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Non-Pesticidal Management of Pests: Status, Issues and Prospects - A Review

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ABSTRACT

This review paper attempts to bring various issues in the light of recent developments in eco-friendly pest management approaches. Indiscriminate use of pesticides along with monocropping has resulted in the severe dwindling of natural enemies of pests leading to major pest out breaks. This paper discusses the issues related to pest management and in the process of controlling pest, how farmers entered into debt traps and committed suicides. The key issues emerging include increased inputs costs, yield loss due to pest damage, integrated pest management, access to alternative technologies, importance of traditional knowledge, impact of pesticides on environment and human health. The successful alternative non-pesticidal management methods are highlighted in the paper. There is a strong need of policies for development and promotion of environmental friendly alternatives to pesticides and simultaneously long term research must be conducted on multiple uses of non-pesticidal management approaches.

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Introduction

Green revolution model of agriculture introduced in 1960s focused on high yielding seed varieties (HYVs) and high external inputs, which eventually resulted in monocrops and the chemicalisation. The Green revolution was praised by some because it increased yields for certain period, but it also brought with it poisoning of people and animals, loss of genetic diversity of crops, loss of traditional knowledge and practices, loss of local biodiversity, decline in soil fertility, increased farmers' dependency on inputs with consequent indebtedness, and an increase in the number of people living in poverty in some countries in the region (IAASTD, 2009). The 'high yielding' varieties introduced during the green revolution period had a disastrously eroding effect on agricultural biodiversity (Reddy, 2009). The United Nations' Economic and Social Commission for Asia and the Pacific (ESCAP, 2002) expected that by 2005, India would be producing 75 per cent of its rice from just 10 varieties compared with the 30,000 varieties traditionally cultivated. The modern agricultural farming practices and irrational use of chemical inputs over the last four decades resulted in loss of natural habitat balance, decreased ground water level, soil salinisation, pollution due to fertilisers and pesticides, genetic erosion, ill effects on environment, reduced food quality and increased cost of cultivation, making the farmer poorer from year to year (Balak Ram, 2003).

Globally about 50 percent of all food and cash crops are lost to pre and post harvest pests (DFID, 2001). Even in India, with existing protection levels, based on significant advances in crop protection research during the past 40 years, still about 30% of pre-harvest crop yield worth Rs.45,000 crores is lost annually (Agriculture Today, 2012). The use of pesticides in modern farming practices for higher yield has been viewed as an integral part of the success of the agricultural sector. However, most of the pesticides may affect non-target organisms and contaminate soil and water (Chandrika, 2003). The pesticide consumption in India has increased from 434 metric tonnes in 1954 to above 52,979 metric tonnes in the year 2011-12 (see table.1) covering 30% of cropped area. Today, pesticide consumption in India is less than 1 Kg/ha as against 4.5Kg/ha in USA and 11 Kg/ha in Japan (GoI, 2013a). The indiscriminate use of pesticide has created lot of environmental problems (Rajendran, 2003 and GoI, 2008). According to

Table1: **Consumption of Pesticides (Technical Grade) in India during 1991-1992 to 2012-2013.**

(In ' 000 Tonne)

Year	Consumption
1991-92	72.13
1992-93	70.79
1993-94	63.65
1994-95	61.36
1995-96	61.26
1996-97	56.11
1997-98	52.24
1998-99	49.16
1999-00	46.20
2000-01	43.58
2001-02	47.02
2002-03	48.30
2003-04	41.00
2004-05	40.67
2005-06	39.77
2006-07	41.51
2007-08	44.77
2008-09	43.86
2009-10	41.82
2010-11	55.54
2011-12	52979

Source: Ministry of Agriculture, GoI, 2013.

Mancini *et al.* (2005), in India, 60 per cent of all pesticides are used on cotton crops, which account for only 4 per cent of the total crop area. It is alarming to note that about 17.53% of the total pesticides are used only in Andhra Pradesh and it stands first in the country (see table 2). The states of Uttar Pradesh and Maharashtra stand second and third in consumption of pesticides with 16.68 percent and 12.68 percent respectively. As a result of outbreak of *Helicoverpa armigera* in cotton crop in 1997, large amount of money has been spent on pesticides by farmers and its failure to control pest has landed farmers into debt traps and thereby made them to commit suicide. "On average, one Indian farmer committed suicide every 32 minutes between 1997 and 2005. Since

Table2: State-wise Consumption of Pesticides (Technical Grade) in India during 2011-2012.

State/UT	Metric tonnes	Percentage
Andaman and Nicobar Islands	15	0.02
Andhra Pradesh	9289	17.53
Assam	160	0.30
Arunachal Pradesh	17	0.03
Bihar	655	1.23
Chandigarh	-	
Chhattisgarh	600	1.13
Dadra and Nagar Haveli	-	
Daman and Diu	-	
Delhi	-	
Goa	8	0.01
Gujarat	2190	4.13
Haryana	4050	7.64
Himachal Pradesh	310	0.58
Jammu and Kashmir	1711	3.22
Jharkhand	151	0.28
Karnataka	1412	2.66
Kerala	807	1.52
Lakshadweep	-	
Madhya Pradesh	850	1.60
Maharashtra	6723	12.68
Manipur	33	0.06
Meghalaya	9	0.01
Mizoram	4	0.007
Nagaland	15	0.02
Odisha	555	1.04
Puducherry	38	0.07
Punjab	5625	10.61
Rajasthan	2802	5.28
Sikkim	-	
Tamil Nadu	1968	3.71
Tripura	266	0.50
Uttar Pradesh	8839	16.68
Uttarakhand	206	0.38
West Bengal	3670	6.92
India	**52979**	**100.00**

Source: Ministry of Agriculture, GoI, 2013.

2002, that has become one suicide every30 minutes" (Sainath, 2007). After four years of work by more than 400 eminent scientists, the International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD, 2008) concluded that, if we are to feed the people of the world we cannot continue to practice agriculture as it is being done now: "Business as usual is no longer an option". It has been clearly established that the technological gains from the green revolution technologies have exhausted their potential (Kumar et al., 2008).

