# Status of Integrated Pest Management (IPM) in SAARC Countries

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# PREFACE

Integrated Pest Management (IPM) has become very popular during the last two decades particularly in South Asian countries because it calls for the reduction of indiscriminate use of chemical pesticides. IPM is an environment friendly approach to pest management. It is also an important component for Good Agricultural Practices (GAP).

In 2007, an attempt has been made by the SAARC Agriculture Centre to compile all the available information on IPM activities of its member countries in one document. The main objective of the compilation is to share IPM related information of the member countries among their IPM researchers and field practioners. The compilation also provides name and address of persons involved in IPM activities which will serve as a directory of IPM workers in the member state.

The compilation has six chapters and each chapter is a country report of member state except Maldives and Afghanistan. There was one focal point scientist in each of the member state and they were responsible for writing the country report. The country report basically contains the research and extension activities on IPM. It also provides some information on the commitment on IPM by the respective country.

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**Dr. Wais Kabir**
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Chapter 1

# Bangladesh

# Integrated Pest Management Activities in Bangladesh

Awwal Ahmed

## INTRODUCTION

Bangladesh lies in the northeastern part of South Asia between 20$^{o}$34' and 26$^{o}$38' north latitude, and 88$^{o}$01' and 92$^{o}$41' east longitude. The country is bounded by India to the west, the north, and the northeast and Myanmar to the southeast and the Bay of Bengal to the south. The area of the country is 56, 977 sq. miles or 1,47,570 sq. km. The limits of territorial waters of Bangladesh are 12 nautical miles and the area of the high seas extending to 200 nautical miles measured from the base lines constitutes the economic zone of the country.

Except the hilly regions in the northeast and the southeast, some areas of high lands in the north and northwestern part, the country consists of low, flat and fertile land. A network of rivers of which the Padma, the Jamuna, the Teesta, the Brahmaputra, the Surma, the Meghna and the Karnaphuli are important, and their tributaries numbering about 230 with a total length of about 24,140 km. covering the country flow down to the Bay of Bengal. Heavy silts deposited by rivers during the monsoon season are thus continuously enriching the alluvial soil.

Bangladesh enjoys generally a sub-tropical monsoon climate. While there are six seasons in a year, three namely, winter, summer and monsoon are prominent. Winter, which is quite pleasant, begins in November and ends in February. In winter, there is not usually much fluctuation in temperature which ranges from minimum of 7-13$^{o}$ Celsius (45-55$^{o}$F) to maximum of 24-31$^{o}$ Celsius (75-85$^{o}$ F). The maximum temperature recorded in summer months is 37$^{o}$ Celsius (98$^{o}$ F) although in some places it occasionally rises up to 41$^{o}$ Celsius (105$^{o}$ F) or more. Monsoon starts in July and stays up to October. This period accounts for 80% of the total rainfall. The average annual rainfall varies from 1,429 to 4,338 millimetres. The maximum rainfall is recorded in the coastal areas of Chittagong and northern part of Sylhet district, while the minimum is observed in the western and northern parts of the country.

Agriculture is the main economic backbone of Bangladesh, which contributes about one third to the country's gross domestic product (GDP). Approximately 84% of the country's total population is directly or indirectly dependent on agriculture for their livelihood. Crops form the largest sub-sector of agriculture, contributing about 22 % GDP. About 63% of the labour force is employed in agriculture sector of which about 57% are employed in the crop sub-sector alone. The country has a total area of 147,570 square kilometers with a population of 134 million. Its average population density of about 850 per square kilometre is probably the highest in the world. To feed the ever-increasing population it is dire necessity to increase crop production. With limited land area, horizontal expansion is rarely possible, but increase in crop production is still possible with vertical expansion through increasing crop yield per unit area.

One of the main constraints to increasing crop production is the pests. The word "pest" refers to organisms such as insects, pathogens, weeds, nematodes, mites, rodents and birds that cause damage or annoyance to man, his animals, crops or possessions. According to an estimate, annual yield loss due to insect pest alone is 16% for rice, 11% for wheat, 20% for sugarcane, 25% for vegetables, 15% for jute and 25 % for pulse crops. To increase production it is necessary to minimize the crop losses and other constraints to production (i.e. good seed, soil fertility, cultivation practices, water management etc.). This needs to be addressed to increase crop production.

The overall objective of the National Agricultural Policy (NAP) is to make the country self sufficient in food through increasing crop production and ensuring a sustainable food security system. To this effect, the Department of Agricultural Extension (DAE) has prepared a Strategic Plan for 2002-2006. The plan has five general objectives and one of them is to increase agricultural productivity. Therefore, to increase crop production it is imperative to reduce the crop loss caused by pests.

In Bangladesh, chemical control has been the principal method of pest control. Although pesticides may provide temporary relief from pest problems, long-term dependency on pesticides is not desirable. It is now widely accepted that indiscriminate use of pesticides not only creates serious environmental and human health problems but also promotes development of pest resistance to insecticides, destroys beneficial insects, upsets the balance between the pests and their natural enemies leading to the increase in the population of the target pests and even the creation of new pest problems. To avoid such consequences and at the same time to increase the crop production on a sustainable basis, a viable alternative to sole dependence on pesticides for pest management is needed. Integrated pest management (IPM) is considered as the best alternative strategy (Alam, 2007).

## MAJOR CROPS GROWN AND CROP LOSSESS

Agriculture is the main occupation of the people, employing 68.5% of the labour force. This sector directly contributes around 25% to the gross domestic products (according to revised GDP series based on 1995-96 price). Bangladesh has one of the most fertile lands but due to paucity of capital and lack of knowledge of new inputs and technology its yield per unit area is one of the lowest in the world. Rice, wheat, jute, sugarcane, tobacco, oilseeds, pulses and potatoes are the principal crops. Various kinds of vegetables and spices are also produced. The country produces about 51 million kg of tea per year, a sizeable quantity of which is exported to foreign markets after meeting the internal demand.

Bangladesh produces about 1,057 thousands M. Ton of superior quality jute annually and 16% of the export earning come from raw jute and jute manufactures. Among the fruits and nuts grown in Bangladesh bananas, papayas, pineapples, mangoes, jackfruits, guavas, plums and cocoanuts are important. Except cocoanuts, bananas and papayas, which are grown and available throughout the year, others are seasonal. Table 1 presents the area under different crops.

**Table 1. Area under different crops, 2004-05**

| **Crop** | **Cultivable area („000" ha)** | **% of cultivable land** |
|---|---|---|
| Rice | 10369 | 77.68 |
| Wheat | 558 | 4.18 |
| Jute | 391 | 2.92 |
| Oilseeds | 348 | 2.60 |
| Pulses | 383 | 2.86 |
| Vegetables | 292 | 2.18 |
| Potato | 326 | 2.44 |
| Spices and Condiments | 302 | 2.26 |
| Fruits | 139 | 1.10 |
| Tea | 53 | 0.39 |
| Sugarcane | 157 | 1.17 |
| Tobacco | 30 | 0.22 |
| **Total** | **13348** | **100** |

*Source* : BBS. 2005. Planning Division, Ministry of Planning, and Govt. of the People's Republic of Bangladesh.

Bangladesh is marginally deficit in food grains. The Government and the people are making all out efforts to increase the production of food grains and diversify agricultural output.

**Rice.** The scientists of the Entomology Division, Bangladesh Rice Research Institute, Gazipur have so far identified 175 insects of rice crop (BRRI, 1985). Among these insects, 15 are considered major threats to rice crop. These are stem borers, hispa, brown plant hoppers, white-backed plant hoppers, green leafhoppers, rice bugs, swarming caterpillar, ear-cutting caterpillar, case worms, gall midge, mealy bugs, thrips, leaf rollers, long-horned cricket and grasshopper. The average yield loss due to the infestation of major insect pest amounts to 13%, 24% and 18% during Boro, Aus and T. Aman season, respectively and the average is about 18% (Alam *et. al.*, 1981).

Among the 31 rice diseases so far identified, ten are considered as major (Miah and Shahjahan, 1987; Karim *et al.*, 1994; Anon., 1995). The major diseases of rice are tungro, bacterial leaf blight, blast, ufra, sheath blight, sheath rot, stem rot, leaf scald, brown spot, bakanae and foot rot. Quantitative data on losses due to rice diseases have not been available either on a regional or country basis in Bangladesh. About 10-15%, yield losses of rice due to diseases were reported (Chakrabarti *et al.*, 1998). Crop losses of more than 35% or even 80-100% for a single disease, especially in case of rice were recorded in certain years and in certain places in farmers' field conditions in Bangladesh (Shahjahan, 1993).

Rat, the main vertebrate pest of rice, considerably damages rice particularly the deepwater and transplanted Aman rice. The greater bandicoot rat (*Bandicota indica*) and the lesser bandicoot rat (*Bandicota bengalensis*) are the major damaging species. Rodents cause about 5% of the losses in yield, especially to deepwater and transplanted Aman rice. Table 2 gives a list of major pests of rice.

**Table 2. Major insects (15), diseases (10) and rodents (2) of rice in Bangladesh and their nature of damage.**

| Common name | Scientific name | Nature of damage |
|---|---|---|
| | **Insects** | |
| Yellow stem borer | *Scirpophaga incertulas* (Walker) | Caterpillars bore into stem resulting dead heart at the vegetative stage and white head at the later stage. |
| Hispa | *Dicladispa armigera* (Olivier) | Grubs mine into leaf and adults make transparent parallel patches on leaf feeding on chlorophyll |
| Brown plant hopper | *Nilaparvata lugens* (Stal) | Nymph and adult suck sap from leaf and shoot. |
| White-backed plant hopper | *Sogatella furcifera* (Horvath) | |
| Green leaf hopper | *Nephotettix virescens* (Distant) | |
| Bugs | *Leptocorisa acuta* (Thunberg) | Nymph and adult suck milky juice from immature grains of ear. |
| Swarming caterpillar | *Spodoptera mauritia* (Boisduval) | Larva feeds on leaves |
| Ear-cutting caterpillar | *Mythimna separata* (Walker) | Caterpillars cut ripen ears |
| Case worm | *Nymphula depunctalis* (Guenee) | Caterpillars cut leaf and make cases feeding inside |

| Common name | Scientific name | Nature of damage |
|---|---|---|
| Gall midge | *Orseolia oryzae* (Wood-Mason) | Larvae make leaf-gall feeding inside |
| Mealy bug | *Brevennia rehi* Lindinger | Adult and nymph suck sap from plants |
| Thrips | *Frankliniella intonsa* (Trybom) | Nymphs and adults lacerate tissues; affected leaves present yellowish streaks, tips curl and wither |
| Leaf roller | *Cnaphalocrocis medinalis* (Guenee) | Folds leaves and feeds on chlorophyll |
| Skipper | *Pelopidas mathias* (Fabricius) | Caterpillars feed on leaf |
| Grasshopper | *Oxya velox* (Fabricius) | Nymph and adult feed on leaf |
| **Diseases** | | |
| Tungro Virus | *Rice tungro virus* | Stunting and faint mottling occur on the interveins of lower leaves. The older leaves turn yellow orange and then the leaves die |
| Bacterial leaf blight | *Xanthomonas oryzae* | Water soaked, translucent lesions appear on edges near the tips of leaves, which turn yellow to white, the leaf dies |
| Blast | *Pyricularia grisea* | Brown spindle shaped lesions on leaves, stem and grains darker, rotting of neck, dropping of ears, nodes discoloured, affected grains partially filled |
| Ufra | *Ditylenchus angustus* | Eel worms suck the juice of the tender growing parts of the rice plant, brown spots arise on the leaf sheath,ultimately the whole plant dies and rot in water |
| Sheath blight | *Rhizoctonia solani* | Lesions, white, dark-brown margin on leaf sheath, leaf blade dries up from tip downwards, poor filling of grains. |
| Sheath rot | *Sarocladium oryzae* | Dark brown,circular or irregular spot in the sheath covering the panicle. |
| Stem rot | *Sclerotium oryzae* | Yellowing and death of leaves, stem, roots completely and plant dies. |
| Leaf scald | *Gerlachia oryzae* | Lesions appear on leaf tips, the whole leaf dries up. |

| Common name | Scientific name | Nature of damage |
|---|---|---|
| Brown spot | *Drechslera oryzae* *Bipolaris oryzae* | Small brown spots appear after infection, the entire leaf sometimes withers and dries, deep brown or black spots appear on the grains. |
| Bakanae and foot rot | *Fusarium moniliforme* | Elongation of some plants, affected plants are pale green, outermost leaves turn brown and die, plants become slender and weak and die in a week. |
| **Vertebrate pest (Rodents)** | | |
| Black field rat | *Bandicota bengalensis* | Rats make burrows and long tunnels and cut the ripe ears of rice and take them into the burrows of tunnels causing huge loss |
| Big black field rat | *Bandicota indica* | Rats make burrows and long tunnels and cut the ripe ears of rice and take them into the burrows of tunnels causing huge loss |

**Sugarcane.** In Bangladesh, sugarcane occupies about 0.17 m ha both in mill and non-mill zone areas, producing on an average 0.15-0.20 m ton of white sugar and 0.35-0.40 m ton of gur (brown sugar) annually. The average yield of sugarcane in Bangladesh is very low, compared to other sugarcane growing countries of the world. Various factors are responsible for low yield of cane. One of the most important factors is the insect pest and disease infestation. So far, about 70 insect pests, 2 mites and 40 diseases have been identified and reported to feed on sugarcane seriously damaging the crop in Bangladesh. Out of these, 14 insects, 2 mites and 7 diseases are considered as major problems. Insect pests alone damages 20-60% sugarcane (Alam, 1967). According to different survey reports, losses due to these pests are 10-20%. Table 3 presents a list of major pests of sugarcane in Bangladesh.

**Table 3. Major insects (14), mites (2) and diseases (7) of sugarcane in Bangladesh and their nature of damage.**

| Common name | Scientific name | Nature of damage |
|---|---|---|
| **Insects** | | |
| Top shoot borer | *Scirpophaga excerptalis* Walker | Larva bores into the top shoot. |
| Stem borer | *Chilo tumidicostalis* Hampson | Larva bores into the stem. |
| Early shoot borer | *Chilo infuscatellus* Snellen | Larva bores into the stem of 1-3 months old crop and causes dead heart. |
| Pink borer | *Sesamia inferens* Walker | Larva bores into the stem. |
| Root stock borer | *Emmalocera depressella* Swinhoe | Larva bores into the root. |
| White grubs | *Holotrichia seticollis* Moser<br>*H. serrata* Fabricious<br>*Brahmina* sp. | Grubs feed on the roots<br>. |
| Termites | *Odontotermes parvidens* Holm and Holm<br>*O. lokanandi* Chatterjee<br>*Odontotermes.* sp.<br>*Microtermes obesi* Holm<br>*Microtermes* sp. | Nymphs feed on root and make tunnel in the stem. |
| Pyrilla leaf hopper | *Pyrilla perpusilla pusana* Dist. | Both nymph and adult suck sap from leaf. |
| Scale insect | *Melanaspis glomerata* Green | Sucks sap from internode. |
| Black leaf hopper | *Eoeurysa flavocapitata* Muir | Both nymph and adult suck sap from leaf and leaf sheath. |
| Thrips | *Ballothrips serrata* (Kobus) | Sucks sap from the leaves. |
| Woolly aphis | *Ceratovacuna lanigera* (Zehnt.) | Sucks sap from leaf. |
| Mealy bug | *Saccharicoccus sacchari* Cockerell | Sucks sap from leaf and leaf sheath. |
| White fly | *Aleurolobus barodensis* (Mask) | Sucks sap from the ventral side of the leaves. |
| **Mites** | | |
| White mite | *Schizotetranychus andropogoni* Hirst | Sucks sap from the leaves. |
| Red mite | *Oligonychus indicus* Hirst | Sucks sap from the leaves. |

| Common name | Scientific name | Nature of damage |
|---|---|---|
| **Diseases** | | |
| Red rot | *Colletotrichum falcatum* Went | The leaves droop and dry up along the margin. The split cane emits alcoholic smell and shows red tissue with white cross bands. |
| Wilt | *Acremonium furcatum*<br>*A. terricola*<br>*Fusarium moniliforme* | Leaves dry up; stem becomes light and hollow; the pith develops purple or red streaks. |
| Smut | *Ustilago scitaminea* | The growing shoot turns into a long whip-like black growth, covered by a powdery mass of black spores, enclosed in a thin membrane. |
| Pineapple disease | *Ceratocystis paradoxa* | The outer tissue below the rind blight red, a black mass of cottony tissue; emits a distinct odour of pineapple. |
| Mosaic virus | | Mosaic symptoms occasional; a slight curling and puckering of the leaves. |
| Red strip & Top rot | *Pseudomonas rubrilineans* | Long, narrow, red streaks appear on the leaves, only the leaves and top shoots are affected. |
| Striga | *Striga demiflora* | A small plant about 30-45 cm tall, with narrow green and white flowers found growing at the base of canes; affected plants turn yellow. |

**Vegetables.** Bangladesh produces a number of vegetables including eggplant, cucurbits, country bean, cabbage, cauliflower, tomato as important ones. Most of the vegetables are grown in winter during September to February and a very few are grown in summer during March to September. The vegetables cover 201,567 hectares. However, the yield per unit area is quite low since the insect pests cause 30-40% losses in general and even 100% losses in case of menace if no control measure is applied. A conservative estimate puts about annual yield losses in vegetables at 25% due to insect pests alone (Rahman, M.M. 2006). Table 4 gives a list of major pests of important vegetables.

**Table 4. Major pests of vegetables and their nature of damage.**

| Common name | Scientific name | Nature of damage |
|---|---|---|
| **Brinjal** | | |
| Brinjal shoot and fruit borer | *Leucinodes orbonalis* Guenee | The larvae bore into the young shoots, petioles and midribs of the leaves and feed on the internal tissues. The infested shoots droop down and wither.The larvae make tunnels inside the ruit and make the fruit unfit for consumption. |
| Epilachna beetle | *Epilachna vigintioctopunctata* Fab. *E. duodecastigma* Mulsant | Both grubs and adults of the insect feed on the leaves by scraping the leaf surface leaving the midrib. As a result, the infested leaves dry and fall off. |
| Cut worm | *Agrotis ipsilon* (Rottenburg) | The larvae remain hidden under the soil during day time and come out in the night to damage the egg- plant seedlings by cutting at the base of their stems little below the ground level. |
| Jassid | *Amrasca biguttula biguttula* | Both the nymphs and adults of the hopper cause serious damage to the leaves by sucking the cell sap. Heavily infested leaves appear stunted, show yellow mosaic and subsequently dry up. |
| White fly | *Bemisia tabaci* Genn. | The affected leaves show yellowish clumpy spots. The nymphs during feeding secrete sticky honey like substance that cover-up the upper parts of the leaves and flowers. The plants become stunted. |
| Red mite | *Tetranychus urticae* | The mite affected leaves show yellowish clumpy spots. In case of severe infestation, the leaves wrinkle, turn yellow to brown and ultimately droop off. |
| **Cucurbits (sweet gourd, bitter gourd, ribbed gourd, sponge gourd, teasle gourd, white gourd, ash gourd, and cucumber)** | | |

| Common name | Scientific name | Nature of damage |
|---|---|---|
| Pumpkin beetle | *Raphidopalpa foveicollis* (Lucus)<br>*R. abdominalis* (F.)<br>*R. fontalis* (Baly) | The adult beetles cause damage to young seedlings by feeding on leaves making shot holes. The grubs live in the soil and cause damage to seedlings and mature plants feeding on roots. |
| Fruit fly | *Bactrocera cucurbitae* Coquillett | Fruit flies attack the young and tender fruits of various cucurbits. The larvae (maggots) hatched inside the fruits eat away the pulpy tissues inside and make tunnels in fruits and destroy the fruits. |
| **Country Bean** | | |
| Black aphids | *Aphis craccivora* Koch<br>*A. medicagenis* Koch | Both adults and nymphs cause damage to plants by sucking the plant sap from leaves, flowers and young fruits. Leaves crinkle or exhibit a yellowish, mottled or mosaic colouration |
| Bean pod borer | *Maruca (testulalis) vitrata* Geyer | On hatching the young caterpillar feeds on flower buds, flowers and move f rom one flower to another. The infested flowers either drop, form clusters or do not develop into pods. The affected pods become malformed. |
| **Cabbage and cauliflower** | | |
| Tobacco caterpillar | *Spodoptera litura* (Fab.) | Many larvae in gregarious form feed inside the infested cabbage head. It also tunnels into soft tissues such as soft stems, midribs, leaf stalks etc. |
| Diamond back moth | *Plutella xylostela* (Linn.) | On hatching, the young larvae feed by scrapping epidermal leaf tissues and thus produce typical whitish patches. Advance stage larvae bite holes in the leaves. It causes retardation of growth resulting in undersized cabbage heads and cauliflower. |
| Cabbage butterfly | *Pieris brassicae* (L.) | On hatching, the young larvae feed gregariously on leaves for a couple of days. The infested leaves are skeletonized, sometimes the caterpillars bore into the heads of cabbage and cauliflower. |

| Common name | Scientific name | Nature of damage |
|---|---|---|
| **Tomato** | | |
| Cutworm | *Agrotis ipsilon* (Rottenburg) | Same as described under eggplant. |
| White fly | *Bemisia tabaci* Genn. | Same as described under egg plant |
| Fruit borer | *Helicoverpa armigera* | On hatching the larvae feed on leaves and flowers. The advanced stage larvae bore circular holes and thrust only a part of their body inside the fruits and eat the inner contents. The larvae move from one fruit to another and a single caterpillar may eat and destroy 2-8 fruits. |
| **Okra** | | |
| Shoot and fruit borer | *Earias vittella* (Fab.) | The larvae bore into the tender shoots and tunnel downwards. The infested shoots wither; droop down and ultimately the growing points are killed. The caterpillars then bore into the buds and fruits and feed inside them. The damaged buds and flowers wither and fall down. |
| Jassid | *Amrasca biguttula biguttula* Distant | Same as described under egg plant |
| White fly | *Bemisia tabaci* Genn. | Same as described under eggplant |

**Jute.** Jute, the most important fibre cash crop of Bangladesh, covered about 402,000 ha (993,000 acres) in 2005-06. In the same year, Bangladesh produced 838, 000 metric tons yielding 2.85 t/ha (1.34 metric tons per acre) (BBS, 2007). There are two major types of commercial jute grown in Bangladesh. One is *Corchorus capsularis* locally known as deshi and another is *C. olitorius* known as tossa. Cultivation of tossa, which covers about 70% of jute production, is preferred to deshi jute for its superiority in fibre quality. Jute suffers losses in both quantity and quality due to attacks of 19 species of insects, 2 mites and 12 diseases. Out of these, 5 insects, 1 mite and 10 diseases are considered major pests. Average loss of jute fibre due to insect and mite pest is 12-15% whereas disease causes about 17-20% yield loss of jute, which affects the national economy tremendously (Khan, 1991).Table 5 gives a list of major insects, mites and diseases of jute.

**Table 5. Major insects (5), mite (1) and diseases (10) of jute**.

| **Common name** | **Scientific name** | **Nature of damage** |
|---|---|---|
| | **Insects** | |
| Jute stem weevil | *Apion corchori* Marsh | The grubs bore into the stems near the axils of the top leaves. The affected shoots and leaves wither. |
| Jute hairy caterpillar | *Spilosoma (=Diacrisia) obliqua* (Walker) | Caterpillars feed on the leaves and can completely defoliate the fields. |
| Jute semilooper | *Anomis sabulifera* Guen | Caterpillars eat the apical buds and top shoots. |
| Field cricket | *Brachytrypes portentosus* Lich | It cuts of seedling jute plants. In case of serious infestation, the entire crop may be damaged. |
| Cut worm | *Spodoptera litura* Fab | It attacks young jute plants. Mature larvae feed on entire leaf leaving only the ribs. |
| | **Mite** | |
| White/yellow mite | *Polyphagotarsonemus latus* (Banks) | It attacks the apical leaves and causes damage by sucking the plant sap. The young leaves crinkle and curl down, the colour changes to coppery or purplish, finally dry up and fall down. |
| | **Diseases** | |
| Seedling blight | *Rhizoctonia solani* *Colletotrichum corchori* | Attacks root causing death of the plant. |
| Stem rot | *Macrophomina phaseolina* Tassi, Goid | Plant dies at early stage and at secondary stage, the lesion spreads at the stem and sometimes the stem becomes rotten and breaks causing death of the plant. |
| Black-band | *Botryodiplodia theobromae* Pat. | Olitorius are more susceptible than capsularis. Black lesions spread on the stem and deteriorate the fibre. |
| Anthracnose | *Colletotrichum corchori* Ikatatyashida | The fungus attacks young seedlings causing seedling blight. The disease badly affects fibre quality. |
| Die-back | *Gloesporium* sp. Desm and Mont | Plants usually the olitorius varieties begin to dry from the tip downwards at almost full grown stage. |

| Common name | Scientific name | Nature of damage |
|---|---|---|
| Root-rot (Wilting) | *Macrophomina phaseolina* Tassi, Goid *Rhizoctonia solani*, *Pythium* sp. | Root system of an affected plant becomes infected with soil-borne fungi. All the leaves become flaccid at a time and after few days dropping occurs. The base of the plant turns deep brown. |
| Leaf Mosaic | Mosaic virus | Yellow mosaic spots appear usually on capsularis plants at any stage of growth affecting formation of chlorophyll. Infected plants show stunted growth affecting fibre yield up to even 50% |
| Root-knot | *Meloidogyne javanica* *M. incognita* *M. arenaria* | Knots are formed in the root-system affecting spread and conduction of sap. Severely infected plants are shallow rooted and the leaves turn slight yellow. |
| Powdery mildew | *Oidium* Sp. | Fine white powdery mass appears to be accumulated on leaf-surface resulting fall of leaves, flower and fruits. |
| Soft-rot | *Sclerotium rolfsii* Saccardo | Compact white mycelium with brown selerotia grows on lower portion of stem. |

**Tea.** Twenty-five insects, 4 mites and 11 species of nematodes have so far been recorded in tea. Out of these, six insects, two mites and one nematode species are considered major pests (Ahmed, 2005). Crop losses per year due to various pests particularly insects, mites, nematodes and diseases have been reported as 15% (Sana, 1989). Moreover, crop losses to the extent of 50% or more may be inflicted by the advent of an epidemic or outbreak of specific pests in a particular season or tea estate. Table 6 gives a list of major pests of tea.

**Table 6. Major insects (11) and diseases (7) of tea in Bangladesh and their nature of damage.**

| Common name | Scientific name | Nature of damage |
|---|---|---|
| | **Insects** | |
| Tea mosquito bug | *Helopeltis theivora* Waterhouse | Nymph and adult suck sap from young leaves, buds and tender shoots; leaves curl up and deformed; infested shoots dry up and the crop is lost. |

| Common name | Scientific name | Nature of damage |
|---|---|---|
| Green fly/Jassid | *Empoasca flavescens* Fab. | Nymph and adult suck young leaves and tender shoots, growth of the affected leaves becomes uneven, curl, turn brown and dry up. |
| Plant lice/Aphis | *Toxoptera aurantii* Bayer | Nymph and adult suck sap from young leaves, bud and tender shoots; leaves, become crinkled and curled, growth of shoot is retarded. |
| Mole cricket | *Gryllotalpa africana* | Adult cuts off leaves and tender shoots; stems and roots of young seedlings. |
| Scavenger termite | *Odontotermes feae* Wasmann | Nymph and adult feed on root, stem and stump; excavate galleries within the live wood of healthy plants. |
| Live wood termite | *Microcerotermes championi* | Nymph and adult feed on root stem and stump. |
| Live wood termite | *Coptotermes heimi* | Nymph and adult feed on root, stem and stump. |
| Assam tea thrips | *Scirtothrips dorsalis* Hood | Nymph and adult suck unopened and partly opened young leaves and buds; leaf surface becomes uneven, curled; leaves become stunted; immature leaves may look burnt. |
| Red spider mite | *Oligonychus coffeae* (Nietner) | Nymph and adult suck upper surface of the mature leaves; leaf changes to a bronze colour, dries up and drops. |
| Meadow/Root lesion nematode | *Pratylenchus loosi* | Adult sucks root; develop Knots or galls; stunted growth; cells in vascular tissues are blocked; transport of water and solutes is impaired. |
| Root-Knot nematode | *Meloidogyne* spp. | Adult sucks root |
| | **Diseases** | |
| Black rot | *Corticium invisum* | Tender leaves turn black, become soft |
| | | and rot, local dead patches are produced on older leaves in very wet weather. |
| Blister blight | *Exobasidium vexans* Massee | Minute pale brown to pink spots on the upper surface of the young leaf. |

| Common name | Scientific name | Nature of damage |
|---|---|---|
| Die back | *Nectria cinnabarina* | Bushes become moribund, new shoots are thin and weak; small pink cushion-like fruiting bodies appear in large numbers after the shoots die. |
| Red rust | *Cephaleuros mycoidea* Karst<br>*C. parasitica* Karst | The alga forms minute rusty spots on the leaves. |
| Macrophoma/branch canker | Caused by various fungi | Gnarled formations develop in young branches and on the surface of old branches |
| Charcoal stump rot | *Ustulina deusta* (Fr.) | Charcoal like and brittle fructifications appear. |
| Violet root rot | *Spharostible repens* B. & Br. | The roots emit unpleasant sour rancid smell and turn violet to black colour. |

## TREND OF PESTICIDE USE

Pesticides were introduced in Bangladesh in 1956 and had been distributed to the farmers free of cost up to 1973 (100% subsidy). Because of their quick and visible effects, and no cost, the use of pesticides soon became very popular among the farmers for insect pest control of rice and other crops. As a result, the total consumption of pesticides in the country rose from three tons in 1956 to 5,560 tons in 1973. Pesticide use plummeted sharply to about 1,500 tons in 1974-75 and the trend continued up to 1978-79 due to partial withdrawal of Government subsidy from pesticides in 1973-74 (50% subsidy). The Government withdrew subsidy completely in 1979 and the pesticide business was transferred to the private sector. However, to deal with emergency situation, the Government maintained a buffer stock of 15-20 metric tons of pesticides. Pesticide consumption started to rise again from 1980-81 due probably to frequent pest outbreaks and farmers' dependence on pesticidal measures for pest control. Pesticide use peaked to about 7,200 tons in 1992.

It is noteworthy that about 73% (about 4060 tons) of the pesticides consumed in 1973 consisted of conventional pesticides (sprayable and dusts) as compared to about 23% (about 1600 tons) used in 1992. Since conventional pesticides contain much higher amounts of active ingredients, the total amount of active ingredients used in 1992 was about half the amount used in 1972-73. According to an estimate of the Pesticide Association of Bangladesh (PAB), the total quantity of active ingredients used in Bangladesh in 1991 was about 950 tons (PAB 1992, 1993). Considering that 90% of this amount was applied for rice pest control throughout the country, the rice fields received a total of about 855 tons of active ingredients of different pesticides, approximately at the rate of 0.085 kg/ha, which is very low as compared to that presently used in other countries (Karim, 1994).

In 1999, 2462 tons of active ingredients of pesticides were used in Bangladesh over an area of 13.63 million hectare, which is equal to 180g of active ingredients per hectare per year (National IPM Policy, 2002). Table 7 gives pesticide consumption in Bangladesh from 1997 to 2006.

**Table 7. Pesticide Consumption in Bangladesh , 1997 to 2006**

| Year | Insecticide | | | Fungicide | Herbicide | Rodenticide | | Total | |
|---|---|---|---|---|---|---|---|---|---|
| | Granular | Liquid | Powder | | | | | Formulated | Active ingredient |
| 1997 | 8,724.33 | 1,408.77 | 88.10 | 22.10 | 862.00 | 159.88 | 101.82 | 11,367.00 | 2,173.25 |
| 1998 | 9,139.10 | 1,298.85 | 75.73 | 31.38 | 734.71 | 239.15 | 91.74 | 11,610.66 | 1,985.54 |
| 1999 | 11,192.70 | 1,524.76 | 97.65 | 25.67 | 1,065.41 | 315.14 | 119.22 | 14,340.55 | 2,461.21 |
| 2000 | 11,915.67 | 1,789.41 | 78.61 | 25.38 | 1,430.01 | 271.10 | 122.06 | 15,632.24 | 2,942.28 |
| 2001 | 10,788.36 | 1,426.45 | 86.04 | 18.85 | 2,147.57 | 838.00 | 70.30 | 15,375.57 | 3,020.46 |
| 2002 | 12,335.34 | 1,496.85 | 115.06 | 27.06 | 2,418.80 | 963.99 | 36.34 | 17,393.44 | 3,279.94 |
| 2003 | 11,781.35 | 1,830.82 | 122.75 | 32.28 | 2,940.68 | 1,354.01 | 18.55 | 18,080.44 | 3,866.24 |
| 2004 | 12,113.39 | 2,008.27 | 191.49 | 37.62 | 4,279.21 | 3,462.82 | 23.08 | 22,115.88 | 5,165.93 |
| 2005 | 14,061.65 | 2,511.06 | 267.34 | 56.20 | 5,771.74 | 2,774.94 | 23.54 | 25,466.47 | 6,607.42 |
| 2006 | 15,918.44 | 3,159.14 | 453.57 | 60.70 | 8,710.02 | 3,205.39 | 14.74 | 31,522.00 | 9,262.74 |

*Source:* Bangladesh Crop Protection Association (BCPA) c/o. Padma Oil Company Limited (Chemicals Division), 6, Paribagh, Dhaka-1000.

Pesticide use has been on the increase reaching 11,367 metric tons of formulated products or 2,173 metric tons of active ingredients in 1997 and 31522 metric tons of formulated products or 9262 metric tons of active ingredients in 2006. Increase in rice area, increase in cropping intensity and an increase in the area under high yielding varieties led to the increased consumption of pesticides.

**Banned Pesticides in Bangladesh**

Bangladesh is one of the signatories of FAO Code of Conduct on the distribution and use of pesticide. It is endeavoring to implement a role of pesticide in the IPM particularly as defined in the FAO code for ensuring scientifically integrated usage as low volume crop protection agents to ensure friendly environment. Government has banned some pesticides under category 1a (extremely hazardous) and 1 b (highly hazardous) as per WHO classification. Table 9 gives a list of pesticides banned in Bangladesh.

**Table 9. Nine banned pesticides in Bangladesh.**

| Name of pesticide | Class | Registration No. |
|---|---|---|
| Aldrin | 1b | |
| CCA | 1a | AP-221, 300 |
| Chlordane | 1b | AP- 40 |
| Dichlorvos | 1b | AP-03, 13, 26, 27, 41,46,57, 74,79,151,245, 274,325 |
| Dieldrin | 1b | AP-42,73,82,83 |
| Heptachlor | 1b | AP-39 |
| Methamidophos | 1b | AP- 19,25,188 |
| Monochrotophos | 1b | AP-07,18,175,275,284,328,331, 336, 339,340,341,342,388 |
| Phosphamidon | 1a | AP-06,22,148 |

*Source* : PPW, DAE, Khamarbari, Dhaka-1215, Bangladesh.

**IPM IN BANGLADESH**

In Bangladesh, IPM activities first started in 1981 with the introduction of first phase of FAO's Inter-Country Rice IPC Programme with the objective to develop effective pest control methods in South and Southeast Asia. The Bangladesh Rice Research Institute (BRRI) was assigned to carry out research work to develop rice pest control methods and the Department of Agricultural Extension (DAE) was responsible for transferring those methods to the farmers through its upazila and district level personnel by IPC block demonstration. From 1989 to 1995, the integrated pest control (IPC) played a strong catalytic role in promoting the IPM concept and approach among the government officials and donor community. The programme provided IPM training to build the training capacity of the DAE and introduced Farmers' Field School (FFS) for training of farmers. A number of persons from the non-government organizations (NGOs) were also given training on IPM. Because of the success of this programme and based on the need for IPM in Bangladesh, a number of IPM projects on rice and vegetables were in operation during 1995-2003 and executed by different government departments and NGOs. These projects were –

- DAE-UNDP/FAO IPM Project, BGD/95/003 (1996-2001),
- DAE-DANIDA Strengthening Plant Protection Services (SPPS) Project Phase-1, (1997-2002), phase-2, 2002-2006),
- USAID funded IPM Collaborative Research Support Project (IPM-CRSP),
- CARE-Integrated Rice and Fish Projects (INTERFISH) (1993-2000),

- CARE-New Options for Pest Management (NOPEST) (1995-2003),
- AID Comilla's IPM Project (NGO) (1999-2001),
- FAO's Inter-Country Vegetables IPM Programme (1996-1998),
- FAO-EC-CDB Regional Cotton IPM Programme (1999-2004),and
- FAO's Community IPM Programme.

Besides, the Khulna-Jessore Drainage Rehabilitation Project (1997-2002) and Command Area Development (CAD) Project part MB (1997-2002) funded by ADB had component on IPM and worked mainly on rice The Bangladesh Water Development Board (BWDB) was the executive agency of these two projects but DAE implemented the IPM components. Among the above mentioned nine projects, the IPM-CRSP and FAO's Inter-Country Vegetables IPM Programme worked exclusively on vegetable, and FAO-EC-CDB Regional Cotton IPM Programme worked on cotton. Other projects worked on rice and/or vegetable IPM and their main thrust was to provide training to farmers on IPM practices. As such, these projects were of extension led type. Except SPPS and IPM-CRSP, all other projects ended by 2004. SPPS ended in September 2006.

IPM-CRSP is still continuing. The Command Area Development (CAD) Project was implemented during October 1997 to September 2000 in two districts (Pabna and Chandpur) in four upazilas (one in Chandpur and three in Pabna). A total of 115 officials from DAE, 10 officials from the Bangladesh Water Development Board and five staff from NGO were trained through three TOTs. The project also established 408 FFS in rice and provided season-long training on IPM to 12,250 farmers and 75,000 were given exposure to IPM practices through 139 Field Days. In addition, the project provided short training to 2,750 male and female farmers on vegetable cultivation and pest management. The FAO-EC-CDB Regional Cotton IPM Programme started operation in Bangladesh in February 2001 and continued up to October 2004. The European Union funded the project and FAO technically supported it. During the operation period, the project conducted three season-long training of facilitators (ToF) courses and developed 103 (89 from CDB and 14 from NGO) field level officers of the Cotton Development Board and some NGO staff. Besides, the project developed 87 farmers' trainer. The project also established 148 FFS and provided training to 3700 farmers on cotton IPM.

Among the IPM projects, DAE executed the Strengthening Plant Protection Services (SPPS) Project and the DAE-UNDP/FAO IPM Projects were the important ones for rice and vegetable IPM. Training of DAE personnel and farmers was the main thrust of these projects. The projects made remarkable progress and conducted about 27 training of trainers (ToTs) courses where a total of 1,242 DAE staff and 114 NGO staff were trained on practical IPM as facilitators (trainers). Those 1,242 IPM trained DAE staff constituted the upazila IPM team and they provided training to farmers through FFS. As of September 2006, a total of 17,885 FFS were established and about 4,50,000 farmers were trained on rice and vegetable IPM. At present, only one project funded by GOB and implemented by DAE is operating on rice IPM in 244 upazilas having no activities of IPM before. Besides, IPM-CRSP and GOB funded IPM project, BARC is also operating FFS on vegetable IPM in some upazilas. The Bangladesh Agricultural University (BAU) is conducting research on fruit IPM.

The IPM training has rendered a positive impact on the trained farmers. They can understand that not all insects in a crop field are harmful. Beneficial insects (parasites and predators) are many times more in the crop ecosystem than the harmful insects. The IPM training not only increased knowledge of the farmers but also reduced their crop production cost (by reduced use of pesticides) and increased crop yield. Impact assessment studies revealed that the IPM trained rice farmers compared with untrained, on an average, have reduced the use of pesticides by 90% with an increase of crop yield by 10%. Similarly, the IPM trained vegetable farmers have reduced the use of pesticides on an average by 75 % with an increase of crop yield by 12 % (Alam, 2007).

BARI, the largest multi crop research institute of Bangladesh conducted another two research oriented IPM projects on vegetables. One is the "Development of an Integrated Pest Management Strategy for Eggplant Fruit and Shoot Borer in South Asia" funded by Department for International Development (DFID), U.K. through Asian Vegetable Research and Development Centre ( AVRDC), Taiwan. BARI in collaboration with the AVRDC and Natural Resources Institute (NRI), Greenwich University, UK operated this project. Another project of BARI was "Sustainable production and marketing of toxic pesticide-free vegetables" in collaboration with NRI, Greenwich University, UK and Safe (Jubok) Agro-Biotech Ltd., Dhaka, Bangladesh. This project funded by the Delegation to the European Commission to Bangladesh was operated during January 2007 to February 2008.

From several survey studies, it has been observed that in some crops especially in high valued vegetables farmers sometimes apply insecticides indiscriminately and sometimes no waiting periods are given before harvest. Consumers are inevitably exposed to high levels of pesticides through these foods in their diets. BARI scientists have already developed some effective IPM technologies, and some are in pipeline to control the devastating pests especially the insect pests of vegetables and fruits. Some of the IPM technology packages against those pests are as follows:

**Brinjal**. Brinjal is attacked by many insect pests. Among them shoot and fruit borer, jassid, epilachna beetle etc. are considered as the major insect pests. In Bangladesh, brinjal shoot and fruit borer (BSFB), *Leucinodes orbonalis* Guen. is the most destructive insect pest of brinjal. The yield loss caused by this pest has been estimated more than 85% in Bangladesh. Unfortunately even after repeated insecticide spraying the farmers could not control the pest properly as the field population became resistant to the commonly used pesticides. However, an effective and economic IPM package has already been developed. The measures are:(i) prompt removal of pest-damaged shoots and fruits, (ii) use of sex pheromone: to trap all male moths before they mate, (iii) innundative release of bio-control agents like egg parasitoid, *Trichogramma* sp. (@ 1gm parasitized eggs/ha/week), and larval parasitoid *Bracon habetor* (@ 800-1200 adults /ha/week), iv) total reduction or less use of insecticides: to allow natural enemies to proliferate along with a community approach. The above IPM package is gaining popularity among the brinjal growers throughout the country due to its effectiveness, sustainability and less cost involvement. In the brinjal field, infestation of insect pests like jassid, whiteflies are frequently observed. Bio-rationales like neem products i.e. neem seed kernel extract (500 gm crushed neem seed kernel should be soaked in 10 liters of water. The filtered water is then ready for application or neem oil (@5 ml/ liter of water + 5 gm detergent or soap powder) were used to reduce jassid and whitefly infestation.

**Cucurbit crops.** Cucurbit crops like bitter gourd, sweet gourd, cucumber, teasle gourd, ash gourd etc. are attacked by different insect pests but cucurbit fruit fly, epilachna beetle, fruit borers like *Spodoptera sp.* or pumpkin caterpillar are considered as the major pest. In Bangladesh, fruit fly is considered as the major problem for the farmers as they invade the crops in high populations and devastate the cucurbit crops. Due to its nature of damage it is very much hard to control this pest with insecticide. However, it can be cost-effectively control led by the BARI developed IPM technology which comprises of sanitation and use of sex pheromone mass trapping along with community approach. In the cucurbit field infestation of some other pests like epilachna beetle, fruit borer like *Spodoptera sp.* or pumpkin caterpillar are frequently observed. For the control of borer pests, innundative releases of bio-control agents should be done. Bio-rationales like application of neem seed kernel extract can reduce jassid and whitefly and epilachna beetle infestation.

**Tomato.** The key constraints to tomato production relate to tomato leaf curl virus, particularly in summer production when total crop loss is possible because of the efficiency of the vector, *Besimia tabaci*, transmission and susceptibility of currently available varieties. Other key constraint of tomato production is the attack of fruit borer, *Helicoverpa armigera*. Those pest problems can be efficiently and sustainably managed by cultivating two virus and white fly resistant tomato germplasms, viz. TLB182 and TLB111 and through innundative release of bio-control agents like egg parasitoid, *Trichogramma* Sp. and larval parasitoid *Bracon habetor*.

