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# Status of IPM in Indian Agriculture: A Need for Better Adoption

**G V Ranga Rao and V Rameswar Rao**

International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru - 502 324, Andhra Padesh, India.
E mail: g.rangarao@cgiar.org

## Abstract

*Insect pests are well recognized as one of the major limiting factors in enhancing and sustaining agricultural production in India. Recent improvements from research brought considerable change in the cropping systems and allowed farmers to grow several crops throughout the year, which were very seasonal in the past. This also brought significant shift in the insect population dynamics and change in the status of several insect pests. Recent interactions with the farming communities revealed that 93% of the farmers in India had adopted chemical control, 51% farmers get their plant protection advice from dealers, while 22% from extension officials and majority of the farmers (73%) initiate the plant protection based on the first appearance of the pest, irrespective of their population, crop stage, and their damage relationships. The cost of plant protection on various crops ranged from 7 to 40% of the total crop production cost. Though integrated pest management (IPM) has been advocated for the past two decades, only 3.2% of the farmers adopted IPM practices in various crops. IPM research in the past decade brought out changes in the farmers' attitude in pest management, which resulted 20-100% reduction in pesticide use in different crops. The recent farmer participatory approach working in a consortium mode proved very effective in the exchange of technology. Though the results are encouraging, there is a need to further strengthen the IPM adoption in Indian agriculture through increased investments in both basic as well as applied research in plant protection to overcome the prevailing three evil "Rs" (Resistance, Resurgence, and Residues). To be more effective, readdressing the policies for encouraging eco-friendly options and strengthening extension, involving farmers should be considered as high priority.*

**Keywords:** IPM, status, adoption, chemical, biological, agronomic

## Introduction

Indian agriculture is heterogeneous, with a multitude of crops and growing conditions. As population grows, achieving food security, poverty alleviation and improving livelihoods of poor are the critical challenges that need to be addressed in developing countries including India. While addressing the above issues, Indian agriculture research has made substantial progress in production front but not paid much attention for the environment and operational hazards as evidenced by studies from Anupgarh, Rajasthan, India, where intensive agriculture was taken up, farmers adopted huge amounts of pesticides to boost their crop productivity. Exposure of humans to these hazardous chemicals directly in the fields and indirectly through contaminated diet resulted in the occurrence of organo-chlorine residues in blood (3.3-6.3 mg per L) and milk (3.2-4.6 mg per L) samples from lactating women (Ashok Kumar *et al*., 2005). High levels of pesticide residues (15 - 605 times) were observed in blood samples of cotton farmers from four villages in Punjab (Anonymous, 2005). In the past few decades with the benefits of pesticides being clearly recognized, usage has steadily increased from 2.2 g active ingredient (a.i)/ha in 1950 (Vasantharaj David, 1995) to the level of 381 g /ha by 2007 (which is about 170 fold,) (Anonymous, 2009a). Though the present insecticidal use was considered lower than that of the developed countries, considering the intensity of pesticide use in crops such as cotton and vegetables in India the insecticidal pressure on unit area of these commercial crops must be several folds higher than that of pesticide use in developed countries (Taiwan, 17 kg, Japan, 12 kg, USA, 7 kg, Korea, 6.6 kg, Europe, 2.5 kg /ha) (Anonymous, 2007). The excessive dependence on chemical pesticides led to the development of resistance in insect pests to insecticides (Kranthi *et al*., 2002), occurrence of residues in food chain (Ranga Rao *et al.*, 2009b) and resurgence of minor pests (Amit Sethi *et al.*, 2002). Though farmers field schools organized in India on cotton signified the importance of IPM in reducing pesticide induced risks at farm level with out scarifying the yields (Mancini, 2006), high adoption (93%) of chemical control in Indian farming for the management of various insect pests in different crops was noticed (Ranga Rao *et al.*, 2009a).

# Present status and challenges

## Eco-friendly approach

Farmers knew eco-friendly approaches from pre-historic period, however their use never attained significant level to meet the requirement. Integrated pest management (IPM) approach for managing pest problems emphasizes the adoption of available methods and techniques such as cultural, mechanical, biological and judicious use of chemical pesticides in order to contain the pest populations below economic threshold levels (ETLs).