Pesticides allow the use of chemical fertilizers that produce soft disease prone plants, and contaminate water ways and ground water. The chemical fertilizers that come with the pesticide package allow the farmer to boost yield without using compost. But the resulting failure to return organic matter to the soil eventually leads to a break down in soil structure and health, build up of diseases and insects, and loss of productivity that enriches the soil, seeds that are naturally resistant, and a greater biodiversity that protects the crops and provides a greater level of overall production (Reddy, 2010c). Similarly, the indiscriminate use of pesticides has led to development of pesticide resistant strains in insects, resurgence of pest species, direct toxicity to the applicator, destruction of parasites, predators and other beneficial organisms, accumulation of pesticide residues in the agricultural commodities, poisoned food, water, air and soil (Watts, 2010). Above all, the process of modernisation of agriculture has made farmer depend on external input which not only increased costs of cultivation but created ecological crisis.

Though pesticides are not used in all the crops, they do occupy major costs in crops like Cotton, Redgram, Chillies, Paddy and Bengal gram etc. Fifty four percent of the total quantity of pesticides used in India is in cotton, with 17% in rice and 13 % in vegetable and fruits (Devi, 2010). Rola and Pingali (1993) found that the costs related to pesticides use in crop production are higher than the gains from the reduction in crop yield losses. Hence, the economic relevance of pesticide application in crop production is a widely debated topic in environmental economics. Interestingly, bio-pesticide use has increased 66 times in India in 10 years -from 123 tonnes in 1994-95 to 8,110 tonnes in 2011-12 and as a result of this chemical pesticide use has declined by one third during this period (GoI, 2013a). Study done by Alam (2000) in India found that for the use of biopesticides, a key problem was that departments promoting Integrated Pest Management (IPM) have very little knowledge and experience of biopesticides, and most state agricultural universities, on whose recommendations pest control methods are promoted, do not tend to recommend biopesticides. In the absence of active promotion by the agriculture department, the demand for these products has not developed, and most private shops and dealers do not stock and sell biopesticides. The same study recommended that the agricultural departments and universities pay greater attention to the promotion of biopesticides, that IPM training is improved, and that there is a greater focus on cropping techniques and varieties which do not require such a dependence on pesticides

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 which call for a change in approach to pest management. Against this background, Non-Pesticidal Management (NPM) of pests has assumed immense significance in the present context. In this paper, an attempt has been made to bring together different issues related to NPM in the light of recent developments at the global, national and state level. This review paper aims to span the issues related to pest management. It examines the status, issues and prospects related in NPM of pests in India. This paper is organized into eight sections including this introductory section. Second section deals with shifting paradigms in pest management. Socio-economic and technological issues related to pest management and discussed in third section. In the fourth section role of institutions is presented. Fifth section highlights the impact of pesticide use on human and environmental health. The performance of IPM/NPM approaches vis-a-vis pesticide is discussed in chapter sixth. Alternative pest management approaches are discussed in seventh chapter and some concluding observations are made in final section.

II Pest management and Shifting Paradigms

2.1 Integrated pest management (IPM)

The dominant paradigm of pest management largely depends on chemical pesticides. Pesticides sprays can only be applied when the pest is in the most damaging stage of its life cycle, mostly the larval stage. Farmers are suggested to spray when the pest population reaches Economic Threshold Level (ETL). That means farmers are trying to control insects when they are in damaging stage and damaging proportion. Indiscriminate use of pesticides causes the development of genetic resistance in the insects and makes the sprays ineffective. The pesticide sprays also tilt the ecological balance in favour of pests by killing the natural enemies (Reddy, 2010a). Therefore the farmer has to increase the dosage more and more and therefore increase in the cost of cultivation.

In response to rising concern about the sustainability of conventional agriculture, the concept of Integrated pest management (IPM) has been promoted by National Centre for Integrated Pest Management (NCIPM). It is an ecological approach to plant protection, which encourages the use of fewer pesticide applications. IPM has no standard definition, but comprises approaches that range from carefully targeted use of chemical pesticides to biological techniques that use natural parasites and predators to control pests (Sorby and *et al.*, 2003). Since chemical pesticides are expensive for poor farmers, approaches like Integrated Pest Management (IPM) offers the prospect of lower production costs and higher profitability (Susmita *et al.*, 2004). On the other hand, replacing chemical products by biological products by itself may not solve the problem without a fundamental change in the perspective or thinking towards pest management (Ramanjaneyulu *et al.*, 2009). The integrated pest management (IPM) initiatives which have come up as alternative though largely debates about the effects of pesticides on human health and on environment still believe that pesticides are inevitable, at least as a last resort. IPM is being promoted by the government of India and state governments primarily through training and demonstrations in farmers field schools, capacity building programmes for extension personnel and support to state governments for setting up of bio-control and bio-pesticides testing laboratory facilities (GoI, 2013b) It can be seen from table 3 that the consumption of pesticides has declined gradually in Andhra Pradesh from the year 2002-03 to 2008-09. This could be due to two reasons. The first reason being that farmers have started reducing the use of pesticides due to debt traps and suicide experiences of other farmers coupled with the active promotion of IPM approach by the state government. Lesser use of pesticides initially on Bt cotton could be second reason. It is interesting to note that despite the use of Bt cotton varieties, data from table 3 during the years 2010-11 and 2011-12 shows that the claims of companies promoting Bt who argue that Bt cotton cultivation will result in less use of pesticides seem to be totally wrong. In fact the quantity of pesticides used has doubled between

Table 3: State-wise Consumption of Pesticides (Technical Grade) in Andhra Pradesh and Maharashtra during the period 2000 to 2012 in Metric tonnes.

