Rajinder Peshin
Ashok K. Dhawan
Editors

Integrated Pest Management: Innovation-Development Process

Volume 1

Springer

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The fungal pathogen, *Hirsutella* sp., infecting the armyworm, *Spodoptera litura* (Fabricius). This fungus, along with other pathogens are important regulating agents is armyworm populations (Courtesy: Photo by G. R. Carner, Clemson University, Clemson, South Carolina, USA).

Larvae of the parasitic wasp *Cotesia congregata* (Say) (Hymenoptera: Braconidae) emerging from, and spinning coccoons on the back of a tobacco hornworm, *Manduca sexta* (L.) (Lepidoptera: Sphingidae). (Courtesy: Photo by Lisa Forehand, North Carolina State University, USA).

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For our teachers, farmers and colleagues

Preface

The book 'Silent Spring' written by Rachel Carson in 1962, is considered the landmark in changing the attitude of the scientists and the general public regarding the complete reliance on the synthetic pesticides for controlling the ravages caused by the pests in agriculture crops. For about five decades, the Integrated Pest Management (IPM) is the accepted strategy for managing crop pests. IPM was practiced in Cañete Valley, Peru in 1950s, even before the term IPM was coined. Integrated Pest management: Innovation-Development Process, Volume 1, focuses on the recognition of the dysfunctional consequences of the pesticide use in agriculture, through research and development of the Integrated Pest Management innovations. The book aims to update the information on the global scenario of IPM with respect to the use of pesticides, its dysfunctional consequences, and the concepts and advancements made in IPM systems. This book is intended as a text as well as reference material for use in teaching the advancements made in IPM. The book provides an interdisciplinary perspective of IPM by the forty-three experts from the field of entomology, plant pathology, plant breeding, plant physiology, biochemistry, and extension education.

The introductory chapter (Chapter 1) gives an overview of IPM initiatives in the developed and developing countries from Asia, Africa, Australia, Europe, Latin America and North America. IPM concepts, opportunities and challenges are discussed in Chapter 2. The world pesticide use, the environmental and economic externalities of pesticide use in agriculture, with case studies from the USA and India are covered in the next three chapters (Chapters 3, 4 and 5). The brief account of the advances in insect pests, disease pests and plant parasitic nematodes is given in Chapter 6. Crop plant manipulation to affect the pests through host plant resistance and transgenic crops is covered in Chapters 7 and 8. Content area on biological control and environmental manipulation to manage pests is the theme of the Chapters 9 and 10. The behavior modifying strategies in response to external stimuli for pest management are detailed in Chapter 11. The pesticides metabolized from botanicals, one of the first known pesticides, is covered in subsequent Chapter 12. The insect pest outbreaks and field level epidemiological issues of plant diseases and their management have been covered in Chapters 13 and 14. Chapter 15 covers the concepts and principles of integrated disease management of bacterial, fungal and viral diseases. The yield losses caused by insect pests are variable and dynamic.

The methods to measure yield losses with the example of rice crop are covered in Chapter 16. Cotton pest management has been a challenging task the world over, the historical perspective, components of cotton IPM program, insecticide resistance management and transgenic cotton is the focus of Chapter 17. Non-pesticide pest management, reality or myth- the experiences are analysed in Chapter 18. IPM systems for vegetable and fruit crops, their underlying concepts, advancements and implementation are covered in detail in the last three chapters (Chapters 19, 20 and 21).

IPM is a component of sustainable agriculture production, and was in vogue in agriculture before the introduction of synthetic pesticides. The renewed efforts are needed for the adoption of IPM by the end users. The farmers who did not fall in the pesticide trap in 1950s and 1960s were labeled as laggards, and, to use the words of E.M. Rogers (2003) – had the last laugh at plant protection scientists and extension workers. Due care should be taken with respect to euphoria generated by the introduction of transgenic crops in agriculture which may make us complacent as was the case after the introduction of DDT, lest we are caught into 'pesticide cum transgenic treadmill'. There is no permanent, normal professionalism, which can adopt for life, and especially not with complex interactive management systems like IPM (Robert Chambers). IPM-innovation-development process is dynamic, and is incomplete without the participatory development of farmers' compatible IPM systems and its adoption by the end users to its consequences in agriculture production system. Volume 2, Integrated Pest Management: Dissemination and Impact, analyses the success and failures of this aspect of IPM Innovation-Development process.

We are grateful and indebted to the contributing authors for their cooperation and guidance in compiling the book. We are also grateful to the reviewers for their comments on the book chapters. The book provides an invaluable resource material to graduate students, teachers, scientists working in the dynamic field of IPM in particular and agriculture in general.

Jammu, India Rajinder Peshin
Ludhiana, India Ashok K. Dhawan

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Chapter 1
Integrated Pest Management: A Global Overview of History, Programs and Adoption

Rajinder Peshin, Rakesh S. Bandral, WenJun Zhang, Lewis Wilson and Ashok K. Dhawan

Abstract World-wide, integrated pest management (IPM) has become the accepted strategy for plant protection over the last five decades. Cotton growers in the Cañete valley, Peru were amongst the first to adopt a combination of pest management practices to save the cotton crop from the ravages caused by pests despite applying 16 insecticide sprays on average. 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. Advancements made in IPM systems for developing sustainable pest management strategies in the USA, Europe, Australia, Asia, Latin America and Africa have not generally resulted in wider adoption of IPM, though there have been some successes. Pesticides remain the main-stay of many IPM programs throughout the globe. In the USA and Europe, there is government legislation and mechanisms for implementation and evaluation of IPM programs, especially in Europe, where IPM innovation systems involving the government, researchers, farmers, advisory agencies and market forces are part of a system to reduce pesticide use. In the developing countries farmer education in IPM has gained impetus since 1989, through the Farmer Field School (FFS) extension methodology, originally developed for educating farmers in rice IPM. The FFS model of extension has spread from Asia to Latin America, Africa and Eastern Europe. In the developed countries the systematic periodic evaluation of IPM programs provides feedback for improving and formulating future strategies, but in many developing countries there is no periodic evaluation of IPM programs for assessing the extent of adoption and long term impact. This chapter provides a broad overview of IPM programs, policies and adoption of IPM practices in the North America, Europe, Australia, Asia, Latin America and Africa.

Keywords IPM-USA · Europe · Australia · Latin America · Africa · India · China · IPM history · IPM programs · IPM implementations · IPM adoption

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1.1 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, an employee of J.R. Geigy Co., 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). The American Entomologists proclaimed in 1944, ". . .never in the history of entomology has a chemical (DDT) been discovered that offers such promise . . ." (Perkins, 1982). 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 during 1940s, 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.

Entomologists at the University of California, United States of America (USA) developed the concept of integrated pest management (IPM) during the 1950s 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). So the Californian entomologists coined the concept of "supervised control", involving supervision of insect control by qualified entomologists (Smith and Smith, 1949). A decade later this concept had evolved and the concept of "integrated control" which combined and integrated biological and chemical control based on economic threshold concepts was put forward (Stern et al., 1959). 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. She wrote in her book, "We have put poisonous and biologically potent chemicals indiscriminately in the hands of persons largely or wholly ignorant of their potential for harm."

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. In the 40 years since then 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 semio-chemicals, 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 multi-tactical 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). However, not until 1972, were "integrated pest management" and its acronym IPM incorporated into English literature and accepted by the scientific community (Kogan, 1998) and later, in November 1972, the report *Integrated Pest Management* prepared by the Council on Environmental Quality was published (Anonymous, 1972). IPM is the main strategy recommended for pest management under Agenda 21 of the United Nations Conference on Environment and Development (UNCED, 1992).

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). The average growth rate of pesticide consumption world-wide during the period of 1993 to 1998 was in the order of 5 percent per year, exceeding that during the earlier period, 1983 to 1993. Global pesticide market recorded a negative average annual growth rate of 1.3 percent (after inflation) between 1998 and 2007 (Agranova, 2008). However, in 2007 there was a surge in the global sales of pesticides by 8.1 percent (after inflation) which is the largest single year growth for 10 years. The major markets for pesticides are the USA, Western Europe and Japan (Dinham, 2005). In Latin America sales of pesticides rose by 25% in 2004 (Allan Woodburn Associates, 2005) and since then recorded a growth rate of 20% between 2004 and 2007 (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*. There are now many examples of successful IPM systems. The theory and components of IPM are discussed in this volume (Chapters 6 to 21, Vol. 1).

1.2 IPM: A Historical Overview

The term IPM is now more or less universally understood. Even before the term IPM was coined, the reasons for developing and propagating IPM are explained by citing some well documented historical cases. The main reliance on the use of pesticides led to creation of newer pest problems in all the crops and especially in the cotton crop. Due to lack of resistant cultivars, non-adoption of cultural control measures, and non-availability of effective biocontrol agents, the indiscriminate use of insecticides resulted in development of resistance in cotton pests such as American bollworm (*Helicoverpa armigera* (Hubner)), resurgence of pests such as spider mites (*Tetranychus* spp.) and whitefly (*Bemisia tabaci* (Gennadius)) and destruction of natural enemies, which ultimately led to crop failures in some countries. Such failures in cotton production systems were documented in Latin America (Cañete Valley, Peru), Sudan and other places even before the term IPM was coined.

Cañete Valley, Peru had been a successful cotton growing area with progressive farmers. In 1939, the tobacco bud worm (*Heliothis virescens* (Fabricius)) appeared in cotton crops. The spraying of arsenical insecticides and nicotine sulphate resulted in build-up of cotton aphid (*Aphis gossypii* (Glover)) and worsening of the tobacco bud worm problem. By 1949, cotton yields (lint) dropped from about 500 kg ha^{-1} to 365 kg ha^{-1} as natural enemies had disappeared owing to insecticide applications allowing pest populations to resurge after sprays were applied. A new program for pest control practices was introduced including banning the use of synthetic organic pesticides, the reintroduction of beneficial insects, crop diversification schemes, planting of early maturing varieties and the destruction of cotton crop residues. Pest problems subsequently declined dramatically and pest control costs were substantially reduced (Hansen, 1987).

Based on the same principles as IPM, efforts were for "harmonious control" in Canada in the 1950s (Pickett and Patterson, 1953; Pickett et al., 1958). The concept of integrated control in the USA was developed in the late 1950s and it consisted mainly of the use of insecticides in a manner that was compatible with biological control of insect pests (Norris et al., 2003). Cotton production in Sudan also suffered due to over reliance on insecticides. DDT induced outbreaks of cotton whitefly, *Bemisia tabaci* (Gennadius) and the use of parathion against this pest increased the occurrence of cotton bollworm (*Heliothis armigera* (Hüber)) which resulted in reduction in yields (Joyce and Roberts, 1959).

A key feature in the history of IPM is that the concept was first articulated by scientists from the Entomology Department at the University of California, USA. In the 1950s these scientists initiated the development of a new pest management strategy which brought applied ecologists and bio-control experts together (Perkins, 2002). Up to this time, applied entomology in the US had largely been taken over by a toxicology mind-set: find the right poison. The ecologists were ignored in most departments, the United States Department of Agriculture (USDA) had eliminated most classical biological control work, and only the University of California, Entomology Department still had both ecologists and biological control scientists. They worked together to solve the problems, especially resistance and destruction of natural enemies, caused by insecticides.[1] Sterile male releases were tested and demonstrated in 1950s against screw worm fly (*Cochliomyia hominivorax* (Fabricius)) and the second initiative in the USA was the development of the "integrated control" concept in the late 1950s by the entomologists at the University of California on alfalfa (Perkins, 1982). This concept aimed to integrate the use of biological control with chemical control was the beginning of IPM in the USA (Smith and Allen, 1954; Perkins, 2002). This early concept was based on the premise that pesticides could have a minimum impact on the natural enemies of the pest if applied at the correct time and under correct conditions. Economic thresholds, another important concept in IPM, were introduced at that time (Stern et al., 1959) and were the first attempt at providing a rational basis for deciding if a pest population warranted control, based on the value of expected loss from damage and the cost of control.