**Cabbage /cauliflower**. Leaf eating lepidopterous pests like cabbage common cutworm and diamond back moths are the main constraints for cabbage production. Those devastating pests can be efficiently and sustainably controlled by hand picking and destruction of Spodoptera or DBM egg/larvae during initial stage, by artificial release of bio-control agents: weekly release of two parasitoids *Trichogramma* sp., and *Bracon habetor* and by application of biopesticides like neem products.

Farmers, adopting IPM strategy against eggplant, used 22% and 13% less labour in winter and summer seasons, respectively, compared to non-IPM farmers who relied solely on pesticides for insect pest control. Furthermore, the IPM strategies led to lower production costs and higher net incomes. Production costs per hectare for IPM farmers were only TK 67,025 compared to TK 97,783 for non-IPM farmers in winter crops, and TK 85,053 for IPM farmers, compared to TK 128,274 for non-IPM farmers in summer crops (58.39 TK = 1US $). Net income per hectare was TK 91,020 for IPM farmers compared to TK 57,257 for non-IPM farmers in winter crops, and TK 214,002 for IPM farmers compared to TK 36,786 for non-IPM farmers in summer crops. Successful nationwide adoption of IPM in eggplant cultivation will increase profit, protect the environment and improve public health (Rashid *et al,* 2003). In developing sustainable IPM practices for eggplant FSB control, the technologies validated successfully in farmers' fields (Alam *et.al*, 2003; Karim, 2004).

**Ongoing IPM activities by different organisations**

Several IPM programmes are on-going in the country and these are as follows:

| | |
|---|---|
| Crop : Vegetables: | Eggplant, cucurbit crops (sweet gourd, bitter gourd, cucumber etc.), Tomato, Okra, Cabbage |
| Project title: | Facilitating the Development and Spread of the Integrated Pest Management Collaborative Research Support Programme. |
| Administrative Ministry/Division: | Ministry of Agriculture, Bangladesh Secretariat, Dhaka-1000. |
| Executing/Coordinating organization: | Bangladesh Agricultural Research Council (BARC), Farmgate, Dhaka-1215. |
| Implementing agency: | a) Bangladesh Agricultural Research Institute (BARI)<br>b) Department of Agricultural Extension (DAE) |
| Target area: | Four vegetable-growing areas of the country (13 upazillas of Comilla, Narsingdi, Bogra and Jessore districts). |
| Target group: | The mixed level farmers and the vegetable farming community are the ultimate beneficiaries. Vegetable consumers export oriented businessman and traders, and small agro-based industry entrepreneurs' are also important parties in the beneficiary chain. |
| Crops: | Vegetables (Eggplant, Tomato, Cabbage, Cauliflower, Okra, Sweet gourd, Cucumber, Bitter gourd and Country bean.) |
| Project title: | Integrated Pest Management Collaborative Research Support Program (IPM CRSP) in Bangladesh. |
| Managed by: | Virginia Polytechnic Institute and State University (Virginia Tech), USA. |

**Collaborating organizations**

- Bangladesh Institutions: BARC, BARI, BSMR Agricultural University, DAE- Plant Protection Wing, and CARE- Bangladesh.
- US Universities: Virginia Tech, Penn State University, Purdue University and Ohio State University.
- International Agricultural Research Institutes: Asian Vegetable Research and Development Center (Taiwan) and International Rice Research Institute (Philippines) and National Crop Protection Center (NCPC), Philippines.

**Target area.** IPM CRSP activities are going on in the districts of Gazipur, Jessore, Comilla, Lalmonirhat and Chittagong.

**Target group.** Over 90% of the IPM CRSP research and development activities are conducted in farmer fields of different areas through farmer participation. The farmer - participatory researches have acted as `result-demonstration' as well as practical training' for the farmers.

| | |
|---|---|
| Crop: | Rice and vegetables |
| Project title: | Integrated Pest Management Project ((IPM) |
| Sponsoring Ministry /Division: | Ministry of Agriculture |
| Executing /Implementing agency: | Department of Agricultural Extension (DAE) |
| Collaborating agency: | Bangladesh Rice Research Institute (BRRI) and Bangladesh Agricultural Research Institute (BARI). |
| Target area: | The project will be implemented in 244 upazillas Of 58 districts. |
| Target group: | Farmers of 244 upazilas of 58 districts |

**INSTITUTIONAL ARRANGEMENT FOR IPM EXTENSION**

The Ministry of Agriculture, Bangladesh Agricultural Research Council (BARC), Bangladesh Agricultural Research Institute (BARI), Bangladesh Rice Research Institute (BRRI), Bangladesh Agricultural University (BAU) and Department of Agricultural Extension (DAE) are responsible for planning and execution of IPM research and extension activities in the country. International and foreign agencies like UNDP, the Danish International Development Agency (DANIDA), Canadian International Development Agency (CIDA), United Nations Industrial Development Organization (UNDP), International Fund for Agriculture Development (IFAD), Asian Development Bank (ADB) and World Bank are involved in assisting the successful implementation of the agricultural policies in the country through technical and financial assistance.

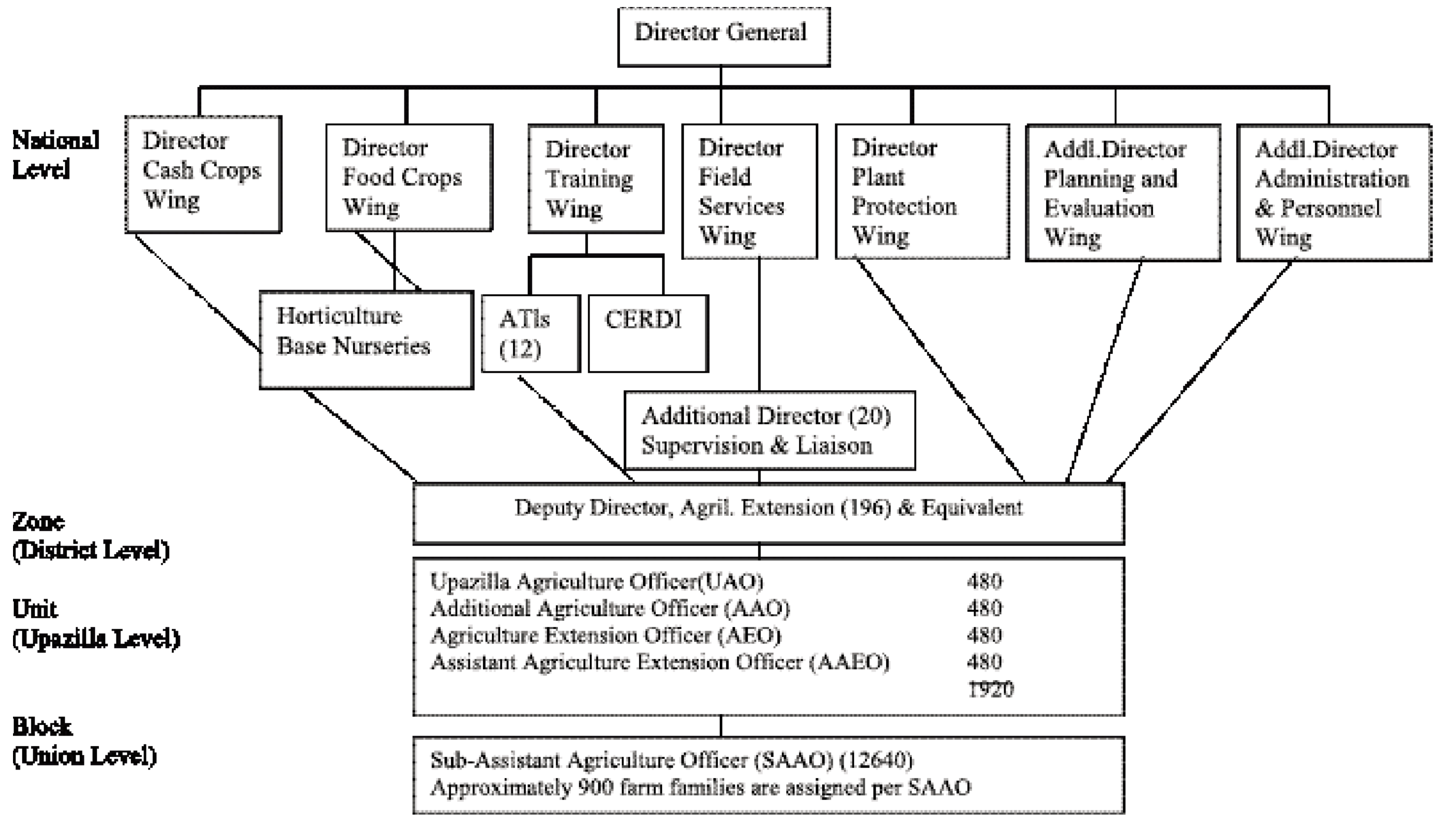
The Economic Relation Division (ERD), Planning commission, Ministry of Finance and the Ministry of Establishment also play a great role in the formulation and implementation of agricultural policies in the country. Organizations like the Bangladesh Agricultural Development Corporation (BADC), Bangladesh Water Development Board (BWDB), Cotton Development Board (CDB), Bangladesh Rural Development Board (BRDB) and Grameen Bank also play important roles in implementing agricultural policies in the country.

**IPM Extension**

The Department of Agricultural Extension is responsible for all aspects of agriculture extension services of the country. There are six divisions (Wings) in DAE including the personnel and administration Wing. The institutional foci for the management of extension service are blocks (union), units (upazila), zones (district) and headquarters (national level). At the national level, the DAE is headed by a Director General who is assisted by a Director from each of the Wings of Field service, Plant protection, Food crops, Cash crops, Planning and Evaluation, Administration and personnel training. The specialist of each wing provides technical supervision over the field extension personnel through appropriate specialists. The line function over the field extension service is exercised by the Field Service Wing.

The zone is the most important focal point for managing the operation of DAE. A Deputy Director is in-charge of the zone assisted by a team of two to four specialists and supervisory staff. The unit is the closest point of institutional service to farmers. Each unit is under the Upazila Agriculture Officer who is supported by four supervisory level officers such as Additional Agriculture Officer (AAO), Agriculture Extension Officer (AEO), Assistant Agriculture Extension Officer (AAEO), Junior Agriculture Extension Officer (JAEO), Plant Protection Inspector (PPI)-1, Mokaddam-1 and Spray Mechanic-1. At the block level, there is a Sub Assistant Agriculture Officer (SAAO) who provides extension service to a group of farmers. A SAAO covers 600-1,200 farm families. Operationally, a block is divided into eight sub-blocks and in each sub-block, there are ten contact farmers (CF) who are contacted by the SAAO once in a fortnight for training and dissemination of pre-tested extension messages (impact). The flow of IPM activity from the headquarters to the farmers is shown in the organizational chart in figure 1.

**Plant Protection Wing.** Director General is the Head of DAE. Under the umbrella of DAE, Plant Protection (PP) is one of the wings headed by a Director. At the national level in DAE, Director, Plant Protection Wing is coordinating and supervising plant protection activities with the assistance of one Additional Director and four Deputy Directors. In each of 64 zones (district level), there is one Plant Protection Specialist (PPS) who is assigned to look after plant protection activities in the district under the control of DDAE. PPS maintains liaison with the Plant Protection Wing for the plant protection activities. In the Headquarter under the control of the Director, Plant Protection Wing, the four sections are working. At the upazilla level, one Agriculture Extension Officer/Additional Agriculture Officer is assigned to carry out plant protection activities along with PPI and other staff. Figures 1 and 2 give the organizational chart of DAE and Plant Protection Wing.




1. **Solid lines indicate direct line of command relationship for staff**
2. **Dotted lines indicate technical guidance, information exchange and communication**

**Fig.1 Organizational Chart of the Department of Agricultural Extension**

Director General,
Department of Agricultural Extension (DAE)
↓
Director, Plant Protection Wing (PPW)
↓
Additional Director (PPW)
↓

| DDAE (S&F) | DDAE (PA&QC) | DDAE (PQ) | DDAE (OP) |
|---|---|---|---|
| Entomologist-1 | PRO-1<br>Chemists-3 | Q. Pathologist-1<br>Q. Entomologist-4 | PCO-2 |

Figure 2. Organizational chart of Plant Protection Wing, DAE.

The responsibilities of the four sections of the Plant Protection Wing are the following:

**Surveillance and Forecasting Section.** This section is responsible for collecting, analyzing and interpreting relevant field oriented pest problem data to make early warning of the probable pest incidence of a particular region and thus to make the farmers aware of the situation beforehand. This section is maintaining liaison with concerned Research Institutes.

**Pesticide Administration and Quality Control Section.** This section is responsible for pesticide administration, registration, standardization, licensing, quality control and screening. It is also responsible for pesticides bioassay, trials, analysis of pesticide residues in crops, foodstuff, soil etc., inspecting formulation plants /manufacturing plants/ dealers' shops/ packaging materials and for maintaining liaison with concerned research institutes and international organizations like FAO, WHO, UNIDO, etc.

**Plant Quarantine Section.** This section is responsible for administrating the existing plant quarantine laws and rules. It initiates new rules and policies on plant quarantine and supervises the activities and maintenance of the existing plant quarantine stations and check posts, maintaining liaison with the relevant organizations and agencies at home and abroad. This section also issues the import permit and phytosanitary certificate for importing and exporting plant and plant products.

**Operation Section.** This section is responsible for carrying out pest control operation. It maintains a limited buffer stock of pesticides and sprayers, which are distributed for demonstration purposes among the poor and marginal farmers at the hour of their crying need.

**IPM Research**

The Bangladesh Agricultural Research Institute (BARI), Bangladesh Rice Research Institute (BRRI), Bangladesh Jute Research Institute (BJRI), Bangladesh Institute of Nuclear Agriculture (BINA), Bangladesh Sugarcane Research Institute (BSRI), Bangladesh Tea Research Institute (BTRI) and Bangladesh Forest Research Institute (BFRI) are responsible in agricultural research in the country. BARC as an apex body coordinates the research programmes of all these institutes. In addition to their routine research programmes, these institutes also carry out research relating to IPM to find out technologies for adoption in the fields. The research usually conducted relating to IPM involves the following:

- Developing varieties tolerant to pest and diseases
- Developing biological control techniques
- Determining economic threshold level of pests and diseases of crops
- Developing cultural practices for pest management
- Developing mechanical control measures for pest management
- Identifying less toxic or selective pesticides for pest control
- Evaluating botanical pesticides against pest control

**PRIVATE SECTOR INITIATIVES ON IPM ACTIVITIES AND FUNDING SOURCES**

Presently, two private organizations are involved in IPM activities. One of them “Safe Agro Bio-tech Ltd. (SABL), established in August 2004 in Dhaka is involved in IPM activities in Bangladesh. It has established a small-scale laboratory in August 2005 mainly for mass production of bio-control agents and sex pheromones with the technical assistance of the Scientific Research Institute for Plant Protection of the Republic of Uzbekistan under a bilateral agreement executed in 2004. Four scientists of Uzbekistan were deputed for a period of two years during 2005-2007. Safe Agro Bio-tech Ltd. has also recruited four local scientists. Another private organization, Safe Agriculture (Bangladesh) Ltd. established during September 2007 is also involved in limited scale mass production of bio-control agents and sex pheromones. Both the private organisations are working in collaboration with different GOs and NGOs, especially with BARI and DAE. They have successfully mass produced several predators (green lace wing, different species of lady bird beetles), egg parasitoids (four species of *Trichogramma*) and larval parasitoids (*Bracon habetor*). Developments of the mass production protocols for other bio-agents are also on going with the technical assistance of different research institutes of Bangladesh, especially with that of BARI. Presently, all the activities are being implemented with their own fund and the present marketing is limited within the Government organized IPM projects under BARI and DAE. However, the farmers are becoming interested to use these techniques in their crops to control the pests.

**GOVERNMENT COMMITMENT ON IPM ACTIVITIES**

There are many definitions of IPM. The FAO defines IPM as:

*"a pest management system that, in the context of the associated environment and the population dynamics of the pest species, utilizes all suitable techniques and methods in as compatible a manner as possible and maintains the pest populations at levels below those causing economic injury."*

The Government of Bangladesh (GOB) has given due importance to IPM, which has been reflected in the Fifth Five-year Plan (1997-2002). The plan stated that:

*"In the fifth plan period, the integrated pest management (IPM) programme will be intensified and expanded in order to safeguard-crops from pests and combat environmental degradation due to pesticide uses. Collaboration among the local government representatives, extension workers and NGOs will be sought to expand IPM programme."*

The National Agriculture Policy (NAP) under section 7.1 stipulated that IPM would be the main policy for controlling pests and diseases. NAP has given importance to the following activities for pest control–

- Farmers will be motivated to use more pest resistant varieties of crops. Modern cultivation practices will be followed so that the incidence of pest infestation is reduced.
- Use of mechanical control measure such as light trap, hand net, etc. will be increased and popularized. Biological control measures will be used to destroy harmful insects and preserve the useful ones.
- Regular training and discussion programmes on IPM will be conducted among the farmers under the supervision of Union Agricultural Development Committee with a view to successful introduction and popularization of the method at the farmers' level.
- Pest surveillance and monitoring system will be strengthened.

**The National IPM Policy**

The Government of Bangladesh (GoB) has given due importance to IPM and has approved the National IPM Policy in April, 2002. The policy calls for the establishment of a National IPM Programme. Draft strategy and action plan for the implementation of the policy have been prepared. The National IPM Policy is now in the process of implementation. In the context of Bangladesh, the term IPM includes elements contributing to an effective, safe, sustainable and economically sound crop protection system. It is not limited to pest management system alone. IPM conserves the natural resources such as the soil, flora and fauna and ensures reliability and stability of agricultural production. Ecological and economic sustainability of agricultural production is the long-term goal of IPM. In fact effective IPM –

- increases self-reliance of farmers by promoting locally developed and adapted crop management practices;
- reduces the risks to farmers, general public and the environment; these include the risks of crop loss and all risks related to the use of pesticides;
- brings enormous savings by reducing the use of farm chemicals;
- reduces use of pesticides at the national level;
- improves the field conditions for beneficial insects and generate extra income as well as nutritious food for the farmers; and
- promotes community activities and the formation of farmer groups (e.g. IPM clubs) and facilitates empowerment of both female and male farmers.

**Objective of the National IPM Policy**

The objective of the National IPM Policy is to enable farmers to grow healthy crops in an increased manner and thereby increase their income on a sustainable basis while improving the environment and community health. To achieve the above-mentioned objective, IPM Policy will pursue the following strategies to –

- Expand IPM on a sustainable basis by establishing a national IPM programme; and
- Facilitate co-ordination of all IPM activities in Bangladesh

**Components of the IPM Policy**

The following are the key components of the IPM policy–

- Maintaining ecological balance,
- Executing appropriate actions on pesticides,
- Operating an effective system for implementing the national IPM programme,
- Developing human resources as the core of IPM and
- Conducting research on IPM.

**Strategies for implementing IPM activities**

- A national IPM programme together with necessary institutional set-up for its implementation will be established.
- The ongoing IPM Projects of DAE will continue their activities and expand until a critical mass of at least 20% of the farmers in each block would receive adequate training so that they can practice IPM.

- Availability of adequate government and donor funds for the continuation of IPM activities by the DAE projects and for the implementation of the National IPM Programme is to be ensured.
- For the expansion and sustainability of IPM, community IPM activities (such as farmer-to-farmer training, establishment of IPM Clubs, etc.) are to be promoted.
- Collaboration among DAE, NGOs and all other agencies and institutions involved in IPM will be strengthened.
- "International Code of Conduct on the Distribution and Use of Pesticides" would be observed in relation to IPM activities.
- Coordination of activities among different Ministries (Agriculture, Fisheries and Livestock, Health, Environment and Forestry, Education, Local Government, etc.) and NGOs will be ensured.
- The Convention on Persistent Organic Pollutants (POP) in reducing or eliminating the production and use of certain pesticides would be observed and implemented.
- IPM related publicity will be promoted through the mass-media and awareness on dangers of pesticides, pesticide residues in food, health and environmental hazards of pesticides will be created.
- A mechanism to monitor pesticide residues in food and the environment will be established.
- A system for certification of pesticide-free agricultural products will be introduced
  Pest diagnostic centers at each Upazila are to be established.
  IPM Congress will be organized for the IPM trained farmers on yearly basis.

## FUTURE PLAN OF ACTION

In Bangladesh, DAE and Agricultural Research Institutes (ARIs) carry out IPM activities. DAE is responsible for the extension work and the ARIs for undertaking research activities on IPM with a view to developing appropriate technologies. Future plan of action of DAE and four lead ARIs of Bangladesh viz. BARI, BRRI, BJRI and BSRI is described below.

### Role of the Department of Agricultural Extension (DAE)

Steps have been taken for the implementation of IPM project based on the satisfactory performance of the $1^{st}$ and, $2^{nd}$ phase of the Strengthening Plant Protection Services (SPPS) Project in attaining self sufficiency in food on sustainable basis without affecting the environment. Funded by GOB, it is operating since July 2006 in 244 upazilas of 58 districts, having no activities of IPM before. Future plan of action of this project will be:

- Attempts will be made for the implementation of the National Integrated Pest Management Policy.

- A total of 6000 Farmers' Field Schools (FFS) will be established.
- Thirty-two farmers' trainers course (two weeks duration) and 2,000 farmer-trainers (FTs) will be developed.
- Six IPM orientation courses will be organized.
- Attempts will be made to provide facilities for establishing 9000 IPM clubs.
- Action will be taken for mass-rearing of parasites and their large-scale release in the field.
- Organic farming demonstrations (rice and vegetable) will be established in each of the suitable agroecological zones of Bangladesh.

**Role of the Bangladesh Agricultural Research Institute (BARI)**

BARI is conducting IPM Researches on vegetables and fruits. The following are the future plan of actions–

- To develop effective bio-rational/bio-chemical based integrated management tactics for important pests of vegetables and fruits.
- To develop resistant/tolerant varieties against important pests of vegetables and fruits.
- To determine the efficacy of bio-control agents and develop methods for conservation and augmentation of those agents.
- To create awareness about the harmful effects of the quick ripening chemicals through research studies.
- To establish IPM villages with all the developed technologies in the pesticide prone regions of the country.
- To develop and establish mass production techniques of different effective bio-control agents at the field level.
- To develop effective mass rearing of bio-control agents to ensure their availability to utilize them in the farmers field.
- To incorporate the developed technologies in the curriculum of the FFS.
- To establish ecologically sound sustainable pest management strategies for the management of important pests of different vegetables and fruits.

**Role of the Bangladesh Rice Research Institute (BRRI)**

BRRI is performing IPM researches on rice. The future plan of action includes the following–

- To develop a mass production technique for important rice insect pest in order to develop resistant varieties.

- To develop the effective alternate host of bio-control agents and develop practices for conservation and augmentation of those agents.
- To isolate effective pathogen of major rice insect pests.
- To develop effective conservation and mass rearing of bio-control agents to ensure their availability to utilize them in the farmers fields.
- To create awareness about the harmful effect of the chemicals through research study.
- Along with the IPM villages, to incorporate the developed technologies in the curriculum of the FFS.
- To get and establish resistant/tolerant varieties against important pests of rice
- To get easily available, cheap and effective management tactics of important pests of rice.
- To establish mass production techniques of different effective bio-control agents in the field level.
- To establish ecologically sound sustainable pest management strategies for the management of important pests of rice.

**Role of the Bangladesh Jute Research Institute (BJRI)**

BJRI conducts integrated pest management research on jute. Future plan of action includes the following–

- Collection, isolation, multiplication of bio-control agents.
- Execution and synchronization of life stages of *Apantales obliqua* and *Spilosoma obliqua* leading to biological control measure of the pest.
- Detection, collection, identification, isolation, cultural techniques, multiplication and preservation of nuclear polyhedrosis virus and granulous virus.
- To develop rearing, storage and transportation techniques of predators and parasites for controlling major pests of jute.
- Determination of efficacy of botanicals on previously mentioned pests.
- Execution of control strategies at greenhouse as well as natural condition.
- Development of rearing, storage and transportation techniques for field application.
- Studies on the dose rate and spreading techniques of virus in the host population.
- To establish the inoculum production methods and inoculation techniques and their rearing, storage, releasing system of bio-control agents at farmers' level.
- Field evaluation of virus against lepidopterous jute pests (Jute hairy caterpillar and Jute semilooper).

- Conduction of farmers training to develop skill for application and promotion of IPM technologies.
- To grow healthy crops without toxic chemicals/residual effect.
- To establish region wise **"**IPM jute model village**"**

**Role of the Bangladesh Sugarcane Research Institute (BSRI)**

BSRI has the programme on IPM research on sugarcane. The following are the future plan of action–

- Verification and refinement of varietal, agronomical (early, late), mechanical and botanical control methods of sugarcane top shoot borer (TSB).
- Verification and refinement of varietal, agronomical (alternate row), mechanical and botanical control methods of sugarcane stem borer (SB).
- Verification and refinement of varietal, agronomical (Pigeon pea, irrigation), mechanical and botanical control methods of sugarcane root stock borer (RSB).
- Verification and refinement of varietal, agronomical (irrigation), mechanical and botanical control methods of sugarcane white grubs (WG).
- Verification and refinement of varietal, agronomical (irrigation, method of planting), mechanical and botanical control methods of sugarcane termites.
- Studies on the efficacy of sex pheromones in controlling TSB, SB and RSB.
- Studies on the efficacy of different light traps in controlling WG.
- Studies on the control of termites with different types of food traps.
- Studies on the control of RSB and termites through crop rotation.
- Development of rearing technique of egg parasitoids of TSB (*Telenomus* spp.), efficacy study and dose determination.
- Development of cheaper rearing technique of egg parasitoid of SB (*Trichogramma* spp.).
- Development of microbial control of SB, RSB, WG and Termites.
- IPM package development against TSB, SB, RSB, WG and Termites.

**SUGGESTIONS AND RECOMMENDATIONS**

- Research on IPM should be strengthened. IPM programmes should accompany proven technology, latest research support, pre-tested IPM methods, selective pesticide products, etc. These are important to create confidence in farmers on IPM methods and sustain IPM activities.
- Greater ARI's participation is needed to strengthen AEZ-based IPM research to support IPM extension with the latest research findings, technology, and expertise.

- Result of all IPM research and wider extension activities carried out by different GOs and NGOs are required to be coordinated and directed under a single command of the DAE.
- The participation of the plant protection industry of Bangladesh in the IPM programmes is to be ensured. They should be encouraged to develop and promote new products and implement IPM programmes by selling appropriate products, techniques and services. They should be encouraged to include IPM information and recommendations on product labels, technical literature and educational materials, establish IPM demonstration sites and farms, integrate marketing and sales performance incentives with IPM performance.
- More careful attention should be given to gender issue. Number of participating women should be at least 33% of the total members involved in all the IPM technology transfer activities.
- Surveillance is one of the important components of IPM. A network of pest surveillance should be established and necessary training facilities should be developed.
- The SPPS II project of DAE covered about 6% IPM trained farmers in 201 upazilas. However, for the expansion and sustainability of IPM technologies it is essential to reach to at least 20% of the farmers in each block. Expansion of IPM to all upazilas up to block level should be considered to expose more farmers to IPM concept on different crops and pests.
- Human resources development (HRD) activities in IPM to produce a core group at all levels from block to national level of DAE, within different stakeholders including NGOs should be strengthened. All Agricultural Training Institutes (ATIs) may be equipped for IPM training.
- Bio-pesticide is very much effective in controlling certain pests. Moreover, it does not have any harmful/negative effect on the environment, beneficial insects and there is no residual effect. It helps in reducing pesticide use. SAARC countries like Bhutan, Nepal, Sri Lanka, Pakistan and India are using bio-pesticides. About 32 companies in India are producing and using bio-pesticides. However, in the existing Pesticide Rules of Bangladesh there is no provision for sale and use of bio-pesticides. Necessary provision should be made in the Pesticide Rules for facilitating the production, sale and use of bio-pesticides.
- Facilities available in the pesticide laboratory of the Plant Protection Wing of DAE are inadequate for prompt analyses and monitoring of quality control. Facilities are required to be expanded along with consideration for establishment of several similar facilities at Divisional/District level, at least to strengthen the monitoring of quality control and feedback devices at farm level..

- Judicious application of selective pesticide products, which is integral with principles of IPM, is essential to reduce unnecessary user-exposure to crop protection products, improve standards of work practice and hygiene, limit residues in the environment and harvested crops and avoid potential problems of pest resurgence and pesticide resistance.
- Farmers take advice from the pesticide dealers/retailers at the time of purchasing pesticides from them. Dealers/Retailers are not sufficiently educated and most of them have not received any training. As a result sometimes they supply wrong pesticides as per availability in their shop due to ignorance. Education qualification of the pesticide dealers/retailers should be at least SSC and there should be special training for them. Government organizations, NGOs and pesticide companies should arrange necessary training to the Dealers/Retailers. Without any training certificate no body should be allowed any license for selling pesticides.
- It is observed that there is no separate shop for selling pesticides only. According to rule there should be a separate shop meant for pesticide selling. At present, pesticides are preserved and sold from the grocers' shop where human food and animal food are also preserved for selling. The PPW of DAE should consider this at the time of issuing license to the pesticide dealers.

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***Appendix 2. Phographs on IPM activities***

*Poison bait trap for controlling cucurbit fruit fly*

*Pheromone trap for controlling cucurbit fruit fly.*

*Observation on fruit fly catch in pheromone trap*

*Application of Neem extract for the control of jute yellow mite*

*Sun dried jute seed mixed with garlic paste for controlling seed borne fungal diseases*

*Decomposed poultry litters for controlling root knot nematode*

## *Appendix 2. Phographs on IPM activities*

*A view of rice FFS*

*One of the booths of field day on IPM*

*Vegetable field observation by FFS participants*

*Rice field observation by FFS participants*

*Sex pheromone trap for controlling brinjal shoot and fruit borer*

*Releasing Trichogramma sp. in bittergourd field*

*Realease of bio control agent against red spider mite of tea*

*Wax moth adult for egg laying in honey comb*

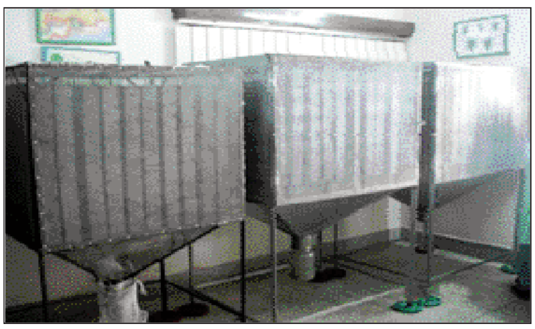
## *Appendix 2. Phographs on IPM activities*

*Wax moth larvae in the artificial diet*

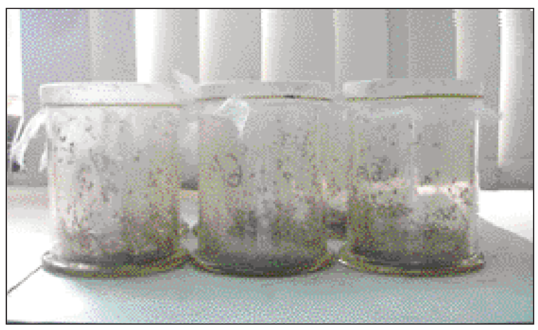
*Full grown larvae of wax moth in the diet for parasitisation with B.habetor*

*Parasitisation with B. habetor*

*Adult B. habetor ready for release in the field*



*Mass rearing and collection box of Rice moth*



*Rice moth adult kept for egg laying*

*Rice moth adult kept for egg laying*

*Collected eggs of Rice moth*

Chapter-2

# Bhutan

# Integrated Pest Management Activities in Bhutan

Doe Doe

## INTRODUCTION

Bhutan is situated in the eastern part of the Himalayas between 88°.7' and 92°.15' east longitude, and 26°.7' and 28°.4' north latitude (Agro-Met Division, CoRRB, MoA from GIS *reconnaissance*). Bhutan has an area extending about 336 km aerial distance from east to west and about 172 km from north to south (Cadastral Information Division, DSLR, MoA). Within this latitude range, Altitude varies, on the average, from 200msl to 7500msl (Atlas of Bhutan, 1997, LUPP, PPD, MoA). These physical features of the diverse mountainous ecological system provide Bhutan with rich biodiversity, making the country one of the ten-biodiversity hot spots today.

Based on altitude, rainfall and temperature the country is divided into six main agroecological production zones (AEZ) from north to south (Figure 1). Table 1 gives the detailed information on the agroecological zones of Bhutan.

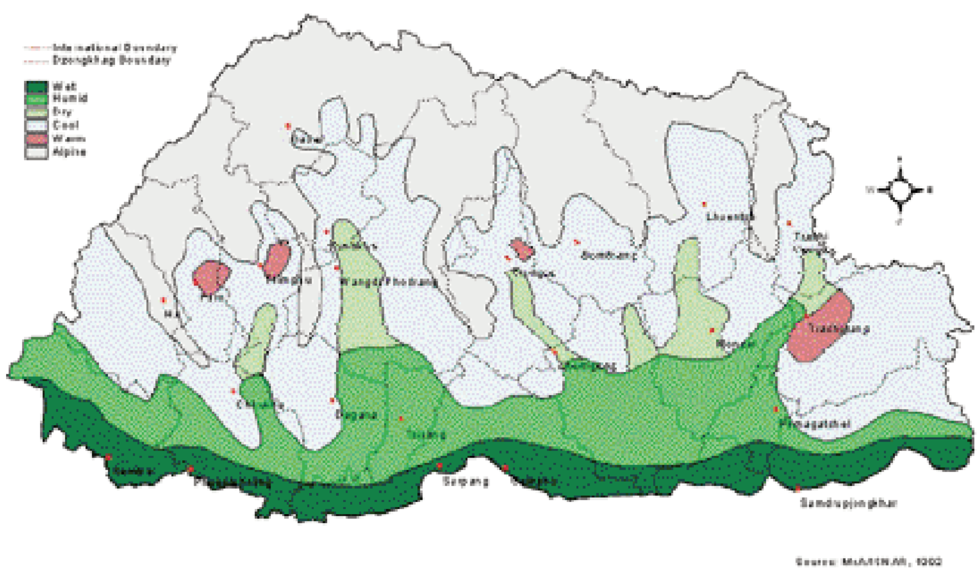
**Table 1. Agroecological zones of Bhutan.**

| Agroecological zone | Altitude range (masl) | Annual rainfall (MM) | Air temperature | | |
|---|---|---|---|---|---|
| | | | Max $^0$C | Min $^0$C | Mean $^0$C |
| Alpine | 3600-4600 | <650 | 12.0 | -0.9 | 5.5 |
| Cool temperate | 2600-3600 | 650-850 | 22.3 | 0.1 | 9.9 |
| Warm temperate | 1800-2600 | 650-850 | 26.3 | 0.1 | 12.5 |
| Dry subtropical | 1200-1800 | 850-1200 | 28.7 | 3.1 | 17.2 |
| Humid subtropical | 600-1200 | 1200-2500 | 33.0 | 4.6 | 19.5 |
| Wet subtropical | 150-600 | 2500-5500 | 34.6 | 11.6 | 23.6 |

*Source:* Department of Agriculture, 1990 and ISNAR, 1992.

In the alpine and cool temperate zones, the pastoral production system dominates with increasing crop production practiced in the lower elevations like buckwheat, barley, mustard, wheat and brassicas as vegetables. Potato and apple are grown to a limited extent. The cropping system is rice based in the warm temperate, humid subtropical and wet subtropical zones. Pome and nuts fruits dominate in the temperate areas, while mandarin orange is grown in the warmer areas.

**Figure 1. Agro-ecological Zones of Bhutan**



The dry subtropical zone is characterized by maize-based cropping system. In the past, slash and burn system of shifting cultivation for producing maize was widely practised. However, based on environmental considerations, this kind of land use has been converted to permanent dryland system of cultivation. Potato and chilli are the main cash crops. In recent years, cultivation of fruits and vegetables are also gaining importance, depending on the availability of water or precipitation.

Of the total land of 40,077 $km^2$, over 72 % are accounted for forest (64.4% tree and 8.1% scrub) and only 7.8% are under cultivation. Table 2 and Figure 2 show the different land use types in Bhutan.

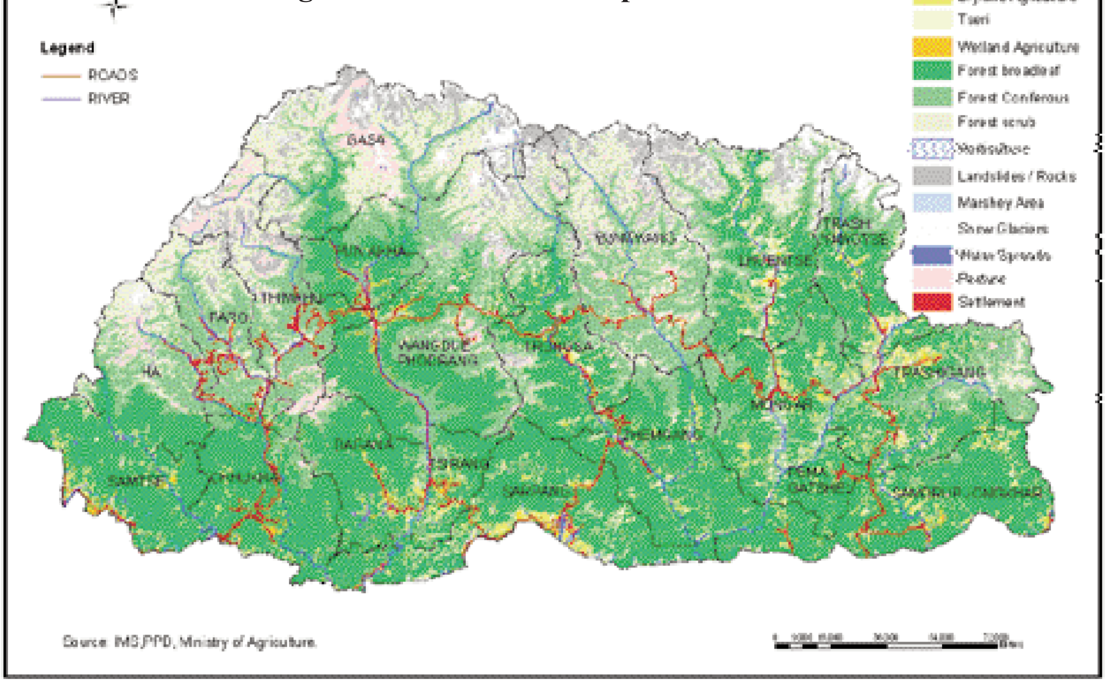
**Table 2. Land area under different land use types.**

| **Land use type** | | **Area ($km^2$)** | **Area (%)** |
|---|---|---|---|
| Forest | | 29045 | 72.5 |
| Pasture | | 1564 | 3.9 |
| Horticulture (Orchad/ Plantation) | | 58 | 0.1 |
| Agriculture (7.7%) | Wetland | 388 | 1.0 |
| | Dryland | 977 | 2.4 |
| | Tseri | 883 | 2.2 |
| | Mixed cultivation | 840 | 2.1 |

*Note: Of the total land are of 40,077 $km^2$, 6,289 $km^2$ (about 15.7%) are occupied by settlement and land that are not used as under snow/glaciers, rocks, water spreads marshy areas and landslips/erosion. Source: Atlas of Bhutan (1997), LUPP, PPD, MoA.*

However, the Tseri (Slash and burn system) cultivation is no more practised as it is converted to permanent dryland cultivation. The average farm size is about 4.1 acres, including a large proportion of relatively unproductive farmlands. Over 50% of the farming, households are less than 3 acres, while 7% of the rural households are landless (10th FYP draft document for MoA). Paddy and maize, the main crops, dominating the wetland and dryland cultivation with about 50,850 ha, accounting for about 79% area coverage. Vegetables and fruit tree cover 9,842 ha and 13,268 ha respectively.

**Figure 2. Land Cover Map of Bhutan**



**AGRICULTURE IN PERSPECTIVE**

Prior to the 1960s, agriculture in Bhutan was purely subsistence farming. With the starting of planned development in 1961, the royal government focused on the development of infrastructure, communication network, and institutions. At that time, since over 90% of the population depended on agriculture, focus and development thrust on agriculture was one of the top priorities. As a result, new technologies like high yielding crop varieties and livestock were promoted. Gradually, agriculture shifted from subsistence to more commercial farming with more increased land under horticultural crop production like potato, apple, citrus, ginger cardamom and so on.

**Table 3. Share of agriculture (%) in GDP based on 2000 prices.**

| Sector | 1980 | 1990 | 2000 | 2003 | Compound growth rate 1980-2003 |
|---|---|---|---|---|---|
| Agriculture | 52.3 | 40.3 | 28.5 | 25.3 | 3.5 |
| ● Agriculture proper | 21.7 | 16.9 | 12.8 | 11.2 | 3.8 |
| ● Livestock production | 16.2 | 12.9 | 8.9 | 8.1 | 3.7 |
| ● Forestry and logging | 14.3 | 10.6 | 6 | 6 | 2.8 |

*Source:* National Accounts Statistics, 2004.

Table 3 indicates that the contribution of agriculture sector in 1980 was over 50%. In relative terms, the trend in GDP contribution by agriculture sector is decreasing because of the exponential increase in the GDP contribution mainly by the industrial and hydropower sectors. In absolute term, agriculture, still the most important sector, is contributing to GDP positively (Table 4), meeting the domestic consumption for the increasing population and providing employment for the 69.1% of the population (Population and Housing Census of Bhutan, 2005).

**Table 4. Agricultural exports in Bhutan**

| 1998 | | 1999 | | 2000 | | 2001 | | 2002 | | 2003 | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| India | COTI | India | COTI | India | COTI | India | COTI* | India | COTI | India | COTI |
| *Value Million NU* | | | | | | | | | | | |
| 486.7 | 192.1 | 484.6 | 184.8 | 392.4 | 132.2 | 498.4 | 178.2 | 600 | 121.6 | 648.3 | 170.9 |
| *Total exports (%)* | | | | | | | | | | | |
| 11.6 | 68.6 | 10.3 | 66.7 | 8.9 | 55.3 | 10.6 | 60.5 | 11.6 | 35.6 | 10.9 | 64.7 |

**COTI = Countries other than India. Source: RMA (Royal Monetary Authority) Annual Reports of 2002-03 and 2003-04.*

In the 6th and 7th five-year plans (FYPs), a huge emphasis was given on agricultural development with the establishment and strengthening of agriculture research and extension system, increased input supply, subsidy and rural credit scheme. Horticultural development received particular attention in the 7th and 8th FYPs with the establishment of Horticultural Division under the Department of Agriculture, supported by a FAO executed UNDP funded Project, entitled the Integrated Horticulture Development Project I & II. With increased focus on agricultural production and as a consequence of increased export earning in the $6^{th}$ and 7th FYPs the plant protection service was strengthened through the establishment of the National Plant Protection Center (NPPC) in 1984 with fund and technical assistance from the then European Union (EU).

Since that time, plant protection service was delivered through the District Agriculture Offices with very little or no technical expert advice or guidance.With the establishment of NPPC as the apex body institutionalized for plant protection service, the pesticides delivery system saw a significant evolution from an unorganized independent procurement system to an organized and centralized system. In the 7th FYP (1992-1997), plant protection emerged from a pesticide-based system to an ecological IPM-based one. The significant changes, taking place in plant protection service, were in tandem with the fast evolving government policies towards sustainability and environmental preservation. The 6th and 7th FYPs also saw a speedy development pace in agriculture with focus on regionally balanced development that translated into the implementation of the Area Development Projects and Programmes to enhance agricultural production.

