Rajinder Peshin
Ashok K. Dhawan
Editors

Integrated Pest Management: Innovation-Development Process

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.

Jammu, India — Rajinder Peshin
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Chapter 18
Non Pesticidal Management: Learning from Experiences

G.V. Ramanjaneyulu, M.S. Chari, T.A.V.S. Raghunath, Zakir Hussain and Kavitha Kuruganti

Abstract Pests and pesticides contribute to the major economic and ecological problems affecting the farmers, crops and their living environment. Two decades of experience in Andhra Pradesh on Non Pesticidal Management shows that pest is a symptom of ecological disturbance rather than a cause and can be affectively managed by using local resources and timely action. The emerging new paradigm of sustainable agriculture shows that the new knowledge synthesized from traditional practices supplemented with modern science can bring in ecological and economic benefits to the farmers. The small success from few villages could be scaled up into more than 1.5 million ha in three years. The costs of cultivations could be brought down significantly without reduction in yield. The institutional base of Community Based Organizations like Federations of Women Self Help Groups provides a good platform for scaling up such ecological farming practices. This experience also shows how the grass root extension system when managed by the community can bring in change and help the farming community to come out of the crisis.

Keywords Non pesticidal management · Pesticides · Natural enemies · Community based organizations · Sustainable agriculture · Local resources

18.1 Introduction

Farming in India evolved over centuries of farmers' innovations in identifying locally suitable cropping patterns and production practices. The crisis of food production and geo-political considerations during 1960s created conditions in many developing countries particularly in India to strive for food self-reliance. The country has chosen the path of using high yielding varieties (more appropriately high input responsive varieties) and chemicals which brought about what is popularly known as the Green Revolution. This continued as a quest for modernization

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of agriculture which promoted the use of more and more of high yielding varieties/hybrids, chemical pesticides and fertilizers across crops and situations displacing farmers' knowledge, own seeds and practices. The country could become self reliant for a while, farmers lost self reliance in the process due to excessive dependency on external inputs and are caught in serious ecological and economic crisis. This crisis is manifesting itself in the form of migration, indebtedness and in extreme cases as farmers' suicides.

In midst of the deep crisis in agriculture farmers and various organizations associated with farmers are trying innovative approaches to sustain agriculture. One such initiative is the "Non Pesticide Management" of crop pests to reduce the costs of cultivation by adopting a set of practices based on farmers' knowledge supplemented by modern science which makes best use of local resources and natural processes by the farmers and women self help groups in Andhra Pradesh. During *kharif 2007* (*kharif* season is synonymous with the wet season, covering the crop growing period April/May through September/October), more than 350 thousand farmers from 1800 villages in eighteen districts of the state are practicing NPM in more than 280 thousand ha in various crops. Sixteen of these districts are part of the 32 districts with serious agrarian crisis identified by the Government of India. The savings (on chemical pesticides) in costs of cultivation on pest management ranged from Rs. 600 to 6000 (US $ 15–150) per ha without affecting the yields. The savings on the health costs are also substantial. Non Pesticidal Management is one of the components of the "Community Managed Sustainable Agriculture" program with technical support from Centre for Sustainable Agriculture and its partner NGOs and financial and administrative support from the Society for Elimination of Rural Poverty, Government of Andhra Pradesh and implemented by Federations of Women Self Help Groups.

18.2 Pests, Pesticides and the Distress

The problems of pests and pesticides in farming are well documented. Among the production inputs in agriculture chemicals especially pesticides occupy major share of costs in crops like cotton, chillies, paddy etc. The pest resistance and resurgence due to abuse of pesticides propelled mainly by a lack of awareness, regulation of pesticide marketing extended on credit with high interests by "all-in-one dealers" (money lenders cum dealers of seeds/fertilizers/pesticides) and lack of market support ended up pushing hapless farmers into a vicious debt trap from which suicides were sought as a way out. The same pesticides which were promoted to solve the farmers' problems were consumed by these farmers to kill themselves.

18.2.1 The Dominant Paradigm

The dominant paradigm of pest management largely depends on use of chemical pesticides. The recommended schedules of the chemical pesticides are based on the studies conducted by the Pesticide Companies and Agriculture Research Institutes. The pesticides and the pesticide recommendations need to be registered with the Central Insecticides Board (CIB). Most of the chemical pesticides are used to kill the pest when it is in the most damaging stage of its life cycle. Farmers are suggested to spray their fields when the insects are in damaging proportions (Economic Threshold Level). The regular use of pesticides creates pressure and result in the development of genetic resistance in the insects and makes the sprays more and more ineffective. All these make the farmer to increase the pesticide doses or go for newer pesticides frequently pushing the farmers into a vicious cycle of pesticides, increasing costs, ill health and debt.

18.2.2 Pesticide Induced Pest Problems

Nearly from the beginning of the Green Revolution increases in insect populations following insecticide applications were detected. In rice insecticide induced increases in populations of plant sucking insects are among the first reliable symptoms of an intensification syndrome that destabilizes production (Kenmore, 1997). The Pesticides often induce pest outbreaks by killing beneficial insects, reducing natural pest control, and resulting in explosive outbreaks of pest species which are either resistant, or physically invulnerable to pesticides. For example, brown plant hopper eggs are laid within the rice stalk and shielded from spray; after spraying, they hatch into a field free of their natural enemies and reproduce explosively without predation (Kenmore, 1980). Systemic pesticides can kill the early "neutral" insects which lure the first generation of beneficials, and kill the beneficials as well (Mangan and Mangan, 1998). Similarly mealy bug and other sucking pests are increasingly becoming a problem in the cotton growing areas of Gujarat and Punjab. This ecological disturbance results in pest shifts as is seen widely today.

18.2.3 Pesticide Resistance

Pesticide resistance which is heritable and results in significant decrease in the sensitivity of a pest population to a pesticide reduces the field performance of pesticides. The percentage of resistant insects in a population continues to multiply while susceptible ones are eliminated by the insecticide (IRAC, 2007). How quickly resistance develops depends on several factors, including how quickly the insects reproduce, the migration and host range of the pest, the crop protection product's persistence and specificity, and the rate, timing and number of applications made. Based on their observations about resistance, farmers use either more concentration of the chemical (higher dose) or more sprays of the same or different chemicals mixed or at short intervals which is often termed as "indiscriminate" use while 'recommendations' ignore the problem (Table 18.1).

Table 18.1 Pesticide recommendations in chillies in 2000 and 2006 against *Helicoverpa*

Pesticide	First report of resistance*	Recommendation in 2000**	Recommendation in 2006**
Quinolphos	2001	2.5 ml/lit	2 ml/litre
Chlorpyriphos	2002	2.5 ml/lit	3 ml/litre

*Fakruddin et al., 2002, Kranthi et al., 2001a,b
**Vyavasaya Panchangam, 2001 and 2006 published by ANGRAU

18.2.4 Pesticide Poisoning

Pesticide poisoning is a significant problem in India. Pesticide poisoning to human beings through exposure to the toxic fumes while spraying is a lesser known and lesser acknowledged aspect of pesticide abuse in places like Warangal in Andhra Pradesh (Kavitha, 2005a,b; Mancini et al., 2005), Tanjavur in Tamil Nadu (Chitra et al., 2006) or Batinda in Punjab (Mathur et al., 2005). There is no systematic documentation of such cases during hospitalization, often they are combined with the ingestion cases. The numbers of deaths that happen prior to hospitalization and not reported are substantially high. The socio economic and environmental conditions in which the agriculture workers and small and marginal farmers work do not permit them to adopt the so called "safe use practices" often promoted by industry or agriculture scientists (Kavitha, 2005b).

There are also several reports on the chronic effects of the chemical pesticides on the farmers (Mathur et al., 2005), growth and development of children (Kavitha, 2005a, Timothy et al., 2005) and women's reproductive health.

18.2.5 Pesticides and Ecological Impacts

The chemical pesticides leave larger ecological foot prints in manufacturing (e.g. Bhopal gas tragedy), storage, transport and usage polluting the soils, water and air. Some amounts of pesticides used in crop production appear as residues in the produce. These residues in food, soil and water enter into the food chain and cause serious health problems to human beings and other living beings (Karanth, 2002, Kavitha et al., 2007). The pesticide residues are even noticed in human milk (Down to Earth, 1997). Studies show that the pesticide residues in soil can kill the soil microbes there by effect the soil fertility. Common pesticides block the chemical signals that allow nitrogen-fixing bacteria to function. Over time, soils surrounding treated plants can become low in nitrogen compounds, so more fertilizer is needed to produce the same yield (Fox et al., 2007).

18.2.6 Pesticide Regulation

In India, the production and use of pesticides are regulated by a few laws which mainly lay down the institutional mechanisms by which such regulation would take place – in addition to procedures for registration, licensing, quality regulation etc., these laws also try to lay down standards in the form of Maximum Residue Limits, Average Daily Intake levels etc. Through these mechanisms, chemicals are sought to be introduced into farmers' fields and agricultural crop production without jeopardizing the environment or consumer health. In spite of these regulatory systems, a number of pesticides banned across the world for their toxicity and residual problem are still produced and used in India.