**Monitoring.** Effective monitoring of pests is a prerequisite for any successful plant protection program. The decision on whether and when to follow control measures is based on the information available on the pest population at a particular time. There are several well defined monitoring tools (directly through field sampling, indirectly by installing traps such as light, suction, sticky, pit fall and pheromones) available in plant protection. Sex pheromones were well adopted for monitoring key pests such as *Helicoverpa, Spodoptera, Pectinophora, Rhinoceros, Aproaerema, Scirpophaga* populations in different cropping systems (Ranga Rao *et al.*, 2004). These tools have been found effective over conventional monitoring through light traps. Though pheromone technology for various species was made available it's adoption was still in infancy. At this stage strict adoption of any surveillance is not in place for effective implementation of IPM programs in India. Considering the importance of the surveillance and monitoring technologies the policies need to be readdressed to make best use of it.

**Host plant resistance.** Among the various options of IPM, growing varieties with resistance to insect pests, if available, offers the most economical way of reducing losses. Several thousands of germplasm has been screened for biotic stresses with considerable success in number of crops such as rice, sorghum, groundnut, pigeonpea, green gram, black gram and horticultural crops.

More than 14,000 germplasm accessions of both pigeonpea and chickpea have been evaluated at research stations and in farmers' fields over many years under high pest pressures. A number of genotypes with resistance/tolerance to one or more pest species have been determined. However, these genotypes often posses other characteristics that are undesirable such as small seeds and unattractive seed color. Thus, the search for pest-resistance should also consider other factors such as agronomic performance, consumer preferences, and disease resistance. As the pursuit of crops with resistance to insect pests will continue, the current pest management programs should include the selective use of recently developed, high-yielding, and disease-resistant varieties that form the foundation of an IPM program.

In addition to conventional plant breeding, new tools of biotechnology are needed to boost the sustainability of crop varieties. In this process, the toxin genes from *Bt* have been inserted into the crop plants in mid 1980's. Since then, there has been a rapid growth in the area under transgenic crops in USA, Australia, China, India, etc. The area planted to transgenic crops increased from 1.7 million ha in 1996 to over 100 million ha in 2006 (James 2007). In addition to the reduction in losses due to insect pests, the development and deployment of transgenic plants with insecticidal genes will also lead to:

- A major reduction in insecticide inputs.
- Increased safety to operators and non-target.
- Enhanced natural enemy activity.
- Reduced amounts of pesticide residues in the environment and food chain.
- A safer environment.

Thus, one of the promising options is to introduce resistance genes from other sources. Effectiveness of utilizing alternate sources of insecticidal genes, including those derived from *Bacillus thuringiensis* and protease inhibitors can form an effective strategy (Sharma *et al.*, 2001).

**Agronomic practices.** The second major component of an IPM program is cultural control which is not a new concept in number of crops in India. Farming systems can be manipulated in a variety of ways. These options include early or delayed sowing, selection of the inter/trap crops, altering plant density or arrangement, sowing genetic mixtures, erection of bird perches, manual collection and destruction of pests and method of irrigation to reduce the impact or severity of insect pests. These maneuvers are location-specific, pest specific, and must be designed to suit local practices and customs.

In pigeonpea, for the control of pod borer, shaking technology was found to be very effective and economical. This technology involves the collection and removal of borer larvae from their feeding sites. This gentle shaking can dislodge 97% of caterpillars of all sizes from the plants instantaneously. This operation is repeated twice or thrice in case of further infestation and found environmentally compatible and economically viable.

Like any other living organisms, insect pests show considerable host-preference for their oviposition and feeding. Research in the past captured the concept of trap crop in population suppression of the two most important defoliators of groundnut (*S. litura*, *H. armigera*) that prefer sunflower for oviposition and larval feeding than the main groundnut crop. A significant change in the larval behavior was noticed on sunflower compared to groundnut i.e., the newly hatched larvae disperse immediately from the egg sites on groundnut crop whereas on sunflower they stay for a week to ten days on the same plant. At this stage the damage on the trap crop can be clearly visible for collection and destruction of the larvae without using any chemical application. Since groundnut is more vulnerable to defoliators before flowering stage (upto 30 days after emergence), it is necessary to protect this crop from defoliators during this phase of the crop. While the larvae feed and develop on the trap crop, the main crop (groundnut) escapes from the critical pest damage. Farmers found that it is easy to remove egg masses and caterpillars from the trap crops. Farmers also realized that sunflower plants could also serve as perches for insectivorous birds like drongos. Thus, sunflower plays dual role in the management of pests in groundnut. This simple concept has been exploited well in groundnut IPM for the management of the key defoliators.