In the 8th and 9th FYPs (1997-2007), the Royal Government enhanced market oriented agriculture with emphasis on both quality and quantity production through strengthening of the then Quality Control and Regulatory Services (QCRS). In the 9th FYP, it was reorganized as the Bhutan Agriculture, Food and Regulatory Authority (BAFRA) for commercialization of agriculture at a much faster pace. The strategy in the 9th FYP was to enhance production, improve production areas accessible to transport facility through provision of farm roads and improve access to market information and technology, and improve market for agricultural produce. However, the development policies prioritized environmental conservation and management of natural resources with gross national happiness (GNH) being the development philosophy, wherein preservation and sustainable use of environmental was underlined. For plant protection service, which had already embarked on IPM as a strategy for carrying out any plant protection activity in the 7th FYPs, this translated into advocating the research and extension knowledge into farmers' practice of pest management on an increasing scale. At the same time, it also led to increased awareness among policy makers, development partners and donors alike.

It is important that agriculture is increasingly becoming commercial with horticultural crops like apple, mandarin orange and potato, gaining more economic importance. At the same time, because of urbanization and need for more cash income, there is an increasing pressure on farm labour. Therefore, agrochemicals like the herbicides are gaining more importance to substitute labour (Table 5).

**Table 5. Herbicide consumption in Bhutan (MT)**

| Herbicide | 1989-90 | 1996-97 | 2000-01 | 2004-05 | 2007-08 |
|---|---|---|---|---|---|
| Butachlor 5G | 30 | 90.62 | 166 | 264 | 250 |
| Metribuzin 70 WP | - | 0.08 | 0.25 | 0.637 | 1.1 |

Commercialization of agriculture, wherever possible, is encouraged and promoted for poverty alleviation, income generation and household food security goals. Therefore, the IPM approach is the most important tool for overseeing the judicious use and discouraging abuse and misuse of pesticides. It preserves and complements the efforts of taking advantage of the comparative advantages into the niche crops that our pristine environment provides, especially, towards encouraging organic crops and homegrown products. The 10th FYP (from July 2008) has prioritized agriculture to alleviate poverty through increasing income of the rural population. Again, GNH is the overriding development philosophy, which underlines the preservation and sustainable use of natural resources.

Due emphasis has been laid on capitalizing the comparative advantage of the pristine environment through the promotion and enhancement in the organic production of niche crops. For plant protection service, it will entail research and development efforts into pest control measures that are acceptable for organic production and certification. However, the IPM approach will be essential for supporting and promoting commercialization of agriculture wherever organic production will not be recommended until organic pest management technologies, matching the conventional ones, could be demonstrated in crops like citrus, apple and potato. Therefore, IPM will be the overriding pest management policy for the National Plant Protection Services in the near future.

## MAJOR PESTS AND CROP LOSSES

Table 6 indicates the average crop loss, which is not based on field study. However, crop losses locally could be as high as over 90 %. For instance, the maize Tursicum blight and grey leaf spot diseases caused over 90 % losses (in some places in Trashigang and Mongar in 2006-07). Similarly, rice blast caused total loss of rice production for some farmers (1995-96) in Paro and stem borer, over 90% loss in Samtse (in 2005); tuber moth, over 95 % loss of potato tubers in some places in Khaling and Yangneer in Trashigang in 2006; and fruit fly, up to 80 % loss of mandarin orange in 1990.

**Table 6. Major crops and estimated losses to crop pest and diseases.**

| **Major crop** | | **Insect pest** | **Disease** | **% loss (Est)** | **Remark** |
|---|---|---|---|---|---|
| Field crop | Maize | *Agrotis ipsilon* (Cut worm) | *Exserohilium turcicum* (Tursicum leaf blight); *Cercospora zeae maydis* (Grey leaf spot); | < 10 | No study was conducted for estimating crop losses due to pest and diseases. However, based on the field experiences of our plant protection personnel, working regularly in the field, the best estimated figure that could be close to the reflected actual loss. |
| | Rice | Leaf defoliators *Mythimna separata* (Paddy army worm); *Pelopidas* spp (skipper); *Nymphula depunctalis* (Case worm); *Dicladispa armigera* (Rice hispa); *Sesamia inferens* and *Chilo partellus* (Purple and pink stem borers); *Leptocorisa oratoria* (Gundy bug) | *Pyricularia oryzae* (Rice blast); in nursery bed: *Bipolaris oryzae* (Brown spot) and *Pyricularia oryzae* (Rice blast) | < 10 | |
| | Wheat and barley | *Rhopalosiphum padi* (Linnaeus) (Grain aphid); *Sitobion avenae* (Fabricius) (Grainaphid); *Dolycoris indicus* (Stal) (Shield bug); | *Ustilago segetum* (Bull) (Loose smut); *Tilletia tritici* (Bjerk) (bunt); *Puccinia graminis* Pers. (Stem rust); *P. recondita* Rob. (Brown rust); *P. striiformis* Westend (Yellow rust); *Septoria* spp. (Leaf and glume blotch) | < 10 | |

| **Major crop** | | **Insect pest** | **Disease** | **% loss (Est)** | **Remark** |
|---|---|---|---|---|---|
| Horticultural crops | Mandarin | *Bactrocera minax* (Endelein) (Fruit fly); *Anoplophora* nr. *versteegi* (Trunk borer); *Rhynchocoris poseidon* (Shield bug); *Diaphorina citri* (Psylla as vector); Toxoptera citricida (Brown citrus aphid); *Saissetia coffeae* (Helmet scale); *Lepidosaphes beckii* (Citrus mussel scale); *Phyllocnistis citrella* Stainton (Leaf miners in nursery) | *Liberibacter asiaticus* (Citrus HLB disease); *Phytophthora* spp. (root rot); *Erythricium salmonicolor* (Berk & Br.) (Pink disease); *Acrosporium tingitaninum* (Powdery mildew); *Elsinoe fawcetti* (Citrus scab) | < 15 | No study was conducted for estimating crop losses due to pest and diseases. However, based on the field experience of our plant protection personnel who are regularly in the field, the best estimate figure that could be close to the actual loss is reflected. |
| | Apple | *Argyresthia sp.* (Fruit borer); *Quadraspidiotus perniciosus* (Comstock) (San jose scale); *Panonychus ulmi* (Koch) (Red spider mite); *Hyperstylus* sp. Nr. *chloris* (Green apple weevil); Fruit beetles (*Popippia pilicollis* and *Protaetia neglecta* (Hope) | *Venturia inaequalis* (Cooke) (Apple scab); *Marssonina coronaria* (Ell. et J.J. Davis) (Apple blotch); *Gymnosporangium* sp. (Himalayan apple rust) | < 10 | |
| | Potato | *Phthorimaea operculella* (Zeller) (Tuber moth: field and mainly store); *Phyllophyga* sp. (White grub); *Agrotis segetum* (Denis and Schiffermuller) (Cutworm); Potato aphids (as vectors of viruses): *Myzus persicae*; *Aphis* spp.; | *Alternaria solani* (Early blight); *Phytophthora infestans* (Late blight); scab, viruses (PVA, PVS, PVX, PVY, PLRV); *Ralstonia (Pseudomonas) solanacearum* (Bacterial wilt or brown rot) | < 15 | |
| | Chilli | *Heliothis* sp. & *Helicoverpa armigera* ( fruit borer) | *Phytophthora capsici* (Chili blight) | < 10 | |
| | Arecanut | *Rhynchophorus ferrugineus* (Asiatic palm weevil) | *Phytophthora* spp. (Bud rot) | < 10 | |
| | Ginger | *Mimegralla coerulefrons* (Rhizome fly) | *Fusarium* sp. (Rhizome rot) | < 10 | |
| | Cardamom | Vectors of chirkey and foorkey disease: *Rhopalosiphum maidis* (Maize aphids); *Brachycaudus helichrysi* (Leaf curling plum aphids) | Foorkey and chirkey, *Fusarium* sp. (Wilt) | < 15 | |
| Storage Pests | Cereals (Maize, Rice, Wheat) | *Sitophilus oryzae* (grain weevil); *Sitotroga cerealella* (grain moth); *Tribolium castaneum* (Rust red flour beetle) | *Fusarium* spp. & *Aspergillus* spp. (Ear rots and grain molds) | < 10 | |

## IPM PROMOTION AND TREND OF INSECTICIDE USE

### IPM: A historical perspective

Until the 1980s, the District Agriculture Offices (DAOs), having no well-organized apex body, provided plant protection services. A rudimentary Plant Protection Programme was established in 1978-79. This Programme initiated the process of establishing a Plant Protection Service Centre in the early 1980s with proposed funding and technical assistance from the then EEC. By 1984-85, NPPC was established with fund and technical assistance from the then EEC through a Plant Protection Project (NA/82/18). Before the 1980s, pesticide requirement for each district was procured and distributed free of cost by DAOs independent of each other. This was in line with the government policy of providing subsidy on agricultural inputs and for encouraging farmers to adopt new technologies for increasing production. With the establishment of NPPC, particularly with the execution of the EEC Plant Protection Project from 1984-85 to 1989-90, the pesticides procurement and distribution system was streamlined. However, pesticides were provided at full subsidy as a strategy for increasing production and productivity even during this project period. Towards the later part of the project (1989-90), and during the extension phase (Up to December 1992), NPPC started to promote the IPM approach for pest management.

At the national level, this overlapped with the Royal Government (the National Environment Commission—NEC, the responsible agency) organized a national workshop in 1990 in preparation for the United Nations Conference on Environment and Development (UNCED) held in Rio de Janeiro in 1992. The Royal government is one of the signatories of this document. Since that time, IPM as an accepted approach towards pest management was gaining momentum and the second phase of the Plant Protection Project became the Integrated Pest Management Development Project (IPMDP), which commenced by April 1993. Through the project, the NPPC identified pilot sites for development of IPM technologies in collaboration with village communities and Extension service, which was following the concept of farmers' field school.

When the project ended by December 2000, IPM development in citrus, apple, potato and to some extent vegetables was achieved. New initiatives were carried out particularly in citrus, apple and chilli from 2000 to date. However, IPM advocacy and dissemination, particularly the implementation of the Wang Watershed Management Project (WWMP) in year 2000 (terminated in 2007) had a significant effect. The project focused on implementation of Farmers' Field School in citrus, potato, chilli, tomato, cabbage, rice and maize in eight districts (Haa, Paro, Thimphu, Chukha, Tsirang, Dagana, Zhemgang and Sarpang) and over 85 sites covering over 1,700 households. NPPC was involved in imparting training on IPM for pest management to extension staff.

**IPM implementation and pesticides usage**

Significant development occurred in the first phase of the Plant Protection Project both within plant protection system and at the government policy level. Evidently, the transition from pesticides-based pest control (Pest control was underlined at that time) to the ecological concept of pest management (Pest management evolved with IPM) was like a "dream come true" for any project/programme manager without having to lobby for policy support.

Three major developments that helped the transition towards IPM at the plant protection service level were–

- Inventory of outdated pesticides in 1991, which ultimately led to collection and incineration of the obsolete pesticides in 2006;
- Removal of subsidy on pesticides started from July 1990. NPPC started lifting subsidy (@ 15 % in the first four years and then 20% in the subsequent two years) on pesticides and by July 1995, pesticides were charged full. As a result the demand on pesticides reduced (Figure 3); and
- Streamlining of pesticide procurement and distribution system that ensured pesticides regulation and monitoring. Until then, pesticides were procured by DAOs as per the requirement of the district and distributed free of cost. The main draw back of this system was the accumulation of outdated pesticides.

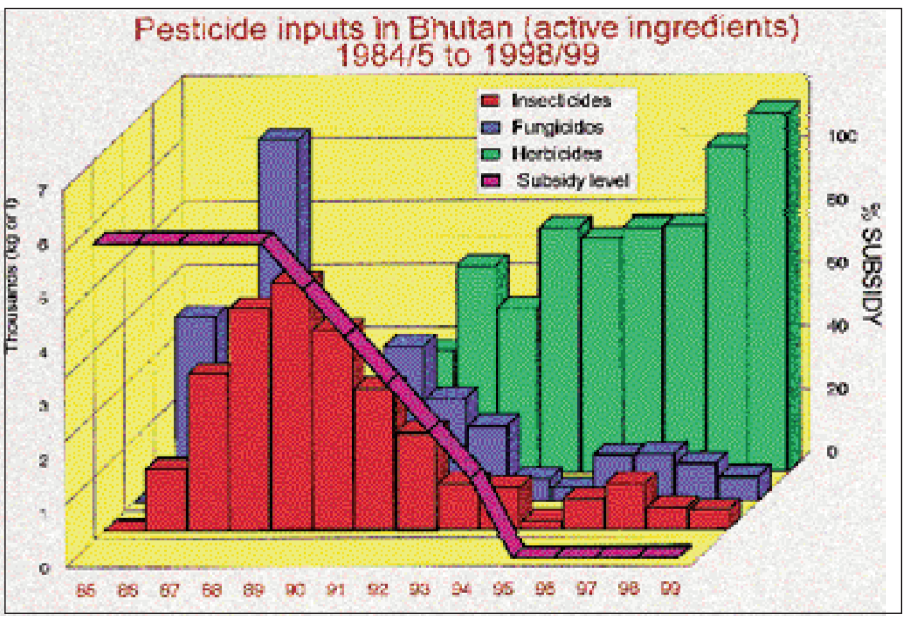



Figure 3. Pesticide usage trend after removal of subsidy.
*Source: IPM Extension Leaflet No. 5, July 2001, IPMDP, NPPC.*

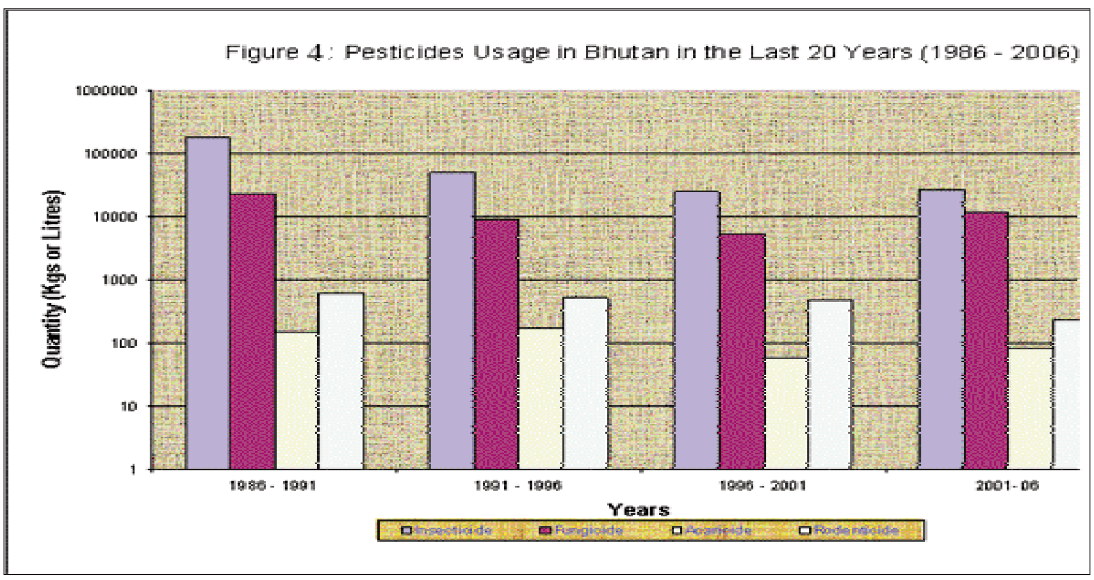
At the national level, the workshop on UNCED in 1990 and signing in 1992 helped plant protection service to move forward with IPM smoothly. With the commencement of 7th FYP (1992-93 to 1997-98), IPM as a pest management policy for NPPC to carry out pest management research and extension activities had taken root. Since that time, IPM has been the pest management policy for the national plant protection services.

Table 7 indicates that huge amount of pesticides were used in the first five years i.e. prior to the implementation of IPM. With the streamlining of pesticides procurement system through NPPC and the removal of subsidy, the consumption of pesticides had dropped significantly. DAOs collect pesticides requisition from the farmers for the crop season through the Extension Agents at the block level. After compiling the requisition, they submit the district requirement to NPPC. NPPC in turn compiles the whole country's requirement and calls for quotation through tendering. Pesticides are distributed based on the submitted requirement. DAOs pay in cash and collect the total amount (a system of Cash and Carry) for the district.

**Table 7. Pesticide usage trend, 1986-2006.**

(Quantity in kg or litre)

| Year | Insecticide | Fungicide | Acaricide | Rodenticide |
|---|---|---|---|---|
| 1986-91 | 173775 | 22770 | 144 | 610 |
| 1991-96 | 48830 | 8673 | 167 | 515 |
| 1996-01 | 24253 | 5331,5 | 56.2 | 463.2 |
| 2001-06 | 26289.6 | 11440.5 | 79 | 225.09 |



Until now, the national pesticides consumption is decreasing (Figure 4). However, with the commercialization of agriculture the consumption of pesticides will increase.
***Note: Log conversion was done for accommodating the lowest value

*Note* : *Herbicides usage was taken out and presented separately as the yearly data could not be obtained and presented*

**IPM ACTIVITIES IN BHUTAN**

With the start of the IPMD project in 1993, NPPC initiated IPM activities for apple, citrus and chilli.

**Apple.** IPM for apple scab management was able to bring down the number of sprays from a recommended 8-9 times in a season to three times by spraying during critical times. Similarly, NPPC was able to bring down the frequency of insecticidal sprays the farmers were carrying out as a prophylactic measures against insect pests. From a prophylactic over use of insecticides, NPPC was able to change it to need-based sprays.

**Citrus.** The focus of IPM was on fruit fly and loranthus control. Through the involvement of the community, first a 12-14 bait spray of protein with malathion 50 EC was developed. Later, spray was applied for three times: the first spray of cypermethrin 10 EC in mid June at mid altitudes and early June at lower altitudes). The second spray of dimethoate 30 EC was applied two weeks later and a third spray of cypermethrin 10 EC, two weeks after achieving successful control of fruit fly in combination with collection and destruction of dropped fruit at 10 days interval.

**Potato.** In potato, NPPC was able to establish that, on an average, there could be about seven folds increase in yield by spraying at least two times of mancozed 75 WP @ 2g /L based on the late blight counting criteria.

**Chilli.** In chili, Phytophthora blight was the main concern. IPM in blight management included selecting healthy pods for collecting clean seeds, raising seedlings on raised bed, following good spacing (20 cm x 15 cm), mulching, and root dipping with fungicides (Ridomil – 8% metalaxyl + 64 % mancozeb). This showed a very good control of blight. By the end of the IPMD Project in 2000, NPPC had developed IPM measures for control of major insect pests, diseases and weeds in the crops mentioned above through the involvement and participation of extension and farmers on a pilot scale (village or community level) which were scaled up (to district level). After the scaling up, leaflets were developed and provided to extension in the field for implementation of the IPM measures. There are reports of the impacts of the IPM measures on all the crops and particularly on the indiscriminate use of pesticides in these crops. However, no follow up activities and impact assessment work could be taken up due to human resource constraint after the termination of TA component with the project. However, in 2000, there was a significant effect on the promotion of IPM in various crops because of the implementation of Wang Watershed Management Project (WWMP).

The project promoted farmers' field school (FFS) method in crops including citrus, potato, chilli, tomato, cabbage, rice and maize covering eight districts (Haa, Paro, Thimphu, Chukha, Tsirang, Dagana, Zhemgang and Sarpang) and 85 sites, involving over 1,700 households. The field schools established at the 85 sites followed the IPM approach for any pest management. For three consecutive years (2004 to 2006 seasons), the farmers in the FFS at 15 location under 3 districts harvested higher yields, up to 60 % higher yields in potato, cabbage, tomato, chilli, and broccoli crops. However, crop yield increased due to good agriculture practice followed by FFS and the IPM approach. NPPC was involved in training of Extension Agents under the WWMP programme areas in IPM approaches and methods.

It is important to mention here that since the later part of the 1980s, NPPC has been advocating IPM approach for managing any plant protection problems including vertebrate pests. Since that time, for the research and development of pest management measures, NPPC has been following the IPM approach in all its activities including extension trainings, presentations and advocacy at the College of Natural Resources (CNR), advisory service or deliberations. As a result, the National Extension System has also taken the IPM approach in their efforts to pest management. Additionally, the awareness about IPM approach, mainly among the farmers and researchers are noticeable. However, no study was carried out to establish such claims.

## INSTITUTIONAL ARRANGEMENT FOR IPM EXTENSION

Bhutan is divided into 20 districts with 202 blocks having agriculture extension personnel called the Extension Agent (EA). Each district has a District Agriculture Officer (DAO) responsible for supporting the block level EAs. Figure 5 shows the coverage of extension services.

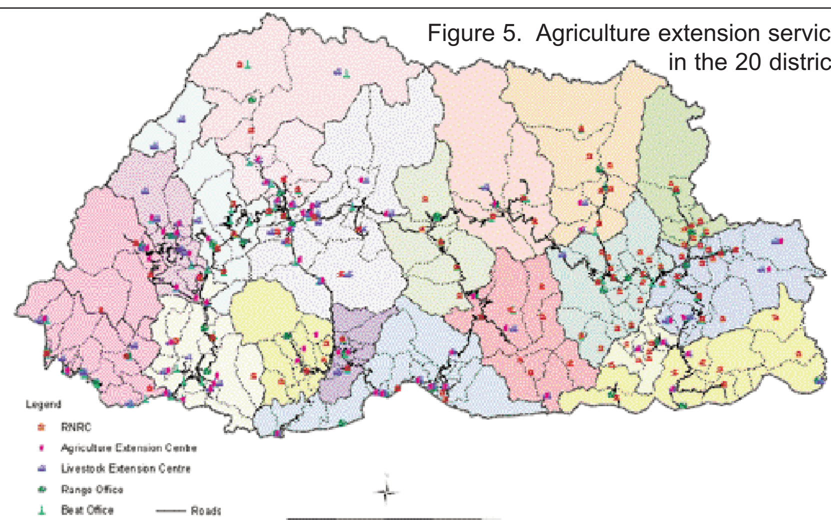



Figure 5. Agriculture extension service coverage in the 20 districts (in pink).

Formally, for IPM extension, the district agriculture services under the district agriculture sector comprising the district and block agriculture extension are responsible for implementation in the field. NPPC in collaboration with research, extension and farmers is responsible for carrying out research and development activities for development of IPM measures on a particular pest. The IPM measures developed, evaluated and validated through farmers' participation are then imparted to extension through various means like training, workshops, visits and extension materials distribution. As shown schematically in figure 6, the unbroken lines indicate the formal and hierarchal channels, while the broken lines indicate the informal channel. Therefore, even for IPM technology transfer, the formal channel is followed, while informal information exchange take place on a regular basis through advisory services, as resource persons during trainings, and field visits organized by the district agriculture sector.

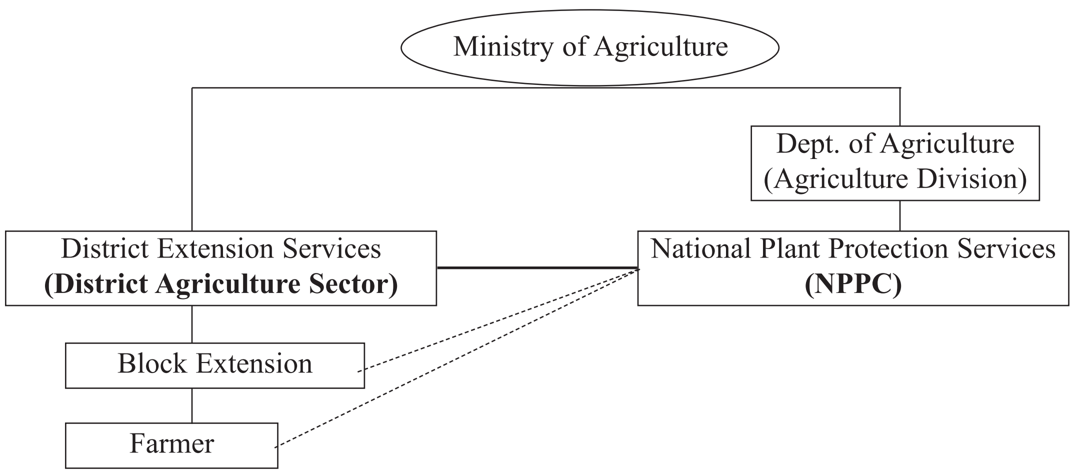



Figure 6. A simplistic schematic presentation of IPM extension_

Besides the formal extension system, the importance of three main technical forums under the Ministry of Agriculture should be highlighted that contributes significantly to the semi-formal transfer of technology, including the dissemination of the IPM measures. For setting the research agenda and fine tuning of research for extension needs the following three main forums through which agriculture research (under the Council of Renewable Natural Resource Research of Bhutan – CoRRB) and Agriculture Extension meet regularly are:

- *Annual Regional Research-Extension Planning and Review Workshop*
- In the workshop, research findings are presented and extension feedbacks are sought for research agenda setting and incorporation of extension issues, so that research outputs are made practical and easily adoptable by farmers.

- *Horticulture and Field Crops Co-ordination Workshop*
- In the workshop, mainly technical aspects of research and coordination issues between various researchers and stakeholders, including extension are deliberated.
- *Annual Renewable Natural Resources (RNR) Conference*
- In the conference, the sub-sector issues that require the endorsement; and policy direction and decision are deliberated.

These technical forums have important role in bridging the coordination and linkage gaps mainly between research and extension, by fostering professional exchanges. Besides, the formal channel of IPM extension, which is through the District Extension, these forums have huge role in IPM extension through the exchanges and deliberations with extension personnel during such meetings.

**PRIVATE SECTOR INITIATIVES IN IPM ACTIVITIES IN THE COUNTRY**

Until now, there are no private sector initiatives in IPM activities in Bhutan. However, there is a growing trend in Bhutan for buying homegrown products due to the growing awareness about health hazards related to commercial agricultural products associated with use of agrochemicals for pest control. Hence, indirectly, this will encourage and promote the adoption of IPM measures in the farmers' fields.

**GOVERNMENT COMMITMENT ON IPM ACTIVITIES**

The Royal Government is fully aware of the comparative advantage it has, in terms of its pristine production ecological conditions and the great gift of bio-diversity vis-à-vis the land holding limitations for economy of scale. Hence, the Royal Government has embarked on the high value and low volume crops like the mushrooms; and medicinal and aromatic plants that are targeted for the organic basket, where our comparative advantage lies. However, for meeting the poverty alleviation, income generation and food security goals, horticultural crop promotion and increasing production and productivity are very important. In the light of such development approach, the government is fully convinced that IPM is the only way for pest management which will foster conservation and protection of our ecosystem that will in turn ensure income generation and food production at minimal environmental cost. Therefore, IPM has remained as the pest management policy for the national plant protection services since the 7th FYP and this policy will be further strengthened in future as the organic programme gains momentum.

On a time scale, the emphasis and focus on sustainable production, with environmental safety in view, emerged vividly towards the second half of 6th FYP (later part of the 1980s). As a result, the sustainable development approach was taken in the 7th FYP development period for all sectors (7th FYP document).The policy for pest management was adopted as IPM and hence, the project that commenced with the 7th FYP was named as IPM .

Development Project Some of the developments, taking place for protection and preservation of environment during the early part of 7th FYP, deserve a mention that had a direct or indirect impact on IPM implementation. Therefore, an overall frame from a development point is presented below.

The significant points include–
*At the national level*

- Signing the Rio de Janeiro Convention (UNCED) in 1992
- Declaration and demarcation of 26 % of total land area as rotect area in 1993
- Passing the Forest and Nature Conservation Act in 1995
- Environment Assessment Act 2000
- Biodiversity Act of Bhutan, 2003
- Ratification of the Basel Convention in 2004 and subsequent destruction of obsolete chemicals with fund from the Swiss Agency for Development Cooperation (SDC), Switzerland in 2006.

*At the sector level*

- Adoption of IPM as a pest management policy and subsequent
    - Removal of subsidy on pesticides from 1990
    - Approval of the IPM Development Project (ALA/92/12) under - NPPC by the Royal Government with fund from the EU (December 1992).
    - Adoption of IPM as a pest management policy in the 7th FYP period
    - Collection (1992-1995) and incineration of 32.19 metric tons of obsolete pesticides in 2006 in Switzerland.
    - Streamlining the pesticides procurement and distribution system as a regulatory measure through NPPC
- Plant Quarantine Act of Bhutan, 1993
- Passing the Pesticides Act of Bhutan in 2000
- Implementation of the Wang Watershed Project with focus on
- Farmer's Field School in 2000
- Instituting Organic programme under the horticulture

The support of the Royal Government to the research and development activities of IPM could be surmised from the above major initiative.  For any future initiatives towards the promotion of IPM, the 9th FYP initiatives which are underway and the planned activities for the same programmes for the 10th FYP will add value. The organic programme (upgraded from the Organic Section) under the Division of Horticulture is one initiative of the government.

It will add value to the IPM programme as the focus of the organic programme will be on promotion of the good agriculture practices (GAP) and organic cultivation, which is complementary to the NPPC's programme focusing the IPM measures for pest management with particular attention given to bio-control measures that are accepted as organic. The government's initiative towards organic in the future FYP is expected to strengthen the IPM base (the R&D and the extension dissemination of IPM technologies and field implementation measures like the IPM farmers' or field school groups). Because, it will only complement and add value to the organic approach to crop production from a system's point of view and also from the point of view of market (where safety and health are primary concerns of the consumers).

## FUTURE PLAN OF ACTION

For NPPC, the policy towards pest management is IPM since the early 1990s. As a result, in all its research and development efforts and extension trainings, including trainings for farmers, and lectures and trainings for CNR students, NPPC has been following the IPM approach. Therefore, the IPM approach has been mainstreamed into all the NPPC research and development activities. However, the NPPC had not been able to assess the impact and need for fine-tuning and sharpening focuses on IPM research and development due to human resource constraints. Therefore, in future, there is a need to recognize and strengthen the base of IPM i.e., from policy directions to research and development efforts and to implementation strategies in the field. Hence, as a first step towards initiating the groundwork for building the IPM base, there is a need to, critically assess the impact of the IPM technologies; the level of adoption; problems of adoption, if any, and then embark on the next step forward, after the assessment. This will have to be an elaborate task that is executed meticulously and professionally. From there the design of the next steps could be carved out. Some key issues that could be highlighted are–

- The planning processes – taking care of longer term manpower deployment tied to a program output (not out put of an activity)
- Manpower constraint
- Program Linkage and hence the coordination of activities
- Networking of professionals
- Implementation approaches and strategies

## SUGGESTIONS AND RECOMMENDATIONS

In the context of Bhutan where the literacy rates of farmers are low, IPM measures should be viewed to have two aspects: one of the hardware parts, i.e., the technology part; and other the software part, which is the social aspect. Many of the IPM measures require the active participation of farmers from a certain physical boundary to work in groups for managing the pest effectively.

It is true in case of controlling fruit fly, citrus psylla (vector of citrus HLB disease), trunk borer and loranthus in citrus, tuber moth and aphids (as vectors of viruses) in potato, fruit borer in apple. In addition, pooling of resources to buy sprayer machine is required for controlling certain other diseases on time, for instance, late blight in potato, apple scab and maize diseases to mention a few. For resource poor farmers, to learn and share the scarce resource is an immense task as an Extension Agent. In our experience, the social aspect takes time in managing than the technical aspect. It is more than educating the farmers; it is about building trust and confidence in each other for sharing resources and working together for finding solutions to a common problem.

Interestingly, farmers could work together towards managing a common challenge. However, it is critical that the professionals (Researchers and extensionists) engaged in the field are linked into the system for intellectual development, exposure, gaining confidence and developing professional and personal relationships with other professionals in the similar fields. It helps establish a professional working interaction that facilitates a constant exchange of information and knowledge between the professionals, which would foster the development of a strong professional team During field implementation of an IPM programme, at a particular moment, one gets stuck because policy issues were not dealt in the past, for instance, community mobilization. It is, therefore, very critical to plan ahead and see if there are any policy issues that need to be clarified to ensure the success of a programme and / a policy flexibility is foreseen while a program is being developed so that changes could be accommodated at a later time frame.

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## Appendix-1. Person engaged/involved in IPM activities in Bhutan

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| Samdrupjongkhar | Tshetrim | 07 251483 | 07 251483 | 17674665 | |
| Lhuentse | Karma Wangchuk | 04 545127 | 04 545129 | 17610744 | |


Aphids monitoring in the field


Farmers' group discussion


Farmrs' traning on IPM


A view of FFS plot


Group planning for FFS


Farmers' training on maize diseases


Group presentation in the FFS


Field observation by group leaders

Training on pest & diseases management

Pest monitoring in the field

Indian Traders Field Inspection

Pheromone trap

Maize farmers training

Maize disease monitorng with farmers

Training on safe application of pesticide

Selection of good potato seeds

# Chapter 3

# India

# Integrated Pest Management Activities in India

O P Sharma

## INTRODUCTION

Indian agriculture has made tremendous progress from the present 0.13 ha per capita land. However, it will further reduce to 0.1 ha in 2020 and more than 50% of the land would be set with different degrees and types of degradation problems. Based on the trends of consumption it is estimated that the total food grain requirements will be more than 240 million tons in near future**.** The production targets and required yield to feed increasing population (@ 1.8% per annum) with present available resources require the higher production in cereals as well as in pulses and oilseeds. Food grain production has increased more than double since 1960, largely as a result of the introduction of new crop varieties and intensification of agriculture, supported by increased applications of irrigation, chemical fertilizers and pesticides. In absence of possibility to increase land and break technical production barriers, there is a possibility to increase yield by preventing pest damage, which amounts to 18% in general. Planners and policy makers, concerned about tougher trade rules in the wake of implementation of World Trade Organization (WTO) agreement, equally support the need and the aims of sustainable agriculture to produce in an environmentally and socially acceptable manner, maintaining the local natural resource base for future generations.

However, some scientists suggest that population and economic growth worldwide have raised the demand for food beyond levels that can be supported by extensive and environmentally benign farming. However, like other eco-conscious group Indian agricultural policy makers are equally committed to integrated pest management (IPM) as defined by the Food and Agriculture Organization (FAO), as an economically viable and socially acceptable approach to crop protection. It is the top priority mission of the Indian Council of Agricultural Research (ICAR) and other crop -based institutes including the Govt. of India to provide safe and effective technologies to protect against unacceptable losses caused by pests, which to an estimate based on 2007 prices works out to Rs.90,000 crores per annum. Crop based ICAR institute along with other Govt. departments has dedicated themselves to various aspects of IPM promotional activities apart from developing IPM technologies.

## AGRICULTURE IN PERSPECTIVE

### Pre-Green Revolution Scenario

Attaining self-sufficiency in food and nutrition with own resources had been the major policy of India since independence in 1947. In the early 1950s, the total food grain production was about 50 million tons, which was not sufficient and led to import 8-10 million tons of food annually. Through the mid 1960s, Indian agriculture was characterized by a rich diversity of crops and land races, high dependence on rainfall, less fertilization good organic matter content and fertility of soil, low cropping intensity and almost no use of chemical fertilizers and pesticides. Farmers depended on use of farm wastes as crop nutrient supplements, irrigation from ponds, rivers, shallow wells, and managed pests through cultural and indigenous techniques involving spray of plant decoctions. However, pest outbreaks occurred, crop productivity was sustainable and the losses were tolerable to farmers to meet their economic and social requirements.

**Green Revolution**

Indian agriculture has undergone unique and spectacular technological transformations that gave rise to "Green Revolution". The success resulted in four-fold increase in production of food grains from 51 million tons in 1950-51 to 214.12 million tons in 2004-05. Similarly, production of oilseeds has increased more than double from 24.75 million tons in 1998-99 within a decade. Similar experience was observed in other crops e.g., pulses, millets and coarse grains There has also been a considerable increase in the production of vegetables and fruits, placing India among the leading producers at the global level, after China and Brazil (Paroda, 2003) apart from uplifting economic conditions of farmers in general. The result of green revolution has also helped adjoining neighboring countries.

**Post-Green Revolution Scenario**

In spite of the impressive achievements, agriculture continues to face infrastructural and technological constraints e.g., only about 36% of the total cultivated land is under assured irrigation system, leaving others completely dependent on rainfall, which is characterized by large variations in terms of precipitation both spatially and in time. Majority of small farmers in different parts of India, gains from application of improved agricultural technology are yet to be realized. In spite of the fact that India ranks next only to the top producers in the world in total production in paddy, wheat, onion, sugarcane, rapeseed, groundnut and sesame seed, the global rankings from productivity are amongst the lowest and need attention. Productivity constraints are quite varied but generally include lack of high yielding pest resistant crop varieties, inadequate crop management, and recurring incidence of insect pests, diseases, weeds etc, which often lead to epidemics.

Intensive agriculture, which led to the Green Revolution, has been featured by increased genetic uniformity of crops, dense plant population, higher fertilization and irrigation, altered cropping systems with immediate profit motives and increased use of pesticides. Like other developing countries, agricultural production and fertilizer use both increased by almost 42%, the latter from an average of 63 kilos per ha of cropland. Although the use of pesticides increased more than 30 times between 1950 and at the end of the 1990s, pests still cost Rs 90,000 lakh annually in lost agricultural production (Singh and Sharma, 2001). General estimate of percentage losses in various crops is as follows: Rice (18.6), wheat (11.4), sorghum (10.0), pulses (7.0), oilseeds (25.0), cotton (22.0) and sugarcane (15.0). At present, the annual losses of agriculture produces due to different biotic factors are enormous (Table 1).

**Table 1. Annual losses of agriculture produce in India.**

| Biotic agent | Losses (in crores) | Percentage of loss |
|---|---|---|
| Weeds | 1980 | 33 |
| Diseases | 1560 | 26 |
| Insects | 1200 | 20 |
| Storage | 420 | 7 |
| Rodents | 360 | 6 |
| Others | 480 | 8 |

*Source*: Pesticide Information (April-June 2001).

The technology of intensive agriculture, no doubt, generated the Green Revolution with emphasis on producing more and more food from the available natural resources, its misuse has led to newer problems–

- Faulty soil and water management like over-exploitation of the land and excessive and untimely use of irrigation water,
- Replacement of a rich diversity of traditional crop varieties with a fewer high yielding varieties and
- Injudicious and indiscriminate use of chemical fertilizers and pesticides (Paroda, 2003).

**Present status of pest in relation to changing cropping system**

The intensive agriculture, especially the introduction of new high-yielding genotypes has become susceptible to the pests and the pathogens and their races already present in the country. The changing cropping patterns including cultivation in non-traditional areas have resulted in a spurt of pests and diseases in various cropping systems and remarkably changed the scenario of biotic stresses (Puri *et al*., 1997). Consequently, new pest problem has not only emerged, but also the minor pests assumed the status of key pests and vice-versa (Table 2). Intensification of cropping systems has led to imbalance in pest scenario, leading to increase in biotic stresses on account of–

- Introduction of new pest problems e.g. cotton leaf curl virus (CLCV), B Bio-type of white fly (*Bemisia tabaci*= *B. argentifolii*), spiral white fly (*Aleurodicus disperses*), wooly aphid (*Ceratovacuna lanigera*), subabul psyllid, (*Heteropsylla cubana*) and Coffee berry borer (*Hypothenemus hampei*);
- Increased intensity of the existing pests, e.g. white rust of mustard (*Albugo candida*), leaf blight of wheat caused by *Helminthosporium* and *Alternaria* spp, sheath blight of rice (*Rhizoctonia solani*), downy mildew of pearl millet (*Sclerospora graminicola*) whiteflies (*Bemisia tabaci*), rhinocerous beetle

of coconut and oil palm (*Oryctes rhinoceros*), eriophyid mite of coconut (*Aceria guerreronis*), coreid bug (*Paradasynus rostratus* ) , mosquito bug of cashewnut (*Helopeltis antonii*), cotton mealy bug (*Plannococcus* sp) , grape mealy bug, tobacco streak virus (Illar virus), crinkle mosaic virus, citrus die-back, citrus gummosis, guava and pomegranate oily black spot and wilt, white root tip nematode and

- Development of resistance in pests against various pesticides e.g. American bollworm, whiteflies and storage pests e.g., singhara beetle (*Galerucella birmanica*) (Jacoby), tobacco caterpillar (*Spodoptera litura*) (Fab.), gram pod-borer (*Helicoverpa armigera*) (Hubner), white flies (*Bemisia tabaci* (Gennadius), diamond back moth (*Plutella xylostella*) (Linnaeus), jassid *(Empoasca kerri* Pruthi*)*, aphid (*Aphis craccivora* Koch *, Lipaphis erysimi*), red floor beetle (*Tribolium castaneum*), rice weevil (*Sitophilus oryzae*), gram beetle (*Oryzaephilus surinamensis*) , lesser grain borer (*Rhyzopertha dominica*), cigarette beetle (*Lasioderma serricerne*), leather beetle (*Dermestes maculatus*) and khapra beetle (*Trogoderma granarium*) (Dubey and Sharma, 2005). Seven plant pathogens have also developed resistance against fungicides e.g., apple scab (*Venturia inaequalis*), grape powdery mildew (*Gloeosporium* spp, *Uncinula necator* and *Plasmopara viticola*), groundnut (*Aspergillus flavus*), potato (*Phytopthora infestans*), rice (*Dreschlera oryzae* and *Pyricularia oryzae*) and sugarbeet (*Cercospora beticola*).

Sugarcane woolly aphid has become great concern to cane growers of Maharashtra and Karnataka. Chemical control has failed to provide permanent solution as the pest reappears after 20-30 days after insecticide sprays. Bio-intensive IPM approach seems to be the only alternative, hence, conservation and augmentation of potential biocontrol agents (predators and parasites) is being multiplied and used extensively. Rodent pests threatening the bamboo and rice cultivation affect a number of villages in Mizoram (approximate area of 1,000 ha.)

**Table 2. Estimates of crop loss during pre- and post-green revolution due to insect pests (%).**

| **Crop** | **Green revolution** | | |
|---|---|---|---|
| | **Pre-** | **Post-** | |
| | | **1983** | **1993-94** |
| Cotton | 18 | 50 | 50 |
| Rice | 10 | 20 | 25 |
| Brassica veg | NA | 37 | 35 |
| Pulses | 5 | 10 | 30 |
| Sugarcane | NA | NA | 20 |

*Source* : Birthal P.S. 2003 – Policy Paper No.18, NCAP, New Delhi.

Despite advancements in the field of plant breeding and molecular techniques a number of plant diseases (Table 3) continue to be threatening and capable of causing severe damage in the event of epidemics as happened during Irish potato and Bengal famine. Plant viruses are another group of biotic constraints for which till this date there are no economic management strategies. Some of the threatening viruses, which every now and then assume economic importance are as follows: Badnaviruses (Rice tungro), geminiviruses (Legumes, cotton, potato, tomato), potyviruses (Sugarcane, potato, cucurbits, papaya, grain legumes and vegetables), tospoviruses (Vegetables and grain legumes), ilar viruses (Sunflower and legumes), and nano viruses (Bunchy top of banana).

