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9. Integrated Pest Management: An Overview

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Abstract:

Indiscriminate and non-judicious use of pesticides increased to the pest resurgence, resistance, residues and ecological imbalance by killing natural enemies like predators and parasitoids, thus affecting prey-predator dynamics which resulting into environmental pollution. To overcome this, world-widely integrated pest management (IPM) has become the accepted strategy for plant protection over the last five decades. However, it was not until 1959, that the concept of "integrated management" was born in the United States of America (USA). A panel of experts from the Food and Agriculture Organization (FAO) put the concept of IPM in operation in 1968. India has successfully reduced pesticide consumption without adversely affecting the agricultural productivity. This was facilitated by appropriate policies that discouraged pesticide use and favored to IPM application. Despite it, adoption of IPM is low owing to a number of socioeconomic, institutional and policy constraints. The 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.

Keywords:

Integrated pest management (IPM), FAO, pesticides, ecological imbalance, plant protection, constraints.

9.1 Introduction:

In the 1940s, with the introduction of synthetic pesticides, the whole scenario of pest management changed. The over reliance on synthetic pesticides from late 1940s to mid-1960s has been called "the dark ages" of pest control. The insecticidal properties of DDT (dichlorodiphenyltrichlorethane) discovered by the Swiss chemist Paul Muller, in 1939 triggered this "dark age" of pest control. The discovery of the herbicide 2, 4-D stimulated chemical weed control, and discovery of the dithiocarbamate fungicides during the 1930s led to the development of increased reliance on fungicides (Smith and Kennedy, 2002). But the un-sustainability of pesticides was evident by the end of 1950s as complete reliance on pesticide intensive pest management was leading agriculture on a "pesticide treadmill". Resistance of pests to pesticides was observed, the phenomenon of pest resurgence and development of minor pests to major pests due to killing beneficial insects was documented in late twentieth century (Norris et al., 2003). Soon after World War II few scientists realized that indiscriminate use of synthetic organic insecticides would be problematic. Then the development of the concept of integrated pest management (IPM) in response to two major factors: the development of resistance to insecticides and the destruction of insect natural enemies by insecticides aimed at target pest insects. At the time of the first work on IPM, environmental pollution from insecticides was not a major factor in spurring entomologists to develop new practices, even though medical and environmental scientists recognized the widespread, unintended poisoning of people and other species (Perkins, 1982). Rachel Carson (1962) wrote the book Silent Spring that brought the problems caused by pesticides to the attention of the public and the scientists. Silent Spring also got the attention of the scientific community on negative externalities of pesticide use.

The term “Integrated Pest Management” was used for the first time by Smith and van dan Bosch (1967) and in 1969 this term was formally recognized by the US National Academy of Sciences. Over the years, there have been dramatic changes in the technologies available for pest management. In the 1970s, DDT was widely banned due to environmental risks. In 1972, insecticides based on the bacteria, *Bacillus thuringiensis*, were released for control of Lepidopteran pests. Transgenic pest resistant crops were released in 1996, representing the biggest step in technology since the development of pesticides in the 1940s. In the 1960s, the term “pest management” also came into existence and being broader it included other suppressive tactics such as semiochemicals, host plant resistance and cultural control. But with the passage of time integrated pest control and pest management became synonymous and both were based on the concept of integrating a range of control tactics to manage pests, with insecticides as one of the tools rather than the only tool. The basic tactics of IPM were proposed and applied to reduce crop losses against the ravages of pests long before the expression was coined (Jones, 1973; Smith et al., 1973).

Throughout the early twentieth century, plant protection specialists relied on knowledge of pest biology and cultural practices to produce multitactical control strategies (Gaines, 1957). It was not until the incorporation of all classes of pests in the early 1970s that the modern concept of IPM was born (Kogan, 1998; Prokopy and Kogan, 2003). Pest control was understood as the set of actions taken to avoid, attenuate, or delay the impact of pests on crops, as such goals and procedures of pest control were clearly understood (Kogan, 1998). Pesticide use (active ingredients) in agriculture has decreased from 2.6 billion kg in 2004 (Allan Woodburn Associates, 2005) to 1.7 billion kg in 2007 (Agranova, 2008).