Year	Andhra Pradesh	Maharashtra
2000-01	4000	3239
2001-02	3850	3135
2002-03	3706	3725
2003-04	2034	3385
2004-05	2135	3030
2005-06	1997	3198
2006-07	1394	3193
2007-08	1541	3050
2008-09	1381	2400
2009-10	1015	4639
2010-11	8869	8317
2011-12	9289	6723

Source: Ministry of Statistics and programme, Government of India.

the period 2001-02 to 2011-12 with an increase from 3850 metric tonnes to 9289 metric tonnes respectively. Experiences from the field tell us that after the cultivation of Bt cotton, pest load has shifted to other food crops. Despite growing Bt cotton, farmers are still forced to spray pesticides to control sucking pests and diseases other than *Heliothis*, the dreaded boll worm.

It can be found through field experiences that agriculturists adhere to several paradigms. The latest paradigm being the ecology based approach encouraged by Food and Agriculture Organisation (FAO) throughout the world using Farmers Field Schools (FFS) approach. Vasquez-caicedo *et al.* (2000) opined that FFS encouraged farmers to experiment and independently solve their problems through interactive learning and field experimentation with an expectation that these farmers require fewer extension services in future and will be able to adopt the technologies suitable to their conditions. However 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). Unfortunately, proper space was not provided for traditional knowledge and practices or grass root innovations by farmers. Mancini *et al.* (2007) while evaluating the cotton IPM-FFS in Andhra Pradesh reported that farmers' confidence in implementing the new management practices was not strong enough to translate into 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).

2.2 Non-Pesticidal Management (NPM)

Though the pesticides are being encouraged by the industry, public research and extension bodies, there are several successful grass roots experiences emerging from farmers' innovations which call for a paradigm shift in pest management. One such ecological approach is Non-pesticidal management of insect pests. It is a 'system that maintains the insect populations at levels below those causing economic injury, by having healthy crop and managing the population dynamics in the crop eco-system'. It is simply not the superimposition of two or more control techniques but an integration of all suitable management techniques in a harmonious manner with natural regulating and limiting elements of the environment. It is a paradigm shift in moving from input centric model to knowledge and skill based model. It involves making best use of natural resources locally available and takes best advantage of the natural process. There are many alternatives available for managing pests (Kashyap, 1998; Reddy, 1999; Ramanjaneyulu *et al.*, 2009 and Reddy, 2010a). Even if a pest becomes hazard there are far safer alternatives than spreading poison. Though biopesticides represent a very small portion of plant protection at present, their role is considered significant (Rao *et al.*, 2007). Traditionally, farmers have been using several practices to prevent the hazards of pests (Rao *et al.*, 2010). In Andhra Pradesh state, over 3,00,000 farmers have adopted Community Managed Sustainable Agriculture (CMSA) covering 1.36 million acres of farmland and 5.1 percent of the net cropped area in the state in just over last four years (Vijay Kumar *et al.*, 2009). The CMSA approach replaces the use of chemical pesticides with a combination of physical and biological measures including eco-friendly bio-pesticides and complements it by adopting biological and agronomic soil fertility improvement measures leading to reduced use of chemical fertilizers. This paradigm shift at farmer and extension system level helped to tackle the pest effectively giving ample benefits to farmers in terms of savings on inputs cost and health costs. The NPM methods being adopted can give employment to villagers supporting local livelihoods whereas on the contrary the amount spent on pesticides mostly goes to pesticides companies (Reddy, 2010b).

III Socio- Economic and Technological aspects of Pest management

3.1 Inputs

Inputs play a key role in crop cultivation, yields and net returns. Along with seed, fertilizers, irrigation and labour, pesticide is an important input. Quantum of pesticide applied influences the cost of cultivation and there by net returns. It was found that cash return is the strongest motivating factor in cropping and livelihood strategies and hence 'effective' pest management must be a 'cost-effective' option (Sinzogan, 2004). Reduced pesticide application results in lower production costs and increased returns to household labour for the producers. A study reported that the pea yields were 23.4% higher in the IPM plots as compared with control plots (Sullivan *et al.*, 1999). Similar was the finding of Chong (2005) who reported that perceived economic benefits comprised anticipated cost savings resulting from the reduced use of pesticides.

Rao and Mahendra Dev (2009) had done a study in 2004-05 on Socio-economic impact of Bt cotton in Warangal district of Andhra pradesh adopting multi-stage stratified random sampling method (covering 623 farmers) and followed double difference method. Their study revealed that the expenditure on insecticides decreased by 18.2 per cent in Bt cotton over non Bt cotton. However, this decrease in cost of insecticides by Rs 594 was more than matched by the increased costs on seed, labour, fertilizers and irrigation. Contradicting this, Study done in 2006 by Narayanamoorthy and Kamalakar revealed that despite the less need to spray pesticides to BT crop, there was an increase of 34 percent in the cost of cultivation of Bt cotton over non-Bt cotton.

3.2 Yield

Yield is an important parameter in crop production and is some times seriously affected by pest incidence. Study done by Ahmed *et al.* (2004) in chittagong district of Bangladesh assessed farmers' pest control methods and direct yield loss assessment of country bean using qualitative and quantitative data related to parameters such as incidence of insect pests, pest control practices, insecticides used, frequency of insecticide application, waiting period for harvest after insecticide application and healthy yield, infested yield and total yield. The study found that, to manage pests, farmers used both chemical and non-chemical practices. The non-chemical methods comprised the use of ash and hand picking of insect pests. The study found that pod infestation by pod borer and aphids in country bean caused direct yield loss of 76.50 to 273.24kg per hectare.

In a participatory study done with more than thousand farmers in Zanzabir on experiences in adoption of IPM, it was found that there was a yield increase for all the crops with the adoption of IPM practices (Zainab *et al.*, 2010). Snow pea yield were 23.4% higher in the IPM plots on average compared to the control plots (Sullivan, 1999). Production in seven of the nine IPM plots recorded higher yields. Moreover; the product quality was found to be higher in the IPM plots as measured by marketable yield at the shipping point grading facilities. Product rejections at the shipping point averaged 6 % less from the IPM plots. Another study found that the farmers using chemical pesticides affirmed that they would accept to reduction in pesticide use provided they are assured of equal or higher yields (Sinzogan, 2004).