**Table 3. Status of key plant diseases of economic importance.**

| **Disease** | **Current Status** |
|---|---|
| Banana leaf spot | 1930 to date several epidemics |
| Botrytis grey mold | Frequent epidemics |
| Cereal smuts | Continuous loss |
| Karnal bunt | Spreading |
| Viral diseases of pulses | Continuous loss |
| Cotton leaf curl | Spreading |
| Mango malformation | Continuous loss |
| Coconut wilt | Spreading |
| *Rhizoctonia* root rot | Continuous loss |
| Downy mildews | Continuous loss |
| Red rot of sugarcane | Continuous loss |
| Grey mildews | Spreading |
| Tobacco streak virus | Spreading |
| Guava wilt | Continuous loss |
| Citrus die back and gummosis | Spreading |
| Parawilt of cotton | Continuous loss |
| Vascular wilt of legumes | Continuous loss |

The greatest benefit of the Green Revolution is often overlooked, had it not been there millions of acres of natural habitat and forest had to be destroyed to make more land available for cultivation to meet food requirements. A lot of natural areas and biodiversity survived because of Green Revolution. However, with the misuse of technology and passage of time adversely affected the biodiversity and ecosystems. Fertilizer use made great headway in providing sufficient food to lower mortality levels, but the environmental degradation resulting from overuse has deteriorated natural resources such as water quality with high nitrates and pesticide residues raising mortality levels. Crop rotations that traditionally included legumes and grass for fodder became less important with the subsidized nutrients resulting in loss of benefits of soil-conserving rotations, improved soil water infiltration, higher organic carbon content, increased water-holding capacity, and erosion. Over intensive agriculture is a major cause of the degradation of natural resources. According to a study the direct environmental costs of British agriculture, for instance, have been assessed at US$ 350/ha per year, which include cleaning pesticides and nitrogen from drinking water, restoring lost habitats and eroded soils.

The quest of relentlessly improving the crop productivity has led to gene erosion due to "gene" or "genome bias". An extreme form of reductionism has taken place in most of the crop improvement programmes and dominated the biodiversity conservation and promotional schemes. Molecular assisted breeding has also directed research towards the development of "super breeds" distributed so widely and universally that others relegated to gene banks or, worse, lost altogether. Mainstream agriculture has become dependent on relatively few breeders, on few breeding strategies, and predominantly on ex-situ gene-banks for new seeds for changing needs. Since the practice of using save seeds, these breeding or conservation strategies primarily focused on single gene logics of pest and disease resistance and high yield.

This bias in genetics towards single characteristics reinforces the decline of diversity in agriculture at the expense of limited knowledge of co-evolution of pathogens, development of races, patho-types and pest resistance. Polygenic resistance is harder to define, though exactly which genes are involved may be unknown but is effective against all races of a pathogen. They are quantitative, because of intermediate levels of reaction ranging from resistant to susceptible. Often, polygenic resistance does not give high level of resistance as major gene resistance thus leading to failures. With farmers around the globe planting three times as much land in "transgenic" crops genetic engineering in agriculture is on the rise, so is the Indian cotton scenario. There is a fear that some natural varieties (local) will disappear forever and will be a serious loss for agriculture. Apathy towards conservation of biodiversity has led to disappearance of many local plant species. Decline in cultivated varieties is a serious loss for agriculture as combating tool for pest management and movement to gain sustainability.

## TREND OF PESTICIDE USE

Prior to 19th century, farmers relied almost exclusively on cultural methods such as healthy seed, crop rotation, and altered date of sowing to manage pests. Chemical control began in the 1870s with the development of arsenic and copper-based pesticides. Pest control strategies changed dramatically with the development of DDT in the late 1930s. Early tests found DDT to be effective against almost all-insect species and relatively harmless to humans, animals, and plants. It was effective at low application levels, relatively inexpensive, hence Indian industries also joined the race and farmers being amazed with results started using without giving second thoughts. Initially it helped but subsequent injudicious use created a vicious cycle, undermining enhanced yield. The results of chemical pesticides were so promising that research focused on synthesis, development and marketing of new efficient molecules. Review of literature indicates that almost all the crops are receiving the pesticide treatments and their financial implication has been worked out (Table 4).

**Table 4. Consumption of pesticides (in term cost) by different crops to manage key pests.**

| Crop | Pesticide consumption (million Rs.) | % of total pesticides consumed |
|---|---|---|
| Cotton | 2472.13 | 44.5 |
| Paddy | 1272.05 | 22.8 |
| Sorghum | 495.40 | 8.9 |
| Fruits and Vegetables | 387.38 | 7.0 |
| Wheat | 354.48 | 6.4 |
| Arhar | 155.20 | 2.8 |
| Groundnut | 136.84 | 2.5 |
| Bajra | 99.05 | 1.8 |
| Maize | 63.62 | 1.1 |
| Sugarcane | 38.41 | 0.7 |
| Ragi | 20.04 | 0.4 |
| Jute | 15.38 | 0.3 |
| Gram | 12.20 | 0.2 |
| Onion | 10.92 | 0.2 |
| Rapeseed | 9.10 | 0.2 |
| Mustard | 3.93 | 0.1 |
| Tobacco | 3.04 | 0.1 |
| Sunflower | 2.45 | 0.1 |
| Potato | 0.95 | 0.0 |
| | 0.10 | 0.0 |

Based on consumption in 2000.

Table 5 presents the chemical companies rapidly expanded their research on synthetic organic insecticides as well as efficient chemical approaches to the control of pest and the same. However, the problems of negative externalities were encountered shortly after the misuse of DDT and other imported dirty dozen chemical pesticides in India. In order to manage pests more efficiently producers then turned to the more toxic, organophosphate (OP) and pyrethroid insecticides, which further resulted in development of resistant strains of pest apart from other maladies (Dubey and Sharma, 2003 ). Most of early pesticides were originally based on toxic heavy metals such as arsenic, mercury, lead or copper. However, modern pesticides, focused on organic compound, which are effective in smaller quantities resulting in reduction in per ha usage.

**Table 5. Transition phases in pest management.**

| Decade | Emphasis |
|---|---|
| 1930 | Development of DDT molecule as pesticide |
| 1960 | Introduction, Protection without consideration |
| 1970 | Products with better performances: Efficacy, environment and toxicology |
| 1980 | Shift from efficacy to environment and non-target effects Late 80's- Resistance management |
| 1990 | Shift to clean environment, integrated pest management (IPM) and Resistance management |
| 2000 | Alternatives to chemicals |
| 2002 | Commercialization of transgenic cotton with toxin from *Bt* |

Pesticides continued to be the predominant and much relied weapon used against pests till 1990s and their overuse had witnessed a steady rise over the years. In past it has been increasing @ 2-5% per annum. However, at present, it accounts for 2 % of the total pesticides used in the world. About 96,000 metric tons of technical grade pesticides are currently produced in the country while the projected demand is 100,000 metric tons. According to estimate made by Khan (1996) more than 67% of total pesticides are used in the agriculture sector alone and the rest goes for urban pest management especially for malaria eradication.

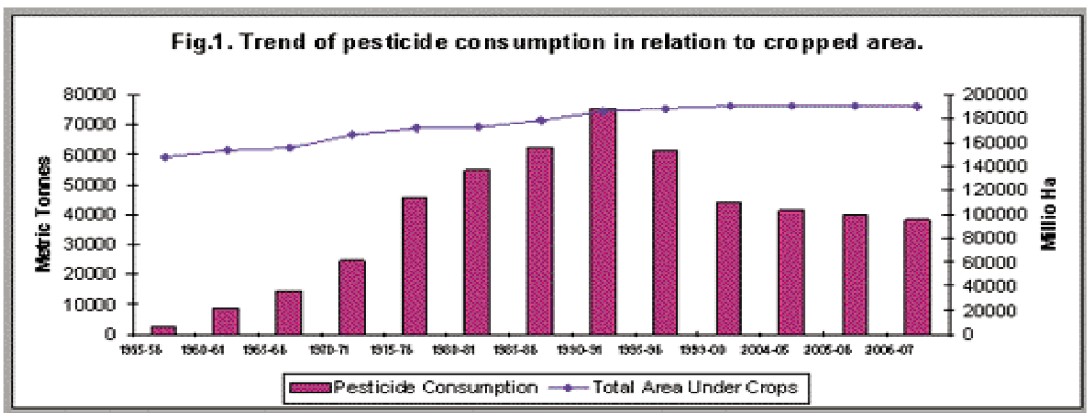

**Fig.1. Trend of pesticide consumption in relation to cropped area.**

Extensive use of chemical pesticides, led to dramatic improvements in the production and productivity of crop plants. However, with passage of time their impact has waned and the pests continued to be a serious production constraint. With advancement in analytical science and electronic media the consumers become concerned both about food quality and the effects of modern farming methods on the natural environment. Pesticides often kill off natural enemies along with the target pest. Once natural enemies were eliminated, pest populations multiplied empirically to higher level. The phenomena often result in the development of resistant ones, which did not exist earlier.

Additional chemical pesticide treatments only repeat this cycle. Adoption of the high yielding crop varieties led to many fold increase in yield and maintaining the same yield level also led to a dramatic increase in pesticide use. The amount of pesticide increased from 2,353 metric tons in 1955 to maximum of 75,033 metric tons in 1990, which afterwards kept on declining to current 39,773 MT (Fig. 1) during 2005-06, while the cropped area remained static (Chand and Birthal, 1997; Singh and Sharma, 2005). When yields were low there was little benefit from pest control. As yields rose, the economic incentive to adopt chemical pest control technologies also rose, out spacing the trend in yield increase. During the 1950s, the benefits of the pesticides were obtained at a substantial cost, and the costs included not only the increase in resistance to pest control chemicals in target populations and the destruction of beneficial insects, but also the direct and indirect effects on non-target organisms. In the early 1960s, public concern about these effects was galvanized by Rachel Carson's dramatic revelations of the effects of the new insecticides by publication of Silent Spring in 1962 (Carson, 1962).

As per keynote address of Dr Pimentel for Wildlife Pesticides and People Conference, the estimated cost to society from pesticide damage to beneficial insects including pollinators is given as \$700 million annually. Scientists all over the world were shaken of their total reliance on chemical pesticides. Problems of indiscriminate use was quite alarming in India, although pesticide consumption (243 g/ha) is far less in comparison to other developed countries like Japan (12 kg/ha), Taiwan (17 kg/ha), Thailand (1.4 kg/ha) and West Germany (3 kg/ha) (Dhaliwal and Arora, 1996; Punjawani, 1998). In our country about 54 and 17% of total pesticides, respectively, are consumed for cotton and rice crops (table 6) alone till Bt transgenic cotton was released in 2002 (Anonymous, 1997). The cropped areas under these crops are only 5 and 24%, respectively. Conventional cotton crop use to receive as many as 15-20 rounds of insecticide sprays right from the vegetative stage till its picking. According to an estimate, 3.75 kg of pesticides were applied to 1 ha of cotton (Birthal and Jha, 1997) before introduction of transgenic. Earlier Andhra Pradesh, Karnataka and Gujarat accounted for 65% of the total pesticide consumption (33.6% are consumed in Andhra Pradesh alone) but due to initiatives taken up by the state Govt. and FAO focus on promotion of IPM have resulted in significant reduction of pesticide use.

Current statistics show that Punjab, Uttar Pradesh and Haryana have emerged as major consumers. Up to 1995-96, the major group of chemical pesticides used in agriculture was insecticide (80%), followed by fungicides (10%), herbicides (7%) and others (3%). However thereafter, the consumption of insecticides declined with simultaneous increase in the percentage consumption of herbicides and fungicides (Table 7). In 1999-2000, the consumption of insecticides was 60%, fungicides 21%, herbicides 14% and others 5%. Although the consumption of pesticides per hectare has remarkably gone down (Anonymous, 2000), the distribution and uses of pesticides on different crops varies remarkably. With launching of horticulture mission and crop intensification percentage of fungicides as well as herbicides has increased significantly. The declining trend of consumption of chemical pesticides during 1990s and as of today is obviously due to increasing awareness of ecological concerns and IPM initiatives taken up by government at state level and availability of safer molecules, which are effective at very low doses and persistence apart from availability of bio-pesticides (Table 8). The latter is yet to cover any significant acreage of crops. However, the change of Government policy is likely to bring changes. Because of combined efforts of research and developmental agencies and changing agroecosystem use of different types of pesticide has undergone drastic changes (Fig. 2) and made place for bio-pesticides.

**Table 6. Pesticide consumption on major crops in India.**

| Crop | Cropped area (%) | Pesticide use (%) |
|---|---|---|
| Cotton | 5 | 45 |
| Rice | 24 | 22 |
| Vegetables and fruits | 3 | 9 |
| Plantation crops | 3 | 7 |
| Pulses and oilseeds | 12.9 | 4 |
| Wheat | 14.2 | 4 |
| Others | 37.9 | 9 |

*Source*: Agrolook, 2000.

**Table 7. Trend of consumption of indigenous pesticides (MT of technical grade) in last five years.**

| Pesticide group | Year | | |
|---|---|---|---|
| | **1995** | **2000** | **2005** |
| Insecticide | 30590 | 23496 | 18876 |
| Fungicide | 9543 | 7522 | 11376 |
| Herbicide | 6379 | 6630 | 4301 |
| Rodenticide | 509 | 512 | 1648 |
| Bio-pesticides | - | 683 | 1101 |

**Table 8. Classification of major insecticides (MT of technical grade) used during last five years.**

| Type of insecticide | Year | | | | | |
|---|---|---|---|---|---|---|
| | **2000-01** | **2001-02** | **2002-03** | **2003-04** | **2004-05** | **2005-06** |
| Organochloride | 3613 | 4758 | 2671 | 2952 | 2170 | 1882 |
| Organophosphates | 18207 | 19892 | 21005 | 19958 | 19865 | 10633 |
| Chloronicotyl | 157 | 171 | 182 | 121 | 199 | 104 |
| Carbamates | 2121 | 1426 | 1639 | 1398 | 1679 | 3167 |
| Pyrethroids | 2426 | 3592 | 2700 | 1198 | 2016 | 3090 |
| Biopesticides | 683 | 902 | 775 | 981 | 1159 | 1101 |

Continuous use of pesticides proved as a powerful selection pressure for altering the genetic make-up of a pest population. Naturally resistant individuals in a pest population were able to survive pesticide treatments, and the survivors passed on the resistance trait to their offspring. This resulted in a much higher percentage of the pest population resistant to a pesticide. In India, 33 key insect pests such as *Helicoverpa*, whitefly, diamondback moth, tobacco caterpillar and mustard aphids have developed resistance to almost all the pesticides being currently used to control them (Mehrotra, 1989; Kishor, 1997; Pawar, 1998; Saini and Jaglan, 1998; Alam, 2000). Similarly, seven plant pathogens have developed resistance against the fungicides. Jalali (1990) has reported a number of soil fungi (especially the anatagonistic ones) and symbiotic bacterium, which has been adversely affected by misuse of fungicides. Impact of pesticides on non-target micro-organisms and weed resistance to herbicides is a serious concern especially because it has developed resistance to four or more chemical classes.

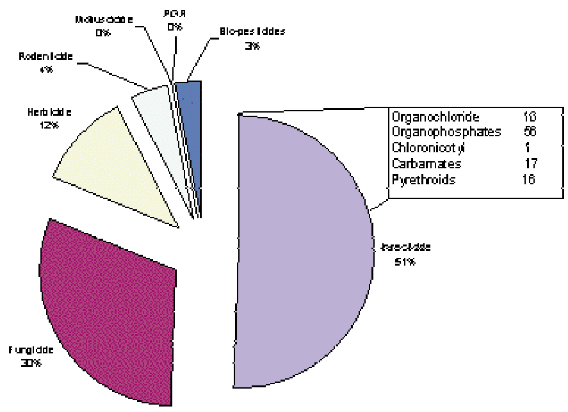


Fig. 2.Categorisation of different pesticides (2005-06)

**Table. 9. Contribution of plant protection in increasing yields of pulses and oilseeds.**

| Crop | Percent increase |
|---|---|
| ***Pulse*** | |
| Pigeonpea | 44.57 |
| Mungbean | 42.20 |
| Urdbean | 48.50 |
| Chickpea | 23.64 |
| Lentil | 25.00 |
| ***Oilseed*** | |
| Sesamum | 55.00 |
| Sunflower | 34-48 |
| Castor | 15.00 |
| Rapeseed-mustard | 26-41 |
| Linseed | 64.00 |

Plant protection measures have contributed significantly in increase of yields (Table 9). However, despite their effectiveness, their misuse adversely affected environment and human welfare. Studies indicate that a complete long-term C:B analysis of pesticide use reduces the perceived economic benefits of pesticides (Pimental et al., 1993). Injudicious use of insecticides has resulted in death of bees, which helps in one third of human food and capable of increasing yield by 14% through cross pollination. Large-scale use of herbicides has resulted in loss of pollen, nectar sources and habitat for natural enemies such as parasitic wasp and other tiny winged parasitoids. Mohan (1987) has observed positive correlation between pesticide use (per ha) and physical disabilities in India. Applications of pesticides inevitably have led to residues in soils, which may have evaporated to the air or washed into watercourses, causing contamination of environment, and endangering human health. In the early 1990s, the World Health Organization estimated that 3 million people a year suffered from acute pesticide poisoning with as many as 200000 of them dying.

More are in the rural India, where conditions virtually prohibit the safe use of dangerous pesticides and cases are not reported. Over the years, DDT, chlordane, hexachlorbenzene (HCB), mirex, endrin, aldrin, eldrin/dieldrin, heptachlor, and toxaphene have been used to defend crops and to protect infrastructures. Although use of pesticides has dramatically decreased, several of them are still in use. Indian experience indicates higher residues in foodgrains, fruits, vegetables, fish, milk and water than the acceptable limits (Dhaliwal and Kalra, 1977; Kalra and Chawla, 1981; Agnihotri, 1983: ICMR, 1993). The poisonous effects of pesticides like DDT, BHC (banned), Endosulfan, Malathion, Parathion-methyl, Monocrotophos, Quinalphos, Dimethoate, Phosphamidon, Cypermethrin and Fenvalerate have been reported from human blood samples and a significant increase in chromosomal aberrations was observed (Rupa *et. al.* 1989; Srivastava *et. al.* 1995). The farm workers are reported to suffer from one or more symptoms of acute pesticide poisoning such as chest constriction, headache, numbness, lethargy, allergies, dermatitis, epigastric pain or blurred vision (Rupa *et. al.* 1989a).

In South India, 36 workers in an industry manufacturing Malathion, Monocrotophos and Dimethoate found to have significant lower level of pseudocholinesterase as compared to 36 other workers without a history of similar exposure. However, their level rose significantly back to the normal range, when transferred to unexposed area (Peedicayil *et. al.* 1991). Inhibition of cholinesterase activity was observed in 34 spray men working in mango orchards, using Monocrotophos, Phosphamidon, Dichlorvos, Oxydemeton-methyl, Malathion, Endosulfan, Parathion-mehtyl, Dimehtoate or Carbaryl throughout the year (Srivastava *et. al.*1991). Increased levels of organophosphorous pesticides (dialkyl phosphate compounds) have been found in children living close to gardens, where these chemicals are sprayed. The children's exposure to the pesticides has also resulted to childhood cancer. Tissues, organs, biological systems and detoxification mechanisms of children are undergoing rapid growth and development, predisposing them to potentially more severe consequences of toxic chemicals (Anon., 2001). Aerial spraying of endosulfan for years, in Kerala by Public Sector Company Plantation Corporation of Keralam has affected the health of families working in cashew plantation. Mentally retarded children are born and people die of cancer (Usha, 2000). The cattles fed with pesticide treated fodder, also got affected. The pesticide residue is observed in the milk from these cattles. The toxicity of quinalphos, dichlorvos, monocrotophos, fenitrothion and phorate to buffalo calves is described (Bal, *et. al.,* 1996). Tanabe *et. al.,* (1998) studied the persistence of organochlorines (DDT), HCH isomers, chlordane compounds, hexachlorobenzene (HCB) and ploychlorinated biphenyls in whole body homogenates of resident and migratory birds from southern India during 1995. Resident birds contained relatively greater concentrations of HCH (14-8,800 ng/g wet wt) than DDTs and PCBs concentrations.

In contrast, migrants exhibited elevated concentrations of PCBs (20-4,400 ng/g wet wt). Agricultural run-off from farms proved to contain significant level of pesticides. Studies carried out in Delhi indicate presence of high level of pesticides (organochlorines) in potable water (Aggarwal et al. 1986, Agarwal, 1997). Similar reports have been made by Dua et al, (1998) and Murlidharan, (2000) from the water samples belonging Uttranchal and Rajasthan. Water samples of well in Bhopal showed residues of total HCH (4640 mg/l) and total DDT (5794 mg/l) (Bouwer, 1989). Organochlorines and organophosphorus residues were also detected in canals used for irrigation and drinking purposes in Aligarh (Ray, 1992). Similar status has been reported from different rivers in India (Mohapatra et al., 1994; Agnihotri, 1994). Studies proved that contamination of fish pond with as little as 0.005 ppm of chlorpyriphos could significantly reduce the zooplanktons and dissolved oxygen level (Ali, 1998; Mani and Konar, 1988). Apart from residue problems soil contamination caused seedling mortality and also made soil unfit for cultivation. Prasad (1986) reported phytotoxic efforts of terbuphos to cowpea plants. Similar observations were also made by Mishra and Prasad (1991) in other crops also.

## PEST MANAGEMENT SCENARIO OF MODERN FARMING SYSTEMS AND ITS IMPACT ON ECOSYSTEM

The intensive use of pesticides in agriculture is a cause of serious concern. The problem is especially serious because of the development of resistance to pesticides in important pests and the presence of pesticide residue in agricultural and dairy products. Pesticide resistance in agriculture was first noticed in India in 1963 when a number of serious pests were reported to have become resistant to DDT and HCH (two of the most commonly used pesticides during the 1960s and 1970s). Since then the number of pests with pesticide resistance has increased. The most serious problem of resistance is witnessed in cotton, for which American bollworm is a serious pest. The bollworm has developed resistance to almost all pesticides in a number of regions, and is particularly serious in parts of Punjab, Haryana, Andhra Pradesh, Karnataka and Maharashtra. Other important pests of cotton, white fly and jassid, have also developed pesticide resistance in some places. Growing pesticide resistance has meant that a large proportion of agricultural production is lost to pests. According to some estimates, these losses amount to between 20- 30% of total production.

There is a gradual change in the pest scenario wherein hitherto secondary pests having minor status has now become well-established key pests in many regions. In recent years large scale adoption of transgenic cotton has led to reduction in pesticide sprays against bollworm. However, a minor pest such as mealy bugs has staged a comeback as potential pest. At one end new pest problems are increasing, the pressure for tighter regulation on pesticide use is growing worldwide as progress is made in cleaning up other forms of toxic pollution, and as scientists unravel the many ways very low dose exposures may be adversely impacting human health, reproduction and development. Following scenario has emerged from current plant protection practices (Dubey and Sharma, 2002)–

- The cost-effectiveness of chemical pesticides is losing fast, especially when pesticides are relied on as the principal mode of pest management and being applied on calendar base;
- Because of adverse side effects of pesticides (Jalali and Sharma, 1993), residues, environmental awareness and increasing demand of international markets for pesticide free foods and demand for stricter pesticides regulation is rising, and
- Confidence is growing in preventive, biologically based Integrated Pest Management systems, which appear slow but are sustainable and steady in action if used as preventive mode especially in the beginning of incidence.

The convergence of these trends is strongly advocating interest in IPM in the agricultural community. A broad-based agenda is unfolding to accelerate the transition from chemical-based pest management systems to multi component, biologically based interventions (Sharma et al., 2000). Economics of rice and rainfed cotton production through IPM has prompted large scale adoption by farmers across country. Country premier Institute like Indian Agricultural Research Institute, New Delhi as well as few state universities has introduced IPM in their course curricula at the post graduate level to cater future needs. Recently, NCERT has also added source material on IPM in its syllabi.

**Era of IPM: Stepping off conventional chemical based plant protection methods**

The solution to the pesticide crisis offered by the plant protection community is Integrated Pest Management (IPM), which involved the integrated use of some (cultural, resistant varieties, biological, and chemical control) or all of the pest control strategies. Though the concept was the first mooted in late 1960s at the Indian Agricultural Research Institute, Delhi by then late Dr Pradhan it has taken India significantly longer period to show results through IPM. The IPM approach has been promoted by the GOI, since 1985, as an eco-friendly strategy of pest containment by exploiting the role of natural agents or forces in harmony with other pest management tactics and with the sole aim to effect minimum disturbance to environment. The Government of India is also a signatory to the Agenda I of United Nations Conference on Environment Development (UNCED) 1992, which has also approved and accepted IPM to reduce the use of pesticides in agriculture.

At the time IPM began to be promoted as a pest control strategy in the 1960's, there was very little IPM technology available to be transferred to farmers. By the 1970s, sufficient research had been conducted to provide the knowledge to successfully implement IPM programmes in important crops, such as rice (with the help of FAO), cotton, sugarcane and vegetables. However, exaggerated expectations about the reductions in pesticide use could be achieved without affecting crop yields could not been realized. Integrated approaches to disease management involving host resistance, fungicides and cultural practices are much more common and gave effective results leading to large scale adoption. Over the period it has been scientifically acknowledged that IPM is a viable technology and can be relied as basis for sustainable agriculture.

The greatest challenge is to do this without harming the environment and depleting the limited resource base for future generations. Thus, IPM has proved as an important principle on which the technology of sustainable crop protection can be effectively relied and based. IPM has expanded in Indian subcontinent but with less vigor due to struggle against well-established network of chemical pesticide distribution system. A rapid adoption of IPM is called for to achieve long-term sustainable systems. Over the decade of research at ICAR and SAU,s sufficient location specific IPM technologies especially on individual IPM components have been developed and validated at research farm level. Keeping in view the global concern, the Government of India as well as ICAR system has recognized the benefits of IPM programme during 1985 and adopted IPM as the cardinal principle and main plank of plant protection strategy in the overall crop production programmes. The Food and Agriculture Organization of the United Nations (FAO) has been at the forefront of promoting and defining food security as a concept that could guide development, and provide expertise and material to the Directorate of Plant Protection, Quarantine and Storage (DPPQ&S), Faridabad as a result a number of state has been covered up for primary food crops. The collective efforts at various levels have resulted in reliance over non-chemical pest management methods especially biological control and cultural practices.

IPM proved complex method for the producer to implement than spraying with shelf ready pesticides on the calendar base. On the contrary, IPM technology required education, skill in pest monitoring and understanding of pest dynamics, and it often involved cooperation among producers en mass for effective implementation (Sharma et al., 2000). At the time, IPM began to be promoted as a pest control strategy in the 1960's, there was very little IPM technology available to be transferred to farmers. By the 1970's, sufficient research had been conducted to successfully implement IPM programmes in high input economic crops, such as rice, cotton, sugarcane and vegetables. However, exaggerated expectations about the possibility that dramatic reductions in pesticide use could be achieved without affecting crop yields could not been realized. As a National policy the Government of India and the Indian Council of Agricultural Research (ICAR) are fully committed to the promotion of the IPM concept. The "Development of Integrated Pest Management practices to optimize plant protection" was under the "Priorities and Thrust Areas" for the Tenth Plan of the Department of Agricultural Research and education of the Ministry of Agriculture of India. The Government is also fully seized of the need for an effective and pragmatic National Pesticide Policy. Various steps have been taken in this direction and specific expert committees have been formed to advise the government on the various aspects of pesticide usage in the country. To ensure stability of crop production, the ICAR has given a major thrust to implementation of numerous research schemes and programmes in all major disciplines of plant protection. Since, 6th Five-Year Plan there has been a major thrust in plant protection by identifying and implementing a number of all-India coordinated research projects exclusively devoted to various subjects concerning plant diseases, insects, weeds and nematodes. Some of these cut across not only crop boundaries but also deal with polyphagous and vertebrate pests such as–

- Biological control of crop pests,
- Nematode pests of crops,
- Honey-bee research and training,
- White grubs (now soil arthropod pests),
- Rodent control,
- Agricultural ornithology,
- Pesticide residue and
- Network project on acarology.

Crop protection is an in-built component of crop improvement research and its various disciplines are incorporated in the Crop Research Institutes as well as in the All India Coordinated Crop Improvement Projects including All India Network Programmes of the Indian Council of Agricultural Research. Two national institutes have been established with the aim at evolving environmentally sound pest management strategies for pest and disease problems in major crops and to give an impetus to biological control programme. The discipline of agricultural chemicals as a separate branch is also now being expanded in many central institutes and agricultural universities. An integrated strategy for the management of major insect pests, diseases, nematodes and weeds has been possible by following strategies–

- Breeding new varieties with built-in resistance to multiple pests,
- Increasing efficiency of methods of pest control through centralized pest surveys and monitoring,
- Use of novel methods like keromones and pheromones etc, for monitoring and trap to kill, and Promoting biological control of pests with the help of their natural
- enemies like parasitiods, predators, pathogens and antagonists.

Easily adoptable and economically viable integrated pest management strategies have been developed for the control of major pests in rice, cotton, pulses, sugarcane etc, wherein PM is an in-built component of national crop improvement programme, hence various disciplines are incorporated in the Crop Research Institutes with the aim at evolving environmentally sound pest management. Reduction of chemical pesticides use can be brought about through promotion of IPM, which involves following steps–

- Use of resistant/tolerant crop varieties
- Adoption of cultural and mechanical practices
- Use of traps (light, sticky, yellow, pit traps and pheromone)
- Pest surveillance/monitoring
- Use of bio-pesticides and microbials
- Spray of chemical pesticides as last resort based on economic threshold level (ETL).

**Breeding for resistance**

Advocating use of resistant/tolerant varieties is an important component of IPM. These may reduce the need for frequent chemical treatments with crop protection products. Plant breeding programmes given emphasis on the updating of genetic resistance to insect pests and diseases (as in cereals) but not all pest problems could be solved by breeding alone. Contribution made by resistant material in avoiding yield losses is quite significant and cannot be written off especially in case of cereals (wheat and rice), oilseeds (mustard and groundnuts) and pulses (pigeonpea and chickpea). Use of resistant varieties also encourages the survival of beneficial in terms of both microbes (fungal and bacterial) and insects apart from adoption on large scale. Developing single or multiple gene-based resistances against key pests got priority over other parameters.

The success in getting resistance against plant diseases is more in comparison to insect pests. It is noteworthy to mention the case of dreaded wheat rusts (*Puccinia graminis tritici, P. recondita tritica, P. striformis*), loose smut (*Ustilago nuda*) and karnal bunt (*Neovossia indica (*Mitra*))* of wheat, *Helminthosporium* leaf spot of rice and vascular wilt (*Fusarium cajani*) of pigeonpea, which played havoc to Indian economy not long ago. Genetic resistance has come as big rescues against soil borne diseases especially wilt and smut diseases having wider host range and difficult to manage. Molecular markers and other genomics information are allowing more precision in breeding for greater tolerance to diseases in many crops. Broad spectrum resistance is now possible with genetic engineering. Marker assisted breeding is being used in rice and other crops for disease resistance strategy. Still better understanding the mechanism of resistance for disease and pests, will allow better deployment of technologies for different pests and diseases. Developments in genetic engineering have further increased the potential for developing pest resistant plants (Pal and Jalali, 1995) and herbicide tolerant crops as proved in case of GM soybeans.

India has commercialized genetically modified cotton which provides resistance to the bollworm complex of pests. Transgenic plants (Bt cotton) offer a novel means of delivering biological agents, where insecticidal proteins (endotoxins) producing genes (cry-1) are introduced genetically into the plant (e.g., transgenic cotton). Currently, the cotton farmers across the country are growing more than 120 transgenic cotton. Since these transgenics have only built-in mechanism of resistance against bollworm, IPM strategies were developed and field validated to manage other pests. The non-target organisms remains unaffected from endotoxins but this particular scientific adventure needs further probing in terms of long term effectiveness and their residual effects on human beings, immediate flora, fauna, bio-diversity and its ability to co-exist with local flora.

**Cultural practices**

Need for ecologically sound, effective and economical pest control methods have prompted renewed interest in cultural methods of pest control. Some of the diverse ways in which cultural methods have proved effective include sanitation (to remove sources of primary inoculums), tillage (to kill resting propagules of soil resident pathogens), application of microbial fortified manures and soil amendments either with plant residues or bio-pesticides, habitat diversification such as crop rotation (to break pathogen life cycle), trap cropping, intercropping (to reduce inoculum), time of planting (to avoid exposure of vulnerable plant growth stage), nutrient and water management etc. The potential for carry over of pest from one season to another can be reduced by destroying stubbles, weeds and other alternate hosts of plant diseases and stem borer by ploughing the field after crop harvest and before sowing. Ploughing during summer helps in eliminating soil pests either by excessive heats or by exposing them to predators.

Studies has proved that armyworms and maize stalk borers often increase in crops grown under reduced tillage and surface accumulation of crop residues under reduced tillage conditions increases the infestation of termites, slugs, some nematodes and diseases. Growing different crops in a rotation helps in reducing the build-up of certain pests, especially those in the soil, such as root feeders, fungal pathogens affecting the root system and nematodes (Singh et al., 2002). Rotation with mustard crop has proved to reduce soil borne pathogens especially soil resident wilt inoculums due to volatile compounds released from root zones. Rotations apart from reducing the weed problems increase the population of predators and parasites. Planting of inter as well as cover crops increases the bio-diversity and helps in conservation of bio-agents in the field. In case of certain national emerging problems such as cotton leafcurl virus alternative host crops (Cucurbits, solanaceous vegetables and citrus orchards) should be avoided if possible. A diverse rotation, using legumes and other cover crops, is at the heart of good humus and biodiversity management in an organic cropping system. Crop rotation also breaks the pest cycle, reducing the incidence of insect pests and diseases. Lower incidence of insect pests was found on legumes intercropped with maize. Intercrops of spinach, beans and tomato reduced the incidence of aphids (*Brevicorynae brassicae*) and caterpillar of diamond back moth (*Plutella xylostella*) in cabbage substantially. Incidence of pod borer (*Helicoverpa armigera*) reduced in chickpea when grown in association with barley, mustard, linseed or coriander. Incidence of chickpea wilt and root rot of pea were considerably reduced when planting was delayed.

Alternate wetting and drying has helped in management of sheath blight disease of paddy especially in northern India. Maize sown late suffers little from damage by maize borer, as by then the egg parasitoid *Trichogramma* is able to keep down the population of the pest. Rice is reported to suffer less from borer attack if transplanted early (by mid June). Early maturing cotton varieties (Desi) have become popular as they escape pink bollworm attack. The scab of potato at the time of tuber formation, wet weather diseases such as anthracnose of beans; early blight and charcoal rot of potato can be checked by furrow irrigation. Diseases, which are favored by high moisture at the soil surface like damping off or collar rot can be minimized by planting crops in ridges or raised beds. Growing of pigeonpea on ridges can prevent *Phytopthora* blight, which otherwise is capable of turning as epidemic (Sharma et al., 2004) especially areas having heavy and water logging soils.

**Monitoring**

Crop monitoring is an important tool and aim to determine when and what action is to be taken. Management of any crop needs routine inspections to assess how well plants are growing and what actions need to be taken on cultivations, pest and disease control. Monitoring for pests is an important part of the need to “walk” through a crop, which sometimes is not practical if land holdings are very large. The community approach of crop health and pest monitoring in general is lacking, hence the same was successfully introduced in Ashta village of Maharashtra and Kaithal in Haryana. Development and availability of pheromones offers interesting new possibilities for the farmer. Currently, it is widely used for certain key pests such as pod borer, Pink and spotted bollworm, Potato tuber moth, white grub, leaf folder etc. Besides selective trapping techniques to monitor the movement of pests or changes in populations during the season, pheromones are also used in “lure and kill” strategies to attract the pest to localized insecticide deposits (as being done in white grub and fruitflies in mango) and reduce the need for overall crop spraying as demonstrated against Pink boll worm (PBW) in Punjab.

Other tools, such as pheromone traps, mating disrupting lures (*Helicoverpa* and pink boll worm), diagnostics and forecasting systems for plant diseases (against apple scab, late blight of potato and Botrytis diseases) have proved their effectiveness and are now available to assist in timing of management operations.Pink boll worm mating disrupting lures also known as PBW Ropel has been successfully tried in mass scale in cotton growing areas of Punjab and Dharwad district of Karnataka. They need to be promoted so that the unwanted spray of pesticides can be reduced down. The Department of Agriculture and Cooperation (DAC) in the Union Ministry of Agriculture has notified the inclusion of “Mating disruptants” pheromones (HP-Rope, HL-Rope, Z-11-Hexadeceal and PB-RopeL) in the Schedule to the Act by Notification No. GSR 10(E) dated 3.1.1996. Oflate NCIPM has developed online discussion forum (http://www.ncipm.org.in/DForum/DForumMain.asp) as well as pest reporting system to generate pest data on uniform pattern. Recently DAC in collaboration with FAO assistance has initiated pest reporting on pilot scale in cotton and rice growing areas of Andhra Pradesh using internet hooked hand held loggers.

## Behavior-modifying chemicals

Use of pheromones to disrupt insect pest mating or to attract pests to pesticides applied traps (e.g., white grub) is becoming popular and is in practice in parts of Rajasthan. Pheromone traps are widely used as crucial tool for monitoring pest population and timing of management practices for key pests of cotton and rice (Singh *et al*., 2002). The use of pheromones has been instrumental in increasing the effectiveness of both monitoring insect populations and in providing adequate information to enable implementation of cost-effective control. Over the last two or so decades information collected from insect monitoring has led to the production of pest forecasting systems that allow farmers to begin spraying at precise time intervals for maximum impact. A recent study in India has looked at how pheromone traps can enhance the yield and lower the control costs for smallholdings that grow their own rice. The target species was the yellow stem borer *Scirpophaga incertulas* which is the most economically important lepidopteran pest of rice in Asia.

The field trials showed that it was a very practical method of control for smallholders as trap placement could be integrated with crop planting. The trial also showed that larval population in the traditional plot could be reduced from 88% to 65% in the pheromone plot. Economic threshold has been developed, standardized and is in use in majority of economic crops. It is based on the concept that most plants can tolerate at least some pest damage before economic loss of yield occurs. Much research has been done to determine this level of damage, often called as the economic injury level, for a variety of crop and pest situations. In an IPM programme where the economic injury level or threshold is known, chemical controls are applied only when the pest capacity for damage is nearing the threshold. When an economic injury level has not been established, common sense is used, and controls are applied when it appears that pest numbers are increasing to damaging levels (Table 10).

**Table 10. Economic threshold levels (ETLs) of major insect pests of agricultural crops in India.**

| Crop | Insect pest | | ETL |
|---|---|---|---|
| | Common name | Scientific name | |
| Cotton | American bollworm | *Helicoverpa armigera* (Hubner) | 5-10 % infestation in floral forms |
| | Pink bollworm | *Pectinophora gossypiella* (Saunders) | 5-10 % infestation in floral forms |
| | Spotted | *Earias* spp. bollworms | 5-10 % infestation in floral forms |
| | Whitefly | *Bemisia tabaci* (Gennadius) | 6-8 adults/leaf or appearance of honey dew on 50 % plants |
| | Jassid | *Amrasca biguttula* (Ishida) | Appearance of yellowing and curling on the leaf margins in the upper plant canopy |
| | Aphid | *Aphis gossypii* Glover | Appearance of honey dew on 50% plants |
| | Thrips | *Thrip tabaci* Lindeman | 5-10 % infested plants |

| Crop | Insect pest | | ETL |
|---|---|---|---|
| | **Common name** | **Scientific name** | |
| Sugarcane | Stem borer | *Chilo sacchariphagus* (Kapur) | 10 % shoot damage at tillering phase |
| Tobacco | Tobacco caterpillar | *Spodoptera litura* (Fabricius) | 1-5% incidence |
| | Whitefly | *B. tabaci* | 5-10 adults/leaf |
| Maize | Stem borer | *Chilo partellus* (Swinhoe) | 5-10 % infestation |
| | Shoot fly | *Atherigona* spp. | 5-10 % dead hearts |
| | Earworm | *H. armigera* | 25-30 % damage to cobs |
| Rice | Stem borer | *Scirpophaga incertulas* (Walker) | 5 % white ears/one egg mass per $m^2$. |
| | Brown planthopper | *Nilaparvata lugens* (Stal) | 10 hoppers/hill |
| | Gall midge | *Orseolia oryzae* (Wood-Mason) | 5-10 % sliver shoots |
| | Leaf folder | *Cnaphalocrocis medinalis* (Guenee) | 10-15 % infested plants |
| Wheat | Aphid | *Schizaphis graminum* (Rondani) | 5-10 % infested plants |
| Grapes | Thrips | *Retithrips syriacus* (Mayet) | 20 % foliar damage |
| Mango | Hopper. | *Amritodus atkinsoni* (Lethiery) | 20 % hopper damage in inflorescence |
| Oranges | Fruitflies | *Carpomyia vesuviana* Costa | 1-2 % incidence |
| Groundnut | Aphids | *Aphis craccivora* Koch | 5-10 aphids/ terminal at seedling stage |
| | Tobacco caterpillar | *Spodoptera litura* (Fabricius.) | 20-25 % defoliation at 40 days |
| Rapeseed | Aphid | *Lipaphis erysimi* (Kaltenbach) | 50-60 aphids/10 cm terminal portion of central shoot 0.5-.10 cm terminal portion of central shoot covered by aphids 40-50 % infested plants |
| Sunflower | Gram pod borer | *H. armigera* | One larvae/head |
| Chickpea | Pod borer | *H. armigera* | 3 eggs or 2 small larvae/ plant |
| | Cut worm | *Agrotis ipsilon* (Rottenburg) | 5 % plant mortality |
| Pigeonpea | Pod borer | H. armigera | 5 eggs or 3 small larvae/ plant |
| | Leaf webber | *Maruca vitrata* (Geyer) | 5 webs/plant |
| Brinjal | Fruit and shoot borer | *Leucinodes orbonalis* Guenee | 1-5 % shoot or fruit infestation |
| Cabbage & | Diamondback moth | *Plutella xylostella* Linnaeus | 1-5% incidence |
| Cauliflower | Tobacco caterpillar | *S. litura* | 1-5% incidence |
| Tomato | Fruit borer | *H. armigera* | 1-5 % fruit damage |

**Bio-pesticides**

Being rich in biodiversity a number of plant extracts have been field evaluated and their active compounds identified. Some of these natural insecticides of commercial importance are the pyrethrins, azadirachtin containing preparations, certain essential oils and phyto oils. Of the 59 plant families shown by Simmonds et al. (1992) to have potent anti-insect activity, the Meliaceae have received most attention, particularly the neem tree, *Azadirachta indica,* which is widely grown in India. Its active constituent, azadirachtin, is a limonoid with antifeedant, growth regulatory and reproductive effects (Mordue and Blackwell, 1993). Our ancestors have known the use of neem as insecticide. It has reference in vedas but the practice was neglected due to lack of faith and scientific knowledge and easy availability of "quick action" pesticides. Use of locally available neem seeds (Neem seed extract 5%) as a pest repellant and antifeedant has not only reduced dependency of chemical pesticides against *Helicoverpa* but has also created employment through neem seed collection by unemployed rural youths while the womenfolk are engaged for its preparation. Some neem products have been found to induce resistance in pea against the powdery mildew (*Erysiphe pisi*) in field conditions. Recently extract of giant knotweed (*Reynoutria sachalinensis*) has emerged as potential source of fungicide against powdery mildews. The Registration Committee has so far registered two insecticides of plant origin viz. Pyrethrum from *Chrysanthemum* and neem based pesticides from neem kernel and neem oil for the control of insect pests of various crops. Two formulations of Pyrethrum i.e., Pyrethrum 0.2% dusts and Pyrethrum 1% EC are registered for use against insect pests in vegetables. Pyrethrum is also used in combination with other insecticides/synergists for the control of household pests. Another pesticide of plant origin viz., Nicotine sulphate extracted from tobacco plant has also been registered for export purposes only. The registration of neem based biopesticides was initiated during 1991. Neem based biopesticides (300 PPM, 1500 PPM, 50,000 PPM) have been granted registration on regular basis under Sec. 9(3) and 9(4) of the Act; whereas a number of neem based products (3000 PPM), 10,000 (PPM) have been registered on provisional basis under Section 9(3B). Following extracts concentrates and formulations have been registered and produced.

a) Neem Extract Concentrate (Tech.)-10% (min.), 15% (min.) and 25% (Min.)
b) Neem formulation containing minimum Azadirachtin contents

| | |
|---|---|
| 0.03% (300 PPM) | 2.0% (20,000 PPM) |
| 0.15% (1500 PPM) | 2.5% (25,000 PPM) |
| 0.3 % (3000 PPM) | 3.0% (30,000 PPM) |
| 1.0 % (10,000 PPM) | 5.0% (50,000 PPM) |

BIS specifications for neem products viz., IS: 14299-1995 (for Technical), IS: 14300-1995 (for formulation) have been published. "Karanjin" (*Pongamia glabra*) and extract of *Cymbopogan* species (botanical pesticides) and *Hirsutella* spp. fungi (bio-pesticides) have also been included in the schedule of the Insecticides Act, 1968. There is a need for emphasis on its efficient and cost-effective production, processing and marketing of not only neem but other less known botanicals also such as pongamia, palmrosa, annona seeds, nuxvomica, and tobacco (Dubey et al., 2002).