The pesticides and pesticide recommendations to control specific pests on crops are to be registered with Central Insecticide Board and Registration Committee (CIBRC). While farmers are blamed for "indiscriminate use of pesticides", studies by Centre for Sustainable Agriculture show that indiscriminate recommendations are made by Agriculture Universities and Departments of Agriculture and Horticulture violating the registration rules. Pesticides are usually registered for one or two crops and one or two pests but sold, recommended and used for other crops and pests as well. (Kavitha et al., 2007). For example, acephate is registered for use only on cotton and safflower in the country. It is not registered for use on chillies, brinjal, cabbage, cauliflower, apple, castor, mango, tomato, potato, grapes, okra, onion, mustard, paddy and many other crops where it is being used extensively now. Further, it is also being recommended by the NARS for use in other crops even without registering the recommendations with CIBRC. Acephate is being recommended for the control of sap sucking pests in most crops. Further, MRLs have been set only for safflower seed and cotton seed for this pesticide. (Website Department of Horticulture, Govt. of AP http://www.aphorticulture.com, Vyavasaya Panchangam 2006–2007, ANGRAU, Central Insecticides Board & Registration Committee's website www.cibrc.nic.in)

18.3 Managing the Problem: Integrated Pest Management

The attempts to overcome the serious economical and ecological problems of the chemical pesticides have given rise to alternative systems to manage pests and pesticides.

18.3.1 Integrated Pest Management

In an attempt to slow the development of pest resistance, improve the financial basis for agricultural production, and improve the health of the farming population, systems of Integrated Pesticide Management have been introduced around the world. IPM is an ecological approach to plant protection, which encourages the use of fewer pesticide applications.

The field experiences gave rise to several paradigms of IPM which agriculturists presently adhere to. The most up-to-date paradigm of IPM is ecology based approach which is promoted by the FAO world wide in the form of Farmers Field

Schools (FFS). Through interactive learning and field-experimentation, FFS programs teach farmers how to experiment and problem-solve independently, with the expectation that they will thus require fewer extension services and will be able to adapt the technologies to their own specific environmental and cultural needs (Vasquez-Caicedo et al., 2000). Extension agents, who are viewed as facilitators rather than instructors, conduct learning activities in the field on relevant agricultural practices. In the FFS, a method called "agro-ecosystem analysis" is used to assess all beneficials, pests, neutral insects and diseases, and then determine if any intervention like a pesticide spray is needed. Economic Threshold Levels are discussed in the FFS, but crop protection decisions are based on conserving beneficial insects/spiders.

The Indonesian tropical wet rice ecosystem the IPM field school experience (Kenmore, 1980, 1996; Way and Heong, 1994; Settle et al., 1996) shows that:

- Beneficial insects/spiders comprise the majority of species in healthy ecosystems. 64% of all species identified were predators (306 species) and parasitoids (187 species); neutrals (insect detritivores, plankton feeders) comprise 19% (Settle et al., 1996) and rice pests constitute only 17% of species.
- Beneficials are extremely effective in controlling major rice pests; very substantial reduction of pesticide applications does not threaten rice yield.
- Contrary to previous understanding, beneficials typically enter the tropical wet rice ecosystem before pests, and feed on detritivores and other "neutral" insects, e.g., Springtails (*Collembola*) and Midge larvae (*Chironomidae*) already present in the rice paddy. Beneficials are therefore present from the start of the crop season and effective in pest control from an earlier stage than had previously been assumed (Settle et al., 1996; Wu et al., 1994)

The learnings from IPM projects and FFS experiences worldwide should have led to research on the complex interaction between crop ecology, agronomic practices, insect biology, and climate change to develop effective methods to manage disease and insect control strategies. Similarly the farmers' knowledge on using the local resources could have been captured and the principles could have been standardized. But FFS mostly remained as a paradigm shift in agricultural extension: the training program that utilizes participatory methods "to help farmers develop their analytical skills, critical thinking, and creativity, and help them learn to make better decisions." The agriculture research and extension system worldwide still continue to believe in chemical pesticide based pest management in agriculture.

The effectiveness of the IPM-FFS could have been enhanced by broadening the focus from a single crop to a broader systems approach, to address other matters, such as water management, crop rotation, crop diversification and marketing (Mancini et al., 2005).

Though FFS is seen as a knowledge intensive process, main focus was on taking external institutional knowledge to farmers. Proper space was not provided for traditional knowledge and practices or grass root innovations by farmers. In a study by Mancini (2006) evaluating the cotton IPM-FFS in Andhra Pradesh, farmers reported that their confidence in implementing the new management practices was not strong enough to translate into a change in behavior. This supports the argument that an effective, empowering learning process is based on experience, rather than on simple information and technology transfer (Lightfoot et al., 2001).

Pesticide industry is aware of the growing pest resistance towards their pesticides. Many of the pesticides become useless as the pests develop resistance and loose their market before they can recover the costs involved in developing the product leaving aside the profits. This situation has forced the pesticide industry to come up with their paradigm of IPM called "Insecticide Resistance Management" (IRM) which is a proactive pesticide resistance-management strategy to avoid the repeated use of a particular pesticide, or pesticides, that have a similar site of action, in the same field, by rotating pesticides with different sites of action. This approach will slow the development of one important type of resistance, target-site resistance, without resorting to increased rates and frequency of application and will prolong the useful life of pesticides. This resistance-management strategy considers cross-resistance between pesticides with different modes of action resulting from the development of other types of resistance (e.g., enhanced metabolism, reduced penetration, or behavior changes) (PMRA, 1999).

Though pesticide industry states that it fully supports a policy of restricted pesticide use within an IPM program, it perceives a clear need for pesticides in most situations. Furthermore, its practice of paying pesticide salespeople on a commission basis, with increased sales being rewarded with increased earnings, is unlikely in practice to encourage a limited use of pesticides (Konradsen et al., 2003).

Right from the time of the Rio Earth conference, India has been highlighting this IPM policy in all its official documents. The ICAR had also established a National Centre for Integrated Pest Management in 1998. In India a total of 9,111 Farmers' Field Schools (FFSs) have been conducted by the Central Integrated Pest Management Centres under the Directorate of Plant Protection, Quarantine & Storage from 1994–1995 to 2004–2005 wherein 37,281 Agricultural Extension Officers and 275,056 farmers have been trained in IPM. Similar trainings have also been provided under various crop production programs of the Government of India and the State Governments (Reports of Government of India available on http://www.agricoop.nic.in).

IPM is sought to be made an inherent component of various schemes namely, Technology Mission on Cotton (TMC), Technology Mission on Oilseeds and Pulses (TMOP), Technology Mission on Integrated Horticultural Development for North East India, Jammu & Kashmir, Himachal Pradesh, Uttarakhand, Technology Mission on Coconut Development etc, besides the scheme "Strengthening and Modernization of Pest Management" approach in India being implemented by the Directorate of PPQ&S [Plant Protection, Quarantine & Storage].

The problems with chemical pesticides also prompted the research systems and industry to look for alternatives. Several schemes and projects have been initiated to research, produce and market biopesticides and biocontrol agents which are recommended as non chemical approaches to pest management.

Today, there is much data generated by the agriculture research establishment in India to show that non-chemical IPM practices across crops have yielded better results in terms of pest control and economics for farmers. However, the field level use of pesticides has not changed much. The official establishment usually claims that pesticide consumption in the country has come down because of the promotion and deployment of IPM practices on the ground by the agriculture research and extension departments (as was informed to the Joint Parliamentary Committee in 2003). However, the actual progress of IPM on the ground has been quite dismal and small.

Further, the government often fails to take into account the fact that even if pesticide consumption has decreased in terms of quantities due to a shift to consumption of low-volume, high-concentration, high-value pesticides, the real picture in terms of number of sprays and costs involved is still the same for the farmers.

The Integrated Pest Management (IPM) initiatives which have come up as alternative though largely debates about the effects of pesticide on human health and on environment still believe that pesticides are inevitable, at least as a last resort and suggests safe and "intelligent use." On the other hand, replacing chemical products by biological products by itself may not solve the problem of pest management with restoration of ecological balance.

While the inevitability of pesticides in agriculture is promoted by the industry as well as the public research and extension bodies. There are successful experiences emerging from farmers' innovations that call for a complete paradigm shift in pest management.

18.4 Shifting Paradigms: Non Pesticidal Management

The ecological and economical problems of pests and pesticides in agriculture gave rise to several eco-friendly innovative approaches which do not rely on the use of chemical pesticides. These initiatives involved rediscovering traditional practices and contemporary grass root innovations supplemented by strong scientific analysis mainly supported by non-formal institutions like NGOs. Such innovations have begun to play an important role in development sector. This trend has important implications both for policy and practice. One such initiative by Centre for World Solidarity and Centre for Sustainable Agriculture, Hyderabad was Non Pesticidal Management.

The "Non Pesticidal Management" which emanates from collaborative work of public institutions, civil society organizations and Farmers in Andhra Pradesh shows how diverse players join hands to work in generating new knowledge and practice, can evolve more sustainable models of development.

Red Hairy Caterpillar (*Amsacia albistriga*) Management (1989–93):

During late eighties, red hairy caterpillar (RHC) was a major pest in the dryland areas of Telangana region of Andhara Pradesh. The pest attacks crops like castor, groundnut, sesame, sorghum and pigeon pea in the early stages and causes extensive damage in dry land areas. This forces farmers to go for 2–3 resowings or late sowing which affect the yield. The problem of crop failure due to delayed and uncertain rainfall was compounded by the damage caused by RCH. Resowings were happening in more than 30% area.