In the USA, IPM synthesized three strong ideas. First, USDA and California entomologists, plus some farmers, had great success in suppressing some pest insects by "classical" biological control. This method required an accurate taxonomy of the pest species, recognition of whether it was native or introduced, and, if introduced, the search of the original home of the invasive pest for its natural insect enemies followed by importation and release of the predatory or parasitic species. Control of cottony cushion scale (*Icerya purchase* – Maskell) by vedalia beetles (*Rodolia cardinalis*) imported from Australia in 1888 was the first great success and it had greatly benefited the California citrus industry and ignited interest in this practice in the State (Perkins, 1982; Sawyer, 1996).

Second, California entomologists were strong ecologists, i.e. they took seriously the need to understand the distribution and abundance plus the population dynamics of pest species. Consistent with the Entomology Department's strong interest in classical biological control, California entomologists understood that native pest species also had natural enemies, even though at times the natural predators and parasites did not suppress the pest population well enough to prevent economic damage. Thus these entomologists had a stronger appreciation for the value of natural enemies than did entomologists in other parts of the United States (Perkins, 1982).

Third, even though the University of California entomologists in the 1950s appreciated the power of classical biological control and careful ecological study, they also were intimately familiar with the many recently identified synthetic insecticides, such as DDT and methyl parathion. Their major insight in creating IPM in fact rested upon their realization that the best suppression practices lay in preserving natural enemies and using the new insecticides only when needed to supplement the suppressive effects of natural enemies. In other words, they developed "integrated

[1] Personal communication from Prof. John Perkins

control" that applied chemicals only if needed and in ways that did not decimate populations of natural enemies. This judicious use of insecticide also helped avoid the problems of resistance, which had begun appearing as early as 1908. By the 1950s, overuse of insecticides had generated numerous well recognized cases of resistance and destruction of natural enemies (Perkins, 1982).

These concepts remained the major themes of IPM throughout much of the 1970s. The United Nations Development Program (UNDP) together with the Food and Agriculture Organisation (FAO) has since 1975 initiated global programs for the development and application of IPM in rice, cotton, sorghum, millet and vegetable crops. All these developments in crop protection have been driven by changing pest problems faced by the farmers, the options available to them and their changing cash and labour requirements (Norton, 1993). Thus with the development of IPM started a search for a perfect definition. A broader definition was adopted by the FAO Panel of Experts in 1968. IPM has been defined by the Panel of Experts on Integrated Pest Control at Food and Agricultural Organisation (FAO), Rome, as:

> A pest management system that, in the context of the associated environment and the population dynamics of the pest species, utilizes all suitable techniques and methods in as compatible a manner as possible and maintains the pest population at levels below those causing economic injury (FAO, 1968).

This definition includes all the management tactics which fits best in the environment and was more oriented towards environment and ecology. A survey has recorded 64 definitions of IPM and the key words included in those 64 definitions suggests that authors attempted to capture (a) the appropriate selection of pest control methods, used singly or in combination; (b) economic benefits to growers and society; (c) the benefits to the environment; (d) the decision rules that guide the selection of the control action, and (e) the need to consider impact of multiple pests (Kogan, 1998).

The focus of IPM began to shift to non-pesticidal tactics in the 1980s, including expanded use of cultural control, introduction of resistant varieties and biological control. In Asia, the Farmer Field School (FFS) approach for disseminating the IPM technology in rice crop was adopted in Indonesia in 1989. Since then, FFS has become a preferred extension methodology for implementing IPM programs in Africa, Latin America, Caribbean and Eastern Europe. FF**S** type model is also carried out in Australia through the Ricecheck Programs and in the USA on fruit trees (Braun et al., 2006).

1.3 IPM Initiatives in the Developed Countries

1.3.1 IPM Programs and Policies in the US

In the 1950s and 1960s, synthetic pesticides were the first choice for pest control. Development of IPM strategies emerged in the USA in 1950s to reduce pesticide use in agriculture (Discussed above in Section 1.2). Shortly after IPM first appeared, Rachel Carson's *Silent Spring* (1962) brought wide recognition to the fact that insecticides had become pervasive environmental pollutants. Both human health and the health of other animals were demonstrably harmed (Dunlap, 1981). Political leaders and the public understood the pollution problem better than they did the problems of resistance and destruction of natural enemies, and thus pollution due to insecticides helped entomologists gather political strength to win appropriations for research on IPM. The laws regulating the pesticides sales in the USA were made stringent. The US Congress overhauled its regulatory scheme for pesticides. After 1972, no pesticide could be sold or used unless it had undergone extensive tests for its environmental damages (Bosso, 1987). In the same year, the report "Integrated Pest management" was published (Council for Environmental Quality, 1972). In the early 1970s, IPM was accepted as the chosen approach for pest management (Geier and Clark, 1978). In 1971, Senate Bill 1794, approving special funding for IPM pilot field research programs was passed (Kogan, 1998). A number of other initiatives were taken as the bill provided the financial support and policy support to IPM programs. A number of IPM programs were implemented in the USA. The California entomologists vastly expanded research in 1970 by collaborating with cotton entomologists to win funding from the National Science Foundation. The multi-university grant became known as the "Huffaker Project," after its chairman, Carl Huffaker of the Entomology Department of the University of California at Berkeley (Perkins, 1982).

The United States Department of Agriculture (USDA), National Science Foundation (NSF) and Environmental Protection Agency (EPA) jointly financed a 5 year program of IPM to cover around 1.6 million hectares (Kogan, 1998) (the Huffakar Project). Six crops viz. – alfalfa, citrus, cotton, pines, pome and stone fruits and soybean were covered under the project (Huffakar and Smith, 1972) which spanned from 1972 to 1978. A second large scale project ran from 1979 to 1985, known as the Consortium for Integrated Pest Management (Frisbie and Adkisson, 1985). The adoption of IPM by growers in these crops led to a 40–50% reduction in the use of the more environmentally polluting insecticides within a five year period and a 70–80% reduction in 10 years (Huffakar and Smith, 1972). The coverage of the project was 5.76 million hectares. The main indicators of adoption were the use of scouting and economic injury levels for spray decisions and the use of selective pesticides (Frisbie, 1985).

In 1978, extension funding was provided to all states to implement educational IPM programs (Olsen et al., 2003). In 1979, this program was expanded to cover 50 states and 45 commodities (Blair and Edwards, 1979). By 1982, 42 states developed extension IPM education programs and the most successful of these were in California and Texas (Olsen et al., 2003). Regional IPM programs were launched with the Consortium for IPM which concluded in 1985.

Economic evaluation of 61 IPM programs conducted by Norton and Mullen (1994) reported that adoption of IPM methods resulted in lower pesticide use. Adoption of IPM strategies saved USA agriculture US$ 500 million per year due to reductions in pesticide use (Rajotte et al., 1987). In 1994, the adoption of IPM for field crops, vegetables, fruits and nuts in selected states covering most of the area

Table 1.1 Extent of adoption of IPM practices in the USA agriculture

Crop	1991–1994 (% area)	2000 (% area) USDA estimates
Cotton	29[1]	86[3]
Fruits and nuts	95[2]	62[3]
Vegetables	86[2]	86[3]
Soybeans	84[2]	78[3]
Corn	90[2]	76[3]
Barley	–	71[3]
Wheat	–	65[3]
Alfalfa-hay	–	40[3]
All other crops and pastures	–	63[3]

Sources: [1]Fernandez (1994); [2]Vandman et al. (1994) Data based on chemical use/cropping practices from 1991 to 1993; [3]USGAO (2001)

under the surveyed crops was least in case of cotton (29%) and the highest for fruits and nuts (95%) (Table 1.1).

National IPM initiatives for implementing IPM practices on 75% of the USA's crop area by 2000 were started in 1993 (Sorensen, 1994). The American Cooperative Extension Service (CES) plays a key role in dissemination of IPM in the United States (Frisbie, 1994). The IPM programs evolved and expanded to include the entire crop pest complex, and there was a greater emphasis on multidisciplinary team approaches to IPM, with CES and research cooperating at all phases of program development, implementation, and evolution (Kogan, 1998).

In the USA, the Government Performance and Results Act of 1993 (GPRA)[2] requires that federally funded agencies develop and implement an accountability system based on performance measurement, including setting goals and objectives and measuring progress toward achieving them. Accordingly, the performance of federally funded IPM program activities must be evaluated. During 2001, the United States General Accounting Office (USGAO) conducted an audit of the US IPM programs to ascertain if the USDA had achieved the targets of 1994 that 75% of the planted crop land should be under IPM by 2000. By 2000, farmer surveys conducted by the USDA indicated that IPM adoption across all crops had increased from 40% in 1994 to 71%. The area under IPM was: cotton-86%, fruit and nuts-62%, vegetables-86%, soybean-78%, corn-76%, barley-71%, wheat-65%, alfalfa-40% and other crops and pasture-63% (Table 1.1). However, total pesticide (technical grade material) use had increased by 4% (from 408.2 million kg in 1992 to 426.4 million kg in 2000), but there was a reduction of 14% in the use of pesticides (from 206.4 million kg to 176.9 million kg) categorized as risky by EPA during the same period (USGAO, 2001). The USGAO (2001) concluded that quantity of pesticide use may not be the most appropriate measure of the success of IPM programs. The methods for measuring IPM's environmental and economic results were questioned for not being well developed. The indicators for categorizing farmers as IPM practitioners are prevention, avoidance, monitoring and suppression (USDA, 1998).

[2] http://www.whitehouse.gov/omb/mgmt-gpra/gplaw2m.html

Table 1.2 Recommendations of USGAO for effective implementation of IPM

• Establish effective department-wide leadership, coordination, and management for federally funded IPM efforts;
• Clearly articulate and prioritize the results the department wants to achieve from its IPM efforts, focus IPM efforts and resources on those results, and set measurable goals for achieving those results;
• Develop a method of measuring the progress of federally funded IPM activities toward the stated goals of the IPM initiative; and
• Foster collaboration between EPA and USDA to support the implementation of pest management practices that may reduce the risks of agricultural pesticide use.

Source: USGAO, 2001

The United States General Accounting Office report 2001, made the recommendations for removing the leadership, coordination, and management deficiencies (Table 1.2).

In spite of all these efforts, however, there is little evidence that IPM (as originally envisioned) has been implemented to any significant extent in American agriculture (Ehler and Bottrell, 2000; Barfield and Swisher, 1994). The impact of IPM programs in terms of adoption of IPM practices by the growers is also questioned and the rate of adoption of IPM has been slow in the USA (Hammond et al., 2006). The failure or apparent failure of these programs can be traced to at least three constraints. Firstly, for farmers, IPM is time consuming and complicated; given the multiple demands of farm production, farmers cannot be expected to carry out the integration of multiple suppressive tactics for all classes of pests. Secondly, pest control consultants who might be hired by farmers usually have little time for closely monitoring pests and their natural enemies/antagonists; besides, many of them are employed by pesticide companies and have a built-in conflict of interest. Also, pesticides can be a cheap insurance policy when there is a possibility of losing an entire crop. Finally, pest scientists in the colleges of agriculture at the state (land-grant) universities have resisted the integration of the pest disciplines; most seem content to study individual ingredients of IPM, and this is reinforced by the incentive system in which they work. The result is a dearth of pest management programs that feature both vertical and horizontal integration (National Roadmap for IPM, May 17, 2004).[3] There are similar concerns at the international level.

The road map for a **N**ational IPM Program in the USA identified strategic directions for IPM research, implementation, and measurement for all pests, in all settings, throughout the country. This included IPM for all areas which include agriculture, structural, ornamental, turf, museums, and public and wildlife health pests. The goals of the **N**ational IPM Program are to improve the economic benefits of adopting IPM practices and to reduce potential risks to human health and the environment caused by the pests themselves or by the use of pest management practices. States receive a grant of US $10.75 million annually for IPM extension

[3] National Site for the USDA Regional IPM Centers Information http://www.ipmcenters.org/IPMRoadMap.pdf

Table 1.3 National Roadmap for implementation and adoption of IPM

In order to reach their full potential, IPM programs must be willingly adopted by agricultural producers, natural resource managers, homeowners, and the general public. The following activities will contribute to the adoption of IPM.

