ 50,000 in plant protection annually. Hence this study was initiated during the cropping season 2000-01 in order to develop an eco-friendly alternative to chemicals for the effective management of pests.

Methodology Followed at Kothapally Watershed

These studies were conducted in the village under farmer participatory integrated watershed management approach. Population dynamics of adult *Helicoverpa armigera* was monitored by using pheromone traps for the first time during 2000-2002. Five farmers each for pigeonpea and chickpea with 0.4 ha area participated in these on-farm bio-intensive pest management (BIPM) studies during the year 2000-01 and 2001-02. The results from these fields were compared with adjacent five farmers fields where repeated application of chemicals were used (non-IPM). During 2000-01, the pigeonpea BIPM farmers applied one spray each of neem and HNPV, followed by manual shaking (3-5 times) and have not applied any chemicals. Non-IPM farmers sprayed 3-4 times with chemicals. During 2001-02 season, BIPM farmers used one spray each of neem and HNPV followed by manual shaking (2-4 times), while non-IPM farmers used 2-3 rounds of chemical sprays. In chickpea, during post rainy season 2000-01 the BIPM plots received 1-3 sprays of HNPV while the non-IPM farmers did not apply any plant protection measures to their crops. During 2001-02, BIPM farmers applied one spray of neem and two sprays of HNPV, while non-IPM farmers used 2 sprays of chemicals.

The cotton BIPM was initiated during 2003-04 and continued for the next two seasons ie, up to 2006. Synthetic chemicals were not used in this BIPM protocol. The bio-intensive pest management protocol was evaluated by 17 farmers during 2003-04, followed by 9 farmers during 2004-05 and 5 farmers during the year 2005-06. Each contact farmer was asked to divide a given field in to two halves, one each for BIPM and farmer practice (FP/Non-IPM). The BIPM protocol involved five items, and small changes in agronomy. The first two are extracts of two botanicals, neem (*Azadirachta indica*) and *Glyricidia sepium* (a leguminous tree), prepared using a biological method. The third is a research product of ICRISAT – the bacterium *Bacillus subtilis* strain BCB19/the fungus *Metarrhizium anisopliae*. The last two components were items that farmers have traditionally usedcow-urine solution, and curd recipe, that involves mixing specific quantities of curd, jaggery (concentrated sugarcane juice) and bread yeast – all mixed in water and sprayed. (Rupela et al.2006).

Results

Monitoring of *Helicoverpa*

Pheromone trap catches clearly indicated two good peaks during August-September with 27 and 23 moths trap^{-1} in the standard weeks 34 and 38, respectively. There was another small peak during standard week 49 (ie, 3-9 December) with 9 moth strap^{-1}. Later the population declined drastically. These adult populations corresponded with peak pest activity during boll formation of cotton and flowering of pigeonpea in October-November months.

Pigeonpea

During 2000-01 season the oviposition of *Helicoverpa* was at its peak during the first fortnight of November with 6 eggs plant^{-1} and it declined to almost one on 10 plants by crop maturity stage ie, the end of December. *Helicoverpa* larval population was at its peak with 10 larvae plant^{-1} during the first fortnight of November and decreased to 2.6 larvae plant^{-1} by end of December. The larval population in BIPM plots was always found lower than those of non-IPM plots, where farmers applied 3-4 sprays of chemicals. IPM interventions resulted in substantial decrease in borer damage to pods and seeds. BIPM plots had 34% pod damage compared to 61% in non-IPM plots. The seed damage was also low in BIPM plots (21%) compared to non-IPM plots (39%). This lower pod borer damage in BIPM plots also reflected in higher yield of 0.77 t ha^{-1} when compared to 0.53 t ha^{-1} in farmer's practice.

The observations on egg and larval population during 2001-02 indicated similar trend as in the previous season. The BIPM interventions resulted in 33% and 55% reduction in pod and seed damage respectively. The BIPM plots yielded 0.55 t ha^{-1} compared to 0.23 t ha^{-1} in non-IPM plots even though the overall yield levels were low.

Chickpea

Observations on egg and larval population during 2000-01indicated the onset of the pests during the first fortnight of November when the crop was around 30 days old (with one egg plant^{-1}), and the number continued to increase until the first fortnight of December when the crop attained podding stage and later declined by the end of January. The difference in plant protection practices between BIPM and non-IPM plots was clearly reflected in low larval population in BIPM fields through out the vulnerable phase of the crop. The BIPM farmers also harvested 3 times higher yields with 0.78 t ha^{-1} compared to 0.25 t ha^{-1} in non-IPM fields which was primarily due to the effective pest management and adoption of improved variety (ICCV 37) developed at ICRISAT.