**Biological Control**

Biological control is used of a specially chosen living organism to control a particular pest. In this programme predator, parasite, entomophagus nematodes, antagonist fungi and bacteria have been used at farm level to manage the harmful insect. Biological Control program also includes selection of a specific pesticide, which are least harmful to beneficial insects, to raising and releasing one insect to have it attack another, almost like a living insecticide. Biological control has been an integral part of IPM and Directorate of Plant Protection, Quarantine and Storage (DPPQ&S) has established 30 bio-control laboratories spread over the country to meet the local need. Further, the effectiveness under high temperature, absence of long term storage technology and need for timely availability of *Trichogramma, Chrysoperla, Cryptolaemus, Leptomastix, Bracon* and *Epiricania* opened opportunities for small entrepreneurs to take up mass production of these bio-agents on a small scale as cottage industry. Since the bioagents cannot be stored for long, ensuring stability of supply and meeting demand are key elements standing in the way of successful implementation of IPM programmes. Being unorganized sector the entrepreneurs are landing up in debt grips which is playing bad role for IPM practices. Efficient regional markets are also needed to match increasing demand with the supply of quality critical IPM inputs. Cost effective technologies for a number of bioagents, such as the egg parasitoids *Trichogramma chilonis*, *T. japonicum,* larval parasitoids *Bracon hebetor, B. brevicornis, Goniozus sp., Brachymeria sp,* and predators *viz., Chrysoperla carnea, C. incarnata*, *Coccinella septumpunctata, Menochilus sexmaculatus* and spiders have been standardised and are now available commercially. However, the potential of the bioagents had not been exploited to the core and there is ample scope under policy of sustainable agriculture.

In undisturbed agroecosystem the natural enemies would keep 60% of the insect pest populations under check, if there were no intervention by chemical pesticides. Conservation and augmentation of bioagents hence is of significance in IPM. Research indicates that Trichogrammatids could be stored for up to 3-4 weeks at $10^0$C. Similarly coccinellids, tachinids and weed insects (with food) could be stored for two months at $15^o$C. *Cotesia flavipes* and *Chelonus blackburni* can be stored in adult stage at 10º C for 15 days. Eggs and cocoons of *Epiricania melanonleuca* can be stored at 10ºC for 20 and 60 days, respectively. A number of wild plants belonging to compositae family, which serves as source of nectar to predators and parasitoids have been identified and need promotion.

Project Directorate of Biological Control, Bangalore and a number of SAU,s especially Gujarat Agricultural University, Anand has perfected the technique and protocols for mass production for 26 Egg parasitoids; 06 Egg larval; 39 Larval / nymphal parasitoids; 26 Predators and 07 Weed feeders. The technology generated by ICAR and SAUs has enabled private sectors to produce *Trichoderma*, *Trichogramma*, HaNPV and BTK and create job opportunities for rural youths. Of late Department of Biotechnology, Delhi has also joined the campaign and is funding state owned universities and NGOs to further improve strains and their mass multiplication. Amongst the microbial pesticides, at least 16 microbes have been in use in the country. Out of these *Bacillus thuringiensis kurstaki*, *Trichoderma* species & NPVs are the most accepted products.

Twenty-five microbial products including *Bacillus thuringiensis*, *B. sphaericus, Trichoderma* species, *Beauveria bassiana* & NPVs are registered with Central Insecticides Board. The 15 parasites and predators widely used in the country do not require registration in India and only 10 are commercially available (Table 11.). Table 12 presents a list of microbial pesticides registration for commercialization and use in the country on various crops.

**Table.11. Botanical pesticides, microbial pesticides, biocontrol insects and biorationals in use in india.**

| | |
|---|---|
| Botanical Pesticides | *Azadirachta (443) , Chrysenthemum (290),* Cymbopogan *(1),* Nicotiana, *Pongamia,* Anona, Derris ,Vitex |
| Microbial | Pesticides *Bacillus thuringiensis* (11)*, B sphaericus* (2)*, B subtilis, Trichoderma* spp(10)*, Pseudomonas fluorescens, Gliocladium species, Beauveria bassiana* (2), *Verticillium lecanii, Metarrhizium anisopliae, Nomuraea rileyi, Hirsutella* spp., Nuclear Polyhedrosis Viruses (3), Granulosis Viruses |
| Biocontrol Insects* | *Trichogramma chilonis, T. japonicum , T. brasilliensis, T. achaeae, T. pretiosum, T. exiguum, Bracon species, Chrysoperla carnea, Epiricania melanoleuca, Cryptolaemus montrouzieri, Encarsia per,niciosi, Goniozus nephantidis, Neochatina bruchi , Cyrtobagous salviniae, Zygogramma bicolorata* |
| Biorationals | Pheromone Traps, Yellow Sticky Traps, Yellow Pans<br>Pheromone Lures* for: *Helicoverpa armigera, Spodoptera litura, Earias vittella, Pectinophora gossypiella, Scirpophaga incertulas, Plutella xylostella, Leucinodes orbonalis, Chilo* species*, Dacus* species, *Bactocera,* White grub Mating disruptants : *Pectinophora gossypiella* PB Rope (1) |

*Number in bracket indicates preparations. * = Registration not required, # = Banned currently.*

To promote IPM state Govt. too has initiated scheme to finance and provide subsidies to entrepreneurs, willing to take up production of microbials (e.g., *Trichoderma*), Viruses (NPV) and bioagents (*Trichogramma* as well as green lace wing). There are about 318 biocontrol laboratories/ units in the country aiming to cater the national requirements of the quality bioagents (e.g., CIPMCs (31 Nos.), ICAR/SAUs/ DBT (48 Nos.), State Biocontrol Labs (98 Nos), and Private Sector Labs (141Nos.)). Department of Biotechnology, control laboratories in different agroecological regions. Survey organised at NCIPM revealed that the quantity of microbials and bio-agents produced are not just sufficient to cover hot areas of concerned pests (Table 13). The status of demand and supply of biocontrol agents has been tentatively worked out (Table 14). Neem and Bt formulations dominate over others in consumption of bio-pesticides (Table 15).

**Table 12. Microbial listed for registration, commercialization and use in the country.**

| S. N. | Pathogen | Disease | Crop |
|---|---|---|---|
| | **Antagonistic to plant pathogenic fungi** | | |
| 1. | *Trichoderma* sp. | Root rot<br>Wilt | Oilseeds<br>Pulses, Oilseeds, Cotton |
| 2. | *Gliocladium* species | Root rot | Vegetable Crops |
| 3. | *Pseudomonas fluorescence* | Root rot | Cardamom, Pepper, Ginger, Turmeric, Carrot, Betelvine, Tomato |
| 4. | *Bacillus subtillis* | Root rot | Vegetable Crops |
| | **Entomopathogens: Fungi** | | |
| 5 | *Beauveria bassiana* | Berry borer<br>Shoot borer<br>Bollworm | Coffee<br>Sugarcane<br>Cotton |
| 6 | *Metarhizium anisopliae* | Borers<br>Pyrilla<br>White grub | Rice<br>Sugarcane<br>Groundnut |
| 7 | *Nomuraea rileyi* | Helicoverpa armigera | Cotton, Pulses<br>Groundnut, Castor |
| | **Spodoptera litura** | | |
| 8 | *Verticillium lecanii* | Aphids<br>Bacteria | Oilseed Crops |
| 9 | *Bacillus thuringiensis var. Kurstaki* | Boll worms<br>Fruit borer<br>Diamond Back Moth<br>*Helicoverpa armigera* | Cotton<br>Brinjal, Tomato<br>Okra<br>Cabbage, Cauliflower<br>Pulses |
| 10 | *Bacillus sphaericus* | Houseflies<br>Mosquito | - |

| S. N. | Pathogen | Disease | Crop |
|---|---|---|---|
| | | **Virus** | |
| 11 | NPV of *Helicoverpa armigera* | *Helicoverpa armigera* | Cotton, Pulses Vegetables Groundnut, Maize |
| 12 | NPV of *Spodoptera* | *Spodoptera litura* | Cotton, Castor Groundnut, Tobacco, Tomato |
| 13 | GV of *Achaea janata* | Semilooper | Castor |
| 14 | GV of *Chilo infuscatellus* | Shoot borer | Sugarcane |

**Table 13. Production potentials of biocontrol agents in India.**

| Biocontrol agent | Production MT tech. |
|---|---|
| *Bacillus* sp. | 132* |
| *Pseudomonas fluorescens* | 126.86 |
| *Trichoderma* sp. | 273.78 |
| *Beauveria bassiana* | 67.0 |
| *Verticillium lecanii* | 10.3 |
| Neem based biopesticides | 551* |
| *Trichogramma* sp. | 2.45 lakh Tricho cards |
| *Chrysoperla carnea* | 181.25 lakh eggs |
| *Cryptolaemus montrouzieri* | 28.07 lakh grubs/beetles |

*Source*:NCIPM survey (30 responses).

**Table 14. Status of estimated demand and supply of biocontrol agents in India.**

| Biocontrol agent | Production | Demand | Area covered |
|---|---|---|---|
| Trichogramma spp. | 14,241.64 (in million Nos) | 14,312.90 approximate | |
| Trichoderma spp.(in Kg) | 4,504.00 | 36,100.00 | {43} lakh ha. |
| NPV (LE) | 21,715.00 | 2,07,700.00 | |

*Source* : Directorate of Plant Protection, Quarantine & Storage, Faridabad Haryana, 2008.

**Table 15. Status of consumption of bio-pesticides and Neem based pesticides (MT).**

| Year | Neem products | *Bacillus thuriengensis* |
|---|---|---|
| 1994-95 | 83 | 40 |
| 1995-96 | 128 | 47 |
| 1996-97 | 186 | 33 |
| 1997-98 | 354 | 41 |
| 1998-99 | 411 | 71 |
| 1999-2000 | 739 | 135 |
| 2000-01 | 551 | 132 |
| 2001-02 | 736 | 166 |
| 2002-03 | 632 | 143 |
| 2003-04 | 824 | 157 |
| 2004-05 | 965 | 139 |
| 2005-06 | 1717 | 203 |
| Total (2005-06) | | 1920 |

*Source* : www.cibrc.nic.in.

Field experience indicates that the use of natural enemies (predators and parasitoids) to suppress pests has come to great rescue especially in case of Sugarcane Pyrilla (*Pyrilla perpusilla*) by *Epicania*, wherein aerial spray with multinational companies was a regular practice. Similar success has been achieved in case of borers (*Helicoverpa armigera*) of cotton, pulses and vegetables by *Trichogramma* and *Chrysoperla* (Dubey and Sharma, 2001). The success of technology included following activities –

- The introduction and establishment of new biological control agents;
- The repeated augmentation of natural enemy populations e.g., *Trichogramma chilonis* and *T. japonicum* in cotton , rice and sugarcane ecosystem;

The adoption of habitat management practices that enhance the impacts of natural enemies already present in an area (e.g., growing of Marigold (*Tagetus* spp), cowpea (*Vigna* spp.), lal-imbadi (*Hibicus subdifera*) and Tobacco (*Nicotiana* spp)). The search for the "right" habitat is imperative because like all living organisms, insect parasitoids and predators have requirements for resources, other than hosts. However, these other sources may or may not be found in the same habitat in which hosts are found. Optimal microclimatic conditions for a given parasitoid, nectar sources, and shelter may exist in some host habitats (crop systems) but not others. One assumes that the habitats in which parasitoids find hosts also provide other needed requisites at optimum levels. There is little empirical or experimental data, to support this to be true, even for unmanaged eco-systems. Conservation of bio-agents through habitat management hitherto not received enough attention and need to be promoted beyond organic agriculture. Many natural enemy species require food sources in the form of pollen, nectar, or innocuous arthropods that are not present in particular crop habitats or artificially created crop architecture.

These food requirements if provided by deliberate development of certain wild vegetation (aromatic) habitats near plantings of the primary and secondary crop can play tremendous role. Careful management of farm land margins, as well as growing tree crops (pomegranade) or hedges (compositae family), as they provide suitable habitat cover and refuge for beneficial insects and other animals (e.g. in rice paddies, field bunds provide important refuges for predatory spiders which help control several important rice pests; and for snakes which help control rats) is required. In case of rainfed cotton growing of maize and cowpea on border increases the population of coccinellids, which migrates to cotton in search of aphids and jassids (Sharma et al., 2000). Success stories have filtered down from a number of states making IPM a potent tool for smooth transition from a high input unsustainable agriculture to low input sustainable agriculture.

Of more than 100 million farms in India, three quarters are one ha or less in area and scattered across a wide range of environment and it is this group which will be most benefited from this technology. Also as environmental problems know no boundaries, we must honor and be committed to responsibility as custodians for conservation of the Earth's natural resources while accepting the challenge of securing food for all. The potential of the bio-agents had not been exploited to the core as the natural enemies have potential to keep 60% of the insect pest populations in nature under check. Conservation and augmentation of bio-agents hence is of significance in IPM. The present level of production of bio-agents is not even sufficient to cover 3% area under any particular crop. The major constraints for promotion of the bioagents include the difficulties in mass rearing technologies, temporal variations, the shorter life span and delay in transit, which often over runs the stage against which the bioagent is effective. Our research should aim to address these to tap their potential.

The Central Insecticidal Board has accepted and Department of Agri. and Coopn, have notified the inclusion of following biopesticides in the schedule to the Act by Gazette notification No. G.S.R.224 (E), dated 26.March 1999.

- Entomogenous fungi e.g. *Beauveria bassiana, Verticillium lecanii, Metarrhizium anisopliae, Hirsutella spp, Nomuraea rileyi* etc.,
- Antagonistic fungi and bacteria e.g. *Trichoderma* spp. (*T. viridae, T. viridae* W.P*, T. viridae 1%*W.P*, T. viridae 0.50%* W.S*, T. harzianum 0.50%* W.S*, T. harzianum 1.150%* W.P) *Pseudomonas ( P. fluorescens1.15%*WP*), Bacillus subtilis, Gliocladium* etc.,
- Mycoherbicides
- Insect repellents
- NPVs and GVs
- Pheromones

Some of the major activities and achievements of DPPQ &S, Faridabad (since 1994 to 2007) in terms of "Monitoring, field release and coverage areas" are praise worthy and are as follows–

- Pest Monitoring : 101.17 lakh ha
- Field releases of biocontrol agents (Augmentation & conservation of biocontrol agents) : 25,385.09 million
- Area Coverage : 77.88 lakh ha

*Source* : Directorate of Plant Protection, Quarantine & Storage, Faridabad ,Haryana, 2008.

Since microbials are living organisms their quality control standards of antagonistic organisms are being enforced in order to convince the effectiveness of alternative pest management practices. These bio-pesticides are now in greater demand from corporate houses involved in group/contact farming and export of organic produce in developing countries. Guidelines or data requirements for registration of microbials under section 9(3) and 9(3b) of the insecticides act, 1968 and Indian Standard Specification has been reviewed to regulate quality and standard of products reaching to farmers. The standards are as follows–

- *Cfu* on selective medium, minimum of $2x10^6$/ml of TH.
- Microbilal contaminants should not increase $1x10^4$/g formulation
- Maximum moisture contents should not be more than 8% for dry formulations of fungi and 12% for bacteria.
- Stability of cfu bacteria counts at $30^0$C and 65% relative humidity.

As a national policy the Government of India and the Indian Council of Agricultural Research (ICAR) are fully committed to the promotion of the IPM concept. The "Development of Integrated Pest Management practices to optimize plant protection" is under the "Priorities and Thrust Areas" for the 10th Plan of the Department of Agricultural Research and education of the Ministry of Agriculture, Government of India also. The Government is also fully seized of the need for an effective and pragmatic National Pesticide Policy keeping in pace with European counterparts. Various steps have been taken in this direction and specific expert committees have been formed to advise the government on the various aspects of pesticide usage in the country. Of late Department of Biotechnology, Delhi and Directorate of Horticulture, Gurgoan under the Horticulture Mission are providing grant-in-aid to establish bio-control laboratories in different agroecological regions and promote its production as cottage industry. Recent debates of climate change and its fallouts has led to adoption of alternative pest management methods and low input agriculture by a number of corporate houses involved in agribusiness. Now there is awareness among these corporate that carbon credits can also be earned by not using pesticides on large scale.

**Chemical pesticides**

As it has been proven time and again that pesticides form the integral part of plant protection without which it will not be possible to have a meaningful plant protection, which should be cost-effective, economical, practical, user-friendly and safe. Thus, it becomes necessary and of utmost importance that the benefits/critical role-played by pesticides in plant protection should be properly and adequately highlighted and emphasized. In the present day context where pesticides are being targeted and blamed for everything, irrespective of benefits arising out use of pesticides need to be selective (table 16). Indian scientists and extension workers are all aware of the problems that can result from over-use and misuse of pesticides, and the concept of economic threshold is well understood. No doubt the indiscriminate use of pyrethroids has led to resurgence of minor pests and development of resistance but these synthetic pyrethroids have played significant role in providing protection to crop against array of pests without which adequate food could have not been produced. Some of new molecules (table 17) like imidachloprid (Gouchu) and oxadiazine (avaunt) has provided very effective protection against hard to hit polyphagous pests of national importance (Rathod et al, 2003). In order to resolve the issue the concept of "Green Chemistry" is gaining importance. Some of new compounds such emectin and spinosad, later derived from soil actinomycete *Saccharopolyspora spinosa* are very effective and ecofriendly. Here the chemistry involves modified engineering practices and bio-remediation, eco-friendly reaction media and concept of atom economy leading to zero wastage.

**Table 16. Gradient shift in usages of pesticides with passage of time.**

| **Segment** | **Conventional molecule** | | **New molecule** | |
|---|---|---|---|---|
| Pest | Insecticide | Dose/acre | Insecticide | Dose/ acre |
| Sucking | Monocrotophos | 250-300 ml | Acetamiprid | 20-60 gm |
| | Dimethoate | 500-600 ml | Imidacloprid | 40-60 ml |
| | Acephate | 250-300 ml | Thaiamethoxa | 40-60 gm |
| Bollworm | | | | |
| Caterpillar | Endosulfan | 500-750 ml | Indoxacarb | 180-200 ml |
| | Quinalphos | 500-750 ml | Spinosad | 75-80 ml |
| | Profenophos | 600-800 ml | | |
| Weeds | Herbicides | Dose/acre | Herbicides | Dose/acre |
| Wheat | Isoproturon | 600 gm | Sulfosulfuron | 13.5 gms |
| | 2-4 D Ethyl Ester | 1000 ml | Clodinofop | 160 gm |
| Rice | Butachlor | 1000 ml | Cinmethylin | 300 ml |
| | 2,4 D Ethyl estr | 1000 ml | Oxadiargyl | 35-50 gm |
| | | | *Almix* | 8 gm |

**Table 17. Comparative effectiveness of generic vs. modern pesticides in management of cotton- sucking pest.**

| Compound | Use rate G ai/ha | Bioactivity rating |
|---|---|---|
| Dimethoate | 300 | ++ |
| Monocrotophos | 300 | ++ |
| Acephate | 500 | ++ |
| Acetamiprid | 10-20 | ++++ |
| Imidacloprid | 25 | ++++ |
| Thiamethoxam | 25 | ++++ |

Most of the pesticides are broadly toxic to pests as well as non-targets resulting in pest resistance, environmental pollution with persistent chemicals, and declines in wildlife populations, dictating a change to a more thoughtful strategy. IPM has replaced the shotgun approach with more sustainable tools, which include non-chemical strategies to prevent and avoid pest problems, and finely tuned chemical weapons targeting specific pests and spare the non-targets especially the beneficial. It involves the integrated use of some (cultural, resistant varieties, biological, and chemical control) or all of the pest control strategies (Dubey and Sharma, 2001(B)). IPM is more complex for the producer to implement than spraying by the calendar, which is not only easy but also off shelf readily available on credit basis. Over the past five decades wide varieties of new chemicals have been introduced for managing pests. A total of 182 pesticides are registered for use in the country under section 9 (3) of the Act, 1968.

The benefits accruing from the use of chemicals have been remarkable though over use of pesticides has resulted in number of adverse effects on environment particularly the contamination of food chain. Therefore, the use of pesticides should be need-based, safe, economical and suitable adjusted to conform to the required IPM schedule. The technology is improving very fast and newer molecules are being developed. With the recognition of IPR under the WTO there is likelihood that the research on pesticides will get a boost and the inflow of certain new molecules, existing molecules and intermediates may get increased. At present the customs laboratories do not seem to be well equipped to check the quality of imported pesticides as a result of which the entry of misbranded products into the country can not be ruled out.

In India, the use of 25 pesticides has been banned and 10 pesticides have been identified for their restricted use in agriculture apart from seven, which has been withdrawn. Further, 18 pesticides have also been refused registration by the Government, therefore, these pesticides are not allowed for use in agriculture systems (Table 18). The pesticide residue in fruits and vegetables has been causing serious concern for post harvest processor and exporters as pointed by some of the NGO. However, these residue limits are subject to variation because of physical weather conditions in different agro-climatic zones. The All India Network Residue Project on pesticide residue is engaged in detection of residues in food and feed and related issues. The use of insecticide mixtures is being further examined for safer and effective application of chemicals. The quality of pesticides will be improved with the support of pesticide referral laboratory being established by ICAR beside Central Insecticidal Laboratory (CIL) located in Faridabad , which is also working to maintain the quality.

**Table 18. List of banned pesticides for manufacture, import and use.**

| **Banned pesticide** | |
|---|---|
| Aldrin | Benzene Hexachloride |
| Calcium Cyanide | Chlordane |
| Copper Acetoarsenite | Cibromochloropropane |
| Endrin | Ethyl Mercury Chloride |
| Ethyl Parathion | Heptachlor |
| Menazone | Nitrofen |
| Paraquat Dimethyl Sulphate | Pentachloro Nitrobenzene |
| Pentachlorophenol | Phenyl Mercury Acetate* |
| Sodium Methane Arsonate | Tetradifon |
| Toxafen | Aldicarb |
| Chlorobenzilate | Dieldrin |
| Maleic Hydrazide | Ethylene Dibromide |
| TCA (Trichloro acetic acid) | |
| **Pesticides restricted for use in India** | |
| Aluminium Phosphide | Methyl Parathion |
| DDT | Sodium Cyanide |
| Lindane | Methoxy Ethyl Mercuric Chloride (MEMC) |
| Methyl Bromide | |

* These pesticides are manufactured in India for export only.
(http://www.cibrc.nic.in/list_pest_bann.htm)

## HUMAN RESOURCE DEVELOPMENT AND IPM EXTENSION

Extension is state government responsibility and the field based trainings to farmers by various agencies have created awareness about the IPM concept and empowered them for taking their own decision in adopting the plant protection methods with need based pesticide use considering the increasing degradation of environment and pesticide residues in farm produce. Because of implementation of IPM programmes with the help of state government agencies, there has been a significant reduction in the consumption of pesticides as evident from Fig. 1. Government of India has taken up massive human resource development programme (Table 19) with the help of state development agencies, ICAR crop based institutes and state agricultural universities to train and update agricultural personnel's and farmers in general with latest advancements in the field of pest management in lieu of changing world trade scenario. Training has led to advantageous position wherein consumption of pesticide use has gone down thereby adding to their savings by not spraying. Education has also led to savings in terms of environment not being polluted, restoration of which is difficult to calculate.

**Table 19. List of activities and number of personals trained in national programme.**

| Activity | Number |
|---|---|
| Master Trainer's Training courses (Seasons Long Trainings) conducted on Various Agricultural/Horticultural crops | 41 Nos |
| Master Trainers Trained through SLTs | 1423 Nos |
| Farmers' Field Schools organized byCIPMCs / KVKs /SAUs | 10562 Nos |
| Agriculture/Horticulture Extension Officers | 43,301 Nos |
| Trained through FFSs<br>Farmers trained through FFSs | 3,18,246 Nos |
| Persons (Pesticide dealers, NGOs, lead farmers, private entrepreneurs etc.) trained under Human Resource Developments Programmes (2&5 days duration) on IPM skills | 5620 |

*Source* : Directorate of Plant Protection, Quarantine & Storage, Faridabad, Haryana, 2008.

Foreign aided training was also conducted in a limited scale focusing on hot spot areas (Table 20). The programme was carried out with the help of FAO-EU sponsorship during 2000-04.

**Table 20. List of activities and number of personals trained in national programme**.

| Agency | No. trained/produced | | No. trained/produced | | No. organized/trained | |
|---|---|---|---|---|---|---|
| | **To F** | **Facilitators** | **FT oF** | **Facilitators** | **FFS** | **Farmers** |
| FAO-EU | 5 | 163 | 3 | 105 | 358 | 13836 |
| Through States | 21 | 524 | 7 | 271 | 1098 | 21992 |

Extension is state subject, however a number of pesticide industries have adopted villages in different agro-ecological regions. IPM is being implemented in all the crops being grown there and pests are being managed with judicious use of label pesticides as last resorts. Proper use of pesticides are preventing pests to develop resistance against them but also helping their existence. Apart from chemical pesticides they are also promoting their own formulations of bio-composters, microbials and botanical formulations.

Information technology (IT) has been fully utilized in the form of development of 18 online databases hosted on http://www.ncipm.org.in/databases.htm. Apart from this user friendly software "Pesticide Advisor" has been developed. It is a relational database comprising of hundreds of past and current schedules, which includes basic chemical information including uses, chemical classifications and structures, toxicity characteristics, including acute toxicity for government approved 188 active ingredients in pesticides with focus on agricultural and urban pest management. With such information, a government planner or research manager or farm worker or pest scout or subject matter specialist can review pest or cropwise and identify an eco-friendly suitable compound based on assessment reports. These reports are based on written record of the government's evaluation of a biocide's or pesticide's risks based on the data provided in the application for registration as well as information on predators, egg parasitoids, risk of farm workers and other non-target organisms. This software is being used by field workers research managers as well as policy planners.

## NATIONAL COMMITMENTS AND IMPLEMENTATION OF IPM TECHNOLOGY

There are over sixty seven (67) definitions of IPM, issued by various national governments, research organisations, NGOs, and universities (Bajwa and Kogan, 2002). Some assume that IPM will eliminate complete use of chemical pesticides, which is most unlikely. The IPM approach has been promoted by the GOI, since 1985 and being followed as defined by the FAO International Code of Conduct on the Distribution and Use of Pesticides (Article 2): Integrated Pest Management (IPM) means a pest management system that, in the context of the associated environment and the population dynamics of the pest species, utilizes all suitable techniques and methods in as compatible a manner as possible and maintains the pest populations at levels below those causing economically unacceptable damage or loss (FAO, 1967). Thus, IPM with best combination of cultural, biological and chemical measures has been advocated to provide the most cost effective, environmentally sound and socially acceptable method for management of pests.

Since IPM is the crop protection system which holistically meets the requirements of sustainable development and agriculture the same has been promoted as a component of Integrated Crop Management (ICM). ICM included IPM and is a whole-farm strategy, which involved managing crops profitably, with respect for the environment, in ways, which suit local soil, climatic and economic conditions. It safeguards the farm's natural assets in the long term. It also includes practices that avoid waste, enhance energy efficiency and minimize pollution. Keeping in view of ill effects of chemical pesticides as described in earlier text, Govt. of India, Deptt. of Agriculture & Cooperation has adopted Integrated Pest Management (IPM) as cardinal principle and main plank of plant protection technology in the country since 1985. Govt of India has geared up its 31 Central IPM Centres (CIPMCs) located in 28 states and union territory with following objectives–

- Monitoring of pests and diseases for forewarning,
- Conservation of natural enemies in farmer's fields,
- Production and field releases of biocontrol agents,
- Promotion of ecofriendly IPM inputs like biopesticides/neem based pesticides,
- Human Resource Development by imparting IPM training to extension officers and
- farmers through FFSs/SLTPs/Short during IPM Prorgramme and
- Popularise IPM technology among farming community.

To impart education CIPMCs state based center are engaged in imparting trainings to state govt functionaries with the help of resource personnel from crop based ICAR organizations and State Agricultural University (table 19). Efforts have led to monitor and contain pest problems in the budding stage only, which has saved millions of exchequer by not using blanket chemical sprays. To strengthen extension department's quality standard literature has been published in consultation with Subject Matter Specialists of SAUs and crop based ICAR Institutes. In this series generic IPM modules have been developed for the 77 crops ( Rice, wheat, maize, sorghum, pearl millet, pigeon pea, black gram/green gram, gram, rajmah, pea, groundnut, soybean, rapeseed/mustard, sesame, safflower, castor, sunflower, potato, onion, tomato, cruciferous vegetables, leguminous vegetables, cucurbitaceious vegetables, brinjal, okra, chillies, cotton, sugarcane, tobacco, citrus, pineapple, sapota, pomegranate, grapes, apple, mango, guava, banana, litchi, papaya, apricot, peach, pear, cherry, walnut, ber, amla, small cardamom, large cardamom, black pepper, coriander, cumin, fennel (saunf), ginger, coconut, cashew, arecanut, oil palm, tea, jack fruit, spinach, broccoli, loquat, strawberry, olive, watermelon, lablab bean , garlic, betelvine. fig, phalsa, saffron, custard apple, persimmon, kiwi, passion fruit and raspberry). These generic IPM modules can be assessed logging to http://dacnet.nic.in/ppin/ipmpakpra.htm. Apart from above mentioned literature other crop specific literature has been developed and published in collaboration with other Govt agencies. Some of these are listed below–

- Manual in Hindi and English on rice and cotton for the Subject Matter Specialists (SMS),
- Farmers field guide in Hindi and English on rice and cotton,
- Handbooks on diagnosis and IPM of cotton pests in English, Hindi, Punjabi and Telugu languages (in collaboration with NCIPM, New Delhi),
- Folders on IPM in Cotton in Hindi, English, Punjabi and Telugu and
- Posters in Hindi and English in cotton and rice for recognition and correct identification of pests and their natural enemies.

Monitoring and evaluation of IPM programmes at the national level has been carried out by independent bodies for the course correction and overall results were praise worthy. Effectiveness and impact of IPM at the field level has been measured in following terms–

- Over all consumption of chemical pesticide in the country reduced from 75033 MT (Tech. grade) during 1990-91 to 39773 MT (TG) in 2005-06,
- Chemical pesticide sprays were reduced to the extent of 50-100% in rice and 29.96 -50.5% in cotton, which are the largest pesticide consuming crop.
- Increase in use of bio- pesticides from 219 MT during 1996-97 to 1920 MT during 2005-06,
- Increase in yield in the range of 6.17% to 40.14% in rice IPM compared to non-IPM fields and
- Increase in yield in the range of 22.7% to 26.63% in cotton IPM compared to non-IPM fields.

Since IPM required education, skill in pest monitoring, understanding of pest dynamics, and cooperation among producers en mass for effective implementation, farmers field schools and validation of the technology was carried out at village level in cotton at village Ashta in central India (Sharma et al., 2000) as well as rice at Shikopur, in western India by NCIPM. In cotton the community based, holistic IPM module with much reliance on naturally occurring biocontrol agents and biopesticides as tools for sustainable production of cotton was successfully validated over 175 ha in the whole village, 'Ashta', District Nanded, Maharashtra from 1998-2001. The IPM interventions included seed treatment with imidacloprid, scouting, placement of pheromone traps for monitoring, two releases of Trichogramma, one spray of HaNPV and 2-3 sprays of neem seed kernel Extract (NSKE). The IPM module resulted in substantial reduction of insecticide use and avoided overhead for the natural force of defense to act.

The population of predatory ladybird beetles was 0.04-0.36 adults/plant under the Farmers' Practice (FP) plots compared to 3.0-4.8 adults/plant in IPM plots. The Population of green lacewing was negligible in FP compared to 1.4 eggs per plant in IPM plots. Field collected larvae had shown 100% parasitization. The biointensive technology provided higher net returns and yields over FP. The average seed cotton yield was 963, 1075, 1002 and 1032kg/ha as compared to 593, 806, 632 and 564 kg/ha during the 1998, 1999, 2000 and 2001, respectively. The system has become self sustainable as the farmers of Ashta have themselves become decision makers and have on their own started adoption of IPM practices. Similarly, IPM for rice was validated on large scale during 1999-2002 and 2002-2003, respectively in the village Shikohpur, Baghpat (Uttar Pradesh) and Chhajpur, Panipat (Haryana), where farmers solely depended on the use of intensive pesticidal applications.

Validated IPM strategies of cotton, rice and tomato–
Rainfed cotton (Village Ashta (MS) / year 2001)

Key pests: *Helicoverpa armigera* was recorded causing heavy damage in majority of the cotton growing areas of southern Maharasthra. However, all the fields under IPM validation at village had low insect infestation and disease incidence.

| **Non-IPM (FP)** | **IPM** |
|---|---|
| Seed treatment with Cruiser<br>Monocrotophos (1)<br>Endosulfan (3)<br>Cypermethrin (1)<br>Fenvalerate (1)<br>Renuka<br>Copper sulphate 1)<br>Total Pesticides used = 4.945 L/ha. | Field sanitation<br>Maize as border crop + cowpea<br>*Setaria* at $10^{th}$ row<br>Seed treatment with Cruiser<br>Synchronized sowing of NHH-44 &<br>Confidor (1)<br>Pheromone traps<br>NSKE (2)<br>HaNPV (1)<br>Total Pesticides used = 0.247 L/ha |

FP = Farmers' practice.

Rice Pusa Basmati – 1 (Village Shikohpur, UP, 2001)

Key pests: Yellow Stem Borer, Leaf folder, Sheath Blight, Bacterial Leaf Blight (BLB)

| **Non-IPM (FP)** | **IPM** |
|---|---|
| NPK : 140:80:10 Kg/ha<br>One seedling/hill<br>12 irrigations<br>Dimecron spray – 1<br>Phorate application (1-2)<br>Copper oxychloride (0-1)<br>Streptocycline sprays (1-2)<br>Carbendazim spray – 1 | Green manuring of Dhaincha<br>Two seedlings/hill<br>NPK : 100:60: 60 Kg/ha<br>Zinc sulphate 25 Kg/ha<br>6 irrigations<br>Seed treatment with carbendazin<br>One release of *T. japonicum* (Based on monitoring)<br>Application of methyl parathion for gundhi bug only in 10 acre fields Spray of streptocycline in about 30 acres for BLB<br>Spray of carbendazim (1-2) in about 20 acre |

Tomato (Bangalore, Kar, 2002)

Key pests: Fruit borer, whitefly, alternaria blight, leafcurl

| **Non-IPM (FP)** | **IPM** |
|---|---|
| Number of pesticide sprays ranged from 32 to 46<br>Local variety | Use of leaf curl tolerant $F_1$ hybrids<br>Soil solarization<br>Raised nursery beds<br>Soil application of *Trichoderma* soil drenching with copper oxychloride<br>Manual collection of diseased leaves & larvae of *H. armigera* staking of plants<br>Spray of NPV<br>Neem cake (250 Kg/ha)<br>Use of Pheromone trap<br>Spray of imidacloprid/ thiomethoxam(2ml/lit) |

*Source*: National Training Course on IPM in Important Field Crops, 24 Sep -14 Oct 2004.

Adoption of IPM approach, which mainly comprised of seed treatment, regular pest surveillance and monitoring through installation of pheromone traps, conservation and augmentation of natural enemies like *Trichogramma chilonis*, need based application of pesticides and some improved crop management practices resulted in drastic reduction in pesticidal application and the yield levels were enhanced to a significant extent. At Shikhopur village, IPM provided consistently higher yield levels of 58.04, 57.40 and 51.60 q/ha of Pusa Basmati-1 over farmers' practice (FP) (48.21, 45.60 and 43.50 q/ha) during 2000, 2001 and 2002 respectively. Besides, input cost was reduced in IPM with high cost benefit ratios (1: 3.18. 1:3.16 and 1:2.21 in IPM, 1: 2.28, 1: 2.12 and 1: 1.64 in FP respectively). The technology has been very well received and still continues to be adopted due to their simplicity and economic viability (Table22) as well as environmental benefits (Table 23). Conservation of naturally occurring bioagents has been scientifically proven through recovery studies.

**Table 22. Economic viability of IPM at village level in farmers participatory mode.**

| Crop and (Location/Year) | Non-IPM (FP) | IPM |
|---|---|---|
| ***Rainfed Cotton: (Ashta/2001)*** | | |
| Cost of plant protection (Rs./ha) | 1217 (11190)* | 928 (10831)* |
| Productivity (q/ha) | 5.64 | 10.32 |
| Cost Benefit Ratio | 1:1.01 | 1:1.91 |
| ***Rice Pusa Basmati – 1: (Shikohpur/2001)*** | | |
| Cost of plant protection (Rs./ha) | 2243 (20980)* | 486 (17733)* |
| Productivity (q/ha) | 45.6 | 57.4 |
| Cost Benefit Ratio | 1:1.21 | 1:1.32 |
| ***Tomato: (Bangalore/2002*** | | |
| Cost of plant protection (Rs./ha) | 15567 (33281)* | 1063 (28683)* |
| Productivity (q/ha) | 265.3 | 647.7 |
| Cost Benefit Ratio | 1:0.95 | 1:5.98 |

*Source*: National Training Course on IPM in Important Field Crops, 24Sep-14 Oct, 2004. * Total cost of production (Rs/ha).

**Table 23. Environmental benefits - Population of predators in rainfed cotton at Ashta**

| Year of study | Area under field validation (ha) | Predator population / 25 plants | | | |
|---|---|---|---|---|---|
| | | IPM | Non-IPM | IPM | Non-IPM |
| 1998-99 | 125 | 0.50 | 0.20 | 2.70 | 0.70 |
| 1999-2K | 100 | 0.80 | 0.20 | 4.50 | 0.60 |
| 2000-01 | 100 | 0.45 | 0.20 | 1.48 | 0.34 |
| 2001-2002 | 100 | 0.85 | 0.17 | 1.52 | 0.83 |

*Source : Annual reports of NCIPM, New Delhi*

**SUGGESTIONS**

To increase yields from the available land, which has not increased significantly during last two decades, requires good crop protection against pre- and post-harvest losses. There is a growing concern about the adverse effects of chemical pesticides due to their indiscriminate use. While on the one hand productive land is contaminated with pesticide residues, on the other substantial revenue is lost due to crop pests and diseases in India, which cannot be simply ignored as residues are being found increasingly in our farm produce posing a threat to human health. In many parts of the country, such as Uttar Pradesh, Punjab and Haryana, human and soil health are in danger due to excessive use of fertilizers and chemical pesticides. The ill effects of chemical pesticides are not visible however; they cannot be ignored hence adequate scientific manpower and infrastructure needs to be developed.

Thus, pesticide residues in soil and pest resistance to pesticides, which has surpassed previous records, are the bane of the Indian farmer. As a result, pest resistance to multiple sprays and the consequent destruction of successive cotton crops has at times led to mass suicides in states like Maharashtra, Andhra Pradesh and violent agitation in Punjab. Our efforts should be to provide new safer and efficacious quality pesticidal products to the farmers and the use of bio-pesticides, bio-control agents need to be encouraged. For this, the Central Pesticide Board (CIB) and Registration Committee (RC) is required to be geared to undertake expeditious scrutiny of data and the Central Insecticide Laboratory (CIL) to verify the claims of the applicants. Since there is sufficient installed capacity for manufacture of pesticides, the policy of granting registration should be reviewed so as to encourage export of pesticides, thus earning foreign exchange for the country. Contributions by Indian scientists on different components of IPM system for majority of crops including horticultural one are well documented but needs to validate on large farms. From last decade the development of biological control of pests/diseases, disease resistant crop varieties, the manipulation of cultural practices to reduce pest/disease incidence, and the use of botanicals, such as neem are the practices largely adopted by farmers in general.

Additionally, crop diversity, intercropping, favored the implementation of IPM at the farm level of small as well as medium farmers. The Department of Agriculture and Cooperation, Government of India has been instrumental in providing financial assistance to various Department of Agriculture and Agricultural Universities for developing and producing biopesticides, biocontrol agents viz., NPV, GV, *Trichogramma, Chrysoperla* and *Trichoderma* at local level. Presently, 10 bio-pesticide production units at semi-commercial level are able to cover an area of 1 million ha./annum in 10 crops against major insect pests in various regions of the country. Under this programme bio-pesticide production units and plant protection clinical centres at regional research stations have also been established to cater local need and correct diagnosis of pest. Significant achievements have been made in critical IPM inputs. Microbial pesticides - stable formulations of (bacteria, viruses, nematodes) that suppress pests by secreting toxins, causing diseases, preventing the establishment of other micro-organisms, or other mechanisms have been achieved. The technology has been transferred to small entrepreneurs and being promoted by the Government of India (GOI), Department of Science and Technology (DST) and ICAR schemes.

IPM is built on detailed knowledge of pest biology, behavior and ecology, not simply chemistry and toxicology. At the time IPM began to be promoted as a pest control strategy in the 1960's, there was very little IPM technology available to be transferred to farmers, hence at present sufficient research had been conducted to provide the knowledge to successfully implement IPM programs in important crops, such as rice, cotton, sugarcane and few vegetables.

In most of the crop based coordinated programme there is one trial on IPM, however the real essence of IPM is lacking as attitude towards bio-pesticides is proving difficult to change. IPM is now widely accepted as an alternative to expensive calendar-based spraying schedule being earlier adopted by majority of farmers. IPM technologies for major economic crops have been (Table 24) field validated and the same can be expanded to cover more areas as per local pest problems.