Discussions with several voluntary agencies, farmers from different regions and few scientists from the subject area established that:

1. This pest infests crops only on light red soils
2. There is only one generation of moths that lay eggs producing the caterpillars which later hibernate in the soils. Adult moths appear in waves at the onset of the monsoon. Controlling the pest necessiated the destruction of the early emergence moths.
3. The caterpillars are also attracted to some wild non-economical plants such as calatropis, wild castor, yellow cucumber.
4. The later instars of larvae had dense red hairs all over the body, which prevents pesticides from reaching the body of the insects as a result any pesticide sprayed will not cause the mortality of the insect.

Package of practices were evolved based on the insect behavior, which can manage the RHC before it reaches damaging stages and proportions. Deep summer ploughing exposes the resting pupae, adults of RHC. These insects are attracted to light-community bonfires. Bonfires were used to attract the insects and kill them. Alternatively light traps (eletric bulbs or solar light) were also used. Trenches around the field to trap migrating larvae by use of calatropis and jatropha cuttings were found to be effective. Neem sprays on the early instar larvae was found to be effective.

During 1989–1993 the program covered 18,260 ha in 95 villages across 12 districts of AP involving 21 voluntary organizations in two phases.

RHC could be effectively managed in dryland crops like castor, groundnut, sesame, sorghum and pigeonpea. Farmers could avoid late sowing and only 4% farmers went for re-sowing in areas where RHC management was followed. After the initial success of these methods, it evolved into a Red Hairy Catepillar Management Program with coordinated of Centre for World Solidarity (CWS), ICAR Zonal Coordinating Unit, Directorate of Oilseeds Research and Department of Agriculture, and the program is still continuing. The CWS sustainable agriculture desk later on evolved into Centre for Sustainable Agriculture which is now engaged in large scale promotion of NPM approach.

Source: Qayum. M.A. and Sanghi. N.K. (1993) Red Hairy Caterpillar Management through Group Action and NPM Methods published by ASW and Oxfam(India) Trust.

Pest is not a problem but a symptom. Disturbance in the ecological balance among different components of crop ecosystem makes certain insects reach pest status. From this perspective evolved the Non Pesticidal Management which is an "ecological approach to pest management using knowledge and skill based practices to prevent insects from reaching damaging stages and damaging proportions by making best use of local resources, natural processes and community action."

Non Pesticidal Management is mainly based on:

- Understanding crop ecosystem and suitably modifying it by adopting suitable cropping systems and crop production practices. The type of pests and their behavior differs with crop ecosystems. Similarly the natural enemies' composition also varies with the cropping systems.
- Understanding insect biology and behavior and adopting suitable preventive measures to reduce the pest numbers.
- Building farmers knowledge and skills in making the best use of local resources and natural processes and community action. Natural ecological balance which ensures that pests do not reach a critical number in the field that endangers the yield. Nature can restore such a balance if it is not too much meddled with. Hence no chemical pesticides/pesticide are applied to the crops. For an effective communication to farmers about the concept effectively, and to differentiate from Integrated Pest Management which believes that chemical pesticides can be safely used and are essential as lost resort it is termed as "Non Pesticidal Management" (Ramanjaneyulu et al., 2004).

18.4.1 The Approaches: Basic Set of Practices Followed

18.4.1.1 Growing Healthy Plants

Good Quality Seed

Selection and use of good quality seed which is locally adopted either from traditional farmers' varieties or improved varieties released by the public sector institutions is important. Farmers are suggested to make their decision based on a seed matrix regarding suitability of the different varieties into their cropping patterns, based on the soil types, reaction to insect pests and diseases and their consumption preference. They maintain the seed in their seed banks. This ensures farmers to go for timely sowing with the seeds of their choice. In rainfed areas timely sowing is one critical factor which affects the health and productivity of the crop. The seed is treated with concoctions depending on the problem for example cow urine, ash and asafetida concoction provides protection against several seed borne diseases

In NPM –main emphasis is to prevent insect from reaching damaging stage and proportions. If the pest reaches damaging stage, reactive inputs locally made with local resources are used. In IPM chemical pesticides are integral part.

like rice blast, or *beejamrut* to induce microbial activity in the soil and kill any seed borne pathogens. Similarly in crops like brinjal where there is a practices of dipping of seedlings in milk and dipping fingers in milk before transplanting each seedling was observed to prevent viral infections. Several such practices are documented and tested by the farmers. Non Pesticidal Management involves adoption of various practices which prevents insects from reaching to damaging stage and proportions (Fig. 18.1).

Reduce Stress

The pest and disease susceptibility increases with abiotic stress. Practices like mulching will improve the soil moisture availability.

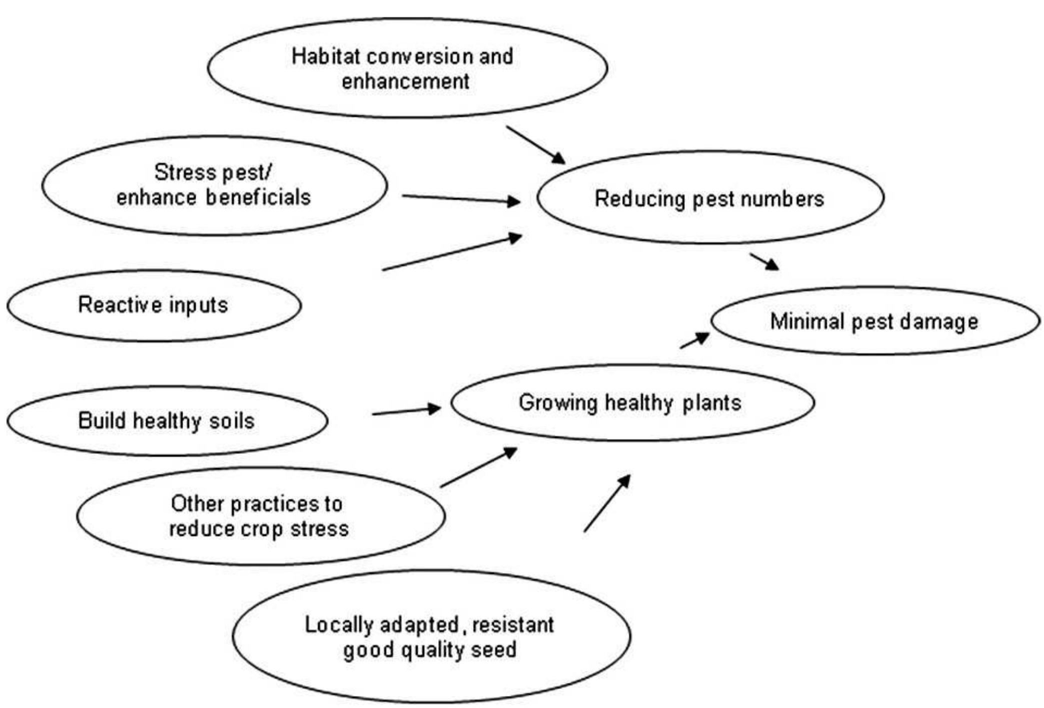

Fig. 18.1 Schematic representation of non pesticidal management

Build Healthy Soils

Healthy soils give healthy crop. Chemical fertilizers especially nitrogenous fertilizer makes the plants succulent and increases the sucking pests like brown plant hopper in rice. Production practices, such as putting on crop residues or other biomass as surface mulch, using compost and green manures, intercropping of legumes in cropping systems, and biocontrol of insect pests and diseases, all help to enhance yields and sustain soil fertility and health (Rupela et al., 2007).

18.4.2 Enhancing the Habitat

18.4.2.1 Crop Diversity

Crop diversity is another critical factor which reduces the pest problems. Traditionally farmers have evolved mixed cropping systems, intercropping and crop rotation systems. These systems will create a better environment for nutrient recycling and healthy ecosystems. On the contrary the monoculture of crops and varieties lead to nutrient mining and insect pest and disease buildup. Under NPM farmers adopt mixed and intercropping systems with proper crop rotations.

18.4.2.2 Trap and Border Crops

Many sucking pests fly from neighboring farmers' fields. In crops like chillies, groundnut, cotton, sunflower where thrips are a major problem, sowing thick border rows of tall growing plants like sorghum or maize will prevent insects from reaching the crop. Farmers adopt marigold as a trap crop for the gram pod borer and it reduces the pest load on pigeonpea. The flowers that have been oviposited by the female moths of *Helicoverpa* can be picked out and destroyed (KVK DDS, 2003) (Table 18.2).

Table 18.2 Trap crops used for pest management

Crops	Pests	Trap crops
Cotton, groundnut	Spodoptera	Castor, sunflower
Cotton, Chickpea, pigeonpea	Helicoverpa	Marigold
Cotton	Spotted bollworm	Okra

Source: KVK DDS, 2003

18.4.2.3 Other Agronomic Practices

Several **c**rop specific agronomic practices like alley ways in rice to allow enough light to reach the bottom of the plant are documented by the farmers and suggested by the scientists (*Vyavasaya Panchangam*, 2007).