During the second year, the larval population at vegetative and flowering stages was more in non-IPM plots, and at pod maturity stage the population reached below economic threshold level (<1 larva plant^{-1}) in both the treatments. This differential population resulted in small reduction in pod damage (4%) and 19% increase in grain yield in BIPM plots. Thus two years data revealed the advantage of BIPM modules over the chemical management of insect pests.

Cotton

During 2003-04, twelve out of 17 BIPM farmers obtained 20-80% higher yields, while four farmers realized 0-20% better yields and in only one farmer's field the yield was lower (4%) in BIPM treatment compared to farmers practice. When all the farmers' yields are considered the BIPM fields yielded 30% better than non-IPM fields. In the next season (2004-05) 4 out of 9 farmers obtained >20% yield (range 20-45%), two out of nine received 5-6% higher yield and three farmers realized less yield in BIPM plots. In the third year three out of six farmers realized 33-74% higher yield and two out of six farmers got 9-12% better yields, while one farmer obtained 3% lower yield in BIPM plots. In general, majority of farmers harvested higher yields through BIPM compared to complete chemical based farmers practice (Table 3).

After realizing the good impact from BIPM in cotton, six farmers from this village adopted the same technology in protecting tomato from insect pests. During 2005, BIPM farmers realized 2-322% yield gain over the plots covered with conventional chemical pest management. The productivity of tomatoes varied from 1.68–7.93 t ha^{-1} in BIPM compared to 1.31–5.34 t ha^{-1} in chemical management. It was also clear from the observations that the difference in productivity varied with the level of inputs put forth by various farmers (Table 4). This clearly indicated the economic feasibility of bio-intensive options over conventional chemicals.

Table 3. Cotton yields in BIPM and FP plots in Kothapally village during 2003-06 (three seasons).

Season (No. of farmers)	Mean yield (t ha^{-1})		
	BIPM	FP	SE±
2003/04 (17)	2.43	1.87	0.080
2004/05 (9)	0.74	0.68	0.058
2005/06 (6)	1.74	1.38	0.096

Table 4. Tomato yields in BIPM and FP treatments in six farmer's fields in Kothapally village during 2005.

Name of farmer	Yield ($t\ ha^{-1}$)		Yield increase over control (%)	Cost of plant protection ($Rs\ ha^{-1}$)	
	BIPM	FP		BIPM	Non-IPM
T. Pochaiah	5.53	1.31	322	2870	2929
B. Narayan Reddy	7.93	5.34	49	2154	2344
Md. Yousuf	3.21	2.35	37	1848	2344
T. Kishtayya	2.12	1.85	15	3144	2929
K. Laxminarayana	2.42	2.22	9	1764	2344
K. Permaiah	1.68	1.65	2	561	2929
Mean	3.82	2.45	55.9	2057	2637
SE ±	0.488				

The BIPM plots always registered higher natural enemy population compared to farmers' practice. There were two coccinellids and one spider in every ten plants in BIPM plots compared to none in FP plots, indicating the congenial conditions provide by BIPM treatments for the augmentation of the natural enemies. Crops generally remained productive for about three weeks longer than the FP plots. That generally senesced suddenly.

Bio-Pesticide Production at Village Level

Realizing the non-availability of good quality bio-pesticides at farm level as the basic constraint, this concept aimed to address this problem through imparting training and establishing the production units at village level. Six farmers and one extension worker from this village were given training on HNPV production, storage, and usage. The villagers quickly adopted the technology and produced 2000 larval equivalents (LE) of virus during 2000-01. Two women of a self-help group (who showed interest) were identified and trained in preparing the wash of compost of neem and *Glyricida*. After two days of training at ICRISAT, the facility for producing the neem and G*lyricidia* compost washes was established in the village during 2004-05. Thus, this approach empowered farmers to produce good quality product at field level with proper guidance.

Way Forward

- In view of the availability of natural resources and the productivity, the plant protection in upstream and downstream systems need to be developed appropriately to avoid pest buildup in the whole system.
- Data on toxic residues on all food, feed and water bodies is of high priority.
- Develop capacity at farm level to impart better knowledge in soil, water, nutrient and pest management in an integrated approach.
- Intensive monitoring of crops at their vulnerable stages by effective means such as pheromones and weather based advisory system.
- Periodic pests and diseases surveys to update the incidence, distribution, economic importance in different geographic regions.
- Crop varieties with resistance to biotic stresses need to be identified and made available to farmers through farmers networks.
- Effective agronomic practices for augmenting natural enemies should be of high priority.
- Use of bio-rationales and indigenous technologies as an alternative to toxic chemicals need to be encouraged.
- Encourage community involvement with effective teams.
- Strategic research generated at the research stations need to be shared periodically through farmer participatory approach.
- Provide input and output market intelligence.
- Establish farm clinics for greater sustainability.

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