- Develop user incentives for IPM adoption reflecting the value of IPM to society and reducing risks to users. Work with existing risk management programs including federal crop insurance, and incentive programs such as NRCS Environmental Quality Incentive Program (EQIP) and other farm program payments to fully incorporate IPM tactics as rewarded practices.
- Provide educational opportunities for IPM specialists to learn new communication skills that enable them to engage new and unique audiences having specific language, location, strategy, or other special needs.
- Create public awareness and understanding of IPM and IPM programs through creative use of mass media and public service advertising.
- Leverage federal resources with state and local public and private efforts to implement collaborative projects.

Ensure a multi-directional flow of pest management information by expanding existing and developing new collaborative relationships with public and private sector cooperators

Source: National Road Map for Integrated Pest Management, 2004. http://www.ipmcenters.org/IPMRoadMap.pdf

programs. Implementation strategies as envisaged in the National Road Map for IPM Program are listed in Table 1.3. The National IPM Program focuses in three areas (i) production agriculture, (ii) natural resources, and (iii) residential and public areas. The USA Government created four Regional Pest Management Centers in the year 2000. These centers (North Central IPM Center, North Eastern IPM Center, Southern IPM Center and Western IPM Center) were established by the Cooperative Research Education and Extension Service (CSREES). These centers are playing a key role in implementing the National Roadmap for IPM which has identified strategic directions for IPM research and implementation. IPM tools are: (i) high-tech pest forecasting, (ii) sensible pest scouting practices, (iii) innovative biological control, and (iv) least toxic chemical option. Centers strengthen state IPM programs. A mid-term review[4] report of these centers has justified their establishment as "the Centers have engaged a wide spectrum of nontraditional partners and reinforced established IPM networks, thus facilitating IPM adoption across the nation." The success stories of these centers are the Great Lakes Vegetable IPM Program in nine states and Ontario, Canada being implemented on annual budget of US $30,000. In these areas 83.5 percent growers were moderate to high IPM adopters (North Central IPM Centre).[5] In the case of the Southern IPM Center, a national warning system designed to help soybean growers to protect their crop from Asian soybean rust (*Phakopsora pachyrhizi*) has saved US $299 million during 2005. The evaluation of the national roadmap (2002) for implementing and adoption of IPM practices in the US agriculture will provide the feedback about the progress of IPM in this decade.

[4] http://www.ipmcenters.org/IPMCenterReview2-06.pdf

[5] IPM success stories. 2008. http://www.ipmcenters.org/SuccessStoriesLowFinal.pdf

1.3.2 IPM Initiatives in Europe

In Europe, IPM programs were originally developed for orchards. In perennial crops IPM is the standard strategy but to a lesser extent in annual crops. The International Organization for Biological Control of Noxious Animals and Plants (IOBC) was established in 1956, for the development of bio-control strategies for major insect pests in Europe. In 1958, IOBC established the "Commission on Integrated Control" and in 1959 a working group on "Integrated Control in Fruit Orchards" (For details see Chapter 14, Vol. 2). Entomologists involved with apple production were the pioneers of IPM and later in the development of Integrated Production (IP) in Europe (Boller et al., 1998). In 1974, IOBC adopted the term "Integrated Plant Protection". IOBC developed IPM systems in all major crops of Europe. IOBC published the basic concept of Integrated Production in 1992, followed by crop specific IPM guidelines for all major crops. Farmers associations, Cooperatives, Non Governmental Organisations (NGOs) and retailers throughout Europe are implementing strategies for reducing pesticide and fertilizer use in European agriculture. Targets for pesticide use reduction have been adopted in Denmark, Sweden, the Netherland, France and Germany. Retailers are procuring low pesticide labeled food products and providing economic incentives to the farmers (Tresnik and Parente, 2007). A total of 65% of the total fruit area in Belgium is managed by a non-profit farmers' association which provides training to farmers in low pesticide use. Farmcare run by the cooperative group in the UK, SAIO and IP-SUISSE in Switzerland, and LAIQ in Italy are providing impetus to IPM. On June 23, 2008, Agriculture Ministers from Europe approved the creation of a European Union – wide pesticide blacklist. The pesticides linked with cancer, DNA mutation, reproductively toxicity and hormonal disruption, which together contaminate 22% of food items will be targeted (PAN, Europe, 2008). Romania, Hungary and Ireland were the only three countries not endorsing the proposal.

The European Union countries provide incentives to the growers for compliance with IPM tactics to reduce pesticide use. The European Commission considered levying taxes on plant protection products to encourage pesticide free or low pesticide farming. Norway and two European Union countries, Denmark and Sweden have levied taxes on pesticides. Sweden started pesticide taxation in 1986 under which pesticide tax was levied at the rate of US $3 (at 2008 rates) per kilogram (kg) technical grade material. Since 2004, the pesticide tax has been raised to US $4.7 per kg use of pesticide (PAN, Europe, 2004). Pesticide use was reduced by 67% during 1990s. A pesticide action plan to achieve 50% reduction in pesticide was launched in Denmark in 1986. In Denmark pesticide taxation was started in 1992 and incentives given to encourage low pesticide farming. In the case of insecticides a 54% tax was levied on the retail price and in the case of herbicides, fungicides and growth regulators a 33% tax was imposed (PAN, Europe, 2004). The pesticide treatment intensity decreased from 3.1 (1990–1993) to 2.1 applications (2001–2003) and is projected to be reduced to 1.4 by 2009 and pesticide use decreased by 25% by 1992, and 50% by 1997 (Cannell, 2007). Norway started a

Table 1.4 IPM initiatives in Europe

Country	Policy Initiatives
Belgium	1. Pesticides on red list totally prohibited as per IOBC norms 2. Since 1988 fruit growers initiative to promote IPM
Denmark	1. Pesticide Action Plan • 1986–1997, the first Pesticide Action Plan targeted a 25% reduction in total pesticide consumption by 1992 and 50% by 1997. It also included measures to encourage the use of less hazardous pesticides. Educating farmers to improve their knowledge and skills • 1997–2003 The second Plan introduced the indicator treatment frequency index. The target was to reach a treatment frequency of less than 2.0 before 2003 and establish 20,000 ha of pesticide-free zones along key watercourses and lakes. • 2003–2009 The objective of the third Pesticide Action Plan is to lower the treatment frequency below 1.7 by 2009, to promote pesticide-free cultivation and establish 25,000 ha pesticide-free zones along watercourses and lakes. This plan includes the fruits and vegetables sector for first time. 2. Pesticide tax a. Insecticide tax 54% of the retail price b. Herbicide, fungicide and growth regulator 34% of the retail price 3. Danish agriculture advisory service to educate farmers about IPM 4. Incentives to encourage IPM *The treatment frequency index expresses the average number of times an agricultural plot can be treated with the recommended dose, based on the quantities sold.
Germany	1986 – Germany makes IPM official policy through Plant Protection Act. Since 2004 the national Reduction Program Chemical Plant Protection encourages implementation of IPM in practice
Italy	1. Environmental NGO promoting pesticide free fruit and vegetables 2. NGO provides guidelines to farmers on IPM. Labeling of IPM produce LAIQ. 3. Transgenic crops not allowed
Netherland	1. 1991 – IPM for crop protection introduced by the cabinet decision in the Netherlands 2. New initiatives based on multi-stakeholders launched in 2003 with Euro 14 million for integrated crop management (ICM) 3. Experimental advisory service for low pesticide farming methods 4. Development of environmental impact cards with indicators 5. Development of best practice protocols for IPM in major crops 6. Market support to ICM. Farmers adopting ICM in apple, strawberry, Cabbage, lettuce etc. offered premium by the market. Supermarket Laurus supply ICM products.
Norway	1. In 1985 pesticide reduction program started 2. In 1988 levied banded tax system based on toxicity @ 2.4 Euro/ha 3. Inspection of spray equipments
Sweden	1. From 1985 to 2003 pesticide tax @ 2 Euro/kg 2. Since 2004 @ 3 Euro/kg 3. Active advisory service to reach farmers. It forecast, demonstrate, lays trials and conduct training

Table 1.4 (continued)

Country	Policy Initiatives
Switzerland	1. Development of low pesticide integrated production (IP) farming protocols 2. Euro 1.6 billion/year direct subsidy to farmers for adopting ecological standards 3. Pest warning services and pragnasis models for taking pest management decisions 4. Testing spray equipments at least once in 4 years 5. All market sell IP SUISSE products
United Kingdom	1. The UK cooperative group one of the largest consumers cooperative in the world manages 10000 ha of cooperative owned land and 20000 ha of farmland owned by land owners. Farmers provided guidelines on Integrated Farm Management and has prohibited use of 23 and restricted use of 32 pesticides which is aimed to reduce pesticide use by 50%. 2. Priority on adoption of biological and mechanical crop protection ahead of pesticides

After: PAN Europe (2005); IP SUISSE (2005); IP SUISSE (2006); PAN Germany (2004); Cannell (2007); Neumeister (2007); http://www.co-op.co.uk

pesticide reduction program in 1988 which employed a levied banded tax system based on toxicity at the rate of US $3.8/ha. This resulted in a 54% pesticide use reduction (PAN, Europe, 2004). Pesticide use was reduced from 8000 metric tons during 1981–1985 periods to 3000 metric tons in 2003 with an average consumption of 1.2 kg active ingredient per hectare (PAN, 2007). In the Netherlands, new initiatives based on multi-stakeholders were launched in 2003 with US $22 million for integrated crop management (ICM) (Cannell, 2007). Since 1985–2006, pesticide use in the Netherlands has been reduced by more than 50% from 21003 metric tons in 1985 to 9411 metric tons in 2006, but increased to 10741 metric tons in 2007 (Milieu en Natuur Planbureau, 2008). Similarly, in the UK the IPM initiatives taken by UK cooperative group by prohibiting 23 pesticides will reduce pesticide use by 50%. The details of the initiatives taken in the selected countries of Europe and their impact are given in Tables 1.4 and 1.5. In Eastern Europe, pesticide use is low as compared to Western Europe. In Poland, 10000 tones of apple (13% of total production) were certified as integrated production during 1999. Better contact with advisors helped the farmers to adopt IPM and 90% of farmers accepted IPM (Niemczyk, 2001). In Central and Eastern Europe, the Farmer Field School (FFS) model for implementation of IPM programs in maize was first introduced in 2003. In Central and Eastern Europe (CEE) the FFS approach was first introduced in seven countries (Bosnia-Herzegovina, Bulgaria, Croatia, Hungary, Romania, Serbia and Montenegroand Slovak Republic) in 2003 through an FAO project for managing an introduced pest on maize, the western corn rootworm (*Diabrotica virgifera* LeConte), by means of IPM (Jiggins et al., 2005). Two other projects have also been introduced in Armenia; one on rodent control through FAO funding and the other with support from USDA has triggered the establishment of an NGO that now coordinates a number of FFS projects in the country (Braun et al., 2006).