On-farm studies in bio-pesticide front indicated 20-40% increased yields in pigeon pea and chickpea (Rao *et al.*, 2007). The same study also revealed that biointensive cotton IPM crops realized 1-30% and vegetable farmers obtained 72% increased yields through better management of pests and augmenting natural enemies. Contrary to this, was the finding of the study done by Susmita *et al.* (2004) in Bangladesh in 2003. A comparison of IPM and conventional techniques was done using input-use accounting, conventional production functions and frontier production estimation along with farmers' assessment of their own health status and local ecological conditions. All of their results suggested that the productivity of IPM rice farming is not significantly different from the productivity of conventional farming.

Iyemgar and Lalitha (2007) concluded that biotechnology has helped in reducing the yield gap between the actual and the potential yields in cotton by resisting the dreaded American bollworm. Rao and Dev (2009) argued that biotechnology helped in improving the viability of small farmers. They felt that technology was scale neutral and profitable to all groups of farmers. However, the study indicates that farmers perceived research on drought tolerance and open pollinated varieties to be very important. Increasing the yields of crops will not by itself solve the problem of hunger. What matters most is who produces the food, who has access to the technology and knowledge to produce it, and who has the purchasing power to buy it (Pretty and Hine, 2001).

3.3 Size class

Kolawale and Laogun (2005) reported that almost all the farmers belonged to one association or the other which invariably created a suitable environment for social interaction and information exchanges related to agriculture. As the agriculture becomes more commercial, the vulnerability of small and marginal farmers increases with no safety net either locally or from the government during the period of crisis (Vasavi, 1999). In the Gautemalan comparative study (Sullivan *et al.*, 1999) of IPM and control case study plots, most of the farmers belonged to the category of small farmers with less than 0.5 hectares. The study points out that the technical recommendation related to pest management should fit into the real context or that socio-economic interventions need to complement technical research and development (Sinzogan, 2004).

Several constraints hinder the spread of non-pesticidal management approach. In a study done by Sinzogan *et al.*, 2004 on cotton in Benin, farmers mentioned technical, institutional and socio-economic production constraints for low yields in cotton. Technical problems relate to pest damage, low soil fertility and weeds problem, whereas institutional and socio-economic problems relate to delays in payments for seed cotton, low price of produce, expensive inputs, lack of technical assistance, and lack of labour.

3.4 Farmers' perception

Farmers' decision about crop protection may depend, among other factors on their knowledge of and experience with pests and diseases and the damage inflicted to cultivated plants. It is widely accepted that pest management extension will be more robust when farmers' perceptions and practices are taken into account (Heong *et a*l., 2002). Pest resistance was an important varietal characteristic along with drought tolerance and suitability for making special products in determining technology choices (Joshi and Pandy, 2005). They found that traditional varieties were considered superior items of taste by farmers. In a study done by Segura *et al.* in Chipas, Mexico in 2004 regarding farmers' perception, knowledge and management of coffee pests it was reported that farmers had low levels of awareness about the existence of natural enemies, despite the use of ectoparasitoid by substantial number of organic farmers. Study done by Sinzogan *et al.* (2004) on cotton in Benin reported a similar finding saying that only few sample farmers had any knowledge about natural enemies which was acquired through extension courses. This calls for the need to increase the awareness of farmers with respect to natural enemies of crop pests and their role in pest control.

3.5 Technology

Access to better technology helps the farming community to reap better harvests from their agricultural fields. Appropriate technology to manage pest is of paramount importance. Pesticides allow the use of modern 'high-yielding' disease-susceptible hybrid and high yielding seeds that are bred only to increase yield in a one-dimensional sense, e.g. to increase yield of grain at the expense of overall biomass per hectare or total productivity (Watt, 2010). Vasavi (1999) felt that the promotion of commercial agriculture, based on the utilization of hybrid seeds, chemical fertilizers and pesticides, in a pre-dominantly semi-arid region has had several repercussions in the form of loss of land race seeds, depletion of soil fertility and the increase in crop susceptibility to pests and diseases which finally led to lack of fit between the ecological specificity of the region and commercial agricultural practices. Ramanjaneyulu and Kavita (2006) opined that the regulation as well as the marketing of Bt cotton hybrids in India reflects a kind of "uniform application of decision" which is inexplicable. They argued that Genetic Engineering Approval Committee, sitting in Delhi, allows Bt cotton hybrids to be grown in different zones irrespective of the differential base line resistance levels of different bollworms to the Bt toxin, the presence or absence of alternate host crops, relative area of Bt cotton in a given region, the toxicity expressed by particular hybrids. They conclude that all possible safer and effective options have not been assessed before zeroing in on Bt cotton as the answer.

Access to good quality pesticides has always been an important aspect in pest management. The problem of spurious pesticides has become quite prevalent in many parts of the country. In a study done by Vasavi (2009) in Bidar district, farmers complained of sale of spurious pesticides and also large scale dilution of the same. More than 40 percent of the study farmers opined that the efficiency of the endosulfan has reduced as compared to its initial introduction. Farmers cited inefficiency of pesticides as a cause of pest problems (Sinzogan, 2004). The pesticide dealers and agents are required to have licenses and be registered. Many distributors in the village are not licensed. From past two decades we have also witnessed the indiscriminate use of pesticides by farmers. Sinzogan (2004) reported that nearly 70% of the conventional cotton farmers and organic cotton farmers did not respect the number of pesticide applications (including the botanical pesticides).