Though several cultural methods have been recommended for control of pests, rotation of groundnut with non-leguminous crops has been suggested to reduce the leafminer populations. Lower leafminer larval densities have been found when groundnut was intercropped with sorghum or millet than in monoculture groundnut (Logiswaran and Mohanasundaram, 1985).

**Biological Approach.** Increased cost and negative effects of pesticides necessitated the idea of biological options of crop protection and production. Various biological options such as releases and augmentation of parasites and predators, entomopathogens, antagonistic microbes, endophytes, animal wastes, botanicals and crop residues serve as an alternative to chemical pesticides. The term covers a range of alternatives to synthetic chemicals. Their main feature is specificity to avoid non-target mortality and associated problems. The use of bio-pesticides is an important component of IPM strategy for major crops including vegetables. The best-known examples are the neem-based products which have shown to be effective against a number of pests, NPV being used for control of important pests like *Helicoverpa armigera* and *Spodoptera* spp. In addition, *Bacillus thuringiensis* (Bt) has gained importance in suppressing pest populations in crops like cotton and vegetables (Raheja, 1998).

Hence, several bio- control programs have adopted release of parasites and predators, application of environmentally safe bio- agents such as botanicals and insect pathogens as one of the prime options for creating greater stability and sustainability in crop protection.

There are several bio-pesticides that are commercially available to farmers. According to the recent information there were approximately 175 registered bio-pesticide active ingredients and 700 products globally. In India, so far only 12 bio-pesticides were registered of which 5 were bacteria (four *Bacillus* species and one *Pseudomonas fluoresens*) three fungal (two *Trichoderma* species and one *Beaveria* species) two viruses (*Helicoverpa* and *Spodoptera*) and two plant products (Neem and *Cymbopogan*). Among various bio-products, *Bacillus thuringiensis* (Bt), *Trichoderma viridae*, *Metarhizium*, *Beauveria bassiana*, Nuclear Polyhedrosis Virus (NPV) and neem are popularly used in plant protection (US Environmental Protection Agency, 2007). Field evaluation of several bio-pesticides either alone or in combination signifies their impact and compatibility with other plant protection options. Several studies indicated their economic feasibility and environmental compatibility to facilitate sustainability in agriculture. A number of neem-based formulations are being produced by small-scale formulators and marketed as insecticides. Most of them are made from neem oil and contain varying amounts of *azadirachtin*. However, there have been problems with inconsistent quality. To overcome this, farmers were encouraged to procure neem seed and prepare their own formulation of neem fruit powder extract (NFPE) using the five-step procedure: Collection, drying, pulverizing, storage and application. However, some studies also indicated the term safe as a relative one and that no plant protection operation is entirely safe to natural enemies suggesting the need for selectivity based on the natural enemy population and effectiveness of IPM option (Ranga Rao *et al*., 2008).

**Chemical Approach.** There are numerous synthetic pesticides available in the market. These are employed both individually and in different combinations. In response to the slow and certain acquisition of insecticide resistance, particularly in *H. armigera*, farmers have resorted to the use of innovative insecticide cocktails, applying these indiscriminately on different crops. Since farmers have adopted chemical control and have liberty to use them irrespective of registration and other policies there was ample evidence of crop failures due to the occurrence of insecticidal resistance to a range of chemicals in key species (Kranthi *et al*., 2002) and the out breaks of secondary pests (whiteflies in cotton, and the recent mealy bug infestation on number of crops across India). As new products are introduced, recommendations also change. Farmers should contact local extension personnel for approved compounds, concentrations, timings, and precautionary information. Another factor note worthy to remember is the occurrence of spurious pesticides in the market and the existing high dependence on the dealer advise system with due credit facility hampering the creditability of the knowledge that has been generated. As long as these existing problems are not addressed the ill effects of chemical control are bound to have negative effects on the IPM programs.