In the European Union, consumption of fungicides is on the higher side (61%) followed by herbicides (28%), insecticides (8%) and growth regulators (3%)

Table 1.5 Impact of IPM in European agriculture

Country	Crops	Area under IPM (ha)	Farmers adopted	Reduction in pesticide use (Technical grade material)	Reference (s)
Austria	Pome fruits	4770	51%	–	Cross et al., 1995
Belgium	All crops	In 2006, 2/3rd of the total area under fruit crops. 28634 ha organic farming	803 farms	–	FGOV, 2008
Belgium	Pome fruits	4510	31%	–	Cross et al., 1995
Belgium	Pear	–	98%	–	Schaetzen, 1996
Denmark	All crops	20000 (pesticide free)	–	Pesticide use frequency 1990–1993 −3.1, 2001–2003 −2.1, Projected 2009 −1.4	PAN Europe, 2007, Nielsen, 2005
Denmark	Pome fruits	960	17%	–	Cross et al., 1995,
Germany	Pome fruits	30440	27%	–	Cross et al., 1995
Italy	Potatoes, peach, apricot, onions, kiwi fruits, tomato, apple lettuce and figs	–	230	–	PAN Europe, 2007
Netherland	Pome fruits	14800	57%	–	Cross et al., 1995
Netherland	All major crops	–	–	50% reduction in pesticide use since 1995	PAN Europe, 2007

Table 1.5 (continued)

Country	Crops	Area under IPM (ha)	Farmers adopted	Reduction in pesticide use (Technical grade material)	Reference(s)
Norway	–	–	–	54% pesticide use reduction. Pesticide treatment intensity was reduced from 2.45 to 2.04 during 2000 to 2002. Projected 1.7 for 2004 to 2009	PAN, Europe, 2004
Sweden				No overall reduction in pesticide use (1991–2002)	PAN, Europe, 2004
Switzerland	Pome fruits	4350	39%	–	Cross et al., 1995
Switzerland	Cereals, rapeseed, potato, fruits, meat, poultry and milk	Cereals-11000 farms[1], Fodder – 13000 farms[1], Rapeseed – 2000 farms[1] Potato – 1200 ha^2	18000 farmers members of IP SUISSE and 3000 out of 4000 fruit producers grow IP SUISSE fruits Apple-92% Strawberrie-85% Raspberries-70%	40% reduction in pesticide use (a.i) during the last 15 years (1990–2005) and was the most successful effort in Europe	Neumeister, 2007 [1]IP SUISSE, 2005 [2]IP SUISSE, 2006
UK	Carrot, potato, cauliflower, mushroom, avocado, pineapple	Cooperative 10000 ha land owned by land owners 20000 ha	–	50% reduction in pesticide use since 1994	Cannell, 2007

Table 1.6 Pesticide sale (technical grade material) in Europe (in tonnes)

Country	Year								Increase/ decrease over 1995 (%)
	1995	2001	2002	2003	2004	2005	2006	2007	
EU (15 countries)	279811	327642	–	–	–	–	–	–	+17
Belgium	10939	8845	9204	–	–	–	–	–	−16
Denmark	4809	2890	2722	–	–	–	–	–	−43
Germany	30468	27885	29531	30164	28753	29512	–	–	−3
Estonia	144	329	267	321	246	–	–	–	+71
Ireland	2291	2486	2796	2913	–	–	–		+27
Greece	8525	11111	–	–	–	–	–	–	+30
Spain	27852	35700	–	–	–	–	–	–	+28
France	84007	99635	82448	74524	76099	–	–	–	−9
Italy	48490	76346	94711	–	–	–	–	–	+95
Hungary	7698	6431	8232	–	–	–	–	–	+7
Netherlands	10924	7987	8073	7868	9071	9309	9411	10741	+2
Austria	3404	3133	3080	3386	3302	3404			0
Poland	6962	8855	10358	7184	8726	16039			+130
Portugal	11818	15491	17435	17046	16938	16346			+38
Finland	1035	1424	1614						+56
Sweden	1224	1738	1711	2049	942	1527	1707		+39
United Kingdom	33668	32971	31064						−8
Norway	931	518	818	689					−26

After: Eurostat (2008) June 9, 2008 http://epp.eurostat.ec.europa (Accessed on July 18, 2008)

(Eurostat, 2002). Pesticide consumption (active ingredients) in the European Union fell by 13% between 1991 and 1995, and it was the highest in Finland (−46%) followed by the Netherlands (−43%), Austria (−21%), Denmark (−21%), Sweden (−17%), Italy (−17%), Spain (−15%) and France (−11%) (Lucas and Pau Vall, 1999). Since 1995 total sales of pesticides (tons of active ingredients) have increased in the European Union except in Belgium, France, Denmark, Germany, Norway and the United Kingdom, and has remained almost static in the Netherlands (Table 1.6). Between 1992 to 1999, the consumption of fungicides decreased by 8% but the consumption of insecticides increased by 4% (Eurostat, 2002).

1.3.3 IPM Programs in Australia

IPM systems in Australia have been developed in pome and stone fruits (Williams, 2000a), cotton (Fitt, 1994, 2004), wine grapes (Madge et al., 1993), citrus (Smith et al., 1997) and vegetables (McDougall, 2007). In case of pome fruits there are national guidelines for integrated fruit production (IFP) in apples.

Progress with the horticultural crops has largely been driven through state based Departments of Primary Industries with support from Horticulture Australia Ltd, which is a national research, development and marketing organization that collects levies of horticultural producers and in partnership with the horticulture sector invests this in programs that provide benefit to Australian horticulture industries. These systems largely focus around the use of natural enemies, including native and introduced predatory mites and a range of hymenopteran parasites, and selective options including mating disruption, to manage introduced pests. Many use annual introductions of these predators or parasites which can be purchased commercially. Systems have been developed to ensure these introductions are effective, including the "pest in first" strategy that ensure beneficial insects (natural enemies) have prey to sustain them, rather than dying out.

There are some outstanding examples of IPM research and uptake in the horticultural industries. Citrus is an example where the introduction of bio-control agents for scale and mite pests, careful cultural control and limited use of selective insecticides has led to dramatic reductions in pesticide use (Smith et al., 1997). Similarly the conservation of native predatory mites in grapes has significantly reduced problems with mite pests of grapes (James and Whitney, 1993). IPM in apples is another example of IPM strategies being combined, including the use of introduced predatory mites, mating disruption and selective insecticides (Thwaite, 1997). In 2002, 80% of apple growers were adopting IPM (IFP).[6] The number of sprays in apple orchards was reduced by 30% (Williams, 2000b). In lettuce crops the advent of the current lettuce aphid, *Nasonovia ribisnigr*i (Mosley) created a significant challenge to IPM. However, this situation is being managed through an overall IPM strategy that emphasizes sampling, identification, management using non-chemical

[6] http://www.daff.gov.au/-data/assets/pdf

means (e.g. weed control, cultivation of crop residues, use of currant lettuce aphid resistant varieties) and selective insecticides (McDougall and Creek, 2007).

Sugar cane production has also been challenged by a range of pests, principally the cane grubs, rodents and soldier flies (Allsopp et al., 1998). Management of the cane grub complex has relied heavily on use of soil applied insecticides; however the loss of organochlorine based insecticides, drove change toward more diverse management systems. However, the cane grub complex includes species with quite different biology and pesticide susceptibility so different tactics are required for different species. Metarhizium fungus, is registered as a biological insecticide for control of the greyback canegrub, *Dermolepida albohirtum* (Waterhouse), as a result of Sugar Research and Development Corporation, Bureau of Sugar Experiment Stations, Commonwealth Scientific and Industrial Research Organisation (CSIRO Australia) and BioCare (now Becker Underwood) research and development funding (Milner et al., 2002). A tactic for helping to manage the intractable sugarcane soldier flies, *Inopus rubriceps* (Macquart) is to deprive them of food (Samson, 2006). Research to improve IPM for the cane grub complex continues and a range of cultural techniques, combined with strategic use of soil applied chlorpyriphos is the current recommendation (Allsopp et al.,2003).

Development of IPM systems has long been a target in grains cropping systems, which include winter cereals, summer and winter grain legumes and pulses and summer grains such as sorghum and maize and oilseeds such as sunflower and canola. A good account of the pests and beneficials in Australian grain crops can be found in (Berlandier and Baker, 2007; Brier, 2007; Franzmann, 2007a,b; Hopkins and McDonald, 2007; Miles et al., 2007; Murray, 2007). IPM in grains has been challenged by the variable climate, especially rainfall, fluctuating markets and crop diversity. This coupled with the low cost of highly effective synthetic pyrethroid insecticides has encouraged the use of prophylactic "insurance" insecticide applications which has unfortunately become common practice in many grain crops and resulted in significant selective pressure for the development of insecticide resistance. In some cases IPM has been perceived as a lower priority, especially in the course grains where there is a lower risk of pest attack. For instance, in the winter coarse grains, pests are only occasionally a problem, while in the summer coarse grains (sorghum and maize) *Helicoverpa armigera* (Hübner) is a pest, but rarely warrants control in maize and is readily controlled with *Helicoverpa* NPV in sorghum (Franzmann et al., 2008). Sorghum midge, *Stenodiplosis sorghicola* (Coquillett) has also been an important pest in late planted sorghum, but selection for plant resistance to this pest has been an outstanding success (Franzmann et al., 2008). However, the grain legumes and pulses are attractive to pests throughout their growing cycle and hence pest management and IPM in these crops is a higher priority. In these crops management of thrips, lepidopteran, hemipteran and mite pests poses a significant challenge which is being targeted by research.

There has been considerable investment in development of IPM systems in grains over many years although the diversity of grain crops and growth during both summer and winter has meant formulation of year-round IPM strategies has been challenging. The Grains Research and Development Corporation (GRDC) collects a levy from grain growers, matched by the federal government, that is used to co-ordinate and fund research and extension activities and IPM, and pest ecology and management has been an important component. Recently the GRDC has initiated the National Invertebrate Pest Initiative (NIPI) in an effort to bring together researchers, extension and industry representatives to help define the pest challenges across the range of grains crops and to develop coordinated IPM support materials and strategies. One outcome from the NIPI project has been the development of the PestFAX/PestFacts which is a free email information service alerting growers and farm advisers across southern Australia to invertebrate pest issues and IPM compatible solutions. A key focus has been on monitoring, including correct pest identification and use of selective control options to help conserve beneficial populations. A similar approach is being used with a 'blog' known as the Beatsheet developed by the Queensland Department of Primary Industries. Another development has been the identification of the need for IPM guidelines for grains which span the range of crops grown in regions throughout the year. Other initiatives include the Grain and Graze program which addresses enterprises with mixed animal and crop production. This is collaboration between the Grains Research and Development Corporation, Meat and Livestock Australia, Australian Wool Innovation Limited, and Land and Water Australia. The IPM component focuses on encouraging farmers to monitor pests, use more selective control options and to using other strategies such as baiting or seed dressings where appropriate. In many northern grain producing regions *Bemisia tabaci* (Gennadius) B-biotype is emerging as a significant issue and ironically, is driving the trend toward use of more selective insecticides to conserve beneficials as control of this pest is expensive and difficult if outbreaks are induced by use of broad-spectrum insecticides.

Rice production has also strived to improve and integrate production practices to improve yields. This has been implemented through the Ricecheck system, developed in the 1980s by New South Wales Department of Primary Industries, which provides rice growers with checks for production at critical phases of crop growth (Singh, 2005). It includes recommendations for control of rice pests, primarily snails and ducks, but also insect pests such as common armyworm *Leucania convecta* (Walker) and rice leaf miner *Hydrellia michelae* (Bock).

IPM has a rich history in Australian cotton (Fitt, 2000), with the failure of cotton production in the Ord River Irrigation Area in north-western Australian in the mid-1970s due to insecticide resistance providing a strong incentive for growers in eastern Australia to manage resistance and adopt more IPM compatible strategies. Accordingly, research on IPM has been supported strongly by the industry through levies on each bale of cotton which are matched by the federal government and administered by the Cotton Research and Development Corporation. In more recent years, the Co-operative Research Centre (CRC) initiative of the federal government has been important, with three successive cotton focused CRCs bringing together university, CSIRO, State Government and industry to collaboratively target issues challenging cotton production, including pest management. The CRC approach has facilitated strong co-operation and integration between agencies in the implementation of IPM in cotton.