IV Institutions

4.1 Traditional Knowledge

Historically pests have been managed by farmers using technologies that are based on their knowledge and experience. Traditional pest management practices consist mainly of cultural control methods such as crop associations, planting and harvesting time, crop rotation, closed season, mechanical control, use of biopesticides, and, sometimes, dealing with pests in a supernatural way. Several researchers have reported that traditional control practices are still the major means of pest management to small-scale farmers in India. (Reddy, 1999; Kumar, 2010; purushottam *et al.*, 2009 and Rao *et al.*, 2010). These control practices are based on built-in features in cropping systems, such as soil type, farm plot location, crop rotation, mixed and intercropping, or on specific responsive actions to reduce pest attack, such as timing of weeding, use of plants with repellent or insecticide action, traps and bird perches. However, detailed information on traditional pest management practices widely used by Indian farmers is often lacking. In general traditional agricultural systems are poorly understood (Reddy, 2010c), and it is often not sufficiently recognized that crop protection is a thoroughly tested and built-in process in the overall production system. In principle, farmers have a good ecological understanding of those pests that can easily be observed (Reddy, 2010a). For example, farmers in India were able to develop a control method against the pests which pupate in soil by way of adopting deep summer ploughing practice which exposes these pupae to sunlight and kills them (Butterworth *et al.*, 2003).

Sinha *et al.* (2008) documented the traditional pest management practices of the communities in the six districts of North east India covering 120 villages under North East Region Community Resource Management project. The study meticulously documented the traditional practices and indigenous knowledge systems. Traditional pest management practices included use of crabs as Gandhi bug attractant; citrus grandis as pesticide or repellent; *Bridelia retusa* as predator (bird) attractant and JAM-an indigenous granary. The study pointed out that communities are very innovative in solving their problems in the absence of sufficient external input. Out of the 46 traditional management practices identified, 33 practices were plant based. Communities were very much aware of the resources available around them and are wise in utilizing the resources in a sustainable manner. They had excellent knowledge about different kinds of pests (bugs, beetles, soil borne pests and rats) and the different concepts (attractants, repellents, insecticidal) employed in conventional pest control. This study highlighted how the documentation of traditional practices can be a sound basis for bio-prospecting of sustainable environment friendly pest management methods.

Traditional agricultural systems are finely tuned and adapted, both biologically and socially, to counter the pressures of what are often harsh and inimical environments. Often such systems represent hundreds of years of adaptive evolution (Abatel *et al.*, 2000; NBSAP, 2001 and Reddy, 2009). A longstanding practice in traditional Indian agriculture is growing two or more crops in a given field at a given time (Satheesh, 2002; Poinetti, 2006 and Reddy, 2011). Farmers use well-adapted crop species in mixtures that are generally more stable than those in pure stands. This practice, although discouraged in favor of mono cropping practices, better meets the agronomic, socio-economic, pest and disease management and nutritional needs of the small and marginal farmers. This includes better food security, optimal use of soil and space, maintenance of soil fertility; especially where intercropping involves leguminous species, better erosion control, and reduction of the need for weeding (Reddy, 2010c). There are also several advantages from the point of pest control (Reddy, 2010b). Pest and disease incidence is reduced and natural enemy abundance favored (Poinetti and Reddy, 2002; Reddy, 2010c and Reddy, 2010d),

Farmers in India also use the practice of diversionary hosts by sowing trap crops such as marigold in redgram and cotton so as to reduce economical damage to main crops (Reddy, 1999 and Reddy, 2010a). In African countries, adjusting planting or harvesting time to escape pest damage is the most important means of keeping pest damage below economic threshold levels. For example, early planting is perhaps the most effective means of control against stem borers on sorghum and maize in many parts of Africa and is widely practiced by farmers (Gebre *et al.*, 1989 and Abate, 1998). Pigeon pea farmers in Medak district of Andhra Pradesh hand pick important pest like *Heliothis* (Reddy, 2010a) larvae and ground nut farmers of Anantapur set bonafires to lure and burn red hairy caterpillar moths (Reddy, 2010b).

In a Bangladesh study done in 2004 with 139 IPM farmers and 689 chemical pest control farmers, Susmita et al. reported IPM techniques such as manual removal of pests (70 % sample), use of natural parasites and predators (58%), light traps (14%), crop rotation (10%) and smoke (5%). All of the surveyed IPM farmers have received formal training from Agriculture Ministry officials. The farmers attributed their adoption of IPM to Ministry officials 'recommendations (41%); cost-saving from reduced pesticide use (33%); environmental benefits (12%); and improved health (6%). About 52% reported increased output; and reported pesticide use fell by 67%. In a study done by Ahemed *et al.* (2004) in Pakistan reported that farmers used fanfan, Nogos, Ripcord, Malathion, Roxion and Sumithion as chemical methods and applying ash and hand picking of insect pests as non-chemical method to control insect pests.

Farmers of certain ethnic groups have a thorough knowledge of the history, biology and biomics of a variety of insect pests (Altieri, 1990). In West khasi Hills and West Garo Hills of Meghalaya in North east, Sinha *et al.* (2004) documented several pest management practices to control pests and diseases. These include mixture of cow dung, cow urine, chilli and garlic; twigs and leaves of Pinus kesiya; use of local crabs to control insect pests of paddy and vegetables; silk worm excreta to control insect pests; raw blood of cow to control bird pests; use of "Re'not-bol' and citrus grandis as pesticide; use of fruits belonging to plants such as *Sapium baccatum roxb., Dendropthoe falcate*(L) Elting, *Morus macroura* Mig and *Bridelia retusa* to attract insect predators; use of mixture of Garlic and Ginger to control pests of paddy; use of neem and *Cannabis sativus* leaves to protect crops from pests; use of 'lime' to control worms damaging pests; use of chilli to repel paddy pests; use of *Dendrocnide sinuate* leaves to control rats; use of *Entada purseatha* seeds to control rats; using Indigenous store house for grains; use of household ash to protect crops; indigenous traps for rats; Scare crows sound creating devices to protect crops and traditional storing of maize, beans and local onion. It becomes apparent from the practices that the communities are very much aware of the plant resources available around them and are wise in utilizing the resources in a sustainable manner. This is evident from the fact that out of 23 practices documented more than 50 per cent are plant based. Similarly, the methods of attracting natural pest predators highlight their understanding of the principles of food web linkages in their indigenous ways. Therefore, it is urgently needed to have a proper documentation of such practices of all the communities in India.