## Discussion

Interaction with farming communities during 2005-07 brought out the levels of plant protection inputs in different crops ranging from 6-44 per cent involving 1-15 sprays. Inspite of chemical sprays farmers also experienced 11-40 per cent crop losses caused by insect pests (Table 1). These studies also revealed the injudicious use of plant protection chemicals, both above and below recommended levels (Table 2). The impact of IPM research organized in collaboration with NARES and NGOs in India showed encouraging results with drastic reduction in chemical use without sacrificing the productivity in several locations (Table 3). 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. Despite techno-economic superiority of IPM over conventional chemical control, adoption of IPM remains restricted to hardly two per cent of the treated area (Pratap S. Birthal and Sharma, 2004). On the other hand, studies organized in a consortium approach clearly brought out the successful implementation of the concept with substantial reduction in plant protection inputs across several locations. Several IPM success stories to support consortium approach such as Ashta in Maharastra (a collaboration among ICRISAT, NCIPM, Cotton research institute, Nanded and farmers) and Punukula in Andhra Pradesh (collaboration among ICRISAT and NGOs' (CWS, SECURE)) were the classic examples with 22-100 per cent reduction in pesticides in a span of 3 years (Table 4). Though some villages such as Punukula had 55 per cent reduction in three years interaction, later became pesticide free villages indicating the need for long term approach in achieving the goal.

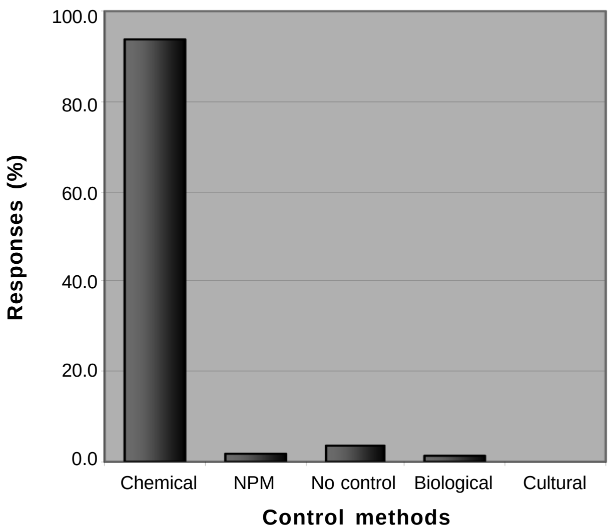


**Figure 1. Adoption of different plant protection options by Indian farmers during 2005-07**

**Table 1. Details of crop loss estimates, cost of plant protection, production, and yields realized on key crops during 2005-2007**

| Crop | No. of farmers | Crop loss by pests(%) | No. of chemical sprays | Cost of plant protection (Rs /ha) | Cost of production (Rs /ha) | Cost of plant protec-tion(%) | Yield t/ha |
|---|---|---|---|---|---|---|---|
| Cotton | 692 | 34.5 | 7.9 | 7446 | 18674 | 40 | 1.8 |
| Cotton-Bt | 66 | 26.3 | 6.8 | 7051 | 21068 | 33 | 2.3 |
| Chilli | 188 | 27.9 | 15.4 | 16515 | 37201 | 44 | 4.1 |
| Rice | 142 | 18.6 | 2.6 | 2648 | 12206 | 22 | 5.1 |
| Pigeonpea | 425 | 30.9 | 2.3 | 1607 | 6514 | 25 | 0.8 |
| Chickpea | 267 | 28.8 | 2.0 | 962 | 7980 | 12 | 1.3 |
| Maize | 72 | 10.6 | 1.3 | 959 | 6901 | 14 | 3.7 |
| Groundnut | 119 | 40.3 | 2.1 | 1474 | 8045 | 18 | 1.2 |
| Sunflower | 21 | 31.9 | 1.5 | 986 | 8565 | 12 | 1.1 |
| Wheat | 90 | - | 1.3 | 613 | 8290 | 7 | - |

**Table 2. Quantities of commonly used pesticides used by farming communities and their recommended doses-2005-2007**

| Chemical (No. of farmers) | Quantity of chemical used (ml /ha) | | |
|---|---|---|---|
| | Mean | Range | Recommended |
| Endosulfan (185) | 1580 | 375-5000 | 1000 |
| Monocrotophos (251) | 1590 | 250-3750 | 750 |
| Indoxacarb (169) | 418 | 63-1250 | 250 |
| Spinosad (133) | 213 | 50-500 | 125 |
| Cypermethrin (82) | 1753 | 250-2500 | 500 |
| Imidacloprid (51) | 305 | 63-750 | 125 |