18.4.3 *Understanding Insect Biology and Behavior*

18.4.3.1 Life Cycle

In most of the insects which completely undergo complete metamorphosis, in the four stages of the life cycle, insects damage the crop only in larval stage and in at least two of the stages are immobile [egg and pupa]. Every insect has different behavior and different weaknesses in each of the stage. They can be easily managed if one can understand the lifecycle and their biology. The different stages in the insect life cycle are morphologically different and relating between one stage and other is difficult unless one studies/observes the life cycle (Fig. 18.2).

Adult stage: Adults of red hairy caterpillars are attracted to light-community bonfires or light traps (electric bulbs or solar light). These can be used to attract and kill them. Similarly adult insects of *Spodoptera* and *Helicoverpa* can be attracted by using pheromone traps. Normally pheromone traps are used to monitor the insect population based on which pest management practices are taken up. The Natural Resources Institute, UK in collaboration with the Tamil Nadu Agriculture University, the Gujarat Agriculture University, the Centre for World Solidarity, the Asian Vegetable Research and Development Centre has evolved mass trapping method to control brinjal fruit and shoot borer and demonstrated it on a large scale (http://www.nri.org, GAU, 2003) The adults of sucking pests can be attracted using yellow and white sticky boards.

Egg stage: Some insects like *Spodoptera* lay eggs in masses which can be identified and removed before hatching. Insects also have preference for ovi-position. *Spodoptera* prefers to lay eggs on castor leaves if available. Hence growing castor plants as trap crop is adopted. By observing the castor leaves farmers can easily estimate the *Spodoptera* incidence. *Helicoverpa* lays eggs singly, but has a preference towards okra, marigold (mostly towards plants with yellow flowers) (Fig. 18.3). Hence marigold is used as a trap crop where ever *Helicoverpa* is a major problem. Rice stem borer lays eggs on the tip of the leaves in nurseries; farmers remove these tips before transplanting (*Vyavasaya Panchangam*, 2007).

Pupal stage: The larvae of red hairy caterpillar burrow and pupate in the soil. Deep summer ploughing, which is a traditional practice in rainfed areas expose these larvae to hot sun which kills them. The larvae of stem borers in crops like paddy and sorghum pupate in the stubbles. So farmers are advised to cut the crop to ground level and clear the stubbles.

18.4.3.2 Biology

The larva of red hairy caterpillar (*Amsacta albistriga*) has a dense body hair over the body hence no pesticide reaches it when sprayed. Therefore, it needs to be controlled in other stages of its life cycle (see box). For any safe and economic method of

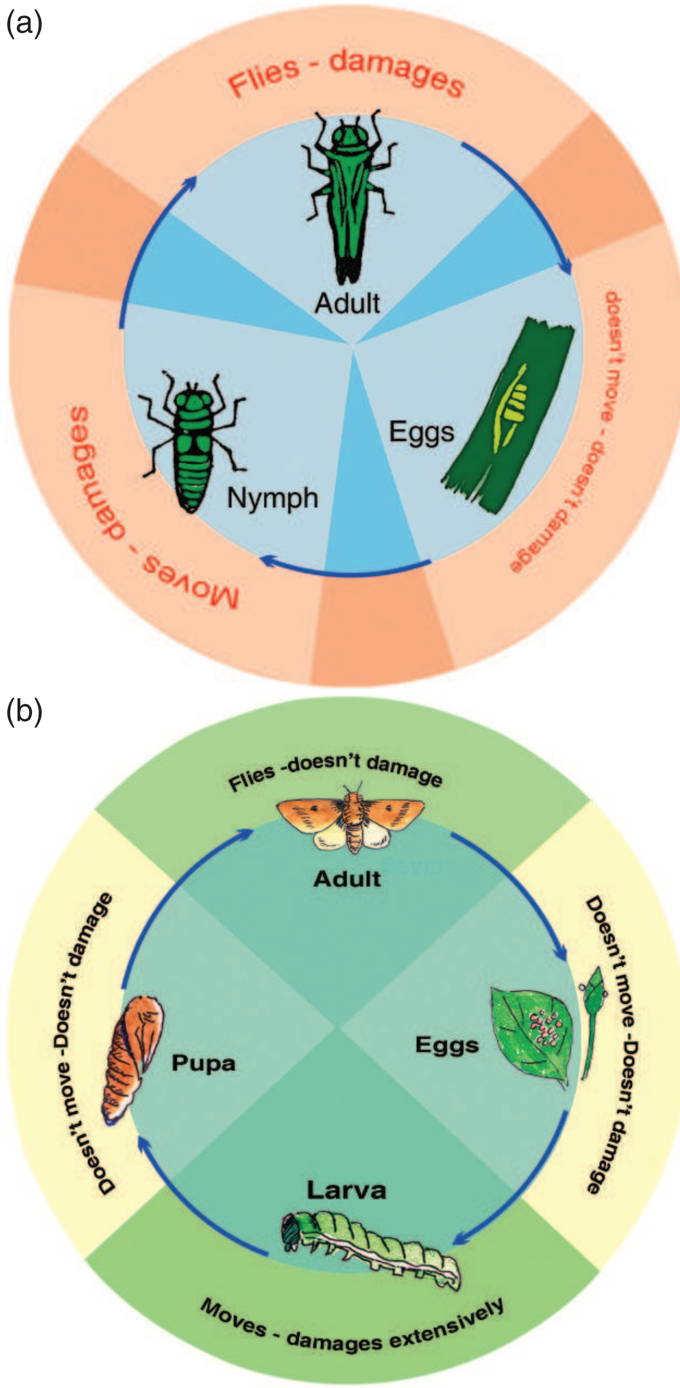

Fig. 18.2 Typical life cycle of insects (a) 3 stages (b) 4 stages

pest management one must understand how the pest live and die, where does it come from and when, where and how does it damage the crop. Knowledge of these biological attributes of pest will help farmers to use NPM methods successfully on a sustainable basis (GAU, 2003).

Traditional Technology with a Modern Twist http://www.icrisat.org

Farmers in south India used indigenous methods like shaking the plants to manage the pod borer (*Helicoverpa armigera*) in pigeonpea until chemical insecticides were introduced in the early 1970s. After crop pollination and pod set, when 1–2 larvae per plant are noticed, three farmers enter the field, one to hold/drag a polyethylene sheet on the ground, while the other two shake the plants. This gentle shaking can dislodge most of the caterpillars from the plants. These dislodged larvae are collected in a sack and destroyed.

During 1998–1999 season, this technology was evaluated in a research watershed (15 ha) at ICRISAT-Patancheru with support from IFAD and in collaboration with ICAR, ANGRAU, MAU, and NGOs under the coordination of CWS.

The results showed 85% reduction in insect population while the larval population in the adjacent, chemically sprayed plots remained high throughout the cropping period. This cost of this practice is just Rs. 280 (US $6) per hectare to have 7 people to shake pigeonpea planes, and collect larvae; while each chemical spray costs Rs. 500–700 (US $11–16) per hectare. This technology, initiated at a few locations during 1997, rapidly spread to more than 100 villages involving several thousand farmers in three states of southern India within two years.

Later, the larvae collected by shaking the plants were used for the multiplication of the Nuclear Polyhedrosis Virus (NPV), a biopesticide that kill *Helicoverpa*.

This project proposal by ICRISAT and CWS had won the World Bank's Development Marketplace Award for 2005.

18.4.4 Understanding Crop Ecosystem

The pest complex and the natural enemy complex are based on the crop ecosystem. The pest complex of cotton is completely different from that of sorghum. The pest complex in wet rice ecosystem differs from the pest complex in dry rice. Decision about any pest management intervention should take into account the crop ecosystem which includes cropping pattern, pest-predator population, stage of the crop etc. Similarly the management practices followed in one crop can not be adopted in all other crops. For example: to manage *Helicoverpa* in pigeonpea, the farmers in Andhra Pradesh and Gulbarga shake the plants and falling insects are collected over a sheet and killed (see box). Similarly in paddy there is a practice of pulling rope over the standing crop to control leaf folder.

(a)

(b)

Fig. 18.3 Egg laying behavior of (a) *Spodoptera litura* (egg mass) (b) *Helicoverpa armigera* (single egg)

18.4.5 Reactive Sprays

Insect population may reach pest status if the preventive steps are not taken in time, changes in weather conditions and insects coming from neighboring farmers fields. In these situations based on the field observations farmers can take up spraying botanical extracts and natural preparations (Green sprays) instead of chemical pesticides. There are wide ranges of these preparations which are evolved by the farmers (CSA, 2007).

Based on the process of making, these sprays can be classified into four categories

18.4.5.1 Aqueous or Solvent Extracts

Extracts are made by dissolving the required material in water (aqueous) or other liquids (solvent). For example, neem seed kernal extract is prepared by dissolving crushed neem seed kernal in water. For extracting "Allenin" from garlic, kerosene is

Fig. 18.4 Shaking method in pigeonpea for removing pests

used as a solvent. After extraction this solution is mixed with chilli extract and used against sucking pests (Prakash and Rao 1997, Vijayalakshmi et al., 1999, Prasad and Rao 2006).

18.4.5.2 Decoctions

For example, plants like tobacco, *Nux Vomica* contain volatile compounds which can be extracted by boiling them in water to get the decoction. Several decoctions are used in pest management (Prakash and Rao, 1997, Vijayalakshmi et al., 1999, Prasad and Rao, 2007).