Cotton is attacked by a range of pest, including the highly damaging *Helicoverpa armigera* and *Helicoverpa punctigera* (Wallengren) (Fitt, 1994). The need for season long control of these pests often disrupted natural enemy populations leading to outbreaks of secondary pests, in turn requiring control. High reliance on insecticides posed significant challenges in terms of public perceptions, environmental pollution, insecticide resistance and secondary pest management (Wilson et al., 2004). In the initial years (1960s and early 1970s) pest management advice mostly came from staff employed by the agrochemical companies. However, in the mid 1970s, independent consultants become more common – these were usually tertiary trained operators that sampled crops and provided growers guidance on the need to spray and the choice of insecticide. Most growers now use a consultant or employ their own agronomist. Innovative research in the late 1970s by CSIRO and State Department of Agriculture and University of Queensland researchers showed the value of more rigorous application of thresholds, selection of softer insecticides and use of cotton's capacity to compensate for pest damage to reduce insecticide use without reducing yield. This was captured in a computerized decision support system, SIRATAC (Brook and Hearn, 1990), that took into account pest abundance and used a *Helicoverpa* development and feeding model to predict crop damage and a crop model to simulate the crops productivity with and without this damage. Control was then recommended only if yield loss was predicted (Hearn and Bange, 2002; Room, 1979). This system was reasonably well adopted, with up to 30% of the industry using it. There was also an additional benefit as knowledge from SIRATAC seeped through the industry – increasing crop checking rigor and the use of valid thresholds by most consultants. In the early 1980s, pesticide resistance in *Helicoverpa armigera* to pyrethroids was detected in eastern Australia and prompted the development of an industry wide insecticide resistance management plan. This plan restricted use of insecticides to a set period during the season, with the aim to provide a generational break in selection of *H. armigera* for each product. This strategy evolved over time to include all insecticides used in cotton, and managing resistance to *H. armigera*, spider mites, aphids and silver leaf whitefly, and was managed by the Transgenic and Insecticide Management Strategies committee, which included research and industry members. The agrochemical industry, researchers, extension staff and consultants all played an important role in the implementation of insecticide resistance management (IRM) and in monitoring resistance levels to establish the effectiveness of the IRMS (Forrester et al., 1993).

In the late 1990s, the emphasis shifted from IRM (which was mainly based on reliance on chemical control) to sustainable and effective IPM, which incorporated IRM. This change was driven by escalating resistance levels and costs, despite the well implemented and adopted IRM strategy. However, IPM was difficult as most available control options were highly disruptive of beneficial populations. The availability of Bt-cotton (Cry1Ac) in the mid 1990s, initially capped to 30% of the area, and the registration of more selective control options for *Helicoverpa* control (e.g. spinosad, indoxacarb and emamectin) greatly helped uptake of IPM as growers could manage this pest with less effect on beneficials (Wilson et al., 2004). At the same time a set of guidelines for IPM were developed, which provided growers with a practical year round strategy to manage pests, conserve beneficials and communicate with each other to co-ordinate efforts (Deutscher et al., 2005). This was supported by well co-ordinated and highly focused extension effort from state and federal extension staff, including IPM field days, regular fact sheets and a well supported website.

Combined these factors led to a significant change in attitude toward IPM. This was further supported by economic analysis which showed that growers using more selective insecticides, which were more expensive, obtained yields similar to growers using cheaper, harder options, but made more money because they sprayed less (Hoque et al., 2000). This outcome, combined with a strong extension effort and the formation of regional IPM groups led to dramatically increased adoption of IPM and a significant decline in insecticide use (Wilson et al., 2004). However, overreliance on these selective compounds meant resistance appeared within 2–3 years of their introduction, so by the early 2000s resistance was again threatening the viability of IPM.

The advent of Bt-cotton with two genes (Cry1Ac and Cry2Ab) allowed the cap on area to be removed. From its initial release in Australia, Bt-cotton had a compulsory resistance management plan, developed in conjunction with industry, research and extension. The dramatic uptake of two gene Bt-cotton which now accounts for $>85\%$ of industry, has seen a further reduction in insecticide use by about 85% (Pyke and Doyle, 2006). This in turn has led to a dramatic reductions in insecticide resistance to insecticides (Rossiter and Kauter, 2006). However, the emergence of sucking pests, no longer controlled by insecticides applied against *Helicoverpa* now poses new challenges to IPM in Australian cotton and this is the focus of a concerted research effort (Wilson et al., 2004). Research continues to develop new tools to support IPM, including new biopesticides for the sucking pests, semio-chemical approaches, and the provision to industry of clear guidelines on the IPM fit of new insecticides.

1.4 IPM Initiatives in the Developing Countries

1.4.1 IPM Programs in Latin America

Cotton pest management in Peru and Nicaragua in the mid 1950s and early 1970s amply proved that sustainable pest management is possible by adopting a combination of pest management tactics. In Latin American countries there are many successful examples of IPM.

In Costa Rica, banana plantations were treated with aerial sprays of dieldrin granules against banana weevil, *Cosmopolites sordidus* (German) and rust causing thrips. The reliance on these aerial sprays resulted in outbreaks of banana stalk borer (*Castiomera humbolti*). By 1958, there were outbreaks of six major lepidopteran pests. Due to the oil crisis in 1973, pesticide sprays were stopped by the United Fruits Company managing the banana crop. Within two years, all pest species had almost disappeared and there were only occasional outbreaks of pests which did not reach economic thresholds due to increases in the natural enemy populations

(Stephens, 1984). In Brazil, in the 1970s and early 1980s, on average of 20–30 pesticide applications were given to tomato crops (around 2000 ha). An IPM program implemented in the Cauca valley (Colombia) in 1985, resulted in a reduction in pesticide applications of 2–3 sprays and savings of US $650/ha. Use of *Bacillus thuringiensis* combined with the release of natural enemies (*Trichogramma* spp.) and conservation of parasites (*Apanteles* spp.) reduced the population of a major pest, the fruit borer (*Scrobipalpula absoluta*) (Belloti et al., 1990). During the late 1970s, the agricultural research and extension services in Brazil initiated an intensive program to transfer IPM technology to cotton farmers (Bleicher et al., 1979). In Brazil in the late 1970s, the resistance of cotton boll worm, *Heliothis virescens* (Fabricius) to organophosphates was a major problem. At that time cotton received 15–20 insecticide applications per season. The launching of the IPM program in 1979, helped significantly to reduce insecticide applications on average to six sprays per season helping to optimize profits through lower production costs for the same level of yield (Pimentel and Bandeira, 1981; Seganmullar and Hewson, 2000). But in 1983, with the introduction of cotton boll weevil, *Anthonomas grandis* from Boheman to Brazil, the number of insecticide applications again rose to 10–12 applications per season. However, after local behavior patterns were established for the new pest, and IPM adapted accordingly, the number of applications decreased again to an average of 8 per season (Seganmullar and Hewson, 2000). IPM has produced excellent economic, social and ecological results in Brazil (Cruz, 1991). Later, the chemical pesticide industry began to collaborate in an IPM program which did not show desired results (Ramalho, 1994). The Latin American Association for Cotton Research and Development established working groups on research and extension in all member countries for exchange of information on IPM in cotton.

In Chile, over 120,000 ha of wheat were sprayed aerially with insecticides to control two aphid species (*Sitobium avenae* and *Metopolophium dirhodum*) in the early 1970s. Due to the high losses caused to the wheat crop, in 1976 the Chilean government in collaboration with FAO initiated an IPM program. Predators and parasitoids were introduced from South Africa, Canada, Israel, Europe and the USA. From 1976 to 1981, 4×10^6 parasitoids were distributed and the pest population was maintained below the economic threshold level (Zuñiga, 1986). Cuba was forced to adopt an IPM policy after the collapse of the socialist block in 1990, which resulted in 60% drop in pesticide imports. Under IPM, the focus was on biological control by establishing 218 centers for the production of biocontrol agents. These centers provided entomopathogens and *Trichogramma* wasps to the farmers (Rosset and Benjamin, 1994).

In Peru, the Peruvian Action Network of Alternatives to Agrochemicals (Spanish acronym RAAA) in 1992 started a training program in the Canete Valley to reawaken farmers' interest in IPM, under the theme "Ecological Pest Management for Cotton Growers". In 1997, a small project on organic cotton production was also set up (CABI, 2000). There is no government extension service in Peru. A Potato IPM Program in Peru has shown a net benefit of US $100–536 per hectare (for details see Chapter 12, Vol. 2). In Colombia in 1997, a growers' cooperative with 180 members, started working on 600 hectares to start an IPM program and in 1998 it had spread to over 2400 hectares (Williamson, 1999). The National Agricultural

Research Institute's (INRA) cotton IPM program in Argentina is researching and implementing, mass production of the predator *Chrysopa* spp. for aphid and cotton pest management. The IPM methods have succeeded in reducing insecticide applications from 11–12 per season to <4 (Williamson, 1999). In Peru, the IPM intervention in cotton resulted in reduction in pesticide use by 50–70% (Castro et al., 1997; Van Elzakker, 1999). Similarly, use of biological control in Argentina resulted in reducing pesticide applications from 11–12 to 4 (Williamson, 1999).

The first attempt to organize farmer training along discovery – learning methods was in Peru. Most training in IPM programs in Latin America had been based on result demonstration methods with little active farmer participation. The FFS approach for providing hands on experience to potato farmers in IPM was introduced by the International Potato Center (CIP) and its institutional partners in Peru in 1997. Between 1997 and 2005, a total of 747 FFS had been implemented in the Latin America and Caribbean countries of Bolivia, Brazil, Colombia, Dominica, Dominican Republic, Ecuador, El Salvador, Guatemala, Guyana, Haiti, Honduras, Jamaica, Mexico, Nicaragua, Peru, Suriname, and Trinidad and Tobago (Braun et al., 2006). The outcome of different IPM interventions in Latin American countries is given in Table 1.7.

1.4.2 IPM Programs in Africa

Egypt in the early 1970s developed effective integrated pest control (IPC) recommendations for cotton crop production consisting of cultural (timely sowing), biological, chemical methods, manual mechanical practice of removing egg-masses of cotton leaf worm, *Spodoptera littoralis* (Boisduval) and regulatory measures. These practices, in combination with some others have been very successful. The average number of sprays in 1975 and later years was less than one. The IPC programs were taken up due to development of insecticide resistance, development of secondary pests and the increasing costs of chemical control. IPC programs in cotton, sugarcane, maize and rice were taken up in Egypt. In Sudan, after the whitefly problem in 1979, when the problem spread out of control, a program for development and application of integrated pest control in cotton was implemented by FAO and financed by the Government of the Netherlands. The first phase was 1979–83; field studies on resistant cotton varieties to whitefly (*Bemisia tabaci*) and identification of suitable natural enemies were undertaken. The second phase continued from 1985 to 1989 under which demonstration trails and introduction of the parasite (*Trichogramma pretiosum*) of *Helicoverpa armigera* were implemented. Farmers were guaranteed compensation for eventual yield loss as 320 hectares were left unsprayed during 1986–1987. Under the third phase, results validated during the second phase were implemented (Oudejans, 1991). The IPM program in Sudan produced good results with more than a 50% reduction in insecticide use (Pretty, 1995; Morse and Buhler, 1997). Farmer field school IPM programs were first introduced in Sudan during 1993 and in Egypt during 1996 (Braun et al., 2006). Phase four of the program began in 1993 and was primarily devoted to IPM in vegetable crops. FFSs were implemented in the Sudan-Gezira Scheme from 1993 to 1996 under the FAO

Table 1.7 Outcome of IPM programs in Latin America

Country	Crop	IPM tactics	Outcome	References
Argentina	Cotton	Knap aerial sack or application of eggs of *Chrysoperla* spp. @ 20000 larva/ha and release of mated adults of *Chrysoperla* @ 100 female/ha	Reduced insecticide applications from 11–12 per season to less than 4	Williamson,1999
Bolivia and Peru	Potato	IPM – FFS	FFS graduates acquired knowledge necessary for the management of late blight, resulting in substantially increased income	van den Berg, 2004
Brazil	Soybean	Monitoring pest damage, establishing economic thresholds and application of specific insecticides	Insecticide application fell by 80–90% between 1974 and 1982	Campanhola et al., 1995
Brazil	Cotton	Manipulation of planting densities (9–10 plants per square meter)	Reduce the infestation of cotton stem borer and increased cotton yield	Santos, 1989
Chile	Wheat	Five species of predators and nine species of parasitoids were introduced against aphids (transmitting barley yellow dwarf virus), responsible for loss of 20% wheat production in 1975	Aphid populations maintained below threshold level by the action of bio-agents	Zuñiga, 1986
Colombia	Cotton	Use of pheromone traps, lure sticks, release *Trichogramma*, 2 *Bt* sprays and use of insecticides	Reduced average pesticide application to 2.3 per season instead of 18–20 application per season	Williamson, 1999
Columbia (Cauca Valley)	Tomato	IPM implemented in 1985, involved the use of microbial insecticides (*Bt*) combined with release of natural enemies such as *Trichogramma* spp. and conservation of natural population of parasite, *Apenteles* spp.	Reduced the pesticide application from 20–30 to 2–3 and saved US $650 per hectare	Belloti et al., 1990