**Table 3. Insecticidal sprays before and after IPM adoption in different crops during 2005-07**

| Crop* | No. of insecticidal sprays | | |
|---|---|---|---|
| | 2005 | 2007 | Reduction (%) |
| Cotton | 11.4 | 3.8 | 65.1 |
| Paddy | 2.1 | 1.6 | 25.6 |
| Pigeonpea | 2.9 | 2.2 | 24.3 |
| Chickpea | 2.9 | 2.3 | 20.7 |

* Information collected from 17 villages involving 261 farmers

The complexity of IPM necessitates active involvement of stakeholders (researchers, extension workers, and farmers) to alleviate apprehensions through participatory/ adaptive research trials. Though, a majority of the farmers are aware of the benefits of collective action, a number of socio-economic and technical factors that act as detrimental for the rapid spread of the programs. In spite of government of India's sincere efforts and allocation of considerable resources towards the implementation of IPM still 93% farmers depending entirely on chemical control and more than 50% of the farmers still getting advice from pesticide dealers seems to be discouraging (Figs. 1 & 2). At this juncture one can not expect high levels of IPM adoption when majority of the farmers initiate chemical sprays with the first occurrence of the pests rather than following the thresh hold concept (Fig. 3). If the country is serious about the ill effects related to plant protection one need to address these issues as an high priority. There are several successful case studies of IPM in India in different crops and those need to be brought forward to build the capacity of the farmers and researchers. 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,

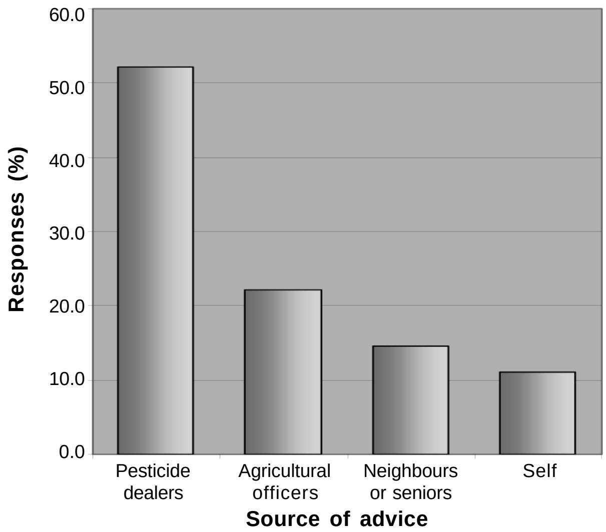


**Figure 2. Source of advice followed in plant protection in India during 2005-07.**

**Table 4. Details of cost of plant protection in IPM and non-IPM fields over project period (1997-2000) at different locations**

| Village (NGO) | Cost of plant protection (Rs /ha) | | |
|---|---|---|---|
| | IPM | Non-IPM | Reduction (%) |
| Hamsanpalli (REEDS) | 898 | 1144 | 21.5 |
| Bollibaithanda (REEDS) | 1194 | 1870 | 36.1 |
| Chincholi (CEAD) | 859 | 1618 | 46.9 |
| Kanjar (CEAD) | 649 | 1467 | 55.8 |
| Maddur (CHRD) | 388 | 1177 | 67.0 |
| Panyala (ROAD) | 584 | 1492 | 60.9 |
| Marlabeed (SEVA) | 318 | 1994 | 84.1 |
| Punukula (SECURE) | 458 | 1017 | 55.0 |
| Deverajugattu (CAFORD) | 431 | 2061 | 79.1 |
| Itagi (PRERANA) | 846 | 1448 | 41.6 |
| Jeedigaddathanda (VIKASAM) | 789 | 3404 | 76.8 |
| Pastapur (DDS) | 406 | 569 | 28.6 |
| Bhavanandapur (TREES) | 353 | 759 | 53.5 |
| Pothinenipalli (PILUPU) | 375 | 821 | 54.3 |
| Ashta (NCIPM/MAU) | 800 * | - | - |
| Nellipaka (FRSF) | 800 | 2000 | 60.0 |
| Sategaon (CARD) | 2490** | 2380 | -4.6 |

* All farmers followed IPM
**High cost was due to high HNPV procurement price
Mean of three seasons data