**Table 24. Available IPM technologies for different crops.**

| Crop | Key pest | Management tactics |
|---|---|---|
| Rice | Brown plant hopper, stem borer, gall midge, Bacterial and fungal diseases | Resistant varieties, cultural methods, pest monitoring, conservation and mass release of biotic agents and spot application of safer pesticides |
| Sugarcane | Tissue borers, pyrilla, scale insects | Resistant varieties, augmentation and release of parasites(*Trichogramma*,*Epicarnia*, *Strumiopsis inference*, *Isotima javensis*, GV etc.), need based pestcides |
| Cotton | Boll worms, jassids, white flies, grey mildew and bacterial blight | Use of transgenics, mass release of biotic agents (NPV, *Chrysoperla*, *Trichogramma* spp., *Bracon* spp.), crude neem extract, need based pesticides |
| Groundnut | White grubs | Cultural and mechanical means (pheromones), seed treatment with safe pesticides |
| Tobacco | Heliothis and Spodoptera | Using castor as a trap crop which acts as cover crop for harbouring natural enemy. Spraying neem seed kernel extract on tobacco seedlings and crops. Spraying NPV and SiNPV |
| Cruciferous vegetables | Diamond back moth, other lepidoptera | Biotic agents, use of trap cropping, neem, Pongamia oil, B.T and need based use of safe chemicals, |
| Mango | Leaf hoppers, mealy bugs, fruit flies | Tree banding, fungal pathogens, pheromones |
| Citrus, Grapes, Guava | Mealy bug | Mass release of *Cryptolaemus montrouzieri* and *Laptomastrix dactylopii* |
| Coconut | Rhinocerous beetle | Use of baculovirus, microbials |
| Aquatic weeds | Water fern and water hyacinth | Introduction and mass releases of exotic weevils, *Crytobagous salvinae* (for water fern) and *Neochitina* spp. (for water hyacinth) |

Concisely, IPM is a strategy to control pests - insects, weeds and plant diseases, for example - using methods that are effective, economical, and the least harmful to the environment. But IPM requires a major change in attitude about the way we currently manage pests and use pesticides, even at home and kitchen gardens. Managing pests requires more than reading a pesticide label and applying the proper dose. IPM seeks to reduce reliance on pesticides by using a range of practices that do the job just as well or better and protect the environment. IPM for the kitchen garden, for example, includes planting well adapted varieties that may naturally resist pests, keeping plants healthy and vigorous, encouraging natural enemies of pests like lady bugs, green lacewing and spiders and, if necessary, spot application of pesticides that are less toxic. IPM has made maximum use of conditions and methods that control pests naturally. NCIPM has field validated and perfected as how IPM can best be used in agriculture to provide sustainable produce while maintaining the clean environment. As on now approximately 4% of arable area is under IPM and efforts are to increase it to 10% by the end of 10th plan. While IPM may be a new concept to many of us, it is an old practice to the farmers of India, which has been forgotten as greed for more food and economic returns.

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**Appendix-2 : Photographs on IPM activities**

*Observation of pheromone trap in rice field*

*Sticky trap to collect insects in cottorn field*

*Explaining about pheromone*

*Monitoring insect pest in rice field*

*Scientists inspecting rice field*


*A view of FFS on chickpea*

*Field observation by scientists and farmers*

*A view of FFS on Cotton*

*Interaction with female farm workers*

*Podborer monitoring in chickpea*

*Cotton farmers filtering crude neem extract*

*Rice field observation by scientists*

Chapter 4

# Nepal

# Integrated Pest Management Activities in Nepal

**K. C. Ganesh Kumar**

## INTRODUCTION

Nepal is a land locked country situated between the People's Republic of China in the north and Republic of India in the remaining sides. The population of the country is 26.42 million and the literacy rate is 40 %. It has an area of 147,181 km? of which 5,1817 km? fall in mountain region, 61,345 km? in the hilly region and 34,019 km? in the Terai region (CBS 2007). Of the total area, 20% are cultivable and another 29% forest. Life expectancy at birth is 64 years. As per the Nepal Living Standards Surveys (NLSS, 2004), the ratio of population living below the poverty line is 30.85 % Growth in farm incomes, remittance and non-farm incomes are credited for bringing down the poverty and it is targeted to reduce to 14 % by 2015. The climatic variation within a short span of north to south is from tundra to subtropical and tropical types.

## AGRICULTURE AND ITS ROLE IN NEPALESE ECONOMY

Agriculture remains Nepal's principal economic activity and influences the overall economic development of the country. Agriculture is the largest single sector, which contributes 35% to GDP, employs 66% of the population, absorbs surplus labour and is a vital developmental tool for poverty alleviation. However, the agriculture sector is still subsistence oriented with the current growth rate trailing at around 3 %. Agriculture is not only important from the perspective of food security but also a major source of income for majority of rural people. Since last two decades, recurrent food emergency has been common phenomena. Hence, increasing and stabilizing the domestic food production for food security has become essential. Majority of the farmers are reliant on rainwater for irrigation as the country lacks major facilities for man made irrigation which is only about 1,059,865 ha. Outbreaks of disease and pests on cultivated plants are another area of concern. Although their frequent occurrences so far recorded are not at the devastating level. However, time to time the situation becomes alarming.

### Major crops grown

The principle agricultural crops include paddy, maize, wheat, oilseeds, pulses, vegetables, fruits and sugarcane. Major exportable agricultural commodities include pulses, raw jute, vegetables, cardamom, tea, coffee, ginger, oranges, non-timber forest products (NTFs) etc. However, the productivity of these crops is lower than the expected level and that of the neighbouring countries. Cereals cover 3,304,330 ha; cash crops, 416,226 ha; pulses, 319,557 ha; fruits 57,595 ha and vegetables, 191,922 ha.

Poverty reduction through expanded employment opportunities by means of commercialization and market promotion of the high value agricultural commodities has been set as the overall vision of the agriculture development programme in Nepal.

At the highest level of policy planning, the government has acknowledged that promoting the agriculture sector is the proper measure for the country to combat poverty. The government is, therefore, implementing a long-term agriculture perspective plan (APP) to address the problem of widespread rural poverty by increasing agricultural growth rate taking advantage of the country's agro-climatic diversity and intensification of agricultural production.

**Highlights of the Periodic Agricultural Development Plans**

**Agriculture Perspective Plan (APP)**

APP has been the basic policy guidelines for all the agricultural development plans in Nepal after 1995. The APP strategy is to accelerate the agricultural growth rate through technological change to obtain strong multiplier effects on growth and employment, in both the agricultural and non-agricultural sectors. The objectives of APP are to accelerate the growth rate and transform subsistence agriculture into commercial one through increasing productivity and to provide opportunities for overall economic growth by fulfilling the preconditions of agricultural development. APP has recognized Integrated Pest Management (IPM) approach as the prime crop management technology in Nepal. It also focuses on the need of private sector, farmers' cooperatives involvement in the delivery of inputs, research and marketing services as well as in the management of infrastructures and assets.The Tenth Plan has just completed which was the central part of poverty reduction strategy to bring the marginalized sections of the population and backward regions into the mainstream of development.

**Three-Year Interim Plan (TYIP)**

Likewise, TYIP has also accepted the need for transforming the subsistence agriculture into a commercialized one to improve the overall quality production and productivity and enhance agriculture trade by improvement of all operations in the value chain. TYIP thrusts are as follows–

- Employment and income generation opportunities to rural youth, women and disadvantaged group,
- Environment friendly technology generation and conservation of agricultural biodiversity, and
- A Farmer Field Schools to educate farmers for a market-oriented economy including farmers to farmer extension services, partnership and collaborative relationship among all the extension service providers (CBOs/NGOs/private sectors) and research agencies.

**Key issues and challenges in agricultural development**

Issues and challenges pertaining to Nepalese agriculture is complex and to list, few of them are as below–

- Investment, restructuring and technological packaging has not been up to the mark especially in rural areas, consequently agriculture in these two decades has not grown and it is just ongoing.
- Uneconomical scale of commercial production for both internal and external markets.
- Competitive disadvantage with respect to neighboring countries' products (due to inequalities in subsidy).
- Limited access of the poor and small farmers to modern technology and Weak linkage among the agencies responsible for agriculture production, agro-industry and trade.

**MAJOR CROP PESTS AND CROP LOSSES**

Farmers in most of the rural areas still practise non-chemical farming and the agriculture is still free from the problems of chemical pesticide pollution. With the initiation of agriculture commercialization during the 1960s and 70s use of modern agricultural inputs such as chemical fertilizers, pesticides and improved seeds has increased to boost agricultural productivity. Initially, these factors helped in increase crop yield but ultimately it led to second generation problems and concurrently causing unsustainable benefits. Heavy reliance on expensive inputs has increased production costs and decreased profits for small farmers. Farmers use unsafe pesticides during the pest outbreaks mainly due to ignorance and in their quest for increasing production and farm income.

Although, the national average for pesticide use is very small in Nepal but in most of the cases it has been overused, misused and abused in areas where they are being used. With the increasing negative effect of pesticide residues in the food all over the world, the demand for organic agricultural products is increasing. This calls for the initiation of best option for pest management like IPM. Consequently, ecological and sustainable pest management programme made the first move emphasizing on a multi-disciplinary approach in FFS and community networking aspects. In general, 15 % of crops are lost in pre- and nearly 20 % in post-harvest periods in all major crops due to various pests and diseases. Table 1 shows the major crop pests of Nepal

**Table 1. Major insect pests, diseases and weeds.**

| | | |
|---|---|---|
| Apple insects | San Jose Scale | *Quadraspidiotus perniciosus* |
| | Wooly Aphis | *Eriosoma lanigerum* |
| | Codling Moth | *Laspeyresla pomonella* |
| Apple diseases | Sooty Blotch and Fly Speck | *Leptothyrium pomi* |
| | Pink Disease | *Pellicularia salmonicolor* |
| | Rot | *Phytophthora cactorum* |
| Citrus (fruit) insects | Stem Borer | *Arbela tetraonis, Chloridolum alcamene* |
| | Pink Disease | *Corticium salmonicolour* |
| | Citrus Psylla | *Diaphorina citri* |
| | Trunk Borer | *Monohammus versteegi* |
| | Pumpkin Bug | *Nezara viridula* |
| | Citrus Fruit Sucking Moth | *Ophideres sp.* |
| | Lemon Caterpillar | *Papilio demoleus* |
| | Citrus Leaf Miner | *Phylloenistes citrella* |
| Citrus diseases | Huanglongbing | *Candidatus Liberibacter asiaticus.* |
| | Citrus Canker | *Xanthomonas citri* |
| Mango diseases | Black Spot | *Bacillus magniferae* |
| | Brown Rot | *Physalospora perseae* |
| | Die-back | *Botryosphaeria ribis* |
| | Fruit Anthracnose | *Colletotrichum gloeosporiodes* |
| Mango insects | Fruit Fly | *Chaetodacus incisus* |
| | Hopper | *Idioscopus niveosparsus* |
| Rice diseases | White Tip | *Aphelenchoides besseyi* |
| | Seedling Blight | *Drechslera oryzae* |
| | Foot Rot | *Fusarium Moniliformes* |
| Rice insects | Grasshopper | *Heirieoglyphus banian, Heirieoglyphus forcifer* |
| | Brown Leaf Spot | *Helminthosporium Oryzae* |
| | Rice Hispa | *Dicladispa armigera* |
| | Rice Bug | *Leptocorsia varicornis* |
| | Rice Leaf Hopper | *Nephotettix bipunctatus* |
| | Glume Blight | *Phoma sorghina* |
| | Blast | *Pyricularia oryzae* |
| | Sheath Blight | *Rhizoctonia solani* |
| | Sheath Rot | *Sarocladium oryzae* |
| | Rice stem Borer | *Schoenobius incertellus* |
| | Stem Rot | *Sclerotium oryzae* |
| | Rice weevil | *Sitophilus oryzae, Calandra oryzae* |

| | | |
|---|---|---|
| | Swarming Caterpillar | *Spodoptera mauritia* |
| | False Smut | *Ustilagonaidae virens* |
| | Bacterial Blight | *Xanthomonas campestris pv.* |
| | | *Oryzae* |
| | Bacterial Leaf Streak | *Xanthomonas translucens* |
| Sorghum insects | Ear Head Bug | *Calcoris augustatus* |
| | Mite<br>Stem Borer | *Paratetranychus indicus*<br>*Chilo zonellus* |
| Finger Millet diseases | Blast | |
| | Seedling Blight and Foot Rot | *Helminthosporium nodulosum* |
| | Wilt | *Sclerotium rolfsii* |
| Wheat diseases | Ear Cockle Disease | *Anguina tritici* |
| | Powdery Mildew | *Erysiphe graminis tritici* |
| | Karnal Bunt of Wheat | *Neovossia indica* |
| | Stem Borer | *Nonagriauniformis* |
| | Yellow Rust | *Puccinia glumarum* |
| | Black or Stem Rust | *Puccinia graminis* |
| | Brown Rust | *Puccinia recondita* |
| | Bunt or Stinking Smut | *Tilletia caries, Tilletia foetans, Tilletia indica* |
| | Flag Smut of Wheat | *Urocystis tritici* |
| | Loose Smut of Wheat | *Ustilago nuda, Ustilago tritici* |
| Maize diseases | Stalk Rot of Maize | *Erwinia carotovora* |
| | Downey Mildew | *Sclerospora sacchari, S. rayssiae, S. macrospora, S. phillipinensis, S. sorghi, ravassiae* |
| | Seed and Seedling Blight | |
| | Cob Rot | *Fusarium moniliforme* |
| | Wilt | *Fusarium moniliforme* |
| | Southern Leaf Blight | *Helminthosporium maydis* |
| | Brown Spot | *Physoderma maydis* |
| | Smuts | *Ustilago maydis* |
| | Head Smut | *Sphacelothaca railiana* |
| | Common Smut | *Puccinia sp.* |
| Potato diseases | Late Blight | *Phytophthora infestans* |
| | Potato Wart | *Synchytricum endobioticum* |
| | Brown Ring Rot | *Pseudomonas solanacearum* |
| | Early Blight | *Alternaria solani* |
| | Soft Rot and Black leg | *Erwinia carotovora, Bacillus clostridium, B. mesentrichus, E. roidae* |

**Crop losses due to pests.** The crop lossess of food crops and vegetables in the field and post harvest due to pests in Nepal is given below.

| Crop | Field loss (%) | Post-harvest loss (%) |
|---|---|---|
| Rice | 25-30 | 18 |
| Maize | 20-25 | 17-19 |
| Wheat | 5-10 | 17-20 |
| Vegetables (All perishable) | 25-30 | 28-35 |

## TREND OF INSECTICIDE USE

In Nepal, use of chemical pesticides in field crops was statred during the early 1950s to a limited scale. After the introduction of high yielding varieties and influenced by slogan "produce more campaign", pesticide use especially in vegetables, rice and cash crops gradually increased in terms of quantity and frequency. Pesticide Act was enforced only after 1999. Basically the Act was formulated to regulate the import and use of pesticide and enable the consumer to be safe from biohazards. Now, the total import is in decreasing trend and increasing popularity of IPM is attributed to this. FFS has definitely created awareness among the stakeholders on the misuse of pesticide. However, the chemical pesticide still take up major share in control of the pests in agriculture, livestock, wildlife and public health as availability and know-how on natural enemies, botanicals, growth regulators and pheromones as alternatives to chemical pesticide have not yet fully gained popularity among the farmers.

Although chemical pesticides are comparatively costly in Nepal but because of their qualities in terms of quick action, availability and long-established belief, farmers still rely on pesticides to control pest and diseases. Study shows that average pesticide dose application/ha on paddy, tomato and potato in Kavre and Bhaktapur districts varies from (formulation) 604 to 13,427 g/ha (228 to 8,845 a.i. g/ha). The maximum residual limit (MRL) is usually not being maintained especially in vegetables. However, the national average pesticide use per ha in Nepal is 142 g a.i per ha but in some high value commodities (HVCs) like vegetables, cardamom and tea, it is much more than the national average.

Majority of the farmers using pesticide largely depend on the recommendations made by the dealers. Pesticide hazards occur mostly due to continuous exposure to pesticide during preparation and application in the field. Misuse or negligence on the direction for use in the field crops can create residue problems. The amounts may often be below MRL but their presence itself is a cause of concern. Occasional higher residues in food resulted from wrong use or deliberate overuse/misuse of such pesticides. All persistent organic pesticides (POPs) have been banned since long time and PIC listed pesticides have not been registered. Total amount of obsolete, unwanted and/or banned pesticides stock are approximately 74 metric tons and 43 cylinders of methyl bromide, of which 10.058 metric tons is of POPs group.

**Pesticide use pattern**

Most pesticides used in Nepal are imported from India, some from China and a few from other countries. The use is higher in areas with intensive commercial farming of vegetables, fruits, tea, rice and cotton, indicating the need for intensive implementation of IPMFFS programme. About 290 types of formulations by trade name (Insecticides-202, fungicides-51, herbicides-19, rodenticides-8, acaricides-2, bio-pesticides-5 and others-3) and 71 by technical or common name have been registered for use under pesticides act and rules. In terms of the number of pesticides applied, there were a total of 71 different active ingredients. Classifying these by the WHO risk classification system, on the average, 9.86% were highly hazardous (WHO class Ib), 32.4% moderately hazardous (WHO class II), 2.68% slightly hazardous (WHO class III), 42.26% were low risk (class U/NH) and 2.8% not calculated (NC). Recently Government of Nepal has deregister the methyl parathion and monocrotophos. As there is an open and porous border with India, there is a considerable, but unknown quantity of trade between farmers to farmers close to the border. Issues like illicit import / smuggled pesticides are of trans-boundary natures which are of concern to Nepal in the context of pesticide hazard.

**Table 2. Import and Consumption of pesticides.**

| Year | Quanlity imported | | Quanlity consumed a.i. (mt.) |
|---|---|---|---|
| | a.i. (Mt) | Value in Rs. 000 | |
| 2001 | 146 | 148620 | 160 |
| 2002 | 177 | 153555 | 145 |
| 2003 | 176 | 123158 | 184 |
| 2004 | 154 | 131022 | 159 |
| 2005 | 131 | 130025 | 151 |

*Sourc*e: PR and MD,2062/63.

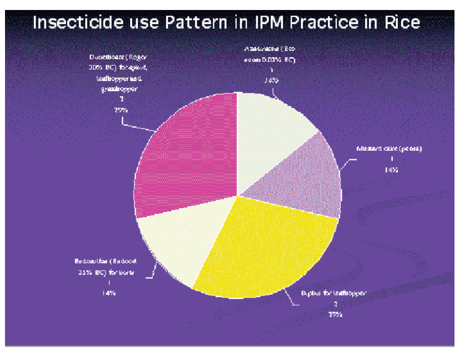



**Figure 1.** Insecticide Use Pattern in IPM Practice in Rice (Based on Random Survey Report)
*(Source: GoN/FAO IPM Project 2003-2007*

`Overuse, abuse and misuse of insecticides are common in Nepal. Adequate awareness on type and level of pesticides and use of protective clothing are not common among the farmers. On the other hand, smuggled, unregistered and sale of banned product, cases of decanting and reweighing, counterfeit products using false labels, sale of expired products with modified expiry dates, and frequent applications at higher dosages are most common examples of misuse cases. Cases of pest resurgence especially in rice crop are frequently observed in some specific locations where there has been heavy misuse of pesticide resulting in killing of natural enemies (NEs). There are cases of pesticide poisoning. These were mainly due to ignorance on the mode of pesticide entry into human body.

## CROP WISE IPM ACTIVITIES

**Rice.** As said earlier, the thrust of Nepalese IPM programme is more on Farmers' field schools, giving them an opportunity to understand ecological and sustainable agriculture so that the farmers can achieve greater control over the conditions of their fields and its surroundings. The overlying far end objective is to empower the farmers with a view to empowering them to make their voice hard at the policy level. Location-specific commodity-based technical recommendations are made by the farmers/group of farmers themselves based on the result of the experiments carried out by the farmers themselves under the farmer and scientific approach. IPM facilitators preparation, awareness creation, training material preparation, IPM group formation, coordination among the various IPM stakeholders are the major activities carried out under the Rice-IPM project.
IPM technologies especially for rice and vegetables have been designed and implemented, but the coverage is very limited.

**Rice specific Recommendations**

- Irrigation system improvement and water management,
- Use of improved varieties as per the suitability of the location,
- Soil nutrient applications as per the soil analysis,
- Farmers understand the good agronomic practices and plant biology,
- Develop habit of regular field visit,
- Correct seed rate use,
- Transplant two seedlings per hill,
- Rice-fish culture effective in leaf folder control in rice, and
- Cut the paddy 15-20 cm high from the ground helps to maintain the spider
- population and enhances the efficiency of NE in the ecosystem.

**Vegetables**

- Agro ecosystem analysis once in a week
- Apply 80.60.30: N.P.K, FYM40 Tons /ha.and 75x60 cm spacing.
- Observe NE and pest population relationship regularly and apply bio-pesticide based on the pest and NE population.
- Use marigold as trap to control the tomato fruit borer, one row of marigold in every 10 rows of tomato,
- Avoid cultivating variety that yields little more but very susceptible to pest and disease.
- Clean the alternate host,
- Avoid Continuous use of single pesticide; apply pesticide undersurface of the leaves in case of leaf blight,
- Monitor the pest regularly and
- Raise vegetable seedlings in raised beds prepared in raised platform

**Coffee**

- Major insects are white stem borer, red stem borer, mealy bug, green scale insects, etc.
- Major diseases are brown eye spot, anthracnose, back, stalk rot of berries and brown blight of leaves and Fusarium wilt are some of the pest of concern in coffee.
- Despite the prevalence of above pests, so far the coffee in Nepal is free of chemical pesticide.

**General recommendations on coffee pest management**

- Regular orchard sanitation and Pruning of the affected plant parts. Every quarterly an intensive monitoring is essential,
- Uproot and burn diseased plants caused by *Fusarium* spp. Apply Trichoderma,
- Maintain adequate overhead shade and mulching must be done
- Use only well decomposed farm yard manure and compost,
- Protect the plant by spraying Bordeaux mixture (0.5 – 1 %) before flowering (February/March), before rain (May/June) and after rain (September/October).
- If detected nematode in the nursery area discard the place. Uproot the heavily infected tree,
- White stem borer management regularly and prune and burn affected parts/plants.
- Before the adults lay eggs (During May -June), scrub the main stem and primary branches and apply a paste of red soil mixed with cow dung on the scrubbed surfaces. A paste made of equal quantity of flowers or leaves of marigold, targets sop.,*Azadirachta indicia*, *Melina azedarch* and cloves of garlic mixed with linseed oil is applied on the scrubbed surfaces in the same month.

**Fruit Fly**

Bury the infested fruit more than 2 feet deep, mowing or shredding ground fruit can provide sanitation by killing the larvae or exposing them to other predators. Neem-based pesticide spray or baiting with various available lures mix with safe pesticide.

***Clubbed root of Cole crops***

- Healthy seedling production and distribution
- Apply lime to raise pH near to 7.
- Proper disposal of clubbed roots of the plants immediately after harvest.
- Not to use infected plants as cattle feed.
- Drainage system to be improved.
- Avoid moving infested soil, equipment or plants to clean fields. Crop rotation best with cereals solarization of nursery bed soils with polythene sheet about 2-3 weeks before sowing.
- Seed treatment, vermin compost, deep ploughing.
- Farm animal urine spray, wood ash spray. Spray of Bt @500gm /ha.

**Citrus Decline**

- Intercropping guava in greening affected area for driving away the citrus psyilla vector.
- Uproot and burn the infected plants even if it is bearing some fruits. Periodic removal of diseased plants.
- Use antagonistic fungi *Trichoderma* sp. to control soil borne disease.
- Add *Trichoderma* in FYM and use nylon nets while raising seedlings in the nursery.
- Use of *Trichoderma harzianum* as seed treatment to control wilt.
- Use *Trichoderma* in combination with oil cake, reduced ginger rot
- Use sweet flag, neem, prickly ash, rape seed, effective against cereals grains weevils, *Sitophillus* sp. *Bruchus* sp.and *Callosobruchus chinensis*. .
- Use entomophagous fungi- *Metarhizium anisopliae* to control white grub.
- Use of tissue culture technique for the production of disease free potato seed tubers or pre basic seeds.

**Some Examples on indigenous knowledge**

**Rice**

- Clipping of seedlings tips,
- Maintaining 6-8 inches of water level,
- cleaning of bonds and terrace walls,
- planting less susceptible variety ,
- Weeding, summer ploughing,
- Use of tobacco leaf extract

Uses of light traps, kerosene lamps, or fire burn in the night time are some common examples of traditional method adopted by the farmers.

## INSTITUTIONAL ARRANGEMENT FOR IPM EXTENSION

Plant Protection Directorate (PPD), Post Harvest Loss Reduction Directorate of the Department of Agriculture (DOA), Nepal Agricultural Research Council (NARC), the Institute of Agriculture and Animal Sciences (IAAS) and Department of Food Quality Control are the major government and semi government institutions that are directly supporting the promotion of IPM in the country. Ministry of Agriculture and Cooperatives (MOAC) is responsible for management of plant pests and post-harvest pests along with plant quarantine, post-harvest issues and pesticides management. PPD is the focal Government agency responsible for IPM programme implementation in the country. It is also designated as National Plant Protection Organization (NPPO) to coordinate the plant protection activities in collaboration and coordination with both national and international plant protection related organizations.Figure 2 shows the institutional linkagesand support flow mechanism for IPM.

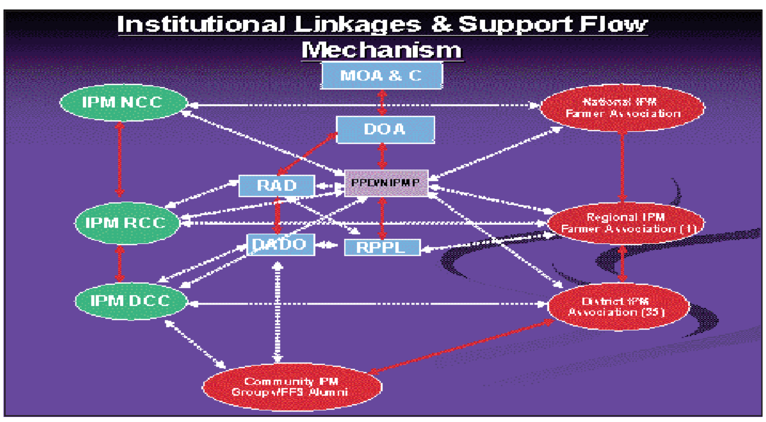



**Figure 2.** Institutional Linkages & Support Flow Mechanism
Source: National IPM Project GON/FAO

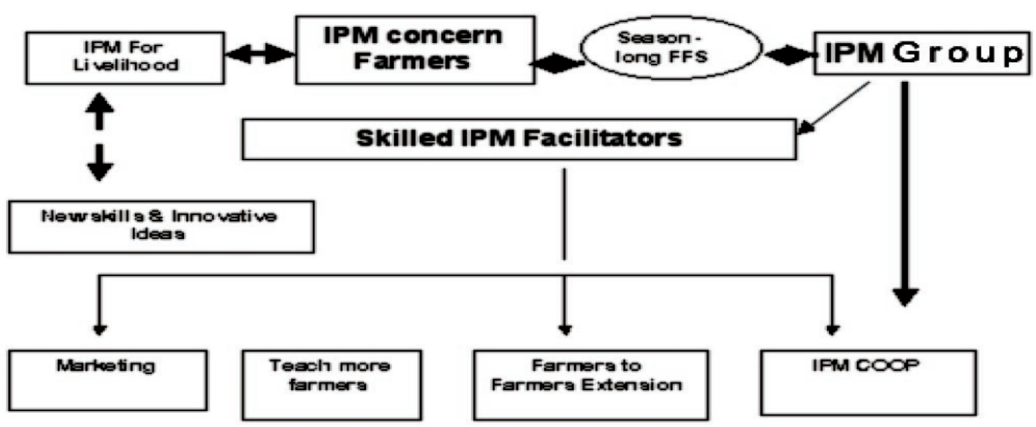
All the 75 districts of the country have a district level Plant Protection Officer (PPO) closely linked to the national agricultural extension system. About 900 Agricultural Service Centers (ASC) located throughout the country supports farmers at the community level. In addition, there are five Regional Plant Protection Laboratories that provide support to the farmers on pest diagnostic and remedial as well as services related with IPM. The Nepal Agricultural Research Council (NARC) an autonomous institution is mandated for developing tools and technology complementary to IPM. Three divisions of NARC namely, Entomology, Plant Pathology and Agronomy are directly engaged in IPM through specific research activities

The other institutions involved are Agriculture Training centre, Institute of Agriculture and Animal Science (IAAS). IAAS also supports in FFS curricula planning and training, laboratory and plant clinic support, and promote participatory action research by the farmers. National IPM Programme also closely collaborates with INGOs/NGOs/CBOs working at field levels for promotion and dissemination of IPM approach through Farmers' Field School and Farmer and Science activities.

**IPM status**

Since 1997, the IPM project with technical support from FAO is engaged in strengthening the institutional capacity and development of trained human resources. In the past, IPM related activities were mainly concentrated in rice and vegetables. However, studies on other commodities were also carried out to gather additional information on local experiences, secondary information from the studies done elsewhere in similar conditions and were reviewed and tailored as an IPM package for further testing, validation and disseminated for adoption by the farmers in the new areas. More than 90 % of the IPM activities are carried out by the government sector in cooperation with FAO and with financial support from the Government of Norway. Information presented in this paper is based on the various report prepared from the same project. Norwegian support has paved the way for IPM movement in the country. Figure 3 shows the operational strategy of national IPM programme.

**Figure 3.** National IPM Programme Operational Strategy



Presently, Nepal has 929 IPM trainers and farmers facilitators of which 139 are officers, 78 non- officers and the rest are farmers mainly for rice and vegetables and fruits crops, Altogether 1200 different farmer field schools (FFS) were organized involving various groups of farmers. Nepal Government succeeded in preparing initial human resources in IPM. IPM trained farmers help other farmers to become experts in their own field by developing their ability to make critical and informed decisions rendering more productive, profitable and sustainable crop production system. IPM now is considered as the standard approach to crop husbandry and pest management in rice and vegetable production. There is increased demand for FFS in other high value crops.

The Government of the Kingdom of Norway since 2003 is supporting through financial assistance to the implementation of national IPM programme as a whole and in particular to institutionalize a sustainable national IPM programme in Nepal within the governmental and non-governmental sectors. Major emphasis of IPM programme in Nepal is on FFS, Farmer and Science, networking and capacity building of farmers. It also emphasizes on strengthening and broader dissemination of agroecosystem based crop production and sensitization, mainstreaming of women and disadvantaged groups. Figure 4 shows the intensity of FFS coverage in different phases in Nepal since TCP, community and UTF IPM programme:

## PRIVATE SECTOR INITIATIVES IN IPM ACTIVITIES

Since 1997 almost all the activities in IPM has been carried out by the government with financial support from Donors mainly Norwegian government and technical assistance from FAO. Lately, some national level NGO has also included IPM in their agricultural development agenda. The financial assistance to implement the IPM activities by these NGOs is mobilized from the donors and international community. Government assistance to them are limited to IPM related policy support and occasional financial support extended through the national IPM programme to complement specific targeted activities.

There is a National IPM Coordination Committee under the chairpersonship of Director General of DOA in which all the stakeholders working in the area of IPM are members. The committee besides providing policy guidance on IPM, also monitors and supervises the effectiveness of the IPM programmes undertaken by various stakeholders, identifies issues and suggests remedies. The committee also monitors and follows up the state of adoption of the technical and financial norms as set by the Government for the implementation of IPM activities. Similar committees are also functional at the regional and district level and been mandated to coordinate the IPM activities at their respective levels.

## GOVERNMENT COMMITMENT ON IPM

IPM in Nepal has been recognized as a strategy that supports the efforts directed towards poverty reduction, ensures food security and environment protection in a sustainable way. It plans to implement participatory IPM using the Farmer Field School approach in all 75 districts of Nepal. It is believed that IPM will increase economic benefits, as well as support farmers' empowerment and mobilization of farmer groups for enhancing productivity of agriculture in the country.

### Towards Institutionalization of IPM Programme

The skills of extension workers as training facilitators and networking in IPM will be further strengthened to enhance the training capacity at the grass root level. It is expected to enhance participatory IPM at the village level, institutionalize *farmer to farmer extension*. The *farmers and science* would be prioritized with special emphasis on the following areas.

- Farmers' empowerment,
- Ensuring Food security ,
- Reduction of chemical pesticide use and promotion of alternative control measures,
- Institutionalization of IPM through development and strengthening of farmers' groups, association/cooperatives and farmers' congresses,
- Development of good agricultural practice (GAP) standards for production and marketing of IPM products,
- Information gathering on pesticide poisoning and pesticide use and its wider dissemination,
- Strengthening pesticide analysis laboratory and facilities to test, validate and recommend bio- and botanical pesticides and
- Establishment of mobile plant clinics to assist farmers in pest diagnosis.

## HIGHLIGHTS OF FUTURE PLAN OF ACTION

- Institutionalization of IPM farmers group, farmer-to-farmer extension, and farmers and science programme.
- Expansion of the FFS on perennial high value crops such as tea, coffee, citrus, and apple, with innovative ideas.
- Strengthening support and backstopping to previous FFS groups and associations to ensure continuity and sustainability of the group activity.
- Improvement in field-based research, and documentation of farmer's field research results including its adaptation and replication in other sites;

- Innovative and farmers demand based research on IPM issues on bio-agent rearing, bio-pesticide testing, and monitoring of pesticide residue.
- Introduce IPM principles and approaches in selected schools and agriculture related vocational training centers.
- Scale up successful IPM technology, methods and strategies identified and developed by farmers.
- Laboratory facilities for bio-agent rearing, indigenous botanical materials testing, validation of imported bio-control agents including development of plant clinics at regional levels.
- Development of major pest forewarning models.
- Training to enhance the organizational and managerial capacity of the self-help groups.
- Access to market for IPM products.
- Field research, on biological pest control, botanical pesticide and agro-based IPM model development.
- Participatory action research on ecology to understand field problems.
- Tailoring and sharing of results of IPM research output.
- Assessment of the extent of pesticide poisoning.
- Jobs in IPM approach.
- Development of standards for Good Agriculture Practices(GAP) and its wider dissemination.
- Develop pesticide tolerant breed of natural enemies (NEs).
- Food supplement application of various sugar additive to attract the parasitoid, and prey.
- NE favourable habitat development with less exposure to toxic substance.

## SUGGESTIONS

Although IPM concepts have been proven to be a good model but its acceptance and application in mass scale is still limited. Farmers still heavily rely on pesticide. Thus, radical change in pesticide formulation and manufacturing from the perspective of IPM is urgently needed. Bioagents could be a revolutionary move in the field of plant protection. Pocket package management concept (wide area coverage) need to be implemented in large scale. *FFS Coffee Shop* can be a good meeting place to discuss the problems on IPM and disseminate technology on farmers to farmers approach.

### IPM Farmers forum

Like in most SAARC countries small scale farmers are the bed rock of Nepalese agriculture. Smallholder agriculture plays important role in overall agriculture development including food security. Hence, the viability of these farmers is the indicator of success of agriculture development programme. The basic sprit of IPM is that it belongs to the farmers, it empowers the farmers and it is originally adopted by the farmers through regular visit to understanding the agro-ecosystem of their surroundings to grow healthy crop. Thus, mechanism to make the farmers the owner and expert of IPM needs to be implemented efficiently. Conducting simple experiments, farmers learn to quest, inquire to plants, understand the plants and plant environment, understand the socioeconomic condition of the farmers. This is called FFS for a sustainable agriculture. The FFS gives farmers a platform to share skills, experiences and knowledge. The demand for better quality technology makes researcher alert. Evolutions of village level diagnostic laboratory should be the goal of all IPM technical activities.

School children are the future agriculturist, doctors, engineers and leaders. In this context, initiation of FFS concept from the school is a good idea that need to be executed and in the long run it will be beneficial to the whole nation**.** When farmers were asked about their priority needs of farming they will bluntly answer that their requirement is water, seed and chemical fertilizer. However, in reality their need is institutional capacity build-up within the farming community. Therefore, developing grassroots level economic activities and market research studies is a great challenge. There should be initiation in line with this.
Awareness creation on natural control methods with term benefits and avoid long-term disaster is the need of the day.

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Ten years of IPM Training in Asia: from Farmer Field School to Community IPM FAO. Editors: John Pontius Rossel Dilts and Andrew Bertlet
Annual report: World Education2004

**Appendix 1. Particulars of persons engaged/involved in IPM activities in Nepal**

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Prof. Dr. F.P. Neupane, Entomologist Plant Protection Society, Harihar Bhawan, Nepal
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Mr. Tara Lama, Programme Director, Li-Bird, Pokhara, Kaski
Mr. Virgu R. Dwadi, Entomologist, WINROCK International, Nepal
Mr. Bhakta Raj Palikhe. Entomologist, Sericulture Development Division, DoA, Khopasi, Kavre.
World Education
Caritas Nepal.
Care Nepal
Li-Bird

**Appendix 2 Photographs on IPM activities in Nepal**

# Chapter 5

# Pakistan

# Integrated Pest Management Activities in Pakistan

Saifullah Talpur

## INTRODUCTION

Agriculture is the mainstay of economy of Pakistan. About 70 % population of the country depend on agriculture, mainly rural families are mostly dependant on it. Pakistan has been growing agricultural commodities with fluctuating production quantities. However, on average production level has been maintained in many crops. Lower yields of different crops may be due to water logging, salinity, non-availability of good seed, small holdings, pest infestations and inefficient transfer of technologies. The entire agriculture-environment poverty nexus must receive greater priority. A depleted and polluted environment adversely affects the poor through increased health problems and lowers the productivity of natural resources. The sector plays a crucial role in preserving the environment. This is because it remains the primary user of natural resources, base land and water. Recognition of this fact perhaps makes the sector even more important than it has been in the past. In addition to natural resource management consideration, the objective of sustainability will influence growth strategies. Further growth must come from yield increase, but in a less damaging way than in the past. This will require more emphasis on raising the knowledge of farmers about crop and resource management, and less emphasis on chemical inputs used in mono cropping.

The overall agricultural economy has an important impact on the total business activities of the country's entire economy. An increase of one rupee in farming and agricultural business production will therefore stimulate as to a rupee increase in the overall business activity. It is clear that in future, the development in agriculture is going to interact with growth, poverty and environment. In the past, little attention was given to the interactions between agriculture, poverty and the environment. Previously policies relied on agriculture to provide food security, and also focused on grain crops, rice and wheat. Poverty reduction and changing demand patterns will require increased attention to other crops. Increased pressure on land will require a shift towards higher value, higher yielding crops and higher cropping intensities. Pakistan has a vast potential for increased agricultural production. The country has large areas of deep soil, favourable topography, suitable climatic conditions and water resources developed in to the largest canal irrigation system in the world. There is a wide gap of yield levels obtained by progressive farmers applying package of proven crop production technology on various areas and the farmers using the out modeled farming methods. The various crops are grown in a number of cropping sequences under different agroecological conditions.

Improved seed health is pre-requisite for achieving increased crop yields through scientific crop management production. Therefore, seed industry has been established but it needs much improvement. Fertilizer is the single important input which contributes substantially towards increased crop yields. Consumption of fertilizer has increased tremendously.

Agriculture requirements of the farmers have tremendously increased because of the rising costs of different inputs and the farm machinery. To meet these demands the government has adopted a liberal policy to provide credit facilities to the farmers on easy terms and conditions.

## MAJOR CROPS GROWN IN THE COUNTRY AND CROP LOSSES BY PESTS

### Background

A major part of the economy depends on farming, collection, storage, processing and the distribution of agricultural business to households. More specifically, the well being of the economy depends on the production, processing and distribution of major crops such as cotton, wheat, sugar and edible oils. In the long run, the agricultural economy has to produce an increasing surplus that may sustain the economic growth and also translate into a more market-oriented economy. In reality the agricultural economy (farming and agricultural business) is the dominant force, which drives the growth and development of national economy. No other sector is larger or more intimately related to individuals and the everyday consumption of necessities than agriculture.

### Cultivated area and production

Agricultural crops can be classified into food crops, cash crops, pulses and edible oil. These crops have their own ecological requirements and are grown in suitable areas of the country. Tables 1 and 2 give the cultivated area and production fo food crop, cash crop,pulse and edible oil for the last ten years in Pakistan:

**Table 1. Cultivated area (‘000 ‘hectares)) of crops by groups in Pakistan**

| Year | Food crop | Cash crop | Pulse | Edible oil |
|---|---|---|---|---|
| 1996-97 | 12113 | 4332 | 1575 | 664 |
| 1997-98 | 12618 | 4423 | 1565 | 650 |
| 1998-99 | 12598 | 4288 | 1531 | 641 |
| 1999-00 | 12734 | 4182 | 1419 | 608 |
| 2000-01 | 12358 | 4078 | 1329 | 516 |
| 2001-02 | 11999 | 4339 | 1380 | 570 |
| 2002-03 | 11990 | 4069 | 1424 | 564 |
| 2003-04 | 12657 | 4291 | 1447 | 698 |
| 2004-05 | 12603 | 4343 | 1492 | 694 |
| 2005-06 | 12896 | 4200 | 1405 | 729 |
| 2006-07 | 13066 | 4320 | 1472 | 754 |

*Source : Agricultural Statistics of Pakistan, 2006-07, Govt. of Pakistan, MINFAL, Economic Trade & Investment Wing, Islamabad*

**Table 2. Production ('000'tons) of crops by groups, (1996-2007)**

| Year | Food crops | Cash crops | Pulses | Edible oil |
|---|---|---|---|---|
| 1996-97 | 22961 | 44015 | 832 | 3774 |
| 1997-98 | 25161 | 55002 | 1007 | 3709 |
| 1998-99 | 24775 | 57058 | 951 | 3602 |
| 1999-00 | 28380 | 48632 | 802 | 4407 |
| 2000-01 | 25986 | 45867 | 621 | 4091 |
| 2001-02 | 24311 | 50400 | 594 | 4080 |
| 2002-03 | 25890 | 54200 | 930 | 3948 |
| 2003-04 | 26854 | 63946 | 871 | 4155 |
| 2004-05 | 29906 | 50000 | 1094 | 5503 |
| 2005-06 | 30395 | 47185 | 685 | 5063 |
| 2006-07 | 32332 | 57236 | 1089 | 5106 |

*Source: Agricultural Statistics of Pakistan, 2006-07, Govt. of Pakistan, MINFAL, Economic Trade & Investment Wing, Islamabad*

The cultivated area and production of important crops in Pakistan for the last eight years are given in Table 3 and 4.