Total sales in 2007 were estimated at US $35.85 billion (insecticides 26.4%, fungicides 23.2%, herbicides 45.6% and others 4.7%) (Agranova, 2008). Despite these statistics there has been significant progress with the uptake of IPM in many countries. The theory and principles supporting IPM have evolved over the last 50 years. In addition new tools and strategies have been developed to support development of IPM systems: newer more selective insecticides, progress in the development of biopesticides, the development of semio-chemical based approaches (attract and kill, mating disruption), improved understanding of the deployment of trap and refuge crops, the use of “push-pull” strategies, techniques to conserve and attract beneficials in systems, use of augmentive biological control and most recently the advent of transgenic crops producing the Cry proteins from *Baccillus thuringiensis*.

Integrated Pest Management (IPM) has had a varied history, with different definitions. It has been implemented under an array of different connotations (Lewis et al., 1997). The term was earlier used as ‘‘integrated control’’ by Bartlett (Bartlett, 1956) and was further elaborated on by Stern and co-workers (Stern et al., 1959). In reference to the concept of integrating the use of bio- logical and other controls in complementary ways, the term was later broadened to embrace coordinated use of all biological, cultural, and artificial practices (van den Bosch and Stern, 1962). The term ‘‘IPM,’’ under various authors have advocated for the principle of incorporating, the full array of pest management practices with production objectives in a total systemic approach. Nonetheless, there is no universally agreed definition of IPM.

9.2 Integrated Pest Management in India:

In India, pest management before the synthetic pesticide era (pre green revolution period) was characterized by the use of cultural and manual mechanical practices based on a farmer’s lifelong experiences. Experts of this era in most of the developing world (tropical areas) were involved in taxonomy, biology of pests, and advocacy of cultural practices (Muangirwa, 2002). With the advent of the green revolution in mid 1960s, a new technological paradigm use of pesticides (in addition to high yielding varieties and fertilizers) was adopted by India, largely imported from the USA. The surprising aspect of this paradigm shift is that insecticide-based insect pest management as the sole pest control strategy was advocated by the agriculture policy planners, entomologists and extension agencies when the world had taken note of the negative impact of pesticide use brought forward by Rachel Carson in her book “Silent Spring” in 1962, and entomologists were developing integrated control tactics (Stern et al., 1959). Pesticide use (mainly insecticide use) increased from 5640 tons in the pre-green revolution era to 21200 tons in 1968–1969 in the green revolution era and reached an all-time high of 75418 tons in 1988–1989. Most of the pesticide was consumed in the green revolution areas of Punjab, Haryana, Andra Pradesh, Western Uttar Pradesh (around 103 districts) and 50 percent in cotton crops which were cultivated on a mere 5 percent of the total cultivable land of 176 million hectares. In India, research on integrated pest management was started in 1974–75 on two crops, rice and cotton, under Operational Research Projects (ORP) (Swaminathan, 1975). Under this, location specific IPM technologies were developed in cotton and rice crops. But it was only in the mid-1980s that the Government of India re-oriented its plant protection strategy. India became a member country of the FAO initiated Inter – Country Program in 1980, but IPM activities have been intensified only since 1993. The results of ORP project were encouraging in reducing pesticide use and increasing productivity. The published literature of the ORP project in cotton (1976–1990) by the project agencies reported that adoption of IPM practices in cotton crop resulted in 73.7 and 12.4 percent reduction in the number of insecticide sprays for control of sucking pests and bollworms, respectively, in 15 villages of Indian Punjab (Dhaliwal et al., 1992). Under the same project in Tamil Nadu in the 1980s, the average quantity of insecticide used (technical grade material) was 3.8 kg/ha in six applications compared to 9.2 kg/ha in 11 sprays in non-ORP villages (Simwat, 1994). The IPM system increased the natural enemy population threefold. The spread of this program was limited to certain areas. A number of IPM programs have been launched in India from 1993 onwards. These are the FAO-Inter Country Program for IPM in rice crops in 1993, Regional Program on cotton-IPM by Commonwealth Agricultural Bureau International (CABI) in 1993; FAO-European Union IPM program for cotton in 2000; National