Presently, the interest in indigenous knowledge research is increasing globally and the contribution of every community to this global knowledge respected. All the nations are recognizing this resource generated by their own citizens. "Regardless of the degree to which they have embraced modernity, local people continue to prefer concrete knowledge, which belongs to them in time and space, and which they deem suitable for particular purposes" (Kolawole, 2005).

4.2 Information/Training

Right kind of information on various aspects of farming is needed for farmers. Little and *et al.* (2000), found that access to information is a key factor in farmer decision making. Availability and variety of sources of information, their reliability and farmers' confidence in them are issues which research and intervention projects need to take into account. Study also pointed out that context affects farmers' priorities and decision criteria, their access to sources of information and advice, and the availability of inputs. In Mekong Delta, the introduction of insecticide reduction interventions such as media campaign to motivate farmers and implementation of Farmers Field School has resulted in reduced spray frequencies of 3.4 to 1.0 spray per season (Huan *et al.*, 1999). In a Kenyan study (little *et al.*, 2000) it was found that those farmers who are not trained in FFS felt that pesticides are necessary to produce a profitable crop contrary to this FFS trained farmers were confident in their pest management capability and relied more on their own knowledge or on their group to solve pest related problems.

4.3 Grass roots Institutions

Little and *et al.*(2000) has taken up a study in India (on cotton) and Kenya (vegetables) with an objective of synthesizing current knowledge on farmer decision-making processes and also to develop and test methodologies for exploring pest management decision-making. This study used a combination of participatory tools: causal diagrams, participatory budgeting and semi-structured interviews. The focus of the exploratory field work was on the dynamic decision- making 'processes' rather than the decision 'event'. The absence of strong representative institutions at the village level inhibits local initiatives that could anticipate and contain the problems such as farmers' suicide (Vaidynathan, 2006 and Sarma, 2004).

V Health

5.1 Human Health

There are two types of health effects resulting from exposure to pesticides: acute and chronic. Acute poisoning has generally been the most recognized form of effects. These days chronic poisoning too is gaining attention. Added to this, pesticides also aggravate existing medical conditions, both acute and chronic such as asthama and allergies, heart and immune system disorders. For 25 years, the insecticide endosulfan was aerially sprayed over cashew nut plantations in Kasargod District of Kerala. People residing in the villages within the plantation experienced an unusually large number of serious neurological, developmental, reproductive and other diseases, including cancer. Watts (2010) found that out of 197cases documented, from only 123 households in kasargod, incidence of high levels of cancer, cerebral palsy, mental retardation, epilepsy, congenital anomalies and psychiatric disorders were seen. The cancers reported included abdominal, uterine, liver, and neuro blastoma. Serious growth retardation and delayed psychomotor development have also been reported. Endosulfan is a known neurotoxicant, blocking inhibitory receptors of the central nervous system and destroying the integrity of nerve cells. It is also a known endocrine disruptor, is mutagenic and causes chromosomal aberrations. Based on self-reported health effects, the Bangladesh study revealed that among conventional farmers, 37% reported frequent health problems such as eye irritation, headaches, dizziness, vomiting, and shortness of breath, skin effects, and convulsions. While among IPM farmers, 29% reported similar health problems. Of these, 54% reported that the health of the laborers working in their field's improved after they switched to IPM.

Chitra *et al.* (2006) in their study in Tanzavur district of Tamil nadu found that 88 percent sprayers did not take necessary personal protective measures while handling pesticides. In Andhra Pradesh state of India 71 per cent of respondents indicated that while spraying pesticides they wore long-sleeved shirts but some also informed that they wore the same clothing for 2-3 days. Similarly in Andhra Pradesh 42 percent of farmers said pesticide protection equipment (PPE) was expensive and 31% said it was

Table 4: Pesticide poisoning cases in India during the years 2000-2009.

State/UTs	Number of poisoning cases
Andaman & Nicobar Islands	69
Andhra Pradesh	564
Arunachal Pradesh	
Assam	2
Bihar	NIL
Chandigarh	NIL
Chhatisgarh	4
Dadra & Nagar Haveli	9
Dadra & Nagar Haveli	NIL
Daman & Diu	NIL
Delhi	17
Goa	NIL
Gujarat	7
Haryana	2453
Himachal Pradesh	465
Jammu & Kashmir	303
Jharkhand	992
Karnataka	NIL
Kerala	12256
Lakshadweep	NIL
Madhya Pradesh	NIL
Maharashtra	37943
Manipur	NIL
Meghalaya	NIL
Mizoram	NIL
Nagaland	NIL
Orissa	28
Pondicherry	7193
Punjab	3058
Rajasthan	2215
Sikkim	NIL
Tamil Nadu	212
Tripura	NIL
Uttaranchal	470
Uttar Pradesh	3325
West Bengal	324
India	71909

Source: Ministry of Agriculture, GoI, 2010.

not available where as in Orissa state, 80 percent of non-wearers indicated that PPE was not available (Pesticide Action Network, 2010). Study done by Mekonnen and Agonafir (2002) in Ethiopia clearly brought out the need for safety education, provision of better facilities, appropriate pesticide protection device and improved hygiene and sanitation for pesticide sprayers. The survey done in 2001-2002 on the traditional pest management practices of the Khasis and the Garos, the two dominant tribal communities of Meghalaya, inhabiting West Khasi Hills and West Garo Hills districts found that 75 per cent of farmers used "moderately Hazardous" to "Highly Hazardous pesticide" (Sinha *et al.*, 2004). But WHO recommends that hazardous pesticides should not be used and moderately hazardous pesticides should be avoided. North east study also found that most of the farmers were unaware of the health hazards caused by inappropriate handling of pesticides. A study in India found that 97 percent of farmers in Orissa and 71 per cent in Andhra Pradesh stored their pesticides at home (Pesticide Action Network, 2010). Same study also found that in Andhra Pradesh over a quarter of respondents did not observe any particular safeguards in storage, but others indicated that they were locked up out of reach of children, and separated from other item.