18.4.5.3 Concoctions

Concoctions are mixtures. For example, five leaves mixture which is a aqueous extract of any five latex producing leaves is used to control pests in Tamil Nadu and other parts of south India (Prakash and Rao, 1997, Vijayalakshmi et al., 1999, Prasad and Rao, 2007).

18.4.5.4 Fermented Products

Products made by fermenting the different botanicals with animal dung and urine. These products have rich microbial cultures which help in providing plant nutrients in addition to acting as pest repellents and pest control sprays. For example cow dung urine-asafetida solution is used to manage rice blast (Prakash and Rao, 1997, Vijayalakshmi et al., 1999, Prasad and Rao, 2007).

The Evolution of Dialogue on Non Pesticidal Management

In 1988, ASW and EZE organized People's Science Conference at Bangalore to promote concept of substituting synthetic chemical pesticides by a non-pesticide approach based on locally available resources. This led to a collaborative program for non pesticidal approach for controlling RHC in 1989 with Zonal Coordinator, Transfer of Technology (ToT) Unit, ICAR, Hyderabad; Department of Agriculture, ASW/CWS; OXF AM; and village based voluntary organizations as partners.

In 1994, CWS organized a workshop in collaboration with National Academy of Agriculture Research Management (NAARM), Hyderabad to bring together initiatives working in NPM across the country. This worshop evolved a joint strategy paper on NPM.

In 1998, CWS organized second National Worshop on Non Pesticidal Management in collaboration with MANAGE in Hyderbad. The workshop which was attended by eminent scientists and civil society organizations called for expansion and popularizing the concept and practices.

In 2004, Punukula, a small village in Khammam district of Andha Pradesh which used to spend about Rs. 4 million annually on chemical pesticides to grow crops like cotton and chillies declared itself as a pesticide free after five years of NPM work. Centre for Sustainable Agriculture was formed to promote sustainable models in agriculture.

In 2005, in the context of serious crisis in agriculture and farmers suicides, NPM got the attention of the Society for Elimination of Rural Poverty, Government of Andhra Pradesh which works with Federations of Women Self Help Groups and began scaling up by adopting an institutional approach across the state.

During *kharif* 2007, more than 350 thousand farmers from 1800 villages in eighteen districts of the state adopted NPM in more than 280 thousand ha in various crops. The success of the program in reducing the costs of cultivation and increasing the net incomes of the farmers has received Prime Minister's attention and was selected for a support under 11th Five Year Plan under National Agriculture Development Project to cover one million farmers cultivating one million ha in over 5000 villages.

In September 2007, CSA and WASSAN (sister organizations of CWS engaged in promotion of NPM) have organized a National Workshop on 'Redesigning support systems for rainfed farming' in collaboration with Rainfed Farming Authority and ICAR in New Delhi. The nationwide experiences of public sector and civil society organizations on local resource based, sustainable models in agriculture were discussed and urged the government to redesign the support systems to help promotion of such practices.

(Based on the internal documents, proceedings of workshops organized by CWS in 1994 and 1998, Ramanjaneyulu et al. (2004))

Transgenic Insect Resistant Crops: Not a solution Either

As the problems of chemical pesticides are becoming evident, the industry has come out with yet another technological fix in the form of insect resistant genitically engineered crops like Bt cotton. The results of the last seven years (2002–2008) of commercial cultivation of the Bt cotton in india, especially in Andhra Pradesh clearly shows devastating effects such technologies can have in the farming communities. This comes from the fact that the seed is four times the price of conventional seeds and Bt crops often are not even completely resistant (http://www.indiagminfo.org). In addition other sucking pests will affect the crop and chemicals are needed again. The first three commercial Bt hybrids released in Andhra Pradesh were withdrawn from commercial cultivation (GEAC, 2005).

It should be added that studies have assessed the variabity of Bt toxin production under carefully controlled conditions, rather than the real life conditions of farmer's fields.Under real life condition toxin product of the crop is extremely uneven (Kranthi et al., 2005).

Transgenitic Bt plants, which produce their own insecticidal toxins, have the similar effects like chemical pesticides. However, unlike topical sprays, which become inactive after a short period of time, transgenetic Bt plants are engineered to maintain constant levels of the Bt toxin for an extended period, regardless of whether the pest population is at economically damaging levels. The selection pressure with transgenic Bt crops will therefore be much more intense (Ramanjaneyulu and Kavitha, 2006).

Today the experience of Bt cotton in several areas specially dryland regions is well known. The sucking pests are on increase. The newer questions like toxicity to smaller ruminants and soil microbes, are raised by several scientists across the world and the farmers are complaining on this issue.

The Economic Analysis of NPM and Bt Cotton

A study was taken up by Central Research Institute of Dryland Agriculture (CRIDA) to compare the performance of NPM in Bt and non-Bt cotton. The study showed that NPM in non-Bt cotton is more economical compared to Bt cotton with or without pestcide use (Prasad and Rao 2006) (Table 18.3).

Table 18.3 Comparative economics of Bt cotton vs Non-Bt cotton with NPM

Strategy	Genotype	No. of chemical sprays	Cost of cultivation ($ US/ha)	Yield (kg/ha)	Gross returns ($ US/ha)	Net returns ($ US/ha)
NPM	Non-Bt	0	407.75	2222.5	1127.5	719.50
NPM	Bt	0	388.89	2220.0	1091.81	702.92
Control	Non-Bt	5.0	409.69	2087.5	1031.25	621.56
Control	Bt	3.8	452.19	2242.5	1111.63	659.44

Source: (Prasad and Rao, 2006)

18.5 Successful Case Studies

18.5.1 Punukula: The Pesticide Free Village

Punukula a small quite village in Khammam district in Andhra Pradesh (AP) created waves by local Panchayat (local self government body) formally declaring itself pesticide-free in 2003. Farmers here gave up using chemical pesticides even for crops such as cotton, chilli and paddy – all known to use notoriously high quantities of pesticides.

From 1986 onwards the State witnessed farmers' suicides due to indebtedness. During 1997–1998 several farmers committed suicides after the cotton crop failed in Telangana region. An estimated 1,200 suicide deaths were reported between June and August 2004. One of the reasons for the rise in suicides has been the crushing burden of debt; many farmers buy expensive seeds and pesticides and when the crops fail, their own survival becomes difficult. Against this scenario the pesticide-free status of the predominantly tribal village of Punukula gains significance.

The Punukula farmers claim that they are able to save up to $ 75,000 every year on agricultural inputs by adopting Non Pesticidal Management approach towards pest management. There is a total of 240 ha of farmland; and on every hectare, they have been able to save at least $ 300 per season, as they do not have to buy expensive pesticides.

Farmers learned using pesticides from the farmers who brought cotton crop to Punukula from Guntur districts about 15 years ago. Initially, the pesticides worked well and several pesticide shops were opened in the nearby town of Palvancha. Pesticide dealers also gave local farmers the latest pesticides on credit. But gradually, the pests became resistant to these pesticides. Monocrotophos, methyl parathion, chlorpyriphos, endosulfan and synthetic pyrethroids... nothing seemed to work. The pests would only come back in greater numbers. Pretty soon, the cotton crop needed greater quantities of pesticides, which meant a higher investment.

In addition to supplying seeds, fertilisers and pesticides, the dealers also lent money to the hapless farmers at high interest rates.

But when yields started reducing – due to pests – and debts increased, some farmers in Punukula committed suicide. The high use of pesticides also posed health-related problems. Women, who did most of the pesticide spraying work, complained of skin problems, blurred vision and body ache.

In 1999, the Socio-Economic and Cultural Upliftment in Rural Environment (SECURE), a local NGO, stepped in and suggested that the farmers try out non pesticidal approaches for pest management. Technical and financial support for this project initially came from the Centre for World Solidarity (CWS) and later from the Centre for Sustainable Agriculture (CSA), both based in Hyderabad. However, the determination and support of five self-help groups (SHGs) run by the village women contributed towards making this shift to ecological methods possible.

SECURE initially began work with 20 farmers, including a few women. Earla Dhanamma, whose husband Nagabhushanam represented the interests of several pesticide companies, also joined in. The farmers were sceptical in the beginning.

Table 18.4 Economics of NPM in Cotton Punukula village (Kharif, 2001–2002)

Particulars	NPM	Conventional*
Avg. Yield (kg/ha)	1575	1450
Cost of plant protection ($ US/ha)	107.50	214.88
Net income ($ US/ha)	85.50	–130

* Conventional pesticide used cotton from neighboring village
(On 6.4 ha, with 8 farmers in Punukula)
Source: Ramanajaneyulu and Zakir Hussain (2007)

But the method of preventing pest attacks by understanding the pests' life cycles did appear both simple and affordable. Instead of chemical sprays, the farmers began preparing sprays made with local and inexpensive material such as neem seed powder and green chilli-garlic extract. The farmers also used pheromone traps to attract moths and destroyed them before they started mating. Some farmers also used 'crop traps' along with the cotton crop they would grow another crop (marigold or castor) that attracted the pests more.