Agricultural Technology Project (NATP) for IPM in 2000 and Insecticide Resistance Management based IPM program by the Central Institute for Cotton Research (CICR), Nagpur in 2002 (Peshin et al., 2007). CICR, Nagpur; the Asian Development Bank (ADB) – Commonwealth Agricultural Bureau International (CABI) and Directorate of Plant Protection Quarantine and Storage, Government of India conducted season – long trainings for IPM – extension workers since 1994 to promote IPM (Bambawale et al., 2004). Central Integrated Pest Management Centers (CIPMCs) were set up in 26 states which promoted the concept of IPM in cotton and rice since the 1990s. Various state departments of agriculture implemented IPM from mid – nineties. The Government of India launched the Technology Mission on Cotton in 2000 (Barik et al., 2002).

FAO-EU launched an IPM program in cotton in India since 2000 for five years. Andhra Pradesh cotton IPM initiative is another active organization in IPM (Anonymous 2001). Multilocation trials have been carried out by the All India Coordinated Cotton Improvement Project (Anonymous, 2004). The Ashta IPM model is also being implemented in Central India. Agriculture Man Ecology (AME) funded by a bi-lateral agreement between the Indian and Dutch governments is implementing IPM farmer field schools in Karnataka, Andhra Pradesh and Tamil Nadu. Sir Ratan Tata Trust project (a private sector funded project) supports the Department of Entomology at Punjab Agricultural University, Ludhiana, India towards further developing, validating and disseminating cotton-IPM technology in cotton growing districts of Punjab since 2002. In the mid-1990s, India abolished its insecticide subsidy resulting in a saving of US $30 million annually and imposed a 10% excise tax, which has resulted in a US $60 million annual revenue to the government. It spends US $10 million per year on IPM-FFS (Kenmore, 1997). In 1994, the Directorate of Plant Protection, Quarantine and Storage, Government of India, the nodal agency for implementing IPM programs, intensified its efforts and adopted FFS model for educating farmers through its 26 CIPMCs (presently there are 31 CIPMCs). These centers have completed pest monitoring in 10.20 million hectares and bio-control agents have been released in 7.79 million hectares up to 2006–2007. The IPM-FFS implemented during the same period are 10562, in which 318246 farmers and 43301 extension functionaries have been trained (DPPQ&S).7 The IPM-FFS has mainly been conducted for rice (5930), cotton (2002), vegetables (951) and oilseeds (916) as well as other crops. The targets for next the five years (XI Plan Period: 2008–2012) are for conducting 3250 IPM-FFS. The IPM–FFS program was designed to be implemented by CIPMCs in collaboration with the state departments of agriculture (the main extension agency in India) with technical support from the state agricultural universities. No coordination between the state agricultural universities and CIPMCs was observed (Peshin and Kalra, 2000) and presently there is no functional coordination between CIPMCs, state departments of agriculture and state agricultural universities in jointly implementing IPM-FFS. These agencies are running their own IPM programs separately or in isolation and sometimes these agencies cater to the same village one after the other (Peshin, 2009). IPM initiatives are hampered by leadership, coordination, management of human and financial resources, and evaluation mechanism of these programs. The Central Government should manage, coordinate and draw a roadmap for IPM implementation; otherwise IPM programs will remain confined to projects and project reports, conference discussions, research journals and one-upmanship between state agricultural universities, state departments of agriculture and CIPMCs. An outlay of US $2.8 million has been earmarked for state level training programs and FFS for the period 2008–2012 out of total outlay of US $266.7 million for "Strengthening and Modernising of