Pesticide poisoning is a major problem in India. The use of pesticides and its handling while use impacts the health of the farmers. Pesticides poisoning to human beings through exposure to the toxic fumes while spraying is lesser known and lesser acknowledged aspect of pesticide abuse in places like Warangal district of Andhra Pradesh (Kavitha, 2005). A study done by Rao *et al.* (2005) in Warangal district of Andhra Pradesh revealed that during the period 1997 to 2002, 8040 patients were admitted to the hospital with pesticide poisoning out of which 22.6 percent died. Two thirds of the patients admitted to hospital were less than 30 years old. Two compounds monocrotophos and endosulfan accounted for the majority of the deaths with known pesticides in 2002. Low-income marginal farmers were more often subjected to severe poisoning than landlords (Mancini *et al.*, 2005). It can be seen from table 4 that between the years 2000-2009 in India, state of Maharashtra has registered highest (37943) poisoning cases followed by Kerala (12256). Despite standing first in terms of pesticide use in the country, state of Andhra Pradesh has registered only 564 cases during the same period.

5.2 Environmental Health

Pesticide contamination poses significant risks to the environment and non- target organisms ranging from beneficial soil microorganisms, to insects, plants, fish and birds. The best way to reduce pesticide contamination (and the harm it cause) in our environment is to use safer, non-chemical pest control (including weed control) methods (Akhtar, 2008). Environmental effects reported from the Kasargod district in India, where many villagers are ill from aerially applied endosulfan, included formed calves and disappearing honeybees. Chickens, jackals, frogs, birds and cows have all died. Calves have stunted growth. Miscarriages, bleeding, infertility and deformities in domestic animals have been reported. Ina study done by Quean (2002), high levels of endosulfan have been found in soil, water and plant tissues.

Kavita (2006) brings out the dual standards of regulators of genetic engineering in the country. She points out that when it comes to Bt plants impacts on soil health, the regulators believe the company's argument which says that there has been no persistence of the toxin or presence of the toxin found in their studies which is quite contrary to the findings of other studies elsewhere which show that the toxin leaves its impact on the soil. Similarly, there are no studies mandated which, for instance, look at the effect of a Bt crop on the subsequent crop, over a three to five year period. She also highlights in her paper that there is no coherent policy in India to debate and take technological decisions related to genetically modified crops.

Biodiversity performs a variety of renewal processes and plants provide services in these agro ecosystems. The diversity of crops and wild plants provides vegetative cover which prevents soil erosion, regulates the water balance and nutrient cycling and aids in the control of the abundance of undesirable organisms (Poinetti and Reddy, 2002; Alteiri and Letourneau, 1982). Certain existing crop mixtures contain built-in elements of pest control, such elements should be identified and then retained in the course of modernization (Altieri, 1993; Poinetti, 2006). Researchers say that when the natural services are lost, due to biological simplification through adoption of monocultures or use of high-input technologies, social, economic and environmental costs can be quite significant. Similarly, Soil fertility management can have several effects on plant quality, which in turn, can affect insect abundance and subsequent levels of herbivore damage (Altieri and Nicholos, 2003). Awareness of health and food safety issues among developing country consumers is also increasing, resulting in higher demand for organic and pesticide free produce (World Bank, 2005).

VI IPM / NPM Vis-a-Vis Pesticides

Pesticides allow the use of inorganic fertilizers that produce disease prone plants, and pollute waterways and groundwater. The inorganic fertilizers that come with the pesticide package allow the farmer to increase yield without using compost. But the resulting failure to return organic matter to the soil eventually leads to a break down in soil structure and health, a buildup of diseases and insects, and a loss of productivity (Watt, 2010). In a study in Uganda by Mark *et al.* (2003), both men and women had favourable attitudes about pesticides indicating that they would like to use more of them. However, men had slightly more favourable attitudes about pesticides than women. The main implication of this study is that gender based knowledge and perceptual differences need to be assessed and incorporated into agricultural research and extension program delivery if these programs are to have meaningful and sustainable impacts.

A baseline survey was done by Sharifi *et al.* (2008) to assess integrated pest management rice farming practices in Marvdasht county of Iran with an objective of identifying the respondents socio-economic characteristics, identify and prioritize existing IPM practices used by farmers and also to identify the rice grower's perceptions and attitudes towards IPM. The farmers were asked to rank the 23 IPM mechanism being followed in rice on a continuum of 0 to 10 point scale. Notable thing was that the respondents were encouraged to add to the list of IPM practices mentioned in the questionnaire. This study revealed that the farmers felt that the heavy pesticide use was very effective to control and eliminate pests. However, the correlation analysis for IPM components revealed that tendency to consumption of pesticides was negatively and significantly correlated with optimal cultural practices, biological and mechanical practices. Contrary to this, in a study done in Gautemala highlands (Sullivan *et al.*, 1999), the insect and disease incidence was similar in both the IPM and control case study test plots of snow pea (*Pisum sativum*). However, Pesticide applications in the IPM plots were significantly reduced, averaging about one-third of the number of applications in the control plots. The study reported that the IPM plots required an average of only 3.7 pesticide application to fully achieve pest management objectives, while the traditional chemical control plots required an average of 10.4 pesticide applications to achieve the same objectives. Application reduction resulted in lower production costs and increased returns to household labour for the producers. In addition to this, the quality of the pea produced was found to be higher in the IPM plots as measured by the marketable yields at the shipping point grading facilities. The product rejections at the shipping point averaged 6% less from the IPM plots (Sullivan *et al.*, 1999). In another study, conventional farmers use an average of 2.33 kg of pesticides per acre, while IPM farmers use 0.77 kg/acre (Susmita *et al.*, 2004). Interestingly, farmers using chemical pesticides affirmed that they would accept to reduction in pesticide use, provided they are assured of equal or higher yields (Sinzogan *et al.*, 2004).

The type of cropping systems also influences the pest incidence and management. Monocropping systems that are convenient for pesticide sprays are attractive to pests and encourage erosion through use of herbicides to remove so called weeds which otherwise hold soil in place, provide habitat for beneficial insects, and feed people (Watts, 2010). "However, the underlying principal of land utilization is to mimic the community ecosystem and therefore capitalize on nature's own superior design for light and nutrient capture, pest control and soil and water conservation" (Osunade, 1996).