In just one season, the positive results began to show. Useful insects such as spiders, wasps and beetles – which feed on cotton pests – returned to the fields once the chemical pesticides were stopped. In the next season, many other farmers came forward to try out the new approach. However, there were several men in the village who found it easier to buy a container of chemical pesticide from a pesticide dealer than go through the trouble of preparing extracts to control pest population (Table 18.4).

But the women's SHGs prevented these men from going back to pesticide shops. Others also realised that pesticides meant higher debts as well as high medical costs. The women even took on the additional work of preparing the anti-pest sprays from neem and chilli-garlic paste. They also ensured that no one brought pesticides in their village.

By 2003, most farmers in this 200-household village had stopped using harmful chemical pesticides. Pesticide dealers stopped coming to the village as sales dropped dramatically. Besides covering 160-odd ha of cotton, the new method was also used in fields growing chilli and paddy. No pesticides were sprayed in 240 acres (96 ha) of farmland during the 2003 *kharif* season. Even during the first crop season of 2004, no pesticides were required.

In August 2004, the women's groups also bought a neem seed crushing machine (extracts for the sprays are prepared from the powder) with support from SECURE and CWS/CSA.

Today, Punukula has become a role model for other villagers who are inspired and impressed by its healthy crops. Around Punukula many villages are inspired to give up chemical pesticide usage.

Punukula farmers now have the money to invest in house repair, livestock and purchase of land. Most of the farmers reported higher income, enabling them to repay old debts. The villagers now firmly believe that the way to get rid of pests is to rid their farming of pesticides.

For the agricultural laborers also, things have improved on many fronts. There was a wage increase from 75 cents to one dollar during the corresponding period [when NPM was practiced]. They do not have to be exposed to deadly pesticides now, nor incur medical care expenses for treatment of pesticides-related illnesses. Some point out that there is even more work for the labourers – in the collection of neem seed, in making powders and pastes of various materials and so on. Farmers are even leasing in land and putting all lands under crop cultivation these days – this implies greater employment potential for the agricultural workers in the village.

Source: (http://www.thehindubusinessline.com/life/2004/10/08/stories/2004100800030200.htm)

18.5.2 Enabavi: A Whole Village Shows the Way

Enabavi is probably the first modern-day organic farming village in Andhra Pradesh. The entire village, in each acre of its land, on every crop grown here, has shunned the use of chemicals in agriculture. They neither use chemical fertilizers nor chemical pesticides in their farming. This in itself meant a tremendous saving for the village in monetary terms. This small village in Lingala Ghanpur of Warangal district shows the way out of agricultural distress that almost all farmers find themselves in today.

Warangal district presents a classic paradox of an agriculturally developed district [with most area occupied by commercial crops] showing the worst manifestation of the distress of farmers – that of the highest number of suicides in the state in the past decade or so. It is a district where farmers' frustration with lack of support systems manifested itself in almost a spontaneous and well-planned agitations of unorganized farmers. Farmers in this district are known to have resorted to violence to end their problems, including resorting to a violent end to their own lives.

Enabavi is a small village which showed the resolve of a strong community which decided to take control of its agriculture into its own hands. With just 45 households in the village belonging mostly to the backward castes, the village started shifting to non-chemical farming about five years ago. Then in 2005–2006, the entire land of 113 ha was converted to organic farming. This is not organic farming as you would normally expect. No expensive external certification here. It is a model of "declared organic farming". Though there are no formal participatory guarantee systems established in the village in this alternative model of organic farming, there is strong social regulation within the community to ensure that there are no "erring farmers". The elders in the village take the youth along with them. They also have started investing in teaching their school-going children the knowledge and skills of non-chemical farming. Special training sessions have been organized by CROPS to rope in children into this new system of cultivation in the village.

The farmers here grow their food crops of paddy, pulses, millets etc., mostly for household consumption. In addition, they also grow crops like cotton, chilli, tobacco and vegetables for the market. Their average spending on chemical fertilizers and pesticides across crops used to be around US $ 220/ha, whereas it was around US $ 31.25/ha for seeds. This more often meant credit from the input dealers, who would also double up as traders for the produce. These traders would dictate the price for the produce in addition to charging interest for the inputs supplied. Now, all this has changed.

The process of change began with a program that CWS had initiated to control the dreaded red hairy caterpillar, in the late 1990s. This was followed by converting all crops to the NPM. Later, some farmers came forward to shift from chemical fertilizers to other methods of soil productivity management. They started looking for other options like tank silt application, poultry manure application, vermicompost, farm yard manure etc. CROPS stepped in at this point of time and subsidized the costs up to 50% for tank silt application and setting up vermicompost units. The farmers set up their units at their fields and started following various ecological practices being recommended to them. They also started to depend on their own seed for many crops, except for crops like cotton. They set up farmers' self help groups for men and women separately and started thrift activities too.

Today, Enabavi has many valuable lessons to teach to other farmers, not just on how to take up sustainable farming. They also have lessons to share on social regulation, learning from each other, the benefits of conviction born out of experience and most importantly, the way out of agricultural distress by taking control over one's own farming.

18.6 NPM Scaling up with SERP

Society for Elimination of Rural Poverty (SERP) is a registered society under Department of Rural Development implementing the largest poverty alleviation project in the state of Andhra Pradesh. The project understands that sustainable poverty eradication requires the recognition of the poor as active partners in the processes of social change; therefore, all project interventions are demand based and are in response to the proposals conceived and planned by the poor.

SERP works towards empowering the poor to overcome all social, economic, cultural and psychological barriers through self managed institutions of the poor. The project reaches the rural poor families through social mobilization processes and formation of SHGs, federation of these into Village Organizations at village level and Mandal Samakhyas at the mandal level. The project envisages that with proper capacity building the poor women's federations would begin to function as self managed and self reliant people's organizations. The poor have started to demonstrate that they can shape their own destinies when adequate knowledge, skills and resource support is accessible to them.

In this context SERP initiated the work on agriculture based livelihood, supporting them to adopt sustainable agriculture practices to reduce the costs of cultivations. Learning from the experiences of villages like Punukula, SERP initiated scaling up of NPM in collaboration with a consortium of Non Governmental Organizations and technical support provided by the Centre for Sustainable Agriculture (CSA).

18.6.1 Critical Issues in Scaling Up

While the sustainable models in agriculture like NPM are established on smaller scale scaling up these experiences poses a real challenge in terms of:

- relevance of small experiences for a wider application,
- availability of resources locally,
- farmers willingness to adopt these practices,
- lack of institutional and support systems,
- supplementing farmers' knowledge and enhancing the skills,
- reducing the time of transformation,
- reaching to larger areas with minimal expenditure, and
- establishing extension system which give community a central stage.

18.6.2 Process of NPM Scaling Up

In December, 2005, a small pilot project was launched in Kosigi Mandal (Blocks in Andhra Pradesh) as a livelihood intervention with the help of WASSAN. Farmers were trained systematically and technical support provided in the form of coordinators who were accountable to the Women SHGs. In 90 ha, average savings of US $ 75/ha on pigeon pea the total savings were US $ 6875 (WASSAN, 2006).

18.6.2.1 Grounding the Work 2005–2006

Based on the experiences drawn from the pilot program for 2005–2006 was initiated by establishing clear institutional system and a community managed extension system in nine districts of AP. Five villages were grouped into a cluster and were provided with a cluster activist. Each village has a practicing farmer selected as village activist who coordinates the village level capacity building programs in the form of Farmer Field Schools. All over nine districts 12,000 farmers with 10,000 ha in both *kharif* and *rabi* (It is synonymous with the dry season, covering the crop growing period October/November through March/April) adopted Non Pesticidal Management. Sixty-two Federations of Women SHGs (Mandal Mahila Samakyas or MMS), 150 Cluster activists and 450 village activists are involved in managing the program. Each MMS entered into an agreement. This clearly established that a paradigm shift in understanding pest management both at farmers' level and extension system level can effectively tackle the pest problem and also give ample benefits to farmers in terms of savings on input costs, health costs etc. Better quality products from such production systems also fetch a better price to farmers and are highly preferred by discerning consumers (refer http://www.downtoearth.org.in/default20060531.htm). Also, the NPM intervention for the first time shifted the control in terms of production back to the farmer (Sopan, 2006).

Awareness was created through state level campaign about the ill affects of pesticides and the potential alternatives. Communication material was developed and distributed for use.

18.6.2.2 Case of NPM in Rice in Kurnool Dist (2005–2006)

During *kharif* 2005, NPM in paddy was taken up in 6 villages of 2 mandals in Kurnool district. It was successfully implemented by 57 farmers in 28.4 ha. On an average there was a saving of $ 125/ha in cost of plant protection compared to conventionally grown rice crop. In yields, NPM farmers got additional yield of around 937.5 kg/ha, which may be attributed to increased number of natural enemy populations in the rice ecosystem that has happened due to continuous monitoring and timely interventions. In monetary terms, a net extra benefit of $ 290/ha was made by NPM farmers compared to non NPM farmers (Table 18.5).