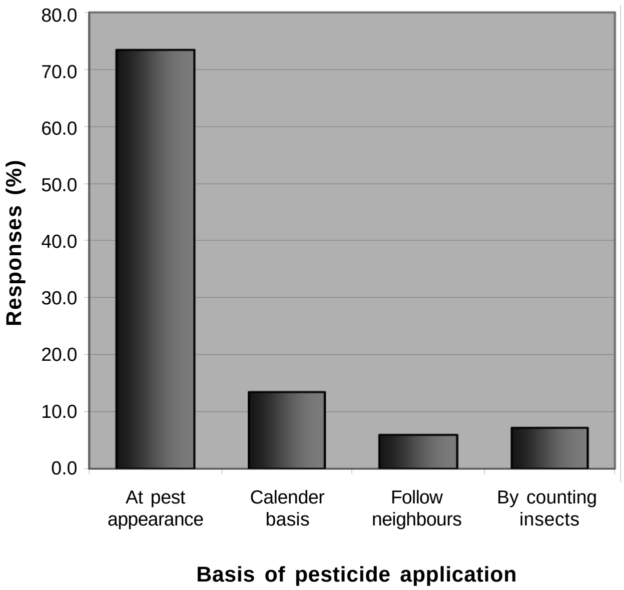


**Figure 3. Criteria of plant protection decision followed by Indian farmers during 2005-07**

provision of institutional credit, subsidies, insurance, exemption from taxes and duties would stimulate production of biopesticides. 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 safety to human health, registration requirements should be relaxed, without compromising the quality standards.

In recent years, the government has banned a number of pesticides for agriculture use 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 in mosquito control, are widely proliferating in agriculture. Further, many pesticides that have been banned elsewhere in the world are available to Indian farmers. Strict enforcement of the regulations governing production, use, distribution, and quality of pesticides would help weed out spurious elements from the market.

At present, though farmers in India were aware of importance of IPM and its impact on health and environment the adoption level was not up to the expected levels. However, latest estimates are quite encouraging with reduction in chemical use to $25.3 billion in 2010 compared to $26.7 billion in 2005. On the other hand interestingly the biopesticides market is growing rapidly from $672 million in 2005 to over $1 billion in 2010. Biopesticides currently has 2.5% of the overall pesticides market, but its share of the market was predicted to increase to over 4.2% by 2010 (Anonymous, 2009b).

## Way Forward

In order to over come the existing evils of Indian plant protection it is believed that the following activities need to be strengthened for the benefit of farming communities, environment and health.

- Investment in the development and implementation of plant protection research need to be enhanced to arrest further degradation of natural resources due to toxic residues and to reclaim them
- Generating and sharing data on toxic residues in food, feed and water bodies is of high priority
- Develop capacity at farm level to impart better knowledge in pest management in an integrated manner
- Intensive monitoring of crops at their vulnerable stages by effective means and linking it to weather based advisory system is essential
- Periodic pests and disease 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
- Adoption of agronomic practices for pest management that augment 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 farmer participation at every stage
- Strategic research generated at the research stations need to be shared periodically through farmer participatory approach.
- Establish farm clinics for greater sustainability
- Future IPM need to be focused on village basis rather than crop based
- Registration, marketing and utilization of IPM inputs with reference to biopesticides need to be readdressed in order to encourage eco-friendly approaches for the benefit of environment and health
- Appropriate certification for IPM/residue free products should be put into practice with input and output market intelligence

## Conclusions

Adequate support for plant protection research is essential to meet the challenges of producing healthy food from the available land with minimal adverse effect on the environment. Technologies such as developing resistant varieties, augmenting natural enemies, improving the cultural control, judicious use of chemical pesticides, and integrating them will have significant role to play in future. High priority should be given to define and adopt the threshold concept in plant protection to produce toxic residue free products to qualify for local and international markets. At this stage implementing classic biological control programs may be of high risk and low impact, hence efforts should be made to evaluate the occurrence of natural enemies and try to augment them.

Though the plant protection research in the past has made significant progress in addressing productivity, hunger and poverty alleviation, it has to go long way to fill the existing gap. This can be achieved through the development of consortium approach by involving International organizations, national agricultural research and extension systems, non-governmental agencies and farmers in the research agenda to meat the needs.