**Table 3. Cultivated area ('000 'hectares) of agricultural commodities in Pakistan, (1999-2007).**

| Crop | 1999-00 | 2000-01 | 2001-02 | 2002-03 | 2003-04 | 2004-05 | 2005-06 | 2006-07 |
|---|---|---|---|---|---|---|---|---|
| Wheat | 8463 | 8180 | 8057 | 8033 | 8216 | 8358 | 8447.9 | 8578.2 |
| Rice | 2515 | 2376 | 2114 | 2225 | 2460 | 2519 | 2621 | 2581.2 |
| Maize | 961 | 944 | 941 | 935 | 947 | 981 | 1042 | 1016.9 |
| Bajra | 313 | 389 | 417 | 349 | 539 | 343 | 440 | 504.1 |
| Sorghum | 357 | 353 | 357 | 338 | 392 | 307 | 254 | 291.6 |
| Barley | 123 | 113 | 110 | 107 | 101 | 93 | 89 | 94.0 |
| Sugarcane | 1009 | 960 | 999 | 1099 | 1074 | 966 | 907 | 1028.8 |
| Sugar beet | 6 | 7 | 8 | 7 | 7 | 2 | 3 | 2 |
| Gram | 971 | 905 | 933 | 963 | 982 | 1093 | 1028 | 1052.3 |
| Mash | 43 | 45 | 54 | 55 | 48 | 37 | 34 | 33 |
| Mung | 202 | 219 | 239 | 257 | 255 | 225 | 208 | 217.8 |

| Crop | 1999-00 | 2000-01 | 2001-02 | 2002-03 | 2003-04 | 2004-05 | 2005-06 | 2006-07 |
|---|---|---|---|---|---|---|---|---|
| Masoor | 54 | 46 | 44 | 49 | 51 | 43 | 33 | 39.0 |
| Rapeseed | 327 | 272 | 268 | 280 | 279 | 257 | 227 | 265.8 |
| / Mustard | | | | | | | | |
| Guar seed | 127 | 136 | 167 | 122 | 174 | 131 | 130 | 163 |
| Groundnut | 92 | 81 | 99 | 86 | 102 | 105 | 93 | 93 |
| Onion | 109 | 105 | 103 | 108 | 109 | 127 | 148 | 131 |
| Potato | 110 | 101 | 105 | 115 | 109 | 112 | 117 | 133.4 |
| Tomato | 29 | 27 | 29 | 31 | 39 | 41 | 46 | 47.1 |
| Pea | 135 | 102 | 96 | 91 | 97 | 83 | 90 | - |
| Turmeric | 4 | 4 | 4 | 4 | 4 | 4 | 3 | 3.9 |
| Garlic | 8 | 7 | 7 | 7 | 6 | 6 | 7 | 7.8 |
| Chillies | 86 | 84 | 48 | 56 | 55 | 48 | 64 | 47.3 |
| Coriander | 6 | 5 | 4 | 4 | 5 | 5 | 5 | 6.3 |
| Ginger | 82 | 77 | 79 | 94 | 119 | 97 | 109 | 80 |
| Sesamum | 71 | 101 | 135 | 87 | 59 | 66 | 82 | 71.4 |
| Apricot | 12 | 12 | 13 | 13 | 28 | 28 | 28 | 29.3 |
| Citrus | 197 | 198 | 194 | 181 | 176 | 183 | 192 | 193.2 |
| Mango | 94 | 97 | 99 | 102 | 103 | 151 | 156 | 164 |
| Banana | 28 | 30 | 31 | 29 | 31 | 33 | 32 | 34 |
| Apple | 51 | 58 | 48 | 47 | 110 | 111 | 112 | 112 |
| Guava | 60 | 63 | 64 | 62 | 61 | 63 | 61 | 62 |
| Peach | 4 | 5 | 5 | 9 | 14 | 15 | 15 | 15.4 |
| Pear | 2 | 3 | 2 | 2 | 2 | 2 | 2 | 2.2 |
| Plum | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7.6 |
| Grapes | 10 | 12 | 12 | 12 | 12 | 13 | 13 | 13.8 |
| Pomegranate | 6 | 6 | 6 | 6 | 13 | 13 | 13 | 13.6 |
| Dates | 76 | 78 | 78 | 77 | 74 | 81 | 82 | 84.8 |
| Almond | 10 | 11 | 9 | 9 | 10 | 10 | 10 | 10.8 |
| Tobacco | 56 | 45 | 49 | 46 | 45 | 50 | 56 | 50.9 |
| Cotton | 2983 | 2927 | 3115 | 2793 | 2989 | 3192 | 3103 | 3074.8 |

*Source: Agricultural Statistics of Pakistan, 2006-07, Govt. of Pakistan, MINFAL, Economic Trade & Investment Wing, Islamabad*

**Table 4. Production ('000'tons for all crops but '000 'bales for cotton) of agricultural commodities in Pakistan**

| Crop | 1999-00 | 2000-01 | 2001-02 | 2002-03 | 2003-04 | 2004-05 | 2005-06 | 2006-07 |
|---|---|---|---|---|---|---|---|---|
| Wheat | 21078 | 19023 | 18226 | 19183 | 19499 | 21612 | 212768 | 23294 |
| Rice | 5155 | 4802 | 3882 | 4478 | 4847 | 5024 | 5547 | 5438.4 |
| Maize | 1652 | 1643 | 1664 | 1737 | 1879 | 2797 | 3109 | 3088.4 |
| Bajra | 155 | 199 | 216 | 189 | 273 | 193 | 220 | 238.0 |
| Sorghum | 220 | 218 | 221 | 202 | 238 | 186 | 152 | 179.5 |
| Barley | 117 | 98 | 99 | 99 | 97 | 91 | 87 | 92.7 |
| Sugarcane | 46332 | 43606 | 48041 | 52055 | 53419 | 47244 | 44665 | 547416 |
| Sugar beet | 159 | 225 | 316 | 215 | 250 | 121 | 93 | 83.6 |
| Gram | 564 | 397 | 362 | 675 | 611 | 869 | 479 | 837.8 |
| Mash | 23 | 25 | 27 | 29 | 24 | 18 | 16 | 15.9 |
| Mung | 94 | 104 | 115 | 138 | 140 | 130 | 113 | 138.5 |
| Masoor | 35 | 26 | 26 | 29 | 31 | 25 | 17 | 21.1 |
| Rapeseed/ Mustard | 297 | 230 | 221 | 235 | 238 | 215 | 171 | 221.0 |
| Guar seed | 121 | 124 | 142 | 104 | 142 | 108 | 99 | 120.9 |
| Groundnut | 99 | 91 | 101 | 90 | 114 | 76 | 171 | 73.9 |
| Onion | 1648 | 1563 | 1385 | 1427 | 1449 | 1764 | 2055 | 1816.5 |
| Potato | 1868 | 1665 | 1730 | 1946 | 1938 | 2024 | 1567 | 2581.6 |
| Tomato | 283 | 268 | 294 | 306 | 426 | 426 | 468 | 502.3 |
| Pea | 78 | 61 | 56 | 54 | 57 | 47 | 52 | - |
| Turmeric | 41 | 42 | 39 | 39 | 38 | 38 | 35 | 36.6 |
| Garlic | 76 | 63 | 56 | 57 | 56 | 55 | 57 | 62.3 |
| Chillies | 115 | 174 | 93 | 98 | 96 | 90 | 122 | 69.5 |
| Coriander | 3 | 2 | 2 | 3 | 3 | 2 | 2 | 3.2 |
| Ginger | 0.05 | 0.04 | 0.04 | 0.05 | 0.05 | 0.05 | 0.05 | 31.0 |
| Sesamum | 35 | 50 | 69 | 19 | 24 | 29 | 35 | 30.4 |
| Apricot | 120 | 125 | 124 | 129 | 210 | 205 | 197 | 177.2 |
| Citrus | 1943 | 1897 | 1830 | 1702 | 1760 | 1943 | 2458 | 1472.4 |
| Mango | 937 | 989 | 1037 | 1034 | 1055 | 1674 | 1753 | 1719.2 |
| Banana | 125 | 139 | 149 | 142 | 154 | 158 | 163 | 150.5 |
| Apple | 377 | 438 | 367 | 315 | 333 | 351 | 351 | 348.3 |
| Guava | 494 | 525 | 538 | 531 | 549 | 570 | 552 | 555.3 |
| Peach | 33 | 32 | 37 | 76 | 76 | 69 | 70 | 71.2 |
| Pear | 37 | 38 | 32 | 32 | 30 | 30 | 28 | 28.2 |
| Plum | 59 | 63 | 63 | 65 | 64 | 60 | 60 | 60.4 |
| Grapes | 40 | 51 | 52 | 51 | 50 | 49 | 13 | 46.5 |
| Pomegranate | 69 | 48 | 53 | 90 | 55 | 49 | 50 | 48.1 |
| Dates | 579 | 612 | 630 | 625 | 426 | 622 | 496 | 426.3 |
| Almond | 32 | 33 | 26 | 23 | 23 | 23 | 23 | 23.3 |
| Tobacco | 107 | 85 | 94 | 88 | 86 | 100 | 112 | 103.3 |
| Cotton | 11240 | 10731 | 10612 | 10210 | 10047 | 14265 | 13018 | 12856.2 |

*Source: Agricultural Statistics of Pakistan, 2006-07, Govt. of Pakistan, MINFAL, Economic Trade & Investment Wing, Islamabad*

**Farm size**

Farm size is quite variable. However, dominant farmers are of small holdings. There are 13% farmers which have under 0.5 ha; 14% with 0.5 to under 1.0; 20% with 1.0 under 2.0; 17% with 2.0 to under 3.0; 17% with 3.0 to under 5.0; 12% with 5.0 to under10.0; 0.5% with 10.0 to under 20 and 2% with. 20.0 to fewer than 60. Distribution of cropped area during 2006-2007 was 66.62% for food crops, 22.03% for cash crops, 7.50% for pulses and 3.84% for edible oil; (GOP, 2006-07).

**Import and export of agricultural commodities**

Imported commodities are oilseeds, wheat and pesticides. Rice, cotton and fruits are exported in sizable quantities. However, some of the exports may suffer in future when regulation of World Trade will be strictly enforced and proper measures are not implemented. Under these regulations marketing of agricultural commodities will be subjected to rigorous testing. The marketable commodities will have to be pest and pesticide free. The commodities may not be available pesticide free but at least pesticides residue level should be below desired level of acceptability. Fruit export is presently in serious danger on the basis of presence of pests especially the quarantine pests and contamination with pesticides.

**Losses**

The history of agriculture is full of instances and examples, where man's interference with the natural balance has resulted into the multiplication of insect pests and diseases and their spread in larger areas; thus creating famine or near famine situations. For example introduction of delta pine cotton in Pakistan has resulted in changing the status of very minor pests e.g. *Heliothis* and *Spodoptera* to serious pests of cotton, resulting in ban on delta pine cultivation. Similarly, cultivation of IRRI 6 is responsible for introduction of rice hoppers. The losses of important crops are discussed below.

**Rice.** A large number of insects attacked the crop (Beg *et al.*, 1975). According to Ghouri, (1977) the losses by stem borers were 17% in 1935, 80% in 1957, 12% in 1963, 30 % in 1970 12% in 1971 and 5% in 1974 in the Punjab. Dyck (1971) observed 15 % damage in different areas of Pakistan. According to Baloch (1975), borers damaged 85 % in the NWFP. Ahmad (1973) estimated average loss to be 18%. Koehler *et al.* (1972) reported that the loss in fine varieties went up to 35 %. There had been borer epidemic on rice in the past. About 30-70% of the crop was lost in large tracts of Pakistan. In 1935, in DG Khan and Muzaffargarh districts, 46.9-87.1% borer damage occurred in the late sown rice crop. In 1942, there was almost total destruction of the crop in Nara Valley region of Tharparker district. In 1952, there was a serious outbreak of rice borers in Tando Mohammad Khan tract of Hyderabad district. In 1952-1953, borer damaged 30-50% rice in the Tharparkar district.

In 1957, the destruction of the crop ranged generally between 30-60 %, while it was not uncommon to find fields, where the borer totally destroyed the crop. The damage was so high that the estimated yield would not pay for the cost of harvesting and hence the crop was abandoned. In 1958, in the same tract in even after repeated treatment of nurseries with pesticides, the loss of crop in several fields was as high as 35%. In Jacobabad district, the losses were observed to range between 30 and 50%, while sight of fields with 70-80% white ear heads was common. Prior to 1955, in the districts of Gujranwala, Sheikhupura and Sialkot, which comprise major rice growing areas of Punjab, borers were seldom reported to damage crops. However, in 1955, the damage was unusually heavy (Moiz, 1967).

White backed planthopper *Sogatella furcifera* is one of the major insect pest of rice in Pakistan (Mahar *et al,* 1978, Majid *et al,* 1979; Salim, 1991). It was first recorded as pest in 1976 and up to 60 % paddy yield was lost in certain parts of Sindh (Mahar *et al.,* 1978). Leaf folder is also causing severe losses to paddy since its outbreak during 1984 (Zafar, 19991) and Inayatuulah *et al.,* (1986) ranked it as one of the major rice pests.

**Maize.** In Pakistan, *Chilo partellus* Swinhoe is the major pest of maize (Latif *et al.,* 1960; Ghani, 1966; Moiz and Qureshi, 1968; Khan and Khan, 1969; Ghouri *et al.,* 1977). Peak attack correlates with the stage of plant growth (Carl, 1962). The loss has been estimated at 1 % of infestation to be 50 and 80 kg /ha in the spring and summer crops respectively. (Mohyuddin *et al.,* 1973)**.**

**Cotton.** Whitefly *Bemisia tabaci* is a serious pest of cotton in the dry areas. It sucks the sap under surface of the leaves. It lowers the vitality of the plants through the loss of cell sap and normal photosynthesis is interfered owing to the growth of sooty mould due to excretion of honeydew by the insect. Dry season with high temperature is favorable for its multiplication. Damage to the crop by jassid *Empoasca (Amrasca) devastans* is caused by the adults as well as nymphs, both of which are very agile and move briskly. Injury to plants is due to the loss of sap and probably also due to the injection of toxins. Owing to the loss of plant vigour, the cotton bolls drop off, causing reduction in yield. Highly humid conditions are suitable for this pest. Adult aphids suck sap from the leaves; resultantly black colour fungi appear on the leaves as well as lint of cotton. Photosynthesis is stopped and the quality of cotton is also negatively affected. Mites suck sap from the lower parts of the leaves. The leaves turn brown and look dry. They also make web on the underside of leaves.Both the adults and nymphs can cause damage.

Dry and hot weather is more favourable for them. Cotton suffered heavy losses due to cotton leaf curl virus disease whose vector is whitefly.Pink bollworm, *Pectinophora gossypiella* and spotted bollworms *Earias insulana* and *E. vittella* are the most destructive pests in Pakistan. Their damage is caused by the caterpillars only. The attacked bolls fall prematurely and those which do mature don’t contain lint of good quality. The Integrated Pest Management Activities in Pakistan damaged seed cotton gives a lower ginning percentage, lower oil extraction and inferior spinning quality. They bore into the growing shoots, flower buds, flowers and fruits of cotton and okra, either killing the plants or causing heavy shedding of the fruiting bodies. In the attacked bolls, larval feeding spoils lint. American bollworm *Helicoverpa armigera* destroys foliage and fructiferous parts are severely damaged by the larvae. They are voracious feeders and usually prefer buds and bolls (WWF, 2006). Damage by *Earias insulana* (Boisd.) was considered one of the reasons for failure of cotton crop in the Punjab during 1928-1929. The attack of both bollworms on green bolls reached up to 30% towards the end of August, 50% towards beginning of October and 70% in the beginning of December It is estimated that 20-40 % loss occurs due to different pests of cotton (Bindra, 1928; Hussain, 1930; Ahmad,1939; Beg and Ghouri, 1980; Ahmad, 1999; Hashmi, 1994).

*Sylepta derogata* (Fab.) started assuming serious proportions around the Daphar forest plantation in 1950, till a major outbreak occurred in 1952. About 2,000 acres of cotton growing in the neighborhood of this plantation were badly damaged. This attack had such an adverse effect on cotton growing in this area that in 1955, a reduction of 66.8% in the acreage under cotton occurred in the villages adjoining Daphar forest plantation, due to fear of damage by this pest (Haq, 1967). It is estimated that about 20- 40% loss is occurring annually due to different pests of cotton (Ahmad, 1999).

**Sugarcane.** Sugarcane is attacked by a variety of insects including stem, top and root borers, Pyrilla, scale insects, mealy bugs and mites. Stem borers, *Chilo infuscatellus* Snell and *Bissetia steniellus* (Hamp.) and the top borer, *Scirpophaga nivella* F. attack sugarcane crop throughout Pakistan. Their damage is extensive, affecting farmers who suffer loss in yield, the mill owners in recovery of sugar. Naqvi (1975) found borers to be more destructive in the coastal areas of Sindh. The sucrose recovery in sugarcane was reduced by 34.2% and the glucose ratio was three times greater in the attacked samples by the infestations of *Pyrilla perpusilla* (Distant) in NWFP (Rahman, 1941). It was estimated that 5.2% joints of sugarcane were infested by borers with 0.55% reduced sugar recovery in NWFP (Irshad *et al.*, 1990). Pyrilla out breaks on sugarcane in Sindh and Punjab put very heavy economic pressure on the growers now a day.

**Fruits.** The fruit fly, *Bactrocera (Dacus) zonata* Saund. infested 45.7% guava at Karachi, 38.6% at Tando Jam and 26% at Larkana while *B. dorsalis* Hend. attacked almost all the ripened fruits of guava at Haripur in 1962 (Irshad and Jilani, 2003). More recently, banana cultivation in Sindh was almost vanished due to bunchy top disease whose vector is an aphid.

**Vegetables.** Cauliflower and cabbage are damaged up to 100% by Plutella xylostella in Pakistan sometime. Similarly, these are also attacked up to 50% by Pieris brassicae (Mushtaque et al., 1995); however it is not clear how much yield is reduced by the attack of these pests.

**Food grain storage.** Losses in post-harvest operations may occur before storage (harvesting, threshing, cleaning, drying, milling) during storage and after storage (processing, cooking, consumption, etc). Baloch and Irshad (1985) reviewed rice losses during post-harvest operations and found them substantial. In Pakistan, Chaudhry (1980) has estimated aggregate losses during various post-harvest operations to be 17.1 % in rice, 15.3 % in wheat and 12.6 % in maize. This shows that a considerable amount of food grain is lost during these operations. Loss to maize crop at the farm level by insects was 6.6% in Rawalpindi district and 2.1% in Attock district (Irshad *et al.,* 1988). Weight loss occurring in the storage is often assessed on data obtained from scientifically controlled experiments. The existing data on weight loss may be sketchy but it is realistic to warrant serious actions involving the necessary expenditure (Irshad and Baloch, 1989). Loss assessment and loss prevention are important in storage (Baloch *et al.,* 1994).

## TREND OF INSECTICIDE USE AS A CONSEQUENCE OF IPM PROMOTION

### Introduction

Integrated pest management (IPM) is basically an interaction of and intervention with insect pests, plants, pest control agents such as pesticides, parasites, parasitoids, predators etc. and factors affecting plants, in such a way that harmonizes their co-existence in favour of farmers in a given agro-ecosystems.

In1989, it was stated that IPM means a pest management system that in the, context of the associated environment and the population dynamics of the pest species utilizes all suitable techniques and methods in as compatible a manner as possible and maintain the pest populations at levels below those causing economically unacceptable damage or loss. In 2001, it was proposed that IPM means the careful consideration of all available pest control techniques and subsequent integration of appropriate measures that discourage the development of pest populations and keep pesticides and other interventions to levels that are economically justified and reduce or minimize risks to human health and the environment. IPM emphasizes the growth of a healthy crop with the least possible disruption to agro- ecosystems and encourages natural pest control mechanisms.

### Use of insecticides

Plant protection with pesticides in Pakistan started in 1947 with only 508 hand sprayers and 16 vehicles. In 1951, locust problem became severe; hence aircrafts for aerial spraying were obtained and utilized. Later, aerial spraying was done against *Pyrilla* infestations in sugarcane in NWFP. After initial success, it was extended to cotton, rice and orchards in the whole country. In many cases, economic returns have only been possible by chemical control. It has been difficult, in the recent past, to grow agricultural crops economically without use of pesticides. However, their adverse effects are now well known (Irshad *et al.,* 2002). Lesser use of pesticide has been discussed much earlier (Irshad, 1978).

Table 5 gives the amount of pesticides used in Pakistan during 1980-1994.

**Table 5. Pesticides used in Pakistan (in metric tons) 1980-1994**

| Year | Quantity | Year | Quantity |
|---|---|---|---|
| 1980-1981 | 665 | 1994-1995 | 24,868 |
| 1981-1982 | 3,677 | 1995-1996 | 43,375 |
| 1982-1983 | 5,000 | 1996-1997 | 43,219 |
| 1983-1984 | 6,588 | 1997-1998 | 38,004 |
| 1984-1985 | 9,213 | 1998-1999 | 41,576 |
| 1985-1986 | 12,530 | 1999-2000 | 45,680 |
| 1986-1987 | 14,499 | 2000-2001 | 61,299 |
| 1987-1988 | 14,848 | 2001-2002 | 47,592 |
| 1988-1989 | 13,072 | 2002-2003 | 69,897 |
| 1989-1990 | 14,607 | 2003-2004 | 78,133 |
| 1990-1991 | 14,743 | 2004-2005 | 129598 |
| 1991-1992 | 20,213 | 2005-2006 | 105164 |
| 1992-1993 | 23,439 | 2006-2007 | 43576 |
| 1993-1994 | 20,279 | Jan-Oct. 2007 | 90676 |

*Source: Agricultural Statistics of Pakistan, 2006-07, Govt. of Pakistan, MINFAL, Economic Trade & Investment Wing, Islamabad.*

In agriculture, pesticides have pivotal role to play. Their use is governed by Pesticide Ordinance 1971 which deals with their import, manufacturing, formulation, sale, distribution and use. It also contains organizational structure of the Agriculture Pesticide Technical Advisory Committee and some other miscellaneous articles. In 1985, Pakistan adopted rules for pesticide registration as per FAO International Code of Conduct. The government also allowed pesticide import under generic names. Pesticides were provided free of cost to the farmers till June 1966. Later token payment of Rs. 0.25 per acre was charged from the farmers. In the same year, it was decided to charge 25 % of the cost and subsequently the subsidy was further reduced. The subsidy was totally abolished in 1980 from Punjab and from Sindh and NWFP in 1982. Pesticides were sold from a flat rate of Rs 0.25/litre to 75 %-subsidized price; distribution by the public sector was done in 1966-74.

There was 50 % subsidy on emulsifiable concentrate/ wettable powder and 75 % on granules; 25% distribution by the public sector and 75% in the private sector in 1975-79 was allowed. There was no subsidy in NWFP, Punjab and Sindh in public/private sector from 1980-85 onwards. Aerial spraying was stopped around 1980 to regulate blanket spraying which was harmful for the environment (Irshad, 2005). Rigorous campaigning along with provision of cheap pest management packages to the farmers are required to reduce the pesticide use in Pakistan. Due to importance and judicious use of pesticides in the concept of IPM a detailed study was undertaken, which gives recommendations for the use of pesticide in the future scenario (FAO- 2001).

Introduction of high yielding varieties using increased fertilizer and plant protection inputs in the 1960s resulted in much talked green revolution in Pakistan. Use of these inputs was initially promoted from public sector extension through free deliveries at farmers' doorsteps. The dependence on the use of these high yielding inputs increased un-proportionately overtime. For instance pesticide use increased from 665 tons in 1980 to over 78,132 tons in 2003. Similarly, fertilizer use increased from 7105 tons to over 19148 tons during the period. The productivity as well as economic returns from these colossal chemicals use resulted in stagnating yields, higher cost of production, low profitability and as a consequence rural poverty increased. Pesticide use and productivity are mostly considered positively, however, analysis shows that this may not be the case always. In Pakistan, this is a reality where, although pesticide use in cotton is constantly increasing, the productivity is not necessary. Generally, it is believed that it is not possible to get as much or higher productivity, using methods and approaches other than pesticides. However, this is not so; for example, in case of wheat, management of rusts, has been successfully demonstrated, using host plant resistance; whereby, improved genotypes of wheat with higher yield potential and rust resistance are being continuously developed through the National Wheat Improvement Programme comprising of national wheat breeders, National Wheat Coordinated Programme and Crop Diseases Research Institute. Similarly, in cotton and vegetables, IPM approaches have been successful and both research and practice of IPM at the farm level has shown success.

The example being the ToT and FFS model tested in Vehari popularly known as the "*Vehari Project"*, where pesticide use was considerably reduced without affecting production through farmer participatory skill enhancement programme using ecological principles. Majority of the pesticides are used on a single crop i.e. cotton. The side effects of pesticides in the forms of resistance to insecticides, resurgence of secondary pests, destruction of natural enemies of pests, polluting soil, water and food with contaminates and affecting human health are now well known. There is great awareness to reduce the use of pesticides. In the light of these considerations, it is now the confirmed policy to have judicious use of pesticides. Therefore, alternate control measures are investigated.

Government of Pakistan initiated a study on externalities of increased use of pesticides in 2000-01. The outcome of this study served as an eye opener at policy, research and extension levels to find that externalities of around US$206 million were produced in just the major cotton growing areas of Punjab Province. Inclusion of this externality in the private cost of the cotton growers further reduced meager benefit cost ratio of 1:1.14 to 1: 0.43. These results were shared with policy makers and understood as great threat to human and animal health, degradation of natural resources, environment and biodiversity losses. This realization paved the way to implement FFS-based IPM programme in Pakistan starting from 2001.

The National IPM Programme managers strived hard to continuously communicate at policy-making levels to introduce most needed reforms in the existing pesticide policy. These efforts have paid their dividend in the form of passage of a comprehensive pesticide policy amendment in pesticide act by the Cabinet during May 2004, which would now be presented in the Parliament for consideration. Other achievements include sanctioning of two mega FFS-based IPM projects one each at federal and provincial levels. The local government and national and international NGOs funding is also solicited for running ToF and FFS.

The National IPM Programme setup by the MINFAL in 2000 has completed the project entitled Policy and Strategy on Rational Use of Pesticides in Pakistan. Subsequently, Nat-IPM with the support of an FAO-EU has also completed project on cotton IPM in Asia where the National IPM Programme has implemented, IPM in the country using the Farmer Field School approach". In 2001-2004, a total of 425 IPM facilitators were trained in 12 ToF courses. A total of 525 crop season long FFSs were conducted in Punjab, Sindh and Balochistan.. The total number of beneficiaries was 12,999 farmers (including 231 women). For sustainability of knowledge and skill of the facilitators/farmers annual facilitation skills enhancement workshops, farmers' congresses, workshops on community and leadership management were organized. As a result of this process, various associations /organizations of IPM facilitators, farmer facilitators and women facilitators have emerged and working sustainably by generating their own resources/with support of NGO's. The FFS based IPM initially experimented on cotton crop has now expanded to the cropping system (i.e. cotton-wheat) and to high value crops like fruits (apple, mango, citrus, peach, guava), vegetables (onion, tomato, cucumber, pumpkin, okra). The FFS-IPM concept has also been upgraded to integrated crop management, best agriculture practices, enterprise development, farm service centers and livestock management etc.

A short-term impact assessment study was carried out in 2003 showed

- 30% increase in cotton yield,
- 43% reduction in use of chemical pesticides,
- 54% reduction in use of highly toxic pesticides,
- 23% increase uses of technical knowledge, recognition of pests/beneficial insects, decision making capacity and field experiments,
- 33% increase in number of farmers joining community organizations,
- 16% reduction in poverty of the target farmers group

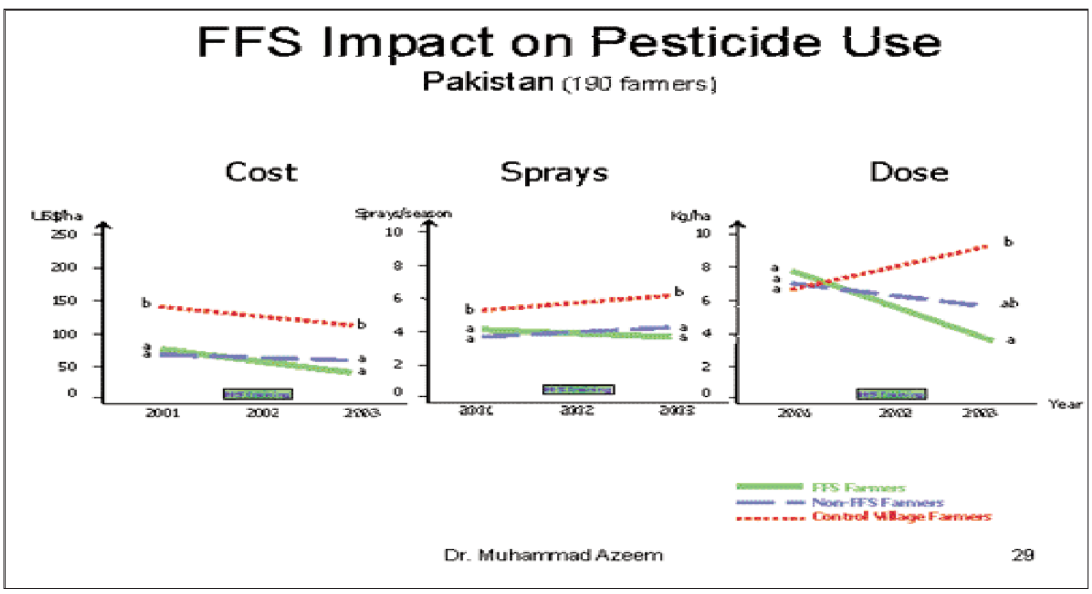
Impacts on biodiversity and biosafety indicators were estimated in the context of total pesticide use, toxicity class of pesticide use, environmental quotients, health hazards, attitude towards environment and pest-predator dynamics at the IPM and farmers plots in Khairpur district of Sindh province. Data used in this analysis include specific sections covered on knowledge and practices of farmers on plant protection measures and improvement in biodiversity, preservation of soil health and empowerment of farmers in decision making on plant protection measures. These data were collected during baseline and post-FFS-impact surveys conducted in 2001 and 2003 respectively. Information collected through season-long cotton eco-system analysis (CESA) was specifically analyzed to determine field biodiversity and environmental gains. A list of statements was used to measure attitude towards environment and pesticide use precautions observed by farmers. The observed bio-diversity was examined through measuring farmers' perceptions on crop-loss assessments. Mean, Standard Deviation and paired T-test statistics was used to highlight the differences in plant protection measures used by sample farmers. Correlation matrix was developed to show association between socio-economic attribute and plant protection measures of the sample farmers. The environmental impact quotient (EIQ) method was used to estimate the total field EIQ of the farmer, ecology and consumer categories. Data on pest and predator population dynamics was analyzed to determine actions and counteraction at various crop growth stages.

Results show that total doses of pesticide chemicals were largely reduced (43%) on FFS farms. Highly toxic class of pesticide use reduction was much higher (54%) which resulted in lowering the EIQ more than 100% as compared to a quantum jump at control farms. The FFS graduate farmers have shown resilience under panicking pest flare up situations. Reduction in the use of highly toxic pesticides at FFS farms had significantly reduced number of poisoning incidences at household level (46%), total workdays lost (83%) and expenditure for poisoning treatment (74%).

The change in the FFS farmers' attitude and beliefs helped them to change pesticide use behaviors for better environment and health improvements. FFS-farmers attendance score and their age and education status are significantly associated with the pesticide applications, observed biodiversity and field EIQ. Old age decision makers' understanding on biodiversity and their attitude towards environment have shown negative association. Educated farmers were better in perceiving biodiversity roles, but education without proper FFS attendance, does not empower farmers to have better attitude towards environment and pesticide use reduction.

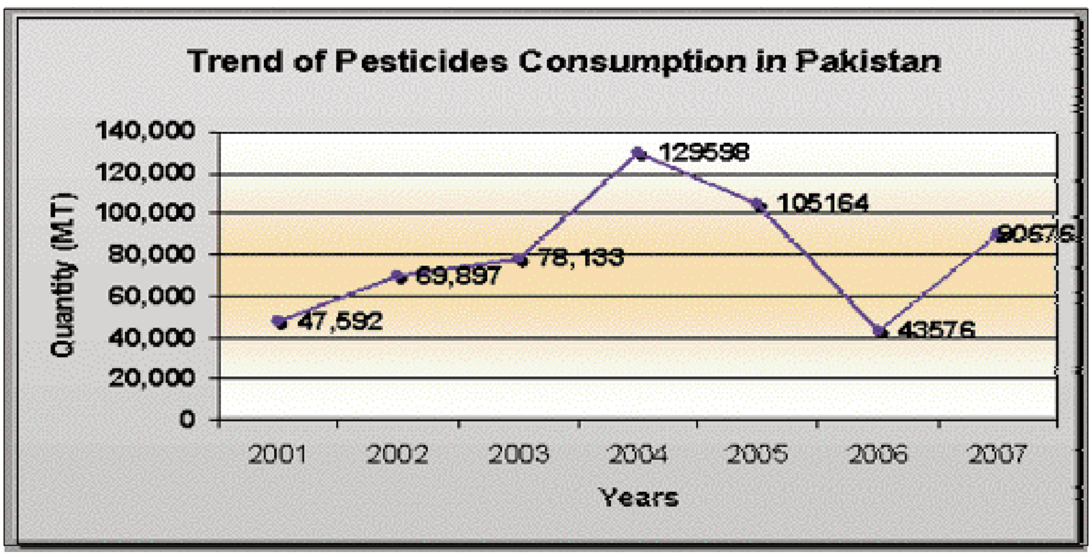
Improvement in environmental impact quotients is an outcome of improvement in decision-making power of farmers, pesticide use reduction, positive attitude towards environment and strong belief on role of biodiversity in plant protection. The ratio of predators and pests indicates that less chemical use gives free hand to predators to flourish, fluctuate and counter the pest pressure, whereas on farmer practice plots, the pesticide aid reduces natural pest control processes; which enhances pesticide use dependencies.

The community level initiatives are suggested to be taken to improve sanitation through recycling agricultural waste and its utilization to manage fertility for sustainable production. The community organizations and women schools can play a catalyst role in this important direction. Information generated through CESA on pest and predator dynamics helps farmers to understand pest-predator interaction to allow nature to work with lesser or most appropriate interventions. More involvement of plant protection experts during both FFS-trainings and post-FFS follow-ups is suggested for improved understanding among farmers, extension agents and researchers. The data collection methods, analyses, interpretations and hypothesis building is recommended to be pursued further for developing appropriate innovations in the FFS-approach and devising certain specific technological packages compatible to local conditions (Nat- IPM, 2007). This is depicted in the following.



The trend of pesticides consumption in Pakistan is fluctuating year by year, there are overwhelming jumps in different years such as, during 1981 pesticides consumption increased by 452.93%, in 1995 it was 74.42%, in 2000, it increased by 34.2% in 2004, the increase in pesticides consumption was 65.87%.

However the trend of pesticide consumption during 2005 and onward up to 2007 is quite different from the previous scenario. During these years the consumption is decreasing. If we compare it with the change in government policies and initiatives in implementation of IPM-FFS based activities in Pakistan, these activities were initiated in 2001, boosted up in 2005 and onward. In this situation it can only be supposed that the trend has changed due to the above mentioned intervenes. The real picture of this change could be observed by a thorough study on impact assessment including all factors responsible for the changed development. The following graph indicates the increase and decrease in the consumption of pesticides during the last seven years (2001-2007).



**Ongoing IPM activities by different organizations including local innovation(s) in IPM.**

**Status of IPM in Pakistan**

In Pakistan, studies on IPM were started in 1974 when these were carried out from 1974 - 1980.This tackled entomology, plant pathology, nematology and weeds all together under one umbrella. Comprehensive experimentation was conducted throughout Pakistan (Beg and Ghouri, 1980). An extension of this project started in 1981 and terminated in 1987. Research and development on IPM was initiated in 1971 by PARC-IIBC station, Rawalpindi (now CABI Bioscience Regional Centre-Pakistan). A seven-year project on cotton bollworms, a three-year project on cotton whitefly, and an institutional three-year support project on IPM, funded by Asian Development Bank, were the first IPM projects. Biological control-based IPM technologies for cotton, sugarcane, maize, fruits and vegetables have also been developed recently. A project on "Cotton IPM Implementation through Training of Trainers (TOT) and Farmer Field School (FFS) was also undertaken in Punjab by CABI Bioscience Centre. The centre has completed IPM projects on fruits and vegetables in NWFP province.

IPM technology comprising of cultural practices, resistant varieties and use of bio-control agents has been developed for managing rice pests in Pakistan. The technology is being disseminated on farmers' fields and pesticide application has considerably been reduced in IPM fields. Lately, the Nat-IPM has begun a farmer-led IPM through FFS, where knowledge is transferred to farmers on their own fields by doing on-farm experiments jointly. Many progressive farmers and Sugar Mills are successfully rearing and augmenting *Trichogramma* sp. and *Chrysoperla* sp. to control pests of cotton and sugarcane. *Chrysoperla* sp. has played an important role in the control of whitefly in cotton crops in the Punjab where chemical control measures had failed. Control of *Helicoverpa* sp. has been demonstrated on small scale with *Trichogramma* sp. on chickpea, sunflower and cotton. Pesticides of plant origin like Triaimol, Nimboli and *Nimbokil* have been locally developed and are being used to control important pests. Similarly, entomopathogenic nematodes have been identified those parasitized on insects.

**Development of Farmer-led Participatory IPM.** The current IPM approach to address the pest problems on cotton crop in Pakistan mainly stems from a three year ADB-funded regional cotton IPM project started in 1994 for India, Pakistan and China, managed by IIBC. In 1995, ADB provided assistance to Pakistan for control of cotton leaf curl virus. Under this project, assistance was provided to CABI Bioscience Pakistan Centre to do a pilot study and test suitability of TOT/FFS approach to IPM implementation on cotton crop in Punjab Province. The stepping-stone of IPM strategy is that it is quite feasible to reduce farmers' current pesticide application by at least 50%, while maintaining or even increasing yields. The key to this IPM strategy lies in the conservation of natural enemies to reduce or replace reliance on chemical pesticides and integrated bio-pesticides. This was proved through field research carried out in the cotton zone of Punjab during 1995-96, that it is possible to reduce insecticide applications from 6-2 per season, under IPM decision making, whilst obtaining the same or even slightly higher yields. About 20% higher economic returns were estimated for adopting IPM- based pest control on cotton crop.

The basic aim of the pilot project was to develop a training curriculum specific to the field situation of Pakistan for the benefit of extension staff and farmers. The resurgence issue of whitefly was used as a medium to demonstrate the effectiveness of IPM methodology. Whitefly is frequently a resurgent pest, which has become a continuous problem when its natural enemies are destroyed by the overuse of pesticides. Under this project, one season long Training of Trainers (TOT) and 10 Farmers Field School (FFS) were conducted. The 23 Agricultural Officers as resource trainers and 250 participating farmers conducted studies at each FFS site to facilitate decision for demonstration of IPM and farmer practices.

**Concepts of TOF and FFS.** Use of Training of Trainers/Facilitators (ToT/F) and Farmer Field Schools (FFS) has been demonstrated as an effective means of IPM dissemination. The approach is field-based and participatory. Each setting has its own problems and solutions, and farmers must be equipped to best address their problems. Under the TOT/FFS, 25 participants (mostly agricultural extension agents, but also representatives from research, NGOs, or others) are trained over a cropping season. The schedule is such a participatory one that all participants of the ToF work in the field with farmers. For first two days each week, the ToF participants observe a selected field and do the agro-ecosystem analysis (AESA) and then discuss what they observed in the field including the soil, the crop health, need for water, insect pests and their natural enemies, etc.

This is done throughout the season of the crop. For next two days the ToF participants break into groups of five each to run 10 FFS and interact with two groups of 25 farmers each in 10 FFS (with 250 farmers). There too, the farmers do the same AESA, where they collect the insects, etc., draw their figures and present results, on the basis of which, further cultural practice and action is decided collectively. This way, the farmers become more organized, vigilant and realistic and if something is not clear, some short and very simple experiments (not too scientific) are set up by them to resolve some unclear issues. Thus, the farmers become better organized, learn to work in community, make their own day to day decisions and become experts so that they do not depend on the chemical companies or extension staff for crop production and become able to resolve conflicts by themselves.

The world experience over the years has shown that the best way for the translation of knowledge is through training of facilitators (TOF) and Farmer Field School (FFS) activities. One of the main reasons for the success of this approach is that the decisions are not preplanned and are not dictated from a central command but are based on the analysis of agro-ecosystem and site situation and are made by the farmers with the help of facilitators. Suitability of FFS in cotton has successfully been demonstrated in various countries. This will not only improve the skill of trainees of the extension staff but would also increase the knowledge and income of farmers. Once empowered with knowledge, the farmers can apply the approaches to all the crops and share their experiences with other farmers too. Adopting conservationist approach as opposed to interventionist approach to pest control, decision-making has paid off wherever it has been implemented.

**ON-GOING IPM PROGRAMMES/ACTIVITIES BY DIFFERENT ORGANIZATIONS**

The national IPM Programme has completed successfully EU/FAO Regional Project on "IPM for Cotton in Asia" and a project by ADB project. Where, the Nat-IPM has implemented, IPM in the country using the Farmer Field School approach". During 2001-2004, a total of 425 IPM facilitators (majority of extension staff, researchers and farmers) were trained in 12 Training of Trainers/Facilitators (ToF) courses. A total of 525 crop season long FFSs were conducted in Punjab, Sindh and Balochistan. The total number of beneficiaries was 12,999 farmers (including 231 women), The National IPM Programme, NARC Islamabad is also implementing a PSDP Project "National Integrated Pest Management" since 2004, funded by MINFAL, Government of Pakistan; the other On-going Projects with the National IPM Programme are: Etiology and Management of Sudden Death Phenomenon in mango (2004-2009) and Agriculture Sector Linkage Programme (ASLP) Mango Project (2006-2009). IPM activities under "the National Integrated Pest Management" PSDP project are being implemented in all four provinces of the country with primary objective of capacity building of farmers under FFS education approach. The programme is coordinating with Provincial Agricultural Departments, Farmer organizations, NGOs and international organizations for promoting effective IPM practices in the country.

Field Implementation (IPM Practices) is an important component of the National IPM Project. Under this component, Nat-IPM Programme is implementing IPM practices through establishment of ToF and FFS to cover fruit, vegetables, rice and cotton crops. Farmer field school (FFS) approaches have been very profitable for promoting IPM through enhancing farmers' understanding of the ecological principles behind the safe and effective management of harmful insect pests and disease causing pathogens. By the end of $4^{th}$ year (2007-08) of the project, a total of 447 IPM facilitators were trained in 16 ToF courses. A total of 1,363 crop season-long FFSs were conducted in Punjab, Sindh, NWFP and Balochistan. The total number of beneficiaries was 32,832 farmers. While the total targets of the project during its complete tenure of five years (2004-2009) are, 20 ToF (Crop season-long training of facilitators), where 500 facilitators will be trained and 2,200 FFS (Crop season-long training of farmers at Farmer Field schools) where 55,000 Farmers will be empowered in IPM on rice, cotton, fruit and vegetable crops.

Impact assessment study of the work done under the project is under process. However, the observations made during the monitoring of the project activities showed that the farmers who have gone through FFS education approach are well prepared and able to take wise decisions regarding the better and mindful management of their crops. The national IPM programme NARC Islamabad is being providing technical backstopping and support to all federal, Provincial Institutions, NGO's and farmer organizations in the implementation of IPM through FFS education approach through out the country. As a result of the achievement up to December 2007, a team of 2,129 trained facilitators has been developed through 82 ToF and 5,211 FFS. Women Open school (WOS) and Children Ecology club (CEC) have completed where total 105,077 farmers (including women and children) imparted crop season-long FFS training on different crops through out the country. Tables 7 and 8 give in respect of different crops and organizations the detail of FFS-based IPM training imparted to the facilitators and farmers.

**Mango.** There are 86 species of insects feeding on it. These include fruit flies, scale insects, mealy bugs and mango hoppers. Among fruit flies, *Bactocera zonata* Saund. and *B. dorsalis* Hend. are serious ones. Before the development of IPM techniques broad-spectrum insecticides were applied. Use of insecticides created outbreaks of scale insects as their natural enemies were killed. In IPM technique, methyl eugenol, a lure was used in traps. Two traps /ha from May to August were placed; this resulted in only 3% fruit damage in places where traps were used as compared to 35 % damage, where traps were not placed. Here scale insect populations were under control due to conservation of about 27 species of natural enemies. Mango mealy bug, *Drosicha stebbingi* (Green) is a serious pest in Pakistan. Hoeing and ploughing and providing shelter for the main coccinellid predator, *Sumnuus renardi* Wse. provided effective control of it. The burlap bands on the trees also provide protection to the congregating adults and may result in the survival of larger populations. Thus, hoeing or ploughing along with burlap bands give complete control and reduces the use of insecticides. Three species of mango hoppers, *Idiocopus nagpuerensis* Pruthi, *I. niveosparsus* (Leth.) and *Amritodus atkinsoni* (Leth.) are serious on mangoes. They feed throughout the year. They move to lower areas of the tree and are found at 1-5 m place on tree during May. A single spray gives good control. At this time, the egg parasitoids are not killed as they are embedded in the plant tissue (Mohyuddin and Qureshi, 1999).

**Apple.** *Cydia pomonella* L, is a serious pest of apple. Timely releases of *Trichogramma chilonis* Ishii, when eggs are available, encouragement of predators by applying farmyard manure around the trees give good control. A half-foot wide gunny bag sprayed with insecticide is tied around the main tree trunk at 3-4 feet height. The larvae come downwards for pupation and are thus killed. These bands are replaced at fortnightly intervals. Pheromone traps containing attractants for the male are fixed at the tree near the storehouses where apples are stored during winter. It kills the moth (Mohyuddin and Qureshi, 1999).