Pest Management Approaches in India" which is meager. In India, many agencies are involved with the implementation/dissemination of IPM technology, but the area covered under IPM is less than 5 percent (Ragunathan, 2005), and there is no extensive empirical impact evaluation of these programs. The actual spread of IPM practices being adopted by farmers is not well documented as was also pointed out by Luttrell et al. (1994) in a comprehensive review of cotton IPM systems of the world. The literature on impact of IPM programs in is mainly based on the project or annual reports of these programs compiled by the implementing agencies which are not based on the systematic evaluation of these programs on a larger scale. These reports lack both internal and external validity. Overall, there is no documented evidence of the adoption and impact of different IPM programs in India, once the IPM training intervention has been withdrawn. The success of different IPM programs depends upon the widespread adoption of IPM practices by the farmers and for that "IPM Innovation System Approach" has to be adopted for coordination of research, extension, farmers, public sector and private sector. Pesticide use (technical grade material) in Indian agriculture has steadily reduced since 1990–91 from 75033 tons to 37959 tons in 2006–07, which is a reduction of 49.41%. There are four reasons for pesticide use reduction.

First and the foremost is the banning of hexachlorocyclohexane (BHC) in April 1997, which accounted for 30 percent of total pesticide consumption in India, and the introduction of high potency newer molecules, like imidacloprid, spinosad, indoxacarb etc. The dosage of these chemicals per unit area is 10–35 fold lower than organophosphates. The second reason is the abolition of insecticide subsidies in the 1990s, and public extension agencies no longer selling insecticides from their input supply outlets. The third reason for the reduction is the introduction of Bt cotton in the 2002 season. India is the world's fifth largest grower of genetically modified crops with an estimated 6.9 million hectares (Bt cotton) sown in 2008.

Since 2002, pesticide use has reduced from 48350 tons to 37959 tons in 2006, a reduction of 21.49%. The fourth reason is the implementation of multiple cotton IPM programs in high pesticide use states like Punjab, Haryana, Andhra Pradesh, Maharashtra, Rajasthan and Tamil Nadu, which among them consume 55% of the total pesticide use. Insecticides account for 64% of the total pesticide consumption. Consumption patterns in different states of India and different crops are highly uneven. In India, overall pesticide consumption per hectare (254 grams) is far less than in the USA, Europe and Japan, but the per hectare insecticide use in cotton is very high. For example, in Punjab, agriculturally the most advanced state of India, it ranges between 5.602 and 8.032 kg/ha (Peshin, 2005).

Objectives of Pest Management:

- To reduce pest population below the economic threshold level.
- Complete control of pest is not the main objective of the integrated pest management.
- To manage insect pests by not only killing them but by preventing feeding, multiplication and dispersal.
- To use eco-friendly methods of integrated pest management and these will maintain quality of environment (air, water, wild life and plant life).
- To make maximum use of natural factors and apply control measures only when needed pest control.
- To use IPM component in sustainable crop production.

9.3 Principles of Crop Protection:

The search for a solution to pest problems that was ecologically compatible and economically feasible rapidly led to integration of tactics. Tactics were used to prevent, kill or suppress the entire range of competing or attacking organisms whether weeds, insects, plant pathogens, nematodes, vertebrate pests or others. Most crops are beset by at least 1 pest species classified in each of the above categories and strategy to control a single pest on a single commodity is unrealistic. The producer obviously needs means to manage each kind of pest simultaneously, sequentially or on demand, and thereby protect the crop. The integration of tactics to manage each species of pest, with close attention to crop damage thresholds as well as the economics of production, led to reconsideration of the basic principles of ecology (Geier, 1966; Geier and Clark, 1961; NAS, 1966) and crop protection. Roberts, (1978) defines fundamental principles which can be applied regardless of the nature of the pest (discipline) encountered or the biological system in question. These 7 principles are: 1) exclusion, 2) eradication, 3) therapy, 4) vertical resistance, 5) horizontal resistance, 6) protection, and 7) avoidance. Together, they provide a framework to integrate tactics for pest control for pest suppression and damage prevention. However, each principle must be redefined for IPM since definitions differ among crop protection disciplines. For example, the meaning of eradication in plant pathology is quite different from its meaning in entomology. Use of tactics from 2 or more principles, such as a resistant cultivar (vertical resistance) and early planting (avoidance) approximates the goal of integrated tactics in an interdisciplinary program. Present commodity IPM programs based on suppressive, preventive and therapeutic tactics are already in use. For example, in the folige industry, use of tissue culture techniques to produce pathogen-free stock, which is planted in sterilized soil, grown in an exclusive greenhouse environment, closely monitored to detect disease or insects and treated with recommended pesticides on demand, is a good example of interdisciplinary management using the described principles.

