Integrated Pest Management: Innovation-Development Process

Rajinder Peshin · Ashok K. Dhawan
Editors

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Volume 1

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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.

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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

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[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. FFS 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 National 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 National 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 Monteneground 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