An all-India survey confirmed that 34% of the respondents as having no idea about IPM and only less than 5% of them as following complete IPM technology (Shetty *et al.*, 2008). From last one decade use of biopesticides has increased in pest management. As per Rao *et al.* (2007) there are several reasons for low uptake of biopesticide science. These include: it is knowledge intensive, needs more time to understand the effectiveness; requires specialized job of intensive pest monitoring, which is a pre-requisite for decision making at farm level and hence farmers considered it as impractical; some farmers felt that they did not have time to keep a close watch on their fields to monitor pests and their natural enemies to calculate economies to calculate economic thresholds. Similarly, Rao *et al.* reported that farmers have several misconceptions about bio-pesticides such as they are less effective, costly, difficult to produce, not compatible with other option; most importantly, in general, the extension programs have very little Knowledge and experience of biopesticides. However, Reddy (2010b) reported the use of several kinds of bio-pesticides by organic farmers in Anantapur district of Andhra Pradesh. The new research is showing that the ability of a crop plant to tolerate insect pest and disease is tied to optimal physical, chemical and mainly biological properties of soils. Soils with high organic matter and active soil biology generally exhibit good soil fertility as well as complex food webs and beneficial organism that prevent infection. On the other hand, farming practices that cause nutrition imbalances can lower pest resistance (Magdoff and Van Es, 2009).

VII Alternative Pest Management Methods

7.1 Need for alternatives

The failure of pesticides to control the pests totally, has forced the people to scout for alternatives. National food security summit organized by the M.S.Swaminathan Foundation in collaboration with the UN world food programme in New Delhi in the year 2004, made the ecological security and the need to sensitize communities on biodiversity as important recommendations out of the ten recommendations they made (Krishnaraj, 2006). Increasing difficulty in controlling *H.armigera* on cotton in recent years has heightened the need to develop and adopt alternative, non-chemical pest management techniques. Obopile and Mosinkie (2007) concluded that the research on *H.armigera* should centre on developing an intergrated pest management programme with emphasis on pest population monitoring, enhancing natural enemies, use of pathogens of *H.armigera*, host plant resistance, cultural methods, and minimal use of insecticides. They also found that ploughing in of late maturing crops in winter increase the mortality of any pupae formed in cropland by exposing them to heat and predation. The other cultural control method is early planting which avoids the seasonal peaks of population that occur late February to March thereby avoiding very heavy larval infestations and reducing the over-wintering population. At this time the infestation is mainly eggs and young larvae which are easier to control.

Infact in 2004, a village called Punukula in Palvancha mandal becomes the first in the state of Andhra Pradesh to completely implement non-pesticidal practices. In this village, a large section of farmers have given up use of pesticides entirely, letting natural enemies of pests save their crops (Down to Earth, 2006). However, the state agricultural university and the agricultural department of A.P did not get influenced much with this dramatic story. It's seems NPM has hit the right chord with all- except the state agriculture university and the agriculture department that runs on its advice. How long will they stay away from such a dramatic success story?. Despite bio-pesticides providing environmentally friendly alternative to chemical insecticides, still face a number of constraints such as constraints in their development, manufacture and utilization; lack of effective multidisciplinary research, poor public sector industry linkage and little understanding of quality of the product; lack of education and awareness of bio-pesticide among farmers, extension and policy makers and lack of effective regulations to promote quality biopesticides.

7.2 Innovative approaches to alternative pest management

Since 2007, in the state of Andhra Pradesh in India, an alternative approach to green revolution based agriculture called Community managed sustainable agriculture (CMSA) is being tested and practiced. This approach replaces the use of chemical pesticides with a combination of physical and biological measures including eco-friendly bio-pesticides and complements it by adopting biological and agronomic soil fertility improvement measures leading to reduced use of chemical fertilizers (Vijay Kumar *et al.*, 2009). Over 3 lakh small and marginal farmers have adopted CMSA covering 0.54 million hectares and 5.1 percent of the net cropped area in Andhra Pradesh. Initial results from CMSA in Andhra Pradesh show a significant net increase in farmers' incomes in addition to significant health and ecological benefits. The guiding principles of CMSA include observation and documentation of pest and predator behaviour, pest incidence on the farms; replace chemical pesticides with physical methods of pest management complemented by botanical formulations and bio-pesticides; manage pest populations rather than eliminating pests; focus on balancing predator and pest populations; enhance and maintain soil health; reduced use of synthetic fertilizers; increased crop diversity; preserve and maintain local varieties and crop genetic diversity. CMSA uses an institutional platform of community organizations and their federations to plan, implement, manage and monitor the program and provide a single window approach for delivery of livelihood improvement services and enterprises, exclusively for small-farm holders. The environmental benefits from Sustainable agriculture include better soil health, conservation of agro-biodiversity, fewer pesticide related health problems and small carbon foot prints. CMSA approach challenges the dominant high input subsidized model for agricultural inputs and relies more on the efforts of communities. This triggers a debate on the new paradigm for rainfed agriculture of small holders.

VIII Conclusions

Based on the literature we can conclude that there is a need to have a community centered, biodiversity based non-pesticidal management approach. Several studies have revealed that the adoption of non-chemical methods of pest control or Integrated management of pests has clearly resulted in economic, health and environmental benefits for rural communities. To protect people and environment from pesticides there is a need to shift from chemical based agriculture to an agriculture that embraces ecological practices, traditional knowledge and farmer's rights especially that of women (Watts, 2010). A holistic, systems-oriented approach is needed, with farmers empowered to innovatively manage soils, water, biological resource, pests, disease vectors, genetic diversity and conserve natural resources in a culturally appropriate manner. Review calls for a strong policy support to the development and promotion of environmentally friendly alternatives to pesticides. Similarly, long term research must be conducted on the multiple utilities of non-pesticidal management approach.

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