A. Pest Management Tactics:

There are different pest management tactics to suppress pests. They include host resistance, chemical, biological, cultural, mechanical, sanitary and mechanical controls. The primary pest management tactic involves maximization of built-in pest reduction features of an eco-system. Molecular or genetic mechanisms are potentially manifested in a number of these more specific tactics. Each category, discussed below, employs a different set of mechanisms for suppressing populations.

B. Cultural Measures:

This involves practices that suppress pest problems by minimizing the conditions that favour their existence (water, shelter, food). Some of these factors are intrinsic to crop production while making the environment less favourable for survival, growth and reproduction of pest species. If followed in an appropriate manner, the cultural practices can provide significant relief from pests. The selection of appropriate site for the cultivation of field crops and fruit trees can reduce future infestation from insect pests. The culture should be selected in such a manner that it should be suitable for growing in the area and tolerant to important pests' diseases of the area.

C. Sanitary Control:

Preventive practices are important part of an IPM programme. These include cleaning field equipment (i.e., tillage equipment, haying equipment, etc.), planting certified seeds and quarantine of infested crops or farmlands. These are methods used to prevent the introduction of a pest into the field.

D. Mechanical Control:

This is the use of machinery and other tools to control pests. It involves agricultural practices like tillage, slash and burn, and hand weeding. The pruning of infested parts of fruits and forest trees and defoliation in certain crops help reduce the pest population. Chaffing of sorghum/maize stalks and burning of stubbles kills maize borer.

E. Biological Control:

This involves the use of other living things that are enemies of a pest in order to control it. Sometimes, the term ‘‘biological control’’ has been used in a broad context to encompass a full spectrum of biological organisms and biologically based products including pheromones, resistant plant varieties, and autocidal techniques such as sterile insects. IPM is mainly aimed at developing systems based on biological and non-chemical methods as much as possible.

F. Host Plant Resistance:

This involves breeding varieties with desirable economic traits, but less attractive for pests, for egg laying and subsequent development of insect, disease or nematode. It also involves withstanding the infestation/infection or the reduction of pests to level that they are not large numbers during the plant growth period (Sharma, 2007).

G. Natural Control:

Natural control involves the enhancement of naturally occurring pest management methods to combat pests like using beneficial insects and diseases. Here, insecticides will only be used when they are economically feasible, and it is apparent that natural enemies will not control the pests.

H. Chemical Control:

The therapeutic approach of killing pest organisms with toxic chemicals has been the prevailing pest control strategy for over 50 years. Safety problems and ecological disruptions continue to ensue (Wright, 1996), and there are renewed appeals for effective, safe, and economically acceptable alternatives (Benbrook, 1996). Synthetic chemical pesticides are the most widely used method of pest control. The four major problems encountered with conventional pesticides are toxic residues, pest resistance, secondary pests, and pest resurgence (Lewis, 1997).

The use of natural pesticides and organophosphates that are more environmentally friendly are encouraged and synthetic pesticides should only be used as a last re- sort or only used as required and often only at specific times in a pest's life cycle.