Table 1.7 (continued)

Country	Crop	IPM tactics	Outcome	References
Peru (Ice Valley)	Potato	IPM training in pilot units	Significant reduction of key potato pests damage and reduction in pesticides	Cisneros et al., 1998
Peru	Cotton	Organic cotton	In 1988 yield dropped drastically due to excessive temperature and increased pest pressure (Whitefly – *Bemicia tabaci* (Gennadius) outbreak in particular) but organic farmers received far higher net income than conventional neighbours who increased pesticide application.	Williamson, 1999
Peru (Canete Valley)	Cotton	Manipulation of cultural practices along with spray of *Bacillus thuringensis (Bt)*, rotenone, oils, pheromones, sulfur and release of *Trichogramma* spp.	50% reduction in the cost of production	van Elzakker, 1999
Peru (Canete Valley)	Cotton	Organic cotton	35% less cost of pest management as compared to conventional cotton	Williamson, 1999
Peru (Ice Valley)	Cotton	Release of *Trichogramma* spp. and use of pheromone traps for Indian pink boll worm (*Pectinophora gossypiella* (Saunders))	Pesticides use reduced by 70%	Castro et al., 1997

vegetable IPM project. The long term impact was measured by comparing a baseline study (1993) to mid-term evaluation (1995) and impact evaluation (2001). The FFs trained farmers on an average applied 3.3 applications of pesticide compared to 12.5 by non-IPM farmers. The use of pesticide sprays had decreased from 4.3 to 3.3 in case of IPM farmers and increased from 9.6 to 12.5 in case of non-IPM farmers from 1995 to 2001 (Khalid, 2002). National support for the IPM project is tremendous, and the farmers unions are very supportive. During 1995, Sudan's IPM Steering Committee has been transformed into a permanent National IPM Committee (the report of the programs' 1995 annual review and planning meeting). In Ethopia, the Integrated Pest Management Collaborative Research Support Program (IPM CRSP) was initiated in 1993 with the financial support of the United States Agency for International Development (USAID).

In sub Saharan Africa, Integrated Production and Pest Management (IPPM) is the equivalent of IPM terminology used in other countries. It is broader in the sense that crop management strategies to enhance the very low productivity in African countries are also incorporated in the program. FAO Global IPM Facility is the partner in IPPM –FFS programs. In Zimbabwe, IPPM-FFS resulted in higher yields of cotton while average pesticide applications by IPPM-FFS farmers were 8.1 compared to 14.6 by non-IPPM farmers, and the percent pesticide cost to total cost of production was 33% and 67%, respectively (Mutandwa and Mpangwa, 2002).

There are no extensive periodic evaluation studies on the outcome and impact of IPPM-FFS programs in Africa and as of now no value judgment can be made about these programs. The challenge in sub-Saharan Africa is to increase productivity without pushing the farmers into a pesticide treadmill.

1.4.3 IPM Program in Commonwealth of Independent States

Major areas of cotton production in CIS are Uzbekistan, Turkmenistan, Azerbaijan and Tajaikistan (Sugonyaev, 1994). The IPM programs for cotton in the CIS have been developed on the basis of their practicality and economic expedience (For details refer Chapter 15, Vol. 2). IPM programs are flexible, open system aimed at achieving ecological stabilization. Natural enemies are considered a key component of IPM programs as they suppress 60–70 percent of the pest population (Niyazov, 1992). The pesticides shortages and dramatically increased costs (unlike in former USSR), coupled with public concern have created a sound environment for rapid progress of IPM.

1.4.4 IPM Programs in Asia

Widespread outbreaks of the rice brown planthopper, *Nilaparvata lugens* (Stål) in 1970s and 1980s was caused by the insecticides meant to control it and triggered the development of IPM strategies for pest management. The role of the FAO in dissemination of IPM is well documented. The FAO provided the coordination, leadership and resources to promote IPM, particularly in developing countries. The FAO Inter-country Program (ICP) for the Development and Application of Integrated Pest Control (IPC) in Rice in South and South-East Asia started in 1980. From 1977 to 1987, IPM moved from research towards extension. By 1988, the Training and Visit extension system in the Philippines, Indonesia, Sri Lanka, Bangladesh, India, Thailand and Malaysia attempted to introduce IPM to rice farmers through their system of "impact points" or through strategic extension campaigns (Kenmore, 1997). From 1988 to the present IPM has moved towards education rather than training. The introduction of IPM has been fostered by Farmer Field Schools (FFS), which provide "education with field based, location-specific research to give farmers the skills, knowledge and confidence to make ecologically sound and cost-effective decisions on crop health". The FFS training module is based on participatory experiential learning to help farmers develop their analytical skills, critical thinking and creativity, and help them learn to make better decisions (Kenmore, 1997). The trainer is more of a facilitator rather than an instructor (Roling and van de Fliert, 1994).

IPM-FFS was first started in Indonesia in 1989, after the banning of 57 broad-spectrum pesticides in 1986. IPM-FFS programs were carried out in 12 Asian countries after observing its success in Indonesia. Later on IPM-FFS were implemented in vegetable, cotton and other crops. The program spread to Africa, Latin America, the Middle East and Eastern Europe (van den Berg and Jiggins, 2007). FFS programs are being implemented in 78 countries and four million farmers have been trained under this program, with 91% of these from Bangladesh, China, India, Indonesia, the Philippines, and Vietnam (Braun et al., 2006).The coverage of IPM-FFSs was just 1–5% of all households in Asia (1989–2004). By 2002, ICP had spent US $45 million on training activities in Bangladesh, Cambodia, China, India, Indonesia, Laos, Malaysia, Nepal, the Philippines, Sri Lanka, Thailand and Vietnam. ICP also launched regional programs on IPM in cotton and vegetables. During the 15 year period (1989–2004) approximately US $100 million in grants were allocated to IPM projects in Asia (Bartlett, 2005). Preliminary pooled average results from seven studies on cotton IPM in five Asian countries indicate that FFS graduates increased their income by 31% in the year after training, due to 10% better yields and 39% lower pesticide expenditure, in relation to control farmers (FAO, 2004).

A Global IPM Facility with co-sponsorship of FAO, UN Development Program (UNDP), UN Environmental Program (UNEP), and the World Bank was established in 1995 (Kogan, 1998). A "Global IPM Field Exchange and Meeting" was held in 1993, where participants from Africa, the near East, Latin America, and Europe observed the success of Asian IPM farmers in South-east Asia (Kenmore, 1997). This experience has assisted the development of farmer-centered IPM programs in west, southern, and eastern Africa and is now working in the Near East, Central Asia, and Latin America (Anonymous, 1999). The FAO – European Union IPM program for cotton in Asia was established in late 1999. The program was implemented in six countries: Bangladesh, China, India, Pakistan, the Philippines and Vietnam (Ooi, 2003).

The studies on impact evaluation of IPM-FFS in Asia by the World Bank and FAO provide contradictory results due to methodological problems associated with impact evaluation. The World Bank study conducted by Feder et al. (2004) indicated that the IPM-FFS program in Indonesia did not have significant impact on the trained farmers and their neighbors. The complexity of the IPM information curtails the diffusion process from IPM trained farmers to others and abandoning of top-down approaches of extension by trainers in favor of facilitation mode is a challenge to the effectiveness of this program (Feder et al., 2004). Feder et al. (2004) on the basis of their study concluded that FFS in Indonesia have not induced a significant increase in yields or reduction in pesticides use by the trained farmers relative to other farmers. The farmer to farmer diffusion was not significant. Pesticide use expenditure had increased from 1990–91 to 1998–99 in case of IPM and non IPM farmers by 81 and 169%, respectively and yields had declined by 11 and 15%, respectively (Feder et al., 2004). Yamazaki and Resosudarmo (2007) evaluated the same data set as Feder et al. (2004). The performance of FFS farmers was declining through every cropping season thus the impact of the FFS on rice yield was phasing out over time but pesticide use expenditure reduced. Meta-analysis of 25 short term impact studies commissioned by FAO reported reduction in pesticide use (van den Berg, 2004). These studies have employed "before and after", "with and without" or combination of "with/without and before/after" to study the outcome (immediate impact) of IPM programs. The synthesis of selected studies is presented in Table 1.8.

In the developing countries there is no significant investment in farmer education, thus farmers and consumers have been exposed to environmental and health risks as a result of an induced reliance on synthetic pesticides (van den Berg and Jiggins, 2007). The farmer study groups in the Netherlands (van den Ban, 1957) "U-H clubs" in the USA, "farmer research and development groups" in Australia and the Netherlands, and "breed improvement societies" in England have been cited as examples in which organized farmer education and innovation has occurred (van den Berg, 2004; van den Berg and Jiggins, 2007). These efforts emphasize on field based observation and experimentation, shared learning and systematic evaluation of results. FAO should formulate a policy for extensive evaluation of IPM programs based on evaluation methodologies in the developing countries to measure the adoption, outcome and impact.

1.4.4.1 IPM Programs 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

Table 1.8 Outcome of IPM-FFS programs in Asia

Country	Crop	Outcome
China[1]	Cotton	A decline in insecticide use from 6.3 to 3.1 applications per season a year after training, whereas control farmers continued spraying around 6 times per season. Pesticide volume declined by 82% due to a combination of lower frequency, lower dosages and a shift towards less hazardous chemicals.
Bangladesh[1]	Egg plant	Reduction in pesticide applications from 7.0 to 1.4 applications per season. Increase in yield was also observed.
Cambodia[1]	Rice	Training caused farmers to reduce pesticide volume by 64% and to select relatively less hazardous compounds. FFS farmers were better aware of pesticide-related health risks than non-FFS farmers.
Vietnam[1]	Rice	Insecticide use reduced from 1.7 to 0.3 applications per season. Fungicide use was reduced after training in the North but was increased in the South, probably due to a combination of factors
Sri Lanka[1]	Rice	Insecticide applications reduced from 2.2 to 0.4 applications per season. A 23% yield increase and a 41% increase in profits. Consequently, the overall training costs could be recovered seven-fold within a single season. Impact was present six years after training.
Indonesia[2]	Rice	65% reduction in pesticide use and 15% increase in yield
Indonesia[1]	–	Training caused a change from preventative spraying to observation based pest management, resulting in an overall 61% reduction in the use of insecticides.
Thailand[1]	Rice	60% reduction in the use of insecticides and moluscicides and an increase in knowledge about pests and natural enemies.
Vietnam[1]	Tea	A 50–70% reduction in pesticide use and good prospects for improving crop management and to increase yield.
Sri Lanka[1]	Effect on health	FFS farmers spent considerably less time for spraying pesticides than non-FFS farmers and accordingly exhibited lower cholinesterase inhibition level in blood samples.