Table 18.5 Economics of NPM v/s conventional Paddy in Kurnool dist (2005–2006)

SI. No	Village	Farmers		Area (ha)		Costs of plant protection ($ US/ha)		Yield (kg/ha)	
		NPM	Con	NPM	Con	NPM	Con	NPM	Conventional
1	Arlagadda	16	15	8.4	12.0	10.00	63.13	5683	5613
2	Durvesi	5	15	5.2	59.4	12.26	77.92	6187	6550
3	Bhupanapadu	4	5	1.6	2.0	11.00	50.00	5625	5887
4	Alamuru	17	23	7.6	10.0	12.00	81.00	5545	5380
5	Konidedu	6	9	2.4	3.8	13.00	57.00	6405	5012
6	Panyam	5	9	2.0	3.6	18.12	67.00	6450	4813
	Total								

(Source: Annual Report, NPM, 2005–2006)

Each participating farmer on an average saved up to US $ 160–310/ha (average across crops and across districts) on pest management expenses. With more area and more farmers coming into the program the saving will be higher. The ecological and other benefits would be enormous.

Nearly 30 neem seed powder units were established with SHGs along with 15 NPV units as village enterprises.

The benefits are not only seen in the areas of high pesticide use but also in areas of low pesticide use. The crops could be saved from the insect pests and diseases thus instilling new interest in the farmers.

The experiences during 2005–2006 clearly showed the benefit of moving towards non-chemical approaches in agriculture, and farmers were enthused by these approaches (Tables 18.6 and 18.7). SERP has organized a state level mela at Krishi Vigyan Kendra (KVK), Banaganpalli along with scientists from Agricultural University, ICAR institutions and KVKs.

Table 18.6 Economics of NPM across crops (2005–2006)

Crop	Cost of Plant protection ($ US/ha)		Saving ($ US/ha)
	Conventional	NPM	
Cotton	315	63	252
Chillies	940	125	815
Pigeon pea	94	20	74
Groundnut	94	20	74
Castor	125	25	100
Paddy	125	15	110

Source: (Annual reports of NPM, 2005–2006)

Table 18.7 Reduction in costs of pest management in Ananthapur, 2005–2006

S.NO	Village	No. of. Farmers	NPM area (in ha) (2005–2006)	2003–2004 Pesticide usage (in lit)	Value of pesticides ($ US)	Value of NPM extracts ($ US)	Total saving ($ US)
1	Chinnajalalapuram	39	73	7,000	13,500	1365	12,135
2	Madirepalli	36	56	5,000	10,000	1112	8,888
3	Guruguntla	36	42	4,687	16,400	910	15,490
	Total	111	171	16,687	39,900	3,387	36,513

Source: (Annual Report, NPM, 2005–2006)

18.6.3 Moving to Community Managed Sustainable Agriculture

The successful grounding of NPM during 2005–2006 has given important learning on how any ecologically sound and economically benefiting technology can be scaled up by providing proper institutional support. In 2006–2007, higher number of farmers in the same villages and more villages in the same districts and few newer districts joined the program. The program covered 1250 villages in 17 districts covering wide variety of crops from groundnut, rice, chillies and cotton. Program expanded to districts like Guntur where the pesticide problem is serious and north coastal Andhra Pradesh where the productivity of crops in general is low. The program is implemented in Adilabad, Ananthapur, Chittor, Guntur, Kadapa, Karimnagar, Khammam, Kurnool, Mahaboobnagar, Medak, Nalgonda, Nellore, Ranga Reddy, Srikakulam, Visakhapatnam, Vijayanagaram and Warangal. Program covered more than 80,000 farmers cultivating about 80,000 ha. In addition to pest management, initiations on soil productivity management and seed management have begun on a small scale. Agriculture credit from formal banks was mobilised in 3 districts to the tune of US $ 150 million.

In addition to the NPM, efforts were initiated to establish seed networks so that farmers produce and share their seed. Seed banks have been established in 100 villages where farmers could retain, replace, reuse and revive seed, and are managed by the community. The pilot in Ananthapur has shown good results. Efforts are also on to develop non-chemical soil productivity improvement practices based on the experiences of the villages like "Yenabavi" in Warangal which became the first organic village in the state.

In 2006–2007, while the institutional systems were further strengthened; focus was also given to specific commodities like rice and groundnut in Kurnool district, pigeon pea in Mahaboobnagar district, cotton in Warangal and Khammam and chillies in Guntur district (Table 18.8). The marketing links were established. The NPM products were in demand and could command premium in the market. The local processing and marketing of the commodities have also brought in additional benefits to the farmers.

Table 18.8 Savings on pesticides during 2006–2007

S.NO	CROP	Area (ha)	Avg. Savings/ha ($ US/ha)	Total Savings (Million $ US)
1	Cotton	16,170	312	5.05
2	Paddy	20,112	63	1.27
3	Pigeon pea	9,732	75	0.73
4	Groundnut	9,200	50	0.46
5	Chillies	1500	937	1.41
6	Others	10,400	63	0.66
	TOTAL	67,114		9.56

Source: (Annual Report NPM, CSA 2006–2007)

This scalingup experience in Andhra Pradesh has broken the myth that pesticides are inevitable in agriculture and also provided important lessons on the paradigm shift in technology, institutional systems and support systems required for sustaining agriculture especially of small and marginal farmers.

In 2007–2008, the program was further expanded to cover 1,800 villages in 18 districts. There are more than 350,000 participating farmers cultivating 280,000 ha. In the villages which are in second year, works on soil productivity management with local resources and local seed management have been planned.

- Special focus on certain commodities to deal with post harvest management to increase the value of the commodities. In 2007–2008, village level quality control centers were initiated in chilli producing villages.
- The marketing Community Resource Persons working with women SHGs were also trained in NPM and in 50 clusters (250 villages) they started motivating farmers to adopt NPM practices.
- Best performing villages are identified as resource villages and best practicing farmers are identified as community resource persons who will help in further scaling up of the program.
- Community Seed Banks where farmers produce, save, share and use their own quality seed would be established in 70 villages.

- Program will also be integrated with other ongoing programs like National Rural Employment Guarantee Program (NREGP) to provide further employment opportunities to the agriculture workers.
- Total program expenditure is about US $ 11/ha.

The state government has proposed to scale up NPM into organic farming in 5000 villages over next five years covering 10 million ha with an outlay of US $ 45.5 million. The proposal has been accepted under Additional Central Assistance from Prime Minister's package for distress states called *Rastriya Krishi Vikas Yojana*.

18.7 Conclusions

The pests and pesticides have seriously affected the farm based livelihoods in rural areas. The last three years experience shows that moving towards local resource based sustainable agriculture as the only way to sustain the livelihoods of small and marginal farmers and community based organizations like federations of women self help groups form an excellent institutional platform for scaling up such models. To sustain agriculture and agriculture based livelihoods, this calls for a complete paradigm shift in the way agricultural practices are understood, developed, promoted and supported. The new paradigm is based on the local resource based technologies and a community managed extension systems.

Abbreviations

CIBRC	Central Insecticide Board and Registration Committee
CSA	Centre for Sustainable Agriculture
CWS	Centre for World Solidarity
ETL	Economic Threshold Level
FAO	Food and Agriculture Organisation
FFS	Farmer Field Schools
IARI	Indian Agriculture Research Institute
ICAR	Indian Council for Agriculture Research
IPM	Integrated Pest Management
KVK	Krishi Vigyan Kendra (Farm Science Centres)
MMS	Mandal Mahila Samakya (Federation of Women Self Help Groups)
NPM	Non Pesticidal Management
RHC	Red Hairy Caterpillar
RMG	Rytu Mitra Group (Farmers group)
SERP	Society for Elimination of Rural Poverty
SHGs	Self Help Groups
TMC	Technology Mission on Cotton
TMOP	Technology Mission on Oilseeds and Pulses
WASSAN	Watershed Support Services and Activities Network

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References

AGRAU 2001. *Vyavasaya Panchangam* (Annual Calender of crop production practices in Telugu), published by Acharya NG Ranga Agricultural University, Hyderabad.

AGRAU 2006. *Vyavasaya Panchangam* (Annual Calender of crop production practices in Telugu), published by Acharya NG Ranga Agricultural University, Hyderabad.

AGRAU 2007. *Vyavasaya Panchangam* (Annual Calender of crop production practices in Telugu), published by Acharya NG Ranga Agricultural University, Hyderabad.

Chitra G.A., Muraleedharan, V.R., Swaminathan, T. and Vijayaraghavan, D. 2006. Use of pesticides and its impact on health of farmers in South India. *International Journal of Occupational and Environmental Health* 12: 228–233.

CIRAD-FAO. 2000. Food safety management in developing countries. *Proceedings of the International Workshop, 11–13 December 2000, Montpellier, France, CIRAD-FAO*. CIRAD Montpellier, France.

CSA. 2006. *Annual Report NPM, 2005–2006*, unpublished report by Centre for Sustainable Agriculture, Hyderabad.

CSA. 2007. *Annual Report NPM, 2006–2007*, unpublished report by Centre for Sustainable Agriculture, Hyderabad.

CSA. 2007. Susthira Vyavasayam lo vividha padarthala Tayari (Telugu), (Various preparations in sustainable agriculture) published by Society for Elimination of Rural Poverty, Government of Andhra Pradesh, India.

CWS. 1994. Non pesticidal management in crops. *Proceedings of the Workshop organized by CWS and NAARM*.

CWS. 1998. Non pesticidal management. *Proceedings of the Workshop organized by CWS and MANAGE*.

Down to Earth. 1997. *Toxic Substances in the Human Environment*, 5(19).