I. Regulatory/Legislative Control:

In this process regulatory rules framed by Govt. are brought into force under which seeds and infested plant materials are not allowed to enter the country or from one part to other parts of the country. These are known as quarantine methods and are of two types i.e. domestic and foreign quarantine.

9.4 Advantages of An IPM Programme:

The Advantages of Integrated Pest Management are immense directly to farming and indirectly to society.

a. Integrated Pest Management (IPM) protects environment through elimination of unnecessary pesticide applications. In IPM, pesticides are used at the smallest effective dose when other methods of pest control have failed. Also, they are used in bringing a pest organism to acceptable bounds with as little ecological disruption as possible.
b. IPM improves profitability. Since IPM programme applies the most economical management pest tactics, profitability is ensured for the grower or farmer.
c. It reduces risk of crop loss by a pest. Applying pest management and monitoring tactics will also ensure the reduction of crop loss or damage by pests.
d. Long term sociological benefits of IPM would also emerge in areas of employment, public health, and well-being of persons associated with agriculture.

9.5 Major Constraints To IPM:

A major limitation is the lack of trained personnel. Many farmers are not trained adequately in augmentative biological control, leading to misunderstanding of its potential efficacy.

Logistical problems such as improper timing and delays in shipment can alter the effectiveness of natural enemies. Farmers often believe that natural enemies do not work well, and that low pest populations will cause losses. The use of biopesticides is limited due to moderate toxicity, slow action, host specificity and photo-instability as well as a higher cost. Many farmers are not yet aware of the proper usage and available suppliers of biocontrol agents and biopesticides. A number of botanicals such as karanj, mahua, custard apple, ipomoea, garlic and tobacco have been found to be effective against insect pests and diseases, however in absence of detailed scientific data, except for neem, most of them are localized to rural pockets. Botanicals, particularly neem, have not found much favor with farmers. The necessity for repeated applications, low toxicity and persistence, cumbersome procedures of collection and extraction coupled with low yields have discouraged wide use of neem. IPM adoption is influenced by the cost versus efficacy of products, need for sophisticated information for decision making, ability to integrate new products and techniques into existing farm management practices and managerial skills. Strategies that are being used now may need to be modified to achieve the goal of wider adoption of IPM.

9.6 Conclusion:

The most important aspect of the IPM program in India is the community approach. Both national and state research organizations, along with SAUs, have been actively involved in developing IPM technology for farmers. As a result, a comprehensive package of IPM practices has been developed for rice, cotton, mustard, chickpea, pigeon pea and sugarcane crops. The Indian Council of Agricultural Research and Department of Agricultural Research and Education of the Ministry of Agriculture, Government of India are fully committed to the development and promotion of IPM in the country as evident from the fact sheets of allocations and crop/pest priorities. It is the top priority mission of the ICAR and Government of India to provide safe and effective technologies to protect against unacceptable losses caused by weeds, diseases and insect pests. There is urgent need for decision support software to be developed so as to allow IPM practitioners to estimate cost/benefit for a variety of management inputs and examine profitability of a system. Genetic engineering to enhance the potential of LMOs also needs priority in order to ensure a clean environment and food security. The ICAR and SAUs are continuing to develop IPM programs for other crops such as vegetables, oilseeds and pulses. However, IPM efforts have so far remained restricted to the research activities of ICAR, the SAUs, and the Central IPM Centers of the Ministry of Agriculture. Even though some successful non-chemical methods for control of crop insect pests and diseases have been developed, the transfer of this knowledge to the farmers and extension officers has been relatively slow. Ideally, the IPM approach seeks to understand the causes of pest outbreaks and modify the design and management system to prevent them. Coordinated efforts of research institutes and extension personnel will continue to educate the farming community on IPM practices. Active participation of the farmers, quick dissemination of the technology, area-wide approach and timely supply of inputs including quality biocontrol agents along with new technology such as precision farming, i.e. broad combination of hardware, software, information technology and new product technologies (biotechnology/bio-rational and new selective chemicals) will continue to increase the adoption of IPM.

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