Sources: [1]van den Berg (2004); [2]Miller (2004)

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 (Fig. 1.1). 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

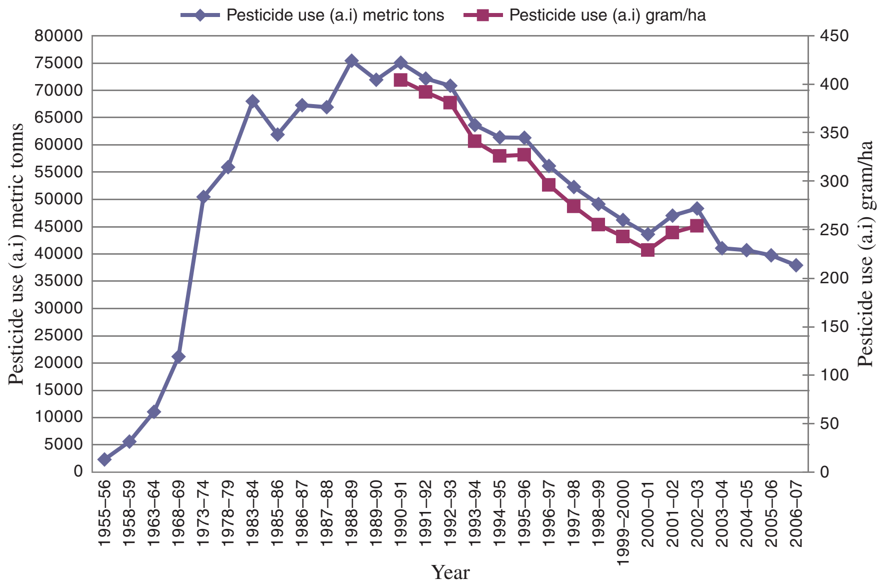

Fig. 1.1 Pesticide consumption in India (1955–56 to 2006–07)
Source: Directorate of Plant Protection Quarantine and Storage, Government of India

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

[7] Information received from Directorate of Plant protection Quarantine and Storage (DPPQ&S), Government of India

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. Results of the selected empirical studies based on the evaluation methodologies are given in Table 1.9.

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% (Fig. 1.1). 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, Andra 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 (Fig. 1.2). 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).

Table 1.9 Outcome of IPM programs in India

Region/State	Crop	Intervention	Outcome	References
Central India	Cotton	IPM intervention	Cost of plant protection reduced by 31.3%. chemical pesticide consumption reduced by 94.3%	Bambawale et al., 2004
Tamil Nadu	Cotton	IPM intervention in four villages	Pesticide application reduced from 11 sprays to 6 sprays in IPM villages	Bambawale et al., 2004
Punjab	Rice	IPM-FFS in 10 villages	Average number of insecticide applications i. Before IPM − FFS = 1.88 ii. During IPM − FFS = 1.10–1.64 iii. After IPM − FFS = 1.44	Peshin and Kalra, 1998
Punjab	Cotton	Insecticide resistance management(IRM) based IPM intervention of Central Institute for Cotton Research, Nagpur, India	1. Average number of insecticide applications with/without IRM i. With IRM = 13.07 ii. Without IRM = 15.43 iii. Difference = 15.29% 2. Average number of insecticide applications before/after IRM i. Before IRM = 15.34 ii. After IRM = 13.07 iii. Reduction = 14.80% 3. Insecticide use (a.i) i. With IRM = 5.602 kg/ha ii. Without IRM = 8.032 kg/ha iii. Difference = 30.25% 4. No significant difference in yields with/without IRM	Peshin, 2005
Central India	Cotton	IPM intervention	Cost of plant protection reduced by 31.3%. Chemical pesticide consumption reduced by 94.3%	Bambawale et al., 2004
Andra Pradesh	Cotton	IPM-FFS	1. The adoption of IPM significantly reduced the use of pesticides. Trained farmers used one sixth of the pesticides to obtain the same yield levels. 2. The year after the FFSs, all farmers decreased the use of highly and moderately toxic pesticides. 3. Number of pesticide applications by IPM-FFS farmers reduced from 7.9 to 1.7 while no significant reduction (From 8.2 to 7.2) in case of non-IPM farmers.	Mancini et al., 2008

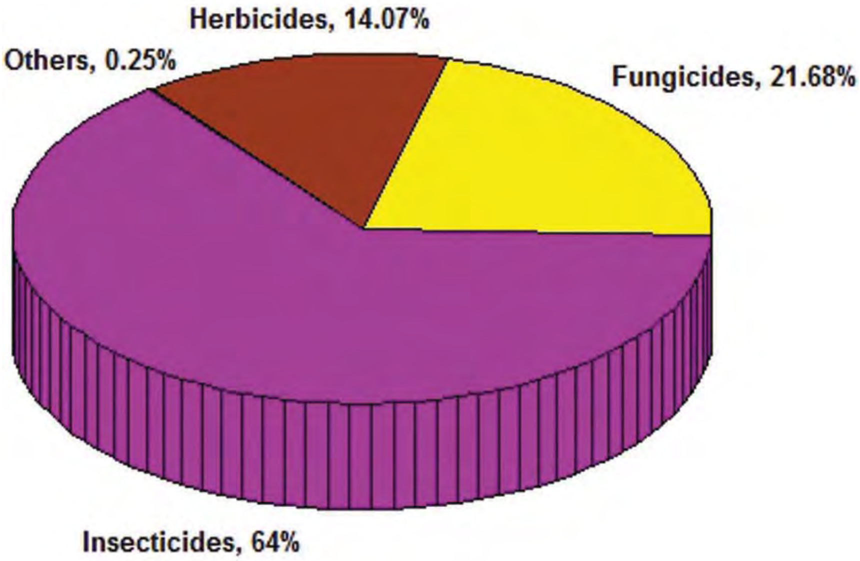

Fig. 1.2 Consumption pattern of different groups of pesticides in India (2003–04)

1.4.4.2 IPM Programs in China

Development Process of IPM Framework in China

China was one of the earlier countries to promote integrated control of plant diseases and insect pests. As early as the early 1950s, China put forward the concept "integrated control" in the relevant literature (Jing, 1997). In 1975, Chinese plant protection scientists formulated the principle of plant protection "Focus on Prevention and Implement Integrated Control", namely the IPM framework. Lately this framework was included or realized in some agriculture-related policies, regulations and provisions in China. Meanwhile the country coordinated and arranged a number of research and promotion programs on IPM and has made great achievements (Zhang et al., 2001).

According to China's level of implementing IPM, the development process of IPM framework in China can be generally divided into three stages (Wang and Lu, 1999):

(i) Pest-centered IPM, i.e., the first-generation IPM. For example, during the period of "The Sixth Five Year Plan" (1981–1985), each of the main pests on a certain crop was controlled to below the economic threshold using physical, chemical and biological control methods.
(ii) Crop-centered IPM, i.e., the second-generation IPM. For example, during "The Seventh Five Year Plan" (1986–1990), with crop as the center, a variety of major pests on the crop were controlled. At this stage, IPM gave full play to the full value of natural control in the agro-ecosystem and IPM systems began to be established. During "The Eighth Five Year Plan" (1991–1995), a large number of IPM systems were developed, assembled, improved and applied in China. In

this period, IPM was demonstrated on more than 200,000 ha of farmlands and promoted on more than 6,670,000 ha, and achieved certain positive results.

(iii) Ecosystem-centered IPM, i.e., the third-generation IPM. The entire field or regional ecosystem was the focus of IPM; a large quantity of advanced scientific information and data were collected and used, and advanced technologies were developed in IPM practices. Overall and global benefit was expected to be increased with the natural control of ecosystems as the main force. At present, China is in the transition phase of the second- and third-generation IPM.

Dissemination and Impact of IPM

The migratory locust, *Locusta migratoria manilensis* (Meyen), was historically a serious insect pest in China. With focus on environmental conditions and farming systems in an IPM framework, specific methods to eradicate locust disaster were presented in early 1957. The eradication program was organized and invested in by government. The growth and reproduction of locusts was finally inhibited and the locust population sustainably controlled by transforming habitats, constructing irrigation systems, stabilizing water table, reclaiming wastelands, implementing crop rotation, planting beans, cotton, sesame, and greening lands (Chen, 1979; Ma, 1958, 1979). The rice stem borer, *Scirpophaga incertulas* (Walker), is a serious rice insect pest across South China. As early as the 1950s, it was found that adjusting farming systems and selecting appropriate planting dates were the main methods to suppress this pest (Zhao, 1958), which has now been applied in IPM practices for this pest. In terms of radiation-sterilizing technologies, during the late 1980s about 150,000 radiation sterilized male *Bactrocera minax* (Enderlein) were released into a citrus orchard with more than 30 hm^2 in Huishui, Guizhou Province, which reduced the citrus injury from 7.5% to 0.005% (Wang and Zhang, 1993). Insect-resistant breeding has also been used since the 1950s. Insect-resistant wheat varieties "Xinong 6028" and "Nanda 2419" have been bred and planted to successfully control the wheat midges (*Sitodiplosis mosellana* and *Comtarinia tritci* (Kiby)) in north China (Wang et al., 2006). During the 1990s, under the support of government, transgenic Bt cotton varieties were bred and used to control cotton bollworm and have achieved remarkable success (Zhang et al., 2001; Chapter 18, Vol. 2). In recent years the application of insect-resistant varieties of cotton, rice, wheat, rapeseed and other crops have also achieved great success in China. According to the statistical data, the total area of transgenic insect-resistant cotton in China has reached 4.667 million ha, with an average income of US $304.3–342.9/ha (US $1 = 7 RMB Yuan). Annual reduction of chemical pesticide applications reaches 20,000–31,000 tons, equivalent to 7.5% of China's annual total production of chemical insecticides (Chapter 18, Vol. 2). In general, past years' IPM programs supported by Chinese government have demonstrated the positive and significant impact of IPM (Table 1.10).

Beginning in 1988, funded by the FAO Inter-Country Rice IPM Program, the Asian Development Bank (ADB) Cotton IPM Program and World Bank Crop IPM Program, a number of FFS-based training courses were organized in China. During 1993–1996, the ADB Cotton IPM Program was implemented in Tianmen, Hubei Province, under the auspices of the National Agricultural Technology Promotion Center of China (Zhang et al., 2002). Since 1996, the FAO Inter-Country Rice IPM

Program was implemented in Gaoming, Guangdong Province (Chen and Du, 2001). Starting in 2000, the EU Cotton IPM Program was implemented in Yingchen, Tianmen and Xiantao of Hubei Province. During the implementation of these programs, training courses to train qualified teachers (TOT) and standardized FFS were held (Zhang et al., 2002). Through running FFS, establishing IPM associations, sponsoring community-based IPM activities, establishing IPM demonstration gardens, and developing and producing pesticide-free agricultural products, a preliminary way to promote IPM was constructed in China (Zhang et al., 2001). Through the above rice programs implemented in China, up till 1999 in total of 2,017 FFS had been sponsored, 66,112 rice farmers, cadres and promotion households had been trained, and hundreds of thousands of farmers were triggered to use IPM technologies. Various IPM programs have made certain achievements: (i) A large number of agricultural extension personnel were trained and a network to promote IPM technologies was initially established. (ii) A number of IPM demonstration gardens were established, which facilitated the development of IPM in local regions. Trained farmers organized farmers' organizations and used IPM technologies of rice and cotton to high valuable and high-dosage pesticide used fruits, vegetables and other specific crops and established demonstration gardens, and tried to produce pollution-free agricultural products. For example, the IPM programs were implemented over 4,000 ha and radiated to 34,000 ha of farmlands in 28 counties, cities and districts around Jianghan Plain of Hubei Province. (iii) The village-based agricultural technology service network systems on the basis of farmers – IPM trained farmers – IPM

Table 1.10 Outcome of some IPM programs in China

Region and period	Crop	IPM intervention	Outcome	References
North China: Jilin Province (1995–1999)	Maize	Pest-resistant varieties, seed-coating technique, fungus and insecticide use, parasitic natural enemy, etc.	Yield increase: 630–1708.5 kg/ha. Ratio of cost *vs.* benefit: 1:18.9–28.1. Crop loss reduction: 7% from 15–20%.	Jin et al., 2000
South China: Guangdong Province (2000–2004)	Rice	Pest-resistant varieties, cultivation techniques, fertilizer use, seed selection and pesticide treatment, selected use of insecticides, etc.	Pesticides reduction: 3–4 times of annual applications' reduction, 28.3–32.4% of dosage reduction, US $14.6–18/ha of pesticides cost reduction, US $15.6–16.3/ha of labour-spraying reduction. Income increase: US $120.2/ha. Natural enemy protection: 5–8 more spiders per hundred rice clusters.	Zeng, 2006

farmers' organizations were initially formed, which linked town stations-county stations-provincial station for plant protection in order to strengthen the liaison and information technology support services (Zhang et al., 2001). (iv) Cultivation benefits of rice and cotton increased by implementing IPM. For example, implementing IPM on rice and cotton can increase income by US $123.4 and 206.4/ha, respectively and reduce the use of chemical pesticides. Pesticide applications on rice and cotton were reduced by 1.8 and 12.2 times, respectively. According to the survey, there were totally 2,325 predatory natural enemies on IPM cotton but only 1,168 predatory natural enemies on non-IPM cotton (Zhang et al., 2002).