Fakrudin, B., Vijaykumar, Krishnareddy, K.B., Patil, B.V. and Kuruvinashetty, M.S. 2004. Status of insecticide resistance in geographical populations of cotton bollworm, helicoverpa armigera in South Indian Cotton Ecosystem during 2002–2003. *Resistant Pest Management Newsletter* 13(2).

Fox, E.J., Jay, G., Erika E., Matthew E.B. and cLachlan, J.A. 2007. Pesticides reduce symbiotic efficiency of nitrogen-fixing rhizobia and host plants, *PNAS*, June 12, 2007, 104(24): 10282–10287, www.pnas.org_cgi_doi_10.1073_pnas.0611710104.

GAU. 2003. Non pesticidal management of brinjal fruit and shoot borer, *Technical Bulletion*, Department of Entomology, Gujarat Agriculture University, India.

GEAC. 2005. *Proceedings of 53rd Meeting of GEAC*, Ministry of Environment and Forests, Government of India http://moef.gov.in/enfor/geac.html.

IRAC. 2007. IRAC Resistance: *The Facts – History & Overview of Resistance* www.irac-online.org accessed on 10th September, 2007.

Karanth, N.G.K. 2002. Challenges of limiting pesticide residues in fresh vegetables: The Indian experience in Hanak E., Boutrif E., Fabre P., Pineiro M., (Scientific Editors). *Proceedings of the International Workshop, CIRAD-FAO, 11–13, December 2000, Montpellier, France, CIRAD-FAO*. CIRAD CD-ROM, Montpellier, France.

Kavitha, K., 2005a. Effects of pesticide exposure on developmental task performance in Indian children. *Children, Youth and Environments* 15(1): 83–114. Retrieved from http://www.colorado.edu/journals/cye.

Kavitha, K., 2005b. *Killing or Poisoning: Pests or Human Beings?* Centre for Sustainable Agriculture, Hyderabad, http://www.csa-india.org.

Kavitha, K., Dharmender, G.R., Rajitha, N., Joseph Royal and Ramanjaneyulu, G.V. 2007. *Pesticides, Residues and Regulation-A Case of Vegetables in Hyderabad Market Report submitted to Humboldt University Berlin*.

Kenmore, P. 1980. *Ecology and Outbreaks of a Tropical Insect Pest of the Green Revolution: The Rice Brown Planthopper, Nilaparvata lugens (Stal).* University of California, Graduate Division, Berkeley.

Kenmore, P. 1996. Integrated pest management in rice. In: Persley, G. (ed), *Biotechnology and Integrated Pest Management*, CAB International, Wallingford pp. 76–97.

Kenmore, P. 1997. A perspective on IPM, *LEISA Magazine*, December, 1997.

Konradsen, F.A, van der Hoekb, W., Cole, D.C., Hutchinson, G., Daisley, H., Singh, S. and Eddleston, M. 2003. Reducing acute poisoning in developing countries – options for restricting the availability of pesticides. *Toxicology* 192: 249–261.

Kranthi, K.R., Jadhav, D., Wanjari, R., Kranthi, S. and Russell, D., 2001a. Pyrethroid resistance and mechanisms of resistance in field strains of helicoverpa armigera (Lepidoptera: Noctuidae). *Journal of Economic Entomology*. 94(1): 253–263.

Kranthi, K.R., Jadhav, D.R., Wanjari, R.R., Ali, S.S. and Russell, D. 2001b. Carbamate and organophosphate resistance in cotton pests in India, 1995 to 1999. *Bulletin of Entomological Research* (91): 37–46.

Kranthi, K.R., Naidu, S., Dhawad, C.S., Tatwawadi, A., Mate, K., Patil, E., Bharose, A.A., Behere, G.T., Wadaskar R.M. and Kranthi, S. 2005. *Temporal and Intra-Plant Variability of Cry1Ac Expression in Bt-Cotton and Its Influence on the Survival of the Cotton Bollworm*, *Helicoverpa Armigera* (Hübner) (Noctuidae: Lepidoptera).

KVK DDS *Annual Report* 2004–2005 unpublished report by Krishi Vigyan Kendra, Pasthapur. http://www.ddsindia.com.

KVK HCT. 2006. *Annual Report NPM, 2005-2006*, unpublished report by Krishi Vigyan Kendra, Banganpalli.

Lightfoot, C., Ramirez, R., Groot, A., Noble, R., Alders, C., Shao, F., Kisauzi, D. and Bekalo, I. 2001. *Learning OurWay Ahead: Navigating Institutional Change and Agricultural Decentralisation*. Gatekeeper Series no. 98. London: IIED.

Mancini, F., Van Bruggen, A.H.C., Jiggins, J.L.S., Ambatipudi, A.C. and Murphy, H. 2005. Acute pesticide poisoning among female and male cotton growers in India, 11(3): Jul/Sep 2005 www.ijoeh.com.

Mancini, F., Van Bruggen, A.H.C. and Jiggins, J.L.S. 2007. Evaluating cotton integrated pest management (IPM) farmer field school outcomes using the sustainable livelihoods approach in India. *Experimental Agriculture*, 43: 97–112 C_ 2006 Cambridge University Press.

Mangan, J. and Mangan, M.S. 1998. A comparison of two ipm training strategies in china: The importance of concepts of the rice ecosystem For sustainable insect pest management. *Agriculture and Human Values* 15: 209–221.

Mathur, H.B., Agarwal, H.C., Johnson, S. and Saikia, N. 2005. *Analysis of pesticide residues in blood samples from villages of Punjab*. Centre for Science and Environment, New Delhi.

PMRA -Regulatory Directive DIR99-06. 1999. *Voluntary Pesticide Resistance-Management Labelling Based on Target Site/Mode of Action*. Published by Pest Management Regulatory Agency, Canada www.hc-sc.gc.ca, http://www.irac-online.org/

Prakash, A. and Rao, J. 1997: *Botanical pesticides in agriculture.* CRC Press, Boca Raton, FL.

Prasad, Y.G. and Rao, K.V. 2006. *Monitoring & Evaluation: Sustainable Cotton Initiative in Warangal District of Andhra Pradesh,* Central Research Institute for Dryland Agriculture, Hyderabad, unpublished report.

Qayum, M.A. and Sanghi, N.K., 1989. *Red Hairy Caterpillar Management through Group Action and NPM Methods*. Report published by ASW and OXFAM.

Ramanajaneyulu, G.V. and Zakir Hussain., 2007. *Redefining Pest Management: A Case Study of Punukula* in 'Sustainable Agriculture-a pathway to eliminate poverty', published by SUSTAINET, GTZ.

Ramanjaneyulu G.V. and Kavitha, K. 2006. Bt cotton in India: Sustainable pest management? *Economic and Political weekly* 18th May, 2006.

Ramanjaneyulu, G.V., Kavitha, K. and Zakir Hussain. 2004. *No Pesticides No Pests*, published by Centre for Sustainable Agriculture http://www.csa-india.org.

Rupela, O.P., Gowda, C.L.L., Wani, S.P. and Hameeda, B., 2007. *Evaluation of Crop Production Systems Based on Locally Available Biological Inputs* in Biological Approaches to Sustainable Soil Systems edited by Norman Uphoff, 2007.

Settle, W.H., Ariawan, H., Astuti, E.T., Cahyana, W., Hakim, A.L., Hindayana, D., Lestari, A.S., Pajarningsih, and Sartanto. 1996. Managing tropical rice pests through conservation of generalist natural enemies and alternate prey, Ecology, 77(7): 1975–1988.

Sopan J. 2006. Out of trap. *Down to Earth* July, 2006 http://www.downtoearth.org.in/default20060531.htm.

Timothy K., Richard W., Sean G. and Chris C. 2005. *Body Burden*, *The Pollution in Newborns*. Environmental Working Group, Washington DC. http://www.ewg.org/reports/bodyburden2/

Vasquez-Caicedo, G., Portocarrero, J., Ortiz, O. and Fonseca, C. 2000. *Case Studies on Farmers'Perceptions about Farmer Field School (FFS) Implementation in San Miguel Peru: Contributing to Establish the Baseline for Impact Evaluation of FFS.* Report to the DECRG from the World Bank, May. As quoted in by Godtland Erin, Elisabeth Sadoulet, Alain de Janvry, Rinku Murgai and Oscar Ortiz (2003) The Impact of Farmer-Field-Schools on Knowledge and Productivity: A Study of Potato Farmers in the Peruvian Andes, Department of Agricultural & Resource Economics, UCB CUDARE Working Papers (University of California, Berkeley).

Vijayalakshmi, K., Subhashini, B. and Koul, S. 1999. *Plants in Pest Control: Pongam, Tulasi and Aloe.* Centre for Indian Knowledge Systems, Chennai.

WASSAN. 2006. *Non Pesticidal Management*, http://www.wassan.org.

Way, M.J. and Heong, K.L. 1994. The role of biodiversity in the dynamics and management of insect pests of tropical irrigated rice: A review. *Bulletin of Entomological Research* 84: 567–587.

Wu, J., Hu, G., Tang, J., She, Z., Yang, J., Wan, Z. and Ren, Z. 1994. Studies on the regulation effect of neutral insects on the community food web in paddy fields. *Acta Ecologica Sinica* 14(4).

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