## References


**Amit Sethi, Bons M S, Dilawari V K and Sethi A 2002.** Response of whitefly *Bemisia tabaci* to selection by different insecticides and genetic analysis of attained resistance. *Resistant Pest Management Newsletter* **12(1) :** 30-35.

**Anonymous 2005.** Very high levels of pesticides found in blood samples in Punjab, India. *The Hindu daily* June 8, 2005.

**Anonymous 2007.** Pesticide consumption lowest in India. http://www.rediff.com/money/2007/may/11pest.htm

**Anonymous 2009a.** Indian pesticides industry, Vital for ensuring food security. http//www.bharatbook.com.

**Anonymous 2009b.** Biopesticides market to reach $ 1 billion in 2010. http://www.ien.com/article/biopesticides-market-to/8648.

**Ashok Kumar, Anju Baroth, Inderpal Soni, Pradeep Bhatnagar and John P J 2005.** Organochlorine pesticide residues in milk and blood of women from Anupgarh, Rajasthan, India. *Environmental monitoring and assessment* **116(1-3) :** 1-7.

**James C 2007.** Global Status of Commercialized Biotech/GM Crops: 2006. ISAAA Briefs no. 35. Ithaca, New York, USA: International Service for Acquisition on Agri-Biotech Applications (ISAAA). http://www.isaaa.org/resources/publications/briefs/35.

**Kranthi K R, Jadhav D R, Kranthi S, Wanjari R R, Ali S S and Russell D A 2002.** Insecticide resistance in five major insect pests of cotton in India. *Crop Protection* **21 :** 449-460.

**Logiswaran G and Mohanasundaram M 1985.** Effect of inter-cropping, spacing and mulching in the control of groundnut leafminer, *Aproaerema modicella* (Deventer) (Gelechiidae: Lepidoptera). *Madras Agricultural Journal* **72 :** 695-700.

**Mancini F 2006.** Impact of Integrated Pest Management Farmer Field Schools on Pesticide Use and Farmers' Ecological Knowledge on Cotton Farming in India. Chapter 3 of the thesis.

**Pratap S Birthal and Sharma O P 2004.** Integrated Pest Management in Indian Agriculture: An Overview pp. 1-10 in Proceedings on Integrated Pest Management in Indian Agriculture (Ed. Pratap S Birthal and O P Sharma), Chandu Press, D-97, Shakarpur Delhi - 110 092.

**Raheja AK 1998.** Role of crop protection chemicals in IPM. In proceedings of the seminar on Integrated Pest Management. Organized by Indian Crop Protection Association held on 3rd April 1998 at New Delhi. Pp.75-78.

**Ranga Rao G V, Nandagopal V, Rameshwar Rao V and Reddy Y V R 2004.** Insect Pheromones of Legume Pests in India: Current Status and Future Requirements. Pages 84-95 *in* Proceedings of the National seminar on Trends in Pheromone Research and Technology, 6-7 February, 2004, Junagadh, Gujarat, India.

**Ranga Rao G V, Visalakshmi V, Suganthy M, Vasudeva Reddy P, Reddy Y V R and Rameshwar Rao V 2008.** Relative toxicity of neem on natural enemies associated with chickpea ecosystem: A case study. *International Journal of Tropical Insect Science* **27(3/4) :** 229-235.

**Ranga Rao G V, Rameshwar Rao V, Prasanth V P, Khannal N P, Yadav N K and Gowda C L L 2009a.** Farmers' perception on plant protection in India and Nepal: a case study. *International Journal of Tropical Insect Science* **29 (3) :** 158-168.

**Ranga Rao G V, Sahrawat K L, Srinivasa Rao Ch, Binitha Das, Kirankumar Reddy K, Bharath B S, Rameshwar Rao V, Murthy K V S and Wani S P 2009b.** Insecticide residues in vegetable crops grown in Kothapalli watershed, Andhra Pradesh, India: A case Study. *Indian Journal of Dryland Agricultural Research and Development* **24(2) :** 21-27.

**Sharma H C, Sharma K K, Seetharama N and Ortiz R 2001.** Genetic transformation of crop plants: Risks and Opportunities for the rural poor. *Current science* **80 :** 1495-1508.

**US Environmental Protection Agency 2007.** Information Published at web site. Info@healthgoods.com

**Vasantharaj David B 1995.** Indian pesticide industry and overview. In Kotharis Desk Book series. Pp. 16-36.


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