Problems in IPM Implementation

On the whole the applications of IPM technologies in China are still highly localized. Pesticide misuses are still common and pesticide residue problems are serious (Figs. 1.3 and 1.4). The chemical pesticide use per unit land is 2.6 times of some developed countries (Liu, 2000; Zhang, 2001). According to a report, in 1999 Anhui Province alone exhausted pesticide 9,650.89 tons (active ingredient), application

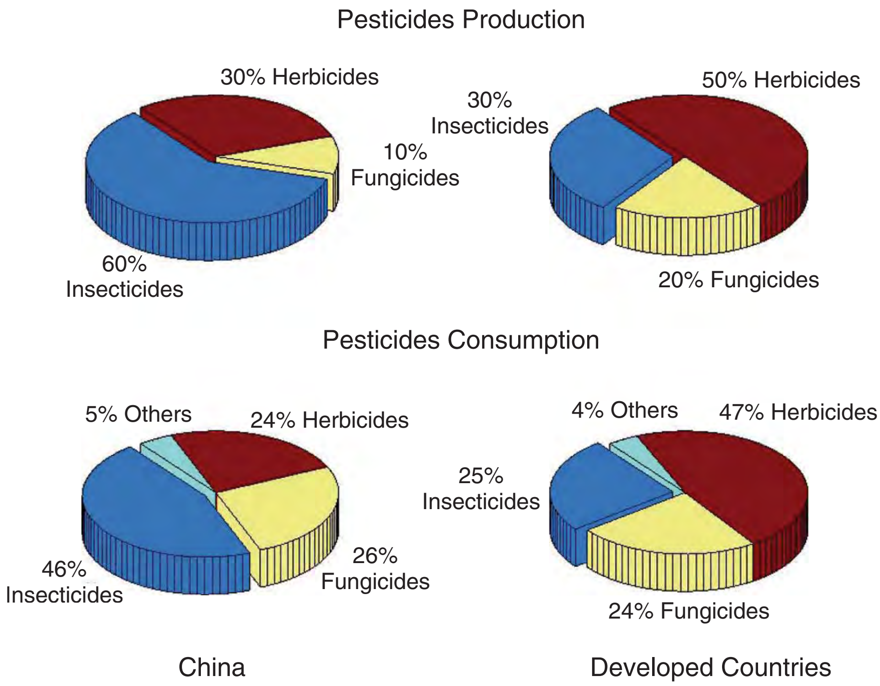

Fig. 1.3 Production and consumption percentages of various pesticides for China and developed countries in past years. Proportion consumption of insecticides in China was much higher than the developed countries. However, a large number of high poisonous insecticides have been banned for using in China since 2007. An ideal development trend is expected in the future.
Sources: http://www.5ilog.com/cgi-bin/sys/link/view.aspx/6329967.htm; http://www.moneychina.cn/html/67/76/76336/1.htm

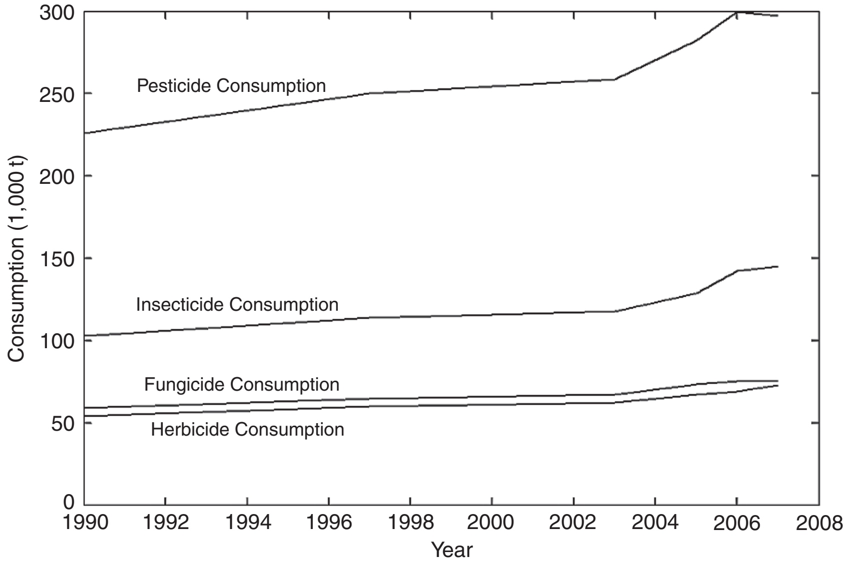

Fig. 1.4 Dynamic changes of pesticides consumption in China. A declining trend in pesticides (total pesticides, insecticides, fungicides) consumption growth is expected in China, although pesticide misuses are still common and pesticide residue problem is serious. Herbicides consumption in China is largely increasing in recent years
Sources: Yu (2006); http://www.1nong.com/info/list40702.html; http://www.chinawz.cn/Report/06-07bg/07nongyao.htm; http://www.toponey.com/Html/20061129151626-1.Html; http://www.chemdevelop.com/Trade/trade2.asp

dosage reached 0.22 g/m^2, increasing by 43.7% and 24.16% over the "The Eighth Five Year Plan" (1991–1995) (Zhang, 2001). Excessive use of pesticides in rice and cotton production reached 40% and 50%, respectively (Chen and Han, 2005). In recent years the annual pesticide poisoning number of farmers in Guangdong Province alone has reached 1,500 and is increasing annually. The lack of application of IPM in China is attributed to the following: (i) under the household contract system, agricultural intensification and on-scale operation could not be realized easily, the farmers have less demand on IPM technologies. (ii) IPM technical extension services systems are insufficient. (iii) Pesticides markets are not ordered, the social environment for IPM application has not yet been established. (iv) We are short of theoretical researches and application technologies of IPM. At present, IPM technologies are not perfect, and monitoring effectiveness and forecasting accuracy are at a lower level (Chen and Han, 2005).

1.5 Experiences, Problems and Perspectives

The relative success of the IPM extension programs is ultimately judged on the adoption rate of the IPM systems (or components *thereof*) and the improvements in the production associated with this (Dent, 1995). Without a unanimously accepted definition there is considerable difficulty in determining the extent to which IPM has been adopted (Norris et al., 2003). The use of truly integrated pest management (based on the definition of IPM discussed in Section 1.2) is still relatively low as a worldwide review of the IPM literature suggests (Kogan and Bajwa, 1999) and as discussed in this chapter. Pest management practices in different agro ecosystems have changed dramatically since the late 1960s in some developed countries (Norris et al., 2003) and since 1980s in most of the developing countries IPM philosophy has made major contribution in that regard.

The constraints in adoption have been in terms of inappropriateness of technology, economic implications, non-availability of appropriate information, acquiring of knowledge and skills by farmers for applying the IPM in their fields, dissemination of IPM, and vast network of chemical industry to lure farmers into using pesticides and the lack of coordination among implementing agencies. Due to the complexities of carrying out IPM, it has been difficult for farmers in carrying out IPM practices like ETL (Goodell, 1984; van de Fliert, 1993; Escalada and Heong, 1994; Matteson et al., 1994; Malone et al., 2004; Peshin, 2005). The compatibility of an IPM practice also plays a role in its adoption. If an IPM practice is not compatible like "*trash trap*" in maize (Bentley and Andrews, 1991) it is a limitation in its adoption. Economic returns/implications of IPM need to be improved and demonstrated to the farmer so that the farmer learns that even buying information and advice can be more profitable than buying chemicals (Lacewell and Taylor, 1980). Growers perceived that IPM practices are more risky than conventional pest management in both the developed countries and developing countries (Grieshop et al., 1990; Norris et al., 2003; Peshin, 2005) so the risk associated must be decreased to make farmers sure of its economic viability. In Europe, the countries where the government policy initiatives in terms of pesticide taxation and providing incentives to farmers for adopting IPM, farmers associations, NGOs and retail market chains all work in unison to promote low pesticide crop production has reduced pesticide use and increased adoption of IPM. Dissemination of IPM technology related information in a top down approach is also a constraint in many developing countries (Kenmore et al., 1995) and lack of proper knowledge about different aspects of IPM like agro – ecosystem analysis and not acquiring required skills for its use acted as barriers (van de Fliert, 1993, Merchant and Teetas, 1994). Vast network of pesticide companies in developed and developing world also lured back the IPM practioners. The company agents scouting farmers' field and assisting them in sampling acts as a barrier for IPM adoption. Counteracting forces even in public extension services confuse the farmers and the lack of commitment of extension agencies to IPM limit its spread and adoption (van de Fliert, 1993) and lack of master trainers acts as an obstacle in the adoption of IPM (Matteson et al., 1994; Peshin and Kalra, 2000).

In developing countries the policy planners are not well conversant with IPM programs and implementation. Similarly, input suppliers are not farmers but traders. They do not have any idea of IPM and are a big hurdle in the implementation of IPM. Farmers are not prepared to adopt simple IPM practices but often are provided with simple solutions with the use of insecticides. The wide gap in technology generated and implemented results in loss of confidence among farmers. The time-lag in technology dissemination is great and in era of fast changing technology, the old system of transfer of technology will not serve the purpose. The use of modern information technology, e-learning, decision support systems, mobile phones, text messaging and video conferencing around the globe can revolutionize the concept of IPM. The IPM technology needs to be farmer friendly. The introduction of transgenic crops creates an opportunity to enhance implementation of IPM, because the need to control a key pest with insecticides is reduced, and this has been the case in some countries (e.g. Australia, India). However, this technology can be seen as a "silver bullet" that replaces the need for IPM, hence diminishing interest. Further, the technology, though offering many benefits is at risk from target pests developing resistance, necessitating complex resistance management strategies in some countries. The current monopoly of this technology by a few large multi-national companies also creates a challenge as farmers in developing countries may be very susceptible to the lure of simplified pest control the transgenics offer but have a poor understanding of the technology's benefits and risks. The inputs are controlled by private sector and are mainly concerned with profit and ignore long term consequences of the technology as was and is the case with pesticides. Farmers in developing and under developed countries will face new problems in implementation of IPM program unless they have access to fast means of transfer of technology so they can have ready access to up-to-date information, government invests in farmers education and agriculture innovation system is put in place.

The constraints for development and uptake of IPM in different agricultural systems can vary. For instance, in most of the Latin American countries there is no public service extension so the farmers are more dependent on agents of chemical industry for information. In the USA the constraints are in terms of IPM adoption which is often more expensive than conventional pesticide based management, due to increased need for population assessment and record keeping. However, where it meets the economic interest of growers adoption is high. In developing countries counteracting approaches, lack of proper dissemination of technology in a participatory mode are the barriers in adoption of IPM. For different crops also the constraints differ.

1.6 Conclusion

Globally the disappointing aspect of the IPM programs is the confusion in actually assessing the adoption and success of IPM programs – what constitutes the adoption of IPM? In many instances IPM programs target small groups of farmers and may achieve considerable success in increasing yield and reducing pesticide use, but do these successes ripple out to the wider farming community? The adoption of IPM has been generally slow in both the developed and the developing world, despite some successes. Pesticides are still the main strategy of many IPM programs. Overall use of pesticides has not decreased in most of the countries with the exception of a few. IPM research and extension programs must be evaluated to formulate strategies to overcome the "real-world" impediments experienced by the farmers (Hammond et al., 2006).

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