**Sugarcane.** Sugarcane is attacked by a variety of insects including stem, top and root borers, Pyrilla, scale insects, mealy bugs and mites. Damage by stem borers is extensive. Farmers were using pesticides, mill owners encourage farmers to spray their crops and the government resorted to aerial spraying. This lead to disturbance of environment,non-economical control and outbreak of non-target pests. Control of stem borers was achieved through introducing a larval parasitoid, *Cotesia flavipes* (Cam.) from Indonesia, Thailand and Barbados, augmentative releases of *Trichogramma chilonis* Ishii and undertaking cultural practices such as earthing up of stubbles, mixed cropping and mechanical control by removing infested tops. Augmentative releases of egg parasitoid. *T. chilonis* were also started in Sindh. Incidence of the parasitoid rose to almost 98% where releases were made and internodes damage was usually below 5% compared with 16% in the control. The significant control of borers was achieved. The techniques developed have attained popularity and a number of sugarcane mills have established biocontrol laboratories.

The larvae of Gurdaspur borer *B. steniellus* remain in diapause in sugarcane stubbles and resume activity after first monsoon rains. Gurdaspur borer infestation was drastically reduced where stubble is covered with earth in June because the moths could not emerge. The emerged moths lay eggs in clusters and the subsequent emerging larvae enter the cane stalks in-groups. Such affected stalks can be seen easily. These are cut and crushed with hammer thus killing the larvae. Even mechanical control of Gurdaspur borer by cutting the tops during appearance of early symptoms of attack alone also provides economic relief. The symptom of attack is the dried up upper leaves of sugarcane.

*Pyrilla perpusilla* Wlk. was a serious pest of sugarcane in the North West Frontier Province (NWFP). To control this pest million hectare was sprayed twice a year, for almost two decades. Even with these sprays, infestation could not be brought to below economic threshold level. *Pyrilla* had developed resistance against chlorinated hydrocarbon group of insecticides. This disturbed the ecosystem and environment and minor insect pests outbreaked. For its control, redistribution of nymphal and adult parasitoid, *Epiricrania melanoleuca* Fletcher, which was abundant in the Punjab, and absent in the NWFP, was undertaken. In 1975, it was redistributed from the Punjab into the NWFP. The impact of redistribution was not known immediately. However it was recorded in high numbers not only in the released sites but throughout the sugarcane growing areas of the Province later on. That was the start of successful story of IPM in Pakistan. It became successfully established and spread widely in a short time. By 1977, it gave complete control of Pyrilla. Aerial spray for Pyrilla was no more required and discontinued. Till to date it is giving excellent results. Millions of rupees have been saved by not resorting to aerial spraying. *E. melanoleuca* was also distributed from the Punjab into Sindh. It became established and gave good control.

Farmer's burn trash after harvesting sugarcane. In trash 100% eggs of Pyrilla are parasitized by the egg parasitoids in January and February. It was ensured not to burn the trash till end of March. Where some of the trash was not burnt but kept on the sides of the field's excellent control was achieved. The early availability of the egg parasitoids was ensured. At present, this method is extensively used in Sindh (Mohyuddin and Qureshi, 1999, 2000).

**Cotton.** Of the total pesticide 70 % are used on cotton in Pakistan. There is a long list of these chemicals, which include 7 carbamates, 24 organo phosphates,10 pyrethroids, 30 mixtures and 1 organo chlorine. Another 56 insecticides with generic names have also been recommended and are being used. In spite of heavy reliance on insecticides, the crop yields have not responded positively. *H. armigera* has shown resistance to 18 organo phosphates, carbamates and pyrethroids, *A. devastans* to 8 pyrethroids and *B. tabaci* to 17 organo phosphates, carbamates and pyrethroids. This dependence on insecticide produces very heavy economic costs. It may be argued that in the absence or reduced sprays, the yield might have been much low. It seems important to apply insecticides on economic considerations. A large complex of natural enemies in cotton ecosystem exists and information on their habitat requirement, biotic potential etc. is available, therefore their utilization seems promising along with some other control measures but after careful gathering of basic data.

To have lesser use of insecticides the experiments have shown that maximum revenues can be obtained with 2 sprays, followed by 3; and net income did not increase with increase in number of sprays, therefore there is a great scope of reducing insecticide use. On-farm research and demonstrations had indicated that it is quite feasible to reduce farmers' current insecticide applications by at least 50%, while maintaining or even increasing yields. The keystone of this IPM strategy lies in the conservation of natural enemies, complementary cultural methods, augmentation of parasitoids, or the use of biopesticides. This increases the farmers' net income by up to 20%. For this farmers need skills in observation and basic ecological study methods. Farmer field school (FFS) approach is under trial (Mohyuddin *et al.,* 1997).

Sex pheromones have been used in Pakistan for mating disruption and reduction of insecticide sprays. The pheromones treated fields had 100 % mating disruption and integrated use of the synthetic sex attractant produced control with reduction of 2 application of conventional insecticides. It seems that sex pheromone application reduces the number of sprays with economic benefits and also natural enemies and environment are least disturbed. However, these have not attained popularity either due to their non-availability, higher costs or less effectiveness in small farmers' fields. Sex pheromones can give better results when the whole IPM package is applied over a large scale and large area. White fly of cotton can be kept under good control by conservation of natural enemies under IPM (Poswal and Williams, 1998). Some IPM models of some crops are reported by Shahid (2003).

**Participatory Innovations by IPM Farmers**

- Development and adoption of Best Management Practices (BMPs) under Farmer Field Schools (FFS) approach;
- Inviting the birds through broad-casting of wet rice grains for boll worm control in cotton crop;
- Inviting the ants and other beneficial insects through spreading sweet (Misti / Sugar) for the control of insect pests;
- Management of the cotton crop through studying the plant compensation behavior by artificial de- topping and de-foliation;
- Experiments on the use of PB-Robe pheromones for the control of Pink Bollworm on cotton crop;
- Control of mealy bug through vigilance and killing/ suppressing by hand in spots;
- Control of Spotted Worm in Okra through vigilance and killing/ suppressing by hand;
- Use of Kortuma + Neem for Bollworm and sucking complex Management
- Fertilizer saving through Chunga (broad-casting) methods
- Insect pest management through studying their behaviour and life cycle;
- Crop management by learning through various studies & experiments;
- Use of Yellow sticky cloth against whitefly Management
- Use of detergent spray against Whitefly Management
- Experiment on hand picking of Bollworm
- Management of nutritional deficiencies in cotton ( Symptom: Parrot Beak like bolls) through Boron
- Sustainable Sugarcane cropping through mulching methodology
- ToT of farmers on Off-Season Vegetable Production Technology

## INSTITUTIONAL ARRANGEMENT FOR IPM EXTENSION

Effectively organized extension services are key element in the process of agricultural development through transfer of improved technologies to the farmers. Due to increasing misuse/overuse of pesticides and their negative impacts on the society, a consultative process among potential stakeholders began in early 2000 and led to the establishment of a National Integrated Pest Management Programme (Nat-IPM) at National Agricultural Research Centre, Pakistan Agricultural Research Council, Islamabad in December 2000 under the ministry of Food, Agricultural and livestock (MINFAL) Government of Pakistan. Ministry of Food, Agricultural and livestock (MINFAL) is also implementing IPM–FFS based activities with the collaboration of federal and provincial institutions, like Central Cotton Research Institutes (Multan and Sakrand), Pakistan Agricultural Research Council, Federal Department of Plant Protection, Provincial Agriculture Research Institutes, Agricultural universities and Provincial Agricultural Extension Departments.

The national IPM programme has established IPM farmer organizations and developed working relations with international, national and regional NGOs. The Programme achievements show that FFS approach in Pakistan has furthered from only crop management to systems management and community development approach and is ripening further to enter into a movement state. At present, beside government organizations about more than two dozens NGOs are involved in the implementation of various IPM-FFS based projects in the country.

Agriculture, being the provincial subject in each province, has its own arrangements. In Pakistan, there are provincial extension departments. These are in the province of Punjab, NWFP. Sindh and Baluchistan. There is also an extension department in the capital at Islamabad. These extension departments have officers and staff for each type of activity related to agriculture, IPM activity is the responsibility of Plant Protection discipline. These play their role by field days, visits, demonstration plots, lectures on radio and television, advertisements in the print and TV Media, pamphlets etc. However, the modern approach of Farmer Field School is tremendously increasing. On line with this a large number of these schools have been established in the whole country. These schools lay emphasis on learning by doing. This system is expanding along with the previously existing system.

## PRIVATE SECTOR INITIATIVES IN IPM ACTIVITIES AND THEIR FUNDING SOURCES IN THE COUNTRY

IPM in the past had been undertaken by the public sector organizations. Some sugar mills are also conducting these studies and implementing in the field by their own resources. In cotton and vegetables IPM approaches have been successful and both research as well as practice of IPM at the farm level has shown success. The example being the ToT and FFS model tested in Vehari popularly known as the "*Vehari Project"*, where pesticide use was considerably reduced without affecting production through farmer participatory skill enhancement programme using ecological principles.

This success and later-on in June 2000, a study was launched on policy and strategy for rational use of pesticides in Pakistan brought a big change in the attitude of both public and private sectors, and also international agencies and donors invested their resources since last decade, in the implementation of IPM through farmer field school approach in the country. NGOs are also on this track and given funds by international donors. These NGOs have compiled various manuals for the benefit of farming communities (Anonymous, 2006; Qureshi *et al.,* 2003; WWF. 2006).The capacity building in IPM activity was enhanced as following (Tables 6 and 7.) by different private/ public sector organizations.

**Capacity Building through FFS-IPM approach in Pakistan up to Dec-2007**

**Table 6.a. Capacity Building of IPM Facilitators**

| Crop season long IPM-ToF trainings | | Nos. of Facilitators Trained |
|---|---|---|
| ToF & FToF | 77 | 2017 |
| WToF | 3 | 62 |
| Grand Total | 82 | 2,129 |

**Table 6.b. Capacity Building of IPM Farmers**

| Crop season long IPM- FFS/WOS/CEC/ FFFS trainings | | Nos. of Farmers Trained |
|---|---|---|
| FFS | 4,827 | 95,173 |
| WOS | 125 | 3,494 |
| CEC | 34 | 770 |
| FFFS | 25 | 640 |
| **Grand Total** | **5,211** | **105,077** |

*ToF = Training of Facilitators*
*FToF = Farmer Training of Facilitators*
*WOS = Women Open School,*
*FFFS = Farm Family Field School*
*WToF = Women Training of Facilitators,*
*FFS = Farmer Field School,*
*CEC = Children Ecological Club,*

**Table 7. Updated Crop wise FFS information in Pakistan up to Dec-2007**

| CROP | FFS | Farmer trained |
|---|---|---|
| Cotton | 3,768 | 70,603 |
| Wheat | 22 | 457 |
| Vegetables | 670 | 16152 |
| Date Palm | 61 | 1159 |
| Mango | 304 | 7224 |
| Citrus | 198 | 4950 |
| Apple | 31 | 565 |
| Sugarcane | 11 | 220 |
| Rice | 137 | 3612 |
| Live-Stock | 9 | 135 |
| **Grand Total** | **5,211** | **105,077** |

**Table 8. Various Public and Private organizations involved in Capacity Building of Facilitators & Farmers in IPM-FFS approach in Pakistan up to Dec-2007**

| **Institute/Organization** | **ToF/ WToF/FToF** | **Facilitators Trained** | **FFS/WOS/ CEC/FFFS** | **Farmers Trained** |
|---|---|---|---|---|
| Nat-IPM-FAO-EU =FFS | 12 | 315 | 512 | 13940 |
| Nat-IPM-FAO-EU =WOS | 2 | 37 | 52 | 993 |
| Nat-IPM Project | 13 | 362 | 877 | 19097 |
| Plan-Pak, Vehari | 3 | 74 | 96 | 2087 |
| KWA-WWF-Pak | - | - | 90 | 1889 |
| WWF-Pakistan | 6 | 150 | 210 | 4734 |
| KWA-FAO-Kashmir & Bahawalpur. | 1 | 32 | 86 | 2330 |
| KWA-UNICEF | - | - | 20 | 1400 |
| Lead-Pakistan, Sindh | - | - | 14 | 260 |
| CCRI-Sindh | - | - | 12 | 300 |
| CARITAS-Sindh | - | - | 12 | 300 |
| Dev-Con-UNDP | - | - | 8 | 200 |
| PRSP-Khanewal | 5 | 141 | 475 | 10498 |
| Agri. Extension, Punjab | 32 | 800 | 2074 | 28818 |
| Agri. Extension, NWFP | - | - | 128 | 3200 |
| Agri. Extension, SOFWM, Sindh | 6 | 158 | 335 | 9881 |
| Agri. Ext.Punjab-Fruit & Veg. | 2 | 50 | 200 | 5000 |
| WADO-Sindh | - | - | 10 | 150 |
| **Grand Total** | **82** | **2,129** | **5,211** | **105,077** |

*Source: National IPM Programme, NARC Islamabad, Pakistan*

These NGOs were funded by UNDP, GEF, EEC, EU, FAO, ADB and USAID etc. In addition to this some public sector organization like National IPM Programme (PARC), CCRI-Sindh, Agri. Extension, Punjab, Sindh, NWFP and Balochistan also have activities of IPM under FFS approach. The detailed list of public & private organizations, who are involved in IPM activities, is given at ***(ANNEXURE-II)***

## GOVERNMENT COMMITMENT ON IPM ACTIVITIES

A UNDP-financed and FAO-administered project to develop a policy and strategy for rational use of pesticides in Pakistan was launched in June 2000. The project aimed at capacity building in policy and data analysis concerning the extent of pesticide use in various crops, assessing the impact of direct and indirect effects of pesticides on human health and the environment, analysis of the pesticide regulatory system, and identifying flaws leading to environmental and economic deterioration. The results of the study provided the fundamental information required for the policy and strategy development. Although, work on IPM research and development, and its practice was initiated a long time ago in Pakistan and has gained real momentum only in the last decade through both national and international cooperation projects,  yet IPM Programme at national level has not been institutionalized as in other countries. it has to be placed as a coherent Programme including all components at the federal and provincial level. There is awareness and commitment at the highest level in the Government of Pakistan to rationalize the use of pesticides and to adopt the alternative approaches and strategies based on IPM rationale.

To achieve this it is necessary to translate to the Government strategy in to action plan whereby the IPM moves from project approach to a viable and sustainable national Programme. IPM was identified as a key element of sustainable agricultural development in the policy and strategy for agriculture developed by government of Pakistan as part of its response to increasing misuse/overuse of pesticides and their negative impacts on the society. A consultative process among potential stakeholders began in early 2000 and led to the establishment of a National Integrated Pest Management Programme (Nat-IPM) at the National Agricultural Research Centre, Pakistan Agricultural Research Council, Islamabad in December 2000 under the Ministry of Food, Agricultural and Livestock (MINFAL) Government of Pakistan. In this context, the commitment of Government of Pakistan is pragmatic, which can be perceived in the Ten Year Perspective Development Plan 2001-11, where emphasis is given on IPM as under: It has been estimated that around 25% of crop outputs are lost due to attack of pests and diseases. Although the application of pesticides has increased over the years, its indiscriminate use should be avoided as it kills useful insects and predators, and causes environmental degradation. In order to reduce pesticide application and promote biological control of insects and pests, Integrated Pest Management (IPM) programmes will be undertaken. Adulteration of pesticides will be controlled through strict implementation of the Pesticides Act.

To address the issue, the Government of Pakistan has taken various steps, to rationalize the use of pesticides and to adopt the alternative approaches and strategies based on IPM rationale. The National IPM Programme, NARC Islamabad setup by the MINFAL, GOP in 2000. National IPM Programme with the support of an FAO-EU has also completed a project on "cotton IPM in Asia" in 2001-2004. The National IPM Programme is implementing an ongoing Project "National Integrated Pest Management" since 2004 and the tenure of this project is up to 2009, funded by MINFAL, Government of Pakistan; IPM activities are being implemented in all four provinces of the country with primary objective of capacity building of farmers under IPM-FFS education approach. The other On-going Projects with National IPM Programme are: Etiology and Management of Sudden Death Phenomenon in mango (2004-2009) and Agriculture Sector Linkage Programme (ASLP) Mango Project (2006-2009).

The Federal Government has provided basic resources to strengthen FFS-based IPM Programme in the country; similarly provincial governments have also established their own FFS-based Community IPM Programmes with the technical support from Nat-IPM. The Women IPM facilitators were able to sign contracts with the local government for expanding women health risk reduction component as well as other income generating activities. The National IPM Programme is working in collaboration with international, national and regional NGOs. The Programme achievements show that FFS approach in Pakistan has furthered from only crop management to systems management and community development approach and is ripening further to enter into a movement state. At present beside government organization about more than two dozens NGOs are involved in the implementation of various IPM-FFS based projects in the country. National IPM Programme has provided technical backstopping and support to all federal, Provincial Institutions, NGO's and farmer organizations in the implementation of IPM through Farmer Field School (FFS) and Training of Facilitators (ToF) education approach through out the country.

## FUTURE PLAN OF ACTION

IPM is relatively safe. In reality conservation/augmentation, releases of new biotic agents may disturb the ecosystem. This is especially true when we are dealing with predators. The most specific natural enemies may not have potential of disturbing the eco-system. If a polyphagous biotic agent is released, it may consume non-target pests, which may be essential for pest complex chain in Pakistan. Almost no study has been done to know the impact of all these biological control protocols in a niche or environment. Moreover the impact of their manipulation may become known after lapse of longer period. A lot of study is needed. It can be true that manipulation of natural enemies does not so severely disturb the habitat as application of insecticides. Majority of the work is going on in different discipline of plant protection like entomology, plant pathology, weed science, nematology, virology and vertebrate control. In majority of cases, work is in isolation. The coordinated approach as envisaged in IPM is broadly missing and this should be taken care.

Some basic studies on IPM like resistance to pesticide, effect of insecticides on natural enemies, sampling techniques and IPM model is still not up to the mark. Presently biological control based IPM is the target therefore effect of insecticides on natural enemies is highly essential. Moreover the methods of preservation and conservation in some ecologies are still to be worked out. Mass rearing laboratories for beneficial organisms are lacking. Statistical approach for population sampling also needs strengthening. In IPM biological control is important component. The important natural enemies of most of the significant pests of crops have been made known in Pakistan (Irshad, 2003; Irshad and Khan, 2005).Their biology and ecology is somewhat known, however there is need to put more efforts in their practical utilization. For this purpose rearing laboratories are required. The training of field staff, researchers and farmers should be based on experimental learning and the whole human resource should be strengthened.

## SUGGESTIONS AND RECOMMENDATIONS

To become more competitive in the future, agricultural system needs to adopt more quickly and must deal with increasingly complex situations. Existing extension and research systems have been effective in the past, but they may no longer meet the requirements of the future. Therefore, a new extension-research and public-private relationship must be sought. In the past, extension services often provided sales promotion by advising farmers on which inputs to buy. Extension agents acted as 'MAILMEN', DELIVERING INFORMATION FROM RESEARCH TO THE FARMERS. In an age of modern communication facilities in every village and scarce public funding, it is necessary to rethink the appropriateness of the past systems. By strictly leaving private sector activities to the private sector (such as sales promotion) and concentrating on public interest issues, extension systems need a new orientation for the future. We can also assume that future extension systems may have fewer employees, which requires that the staff becomes more professional and can effectively deal with a larger number of clients.

To establish such a new system requires that both partners, farmers and extension agents, are trained for their new roles. Farmers must learn to become more self-reliant, organize themselves, and extension agents must learn to become facilitators of the change processes and not just delivery agents. This type of training is not a mere transfer of knowledge or information, but training in new skills. New skills cannot be learned through conventional transfer of technology methods of diffusion processes, but they require that each trainee first practices the skills under expert facilitation until s/he reaches a minimum level of competency (graduation), after which the skills need to be further practiced until they are fully mastered. In this new system, where sales agents and service providers increasingly address farmers, it is necessary that farmers are able to critically review the different technical products and choose the best option for their situation. In a transition period, extension would train farmers for this new role. Afterwards, extension workers would merely coach farmers and farmer groups, as they continue more self-reliantly with this process.

IPM/FFS is a training approach that can provide the services required in this transition process. It trains farmers how to compare new techniques in systematic field evaluations, and it prepares extension agents for their new roles as facilitators and representatives of public issues such as environmental conservation, public health, social participation and organization. The tasks of extension would be "rural adult education", facilitation of change processes and enforcement of regulations. To introduce this new public-private relationship requires extra funds during a transition period in which probably more than half the farmers and all of the extension workers would have to be focused on their new roles. This is possible, if the training programme clearly focuses on the repeated practice of the new skills, which in turn must be able to be replicated without any loss of quality.

To test, whether IPM/FFS is able to provide this transition training, we need to demonstrate that

- Farmers become more self-reliant and able to evaluate new technologies by themselves.
- Extension agents become able to facilitate change processes and dialogues on farmer and public interest issues, including environmental conservation and health.
- Research institutions are able to provide technologies that can be tested by farmers and farmer groups.

To establish a widespread practice of IPM in Pakistan would require the training of a critical mass of the pesticide users on cotton, rice, fruits and vegetables. The size and profile of this target group would need to be more precisely defined. To accelerate the horizontal expansion and achieve the desired output some strategic approaches are essential. To create an overall positive environment a side-by-side impact assessment Programme is imperative to provide an objective understanding of the benefits of Farmer led IPM Programme. The simpler assessment of IPM approaches followed previously only provided the resounding conformation of the ability of natural enemies to keep cotton pests in check and the success of the FFS training approach in convincing farmers to step off the pesticide treadmill in cotton. However, the cost involved for extra vigilance to implement IPM-based crop protection need to be accounted for in future impact analyses.

Only a few indicators were considered in previous simpler impact evaluation analysis. Many more important impact evaluation indicators need to be included in the impact analyses covering; (a) occupational health hazards; (b) environmental pollution; (c) attitudinal and behavioral aspects of pest management; (d) farmers consensus on pest management strategies; (e) residues in food chain and production resources; and (f) management of pest resistance. Persons engaged/involved in IPM activities with their mailing addresses and contact numbers are given in annexure III. Annexure IV shows some photograph of IPM activities in Pakistan.

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## Appendix-1

### Public and private organizations, involved in IPM Activities in Pakistan

| S.No | Name and Addresses |
|---|---|
| 1. | Ministry of Food, Agriculture and livestock (MINFAL), B-Block, Pak. Secretariat, government of Pakistan, Islamabad |
| 2. | Pakistan Agriculture Research Council, National Agriculture Research Centre Park road, Islamabad-45500 Ph: 051-9255063, Fax: 051-9255036 |
| 3. | Provincial Agriculture Extension & Research Departments, Punjab, Sindh, NWFP and Balochistan |
| 4. | Central Cotton Research Institute, Multan Old Shujabad Road, Multan. Ph: 061-9201128- 9200340-41 Fax: 061-9200342, & Central Cotton Research Institute, Sakrand |
| 5. | Food and Agriculture Organization of the United Nations (Pakistan) National Agriculture Research Centre Park Road, Islamabad. |
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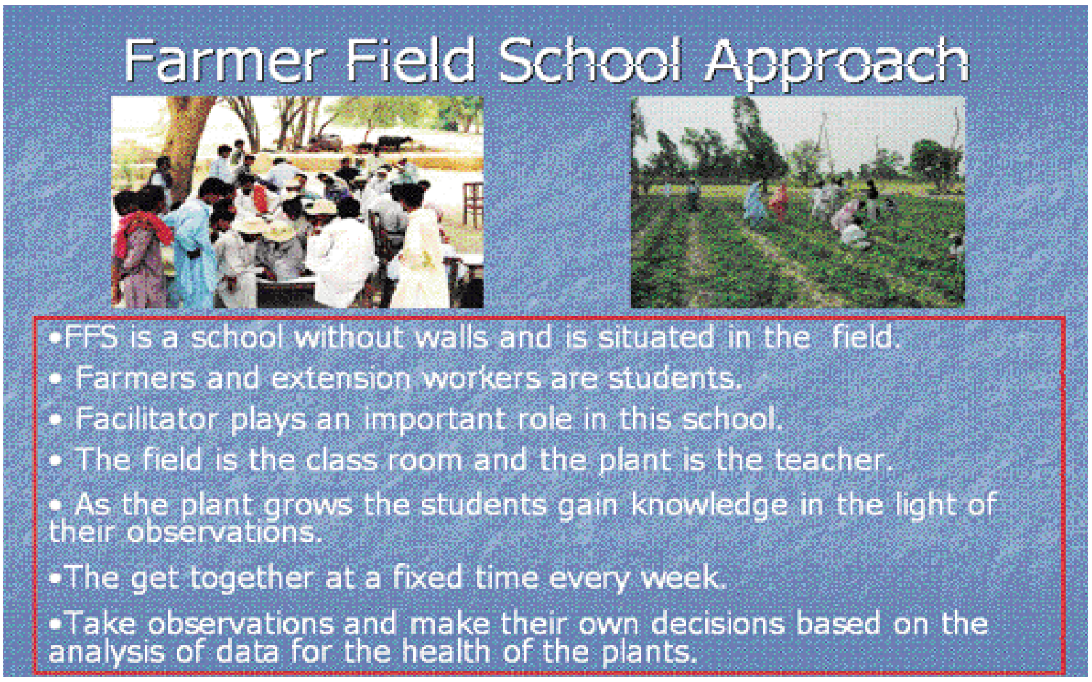
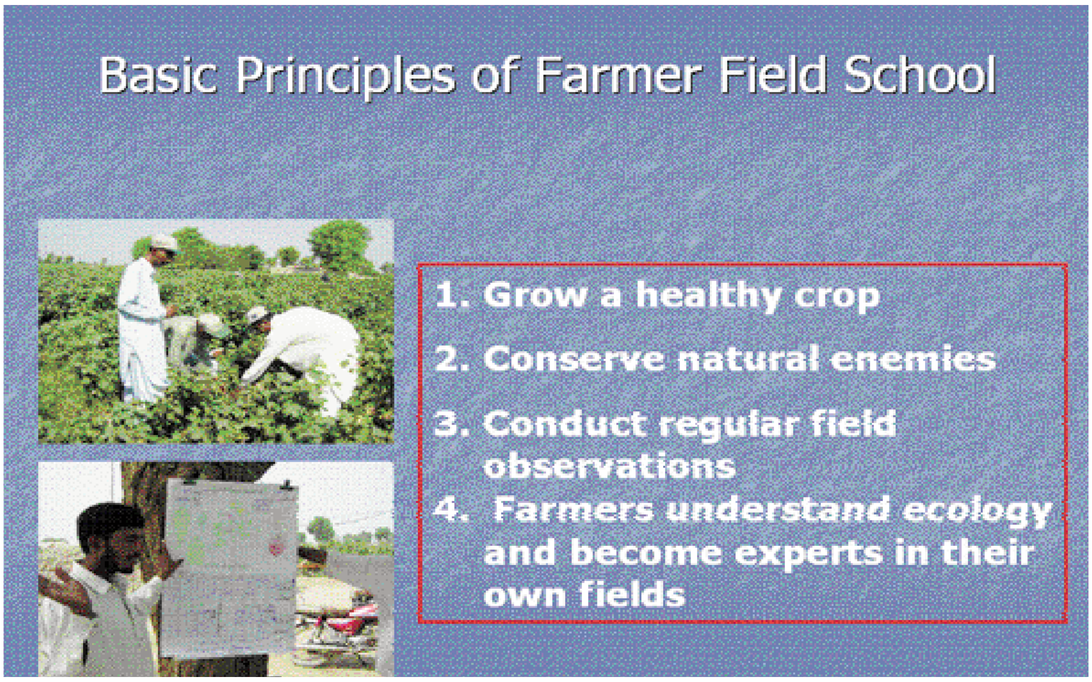
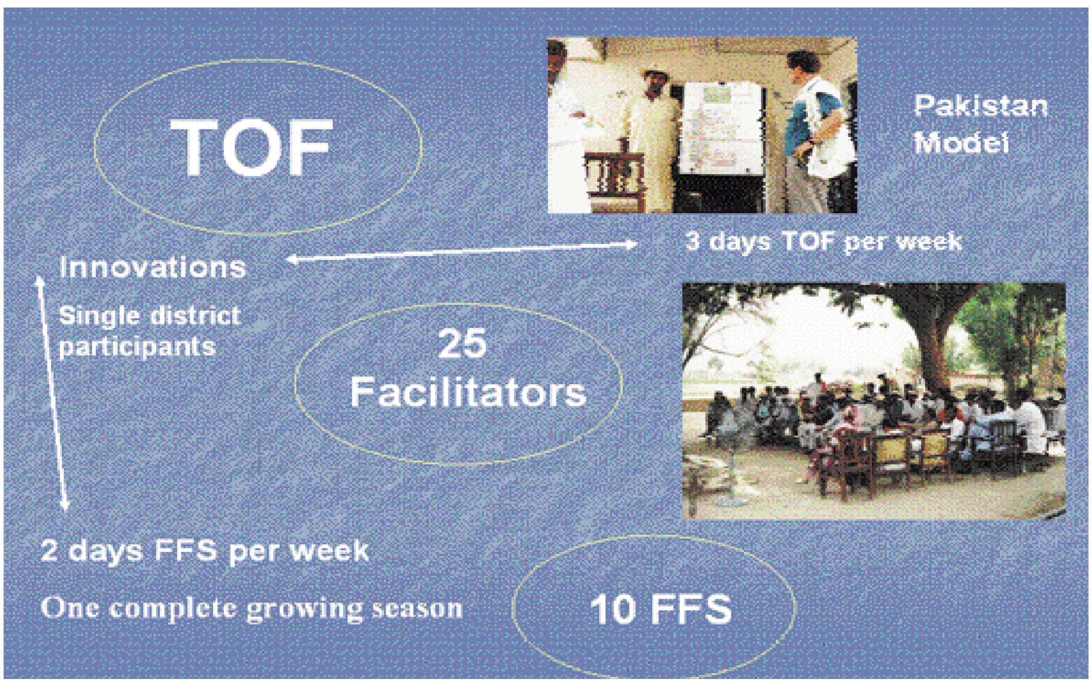
**Appendix-2 Photographs on IPM activities**

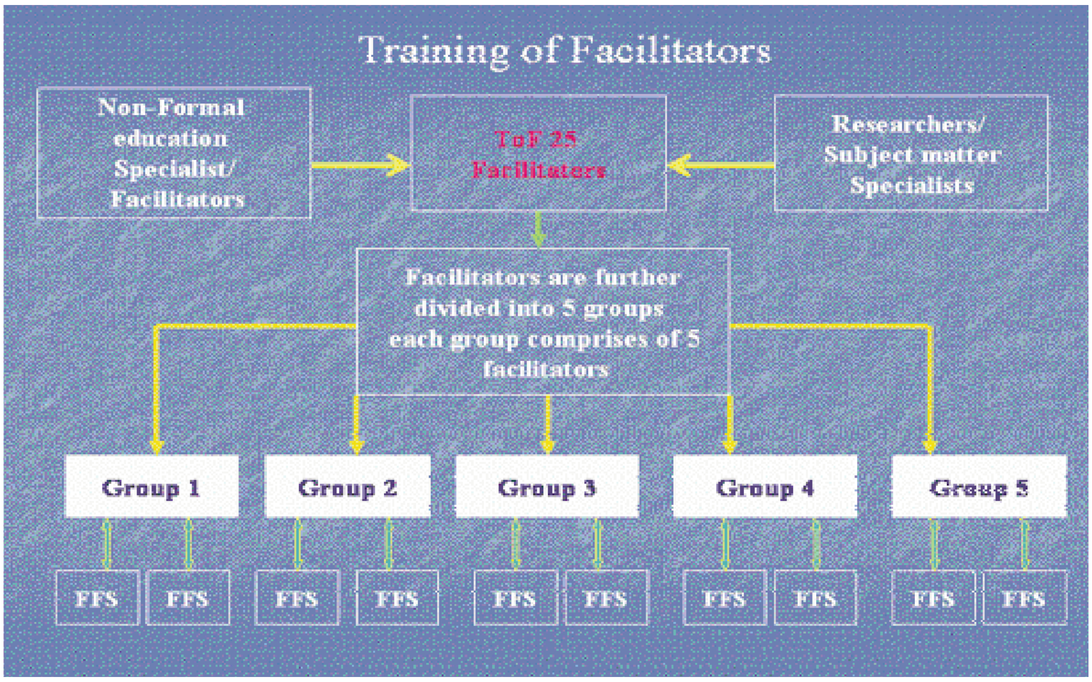



**Appendix-2 Photographs on IPM activities**



**Appendix-2 Photographs on IPM activities**





**Appendix-2 Photographs on IPM activities**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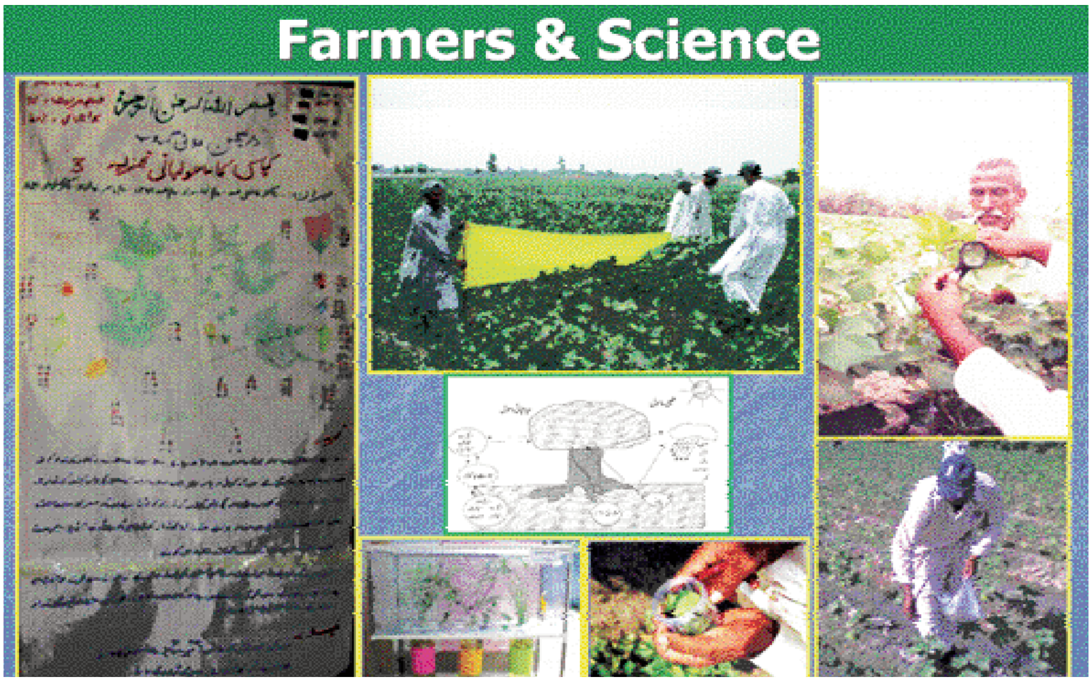



**Appendix-2 Photographs on IPM activities**


Chapter 6

# Sri Lanka

# Integrated Pest Management Activities in Sri Lanka

**K. Piyasena**

## INTRODUCTION

Sri Lanka is an island located between 6º and 10º north latitude, and 80º and 82 º east longitude. It covers an area of 6,552 $km^2$. It has a tropical climate. The country is divided into three penplains, namely the low country (below 300 metres MSL), the mid country (300-1,000 meters MSL) and the up country (over 1,000 meters MSL). The country is divided into eight provinces, which are again sub-divided into 23 administrative districts. The population of the country is little over 19 million. Of this, the labour force employed in agriculture is around 32.2%. With the increasing population the land and man ratio has declined from 2.7 ha/head to 0.38 ha/head within the last 100 years. Nearly 80% of land holdings are less than 1.2 ha and over 40% of them are below 0.4 ha. Agriculture accounts for 16.5% of the gross domestic production (GDP). The per capita GDP at market price in 2006 is US$ 1,355. For many years, Sri Lanka has been a food deficit country, particularly with regard to the requirement of cereals. Imports of rice and wheat flour have been quite substantial to augment local production. While the plantation crops have constantly being providing the scarce and badly needed foreign exchange, a considerable proportion of this had to be re-exported to import our food requirements, particularly rice.

Over the last 3-4 decades, successive governments have attempted to increase rice production, aiming primarily at becoming self-sufficient in food. This has been attempted by providing multipurpose irrigation schemes where large extents of undeveloped land have been brought under irrigation command, settling colonists under these schemes and providing them with facilities to obtain higher yields per hectare. Today we have reached near self-sufficiency in rice. On the other hand, with the increased use of inputs numerous other problems have emerged like minor pests becoming major pests, pest resurgence, high cost of cultivation due to ever-increasing prices, health hazards, high dependence on pesticides etc. As a remedy for most of these problems, IPM was considered, but it became a reality only after the FAO- Inter Country programme was initiated in 1984.

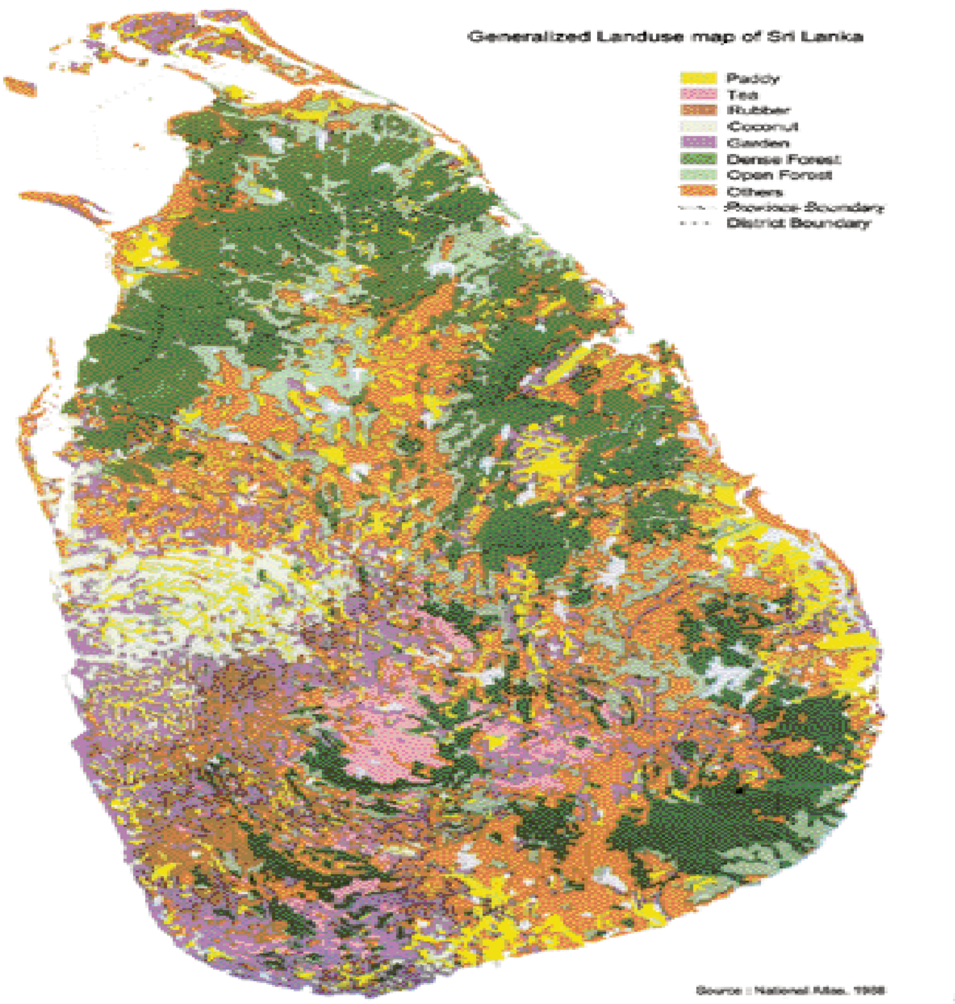
## MAJOR CROPS GROWN AND CROP LOSSES

Permanent crops like coconut, rubber, tea and other export crops contribute to foreign exchange earnings of the country. Tobacco and sugarcane are also grown in addition to these crops. There are separate institutions like Tea Research Institute, Rubber Research Institute, Coconut Research Institute and Sugarcane Research Institute for the development of such crops. Research and Development of food crops is the main responsibility of the Department of Agriculture**.** Food crops are grown mainly during two seasons governed by the rainfall seasonality *maha* season (Northeast monsoon) from September to February and *yala* season (Southwest monsoon) from March to August. Rice is grown during both seasons in the areas where adequate irrigation facilities are available. In some areas when water is limited rice is grown in rotation with other field crops or vegetables in paddy fields during the two seasons. In addition, vegetables are also grown during off-season on highland. Land use for agriculture is shown in the following table. (Table 1)

**Table 1. Land use for food crops in Sri Lanka.**

| Type of crop | Area (ha) | Proportion % from total agriculture land |
|---|---|---|
| Paddy | 685.625 | 41. |
| Subsidiary crops | 131.220 | 8.0 |
| Eg. Finger millet | | |
| Maize | | |
| Green gram | | |
| Cowpea | | |
| Soybean | | |
| Black gram | | |
| Gingelly | | |
| Ground nut | | |
| Red onion | | |
| Big onion | | |
| Chilli (Green) | 29.457 | 1.8 |
| Chilli (Dry) | | |
| Up country vegetables | | |
| Eg. Beans | | |
| Beetroot | | |
| Cabbage | | |
| Carrot | | |
| Knolkhol | 46.614 | 2.8 |
| Leeks | | |
| Raddish | | |
| Tomato | | |
| Low country vegetables | | |
| Eg. Ash plantain | | |
| Ash pumpkin | | |
| Okra | | |
| Bitter gourd | | |
| Brinjal | | |
| Capsicum | | |
| Cucumber | | |
| Red pumpkin | | |
| Snake gourd | | |

*Source:* AgStat (Vol:IV) – Socio Economics & Planning Centre, Department of Agriculture.




**Crop loss due to pests and diseases**

Rice being the major crop receives high priority in national agricultural programmes. Hence, more research has been conducted in the field of rice than in any other crops. Therefore, data are available on the crop losses due to pests in rice, whereas for vegetables and other field crops no studies on crop losses have been conducted. As a result, it is not possible to estimate the crop losses in such crops although the losses are considerably high. On the other hand, compared to rice, other field crops and vegetables consume the highest amounts of pesticides during a cropping season. It is a testimony to the risk factor faced by farmers growing other field crops and vegetables. The major insect pests and diseases of rice in Sri Lanka are shown in Table 2 and vegetable and other crops in Table 3.

**Table 2. Major pests of rice, their occurrence and estimated yield loss in Sri Lanka**

| Insect pest | Agro-zone and season | Crop loss |
|---|---|---|
| Thrips<br>*Stenchaetothrips biformis* | Dry zone (DZ), intermediate rainfed conditions in late sown crops | > 50% under severe infestation zone (IZ) especially under |
| Gall midge<br>***Orseolia oryzae*** | DZ, IZ during *maha* (wet) season. WZ during *yala* (dry) season | 10-30% under severe infestation |
| Stem borer<br>***Scirpophaga incertulas*** | DZ and IZ | Not estimated |
| Leaf folder<br>***Cnaphalocrocis medinalis*** | DZ, IZ during *maha* (wet) season. | 5-25% yield losses |
| Brown Planthopper<br>***Nilaparvata lugens*** | Island wide | 10-50% in infested fields |
| Rice bugs<br>***Leptocorisa oratorius*** | Island wide | 3-6% mean yield loss |
| Rats | WZ and IZ | Average 15% yield loss |

**Table 3. Major pests of vegetables and other food crops**

| Crop | Common name | Name of insect | Crop loss |
|---|---|---|---|
| | Vegetables | | |
| Bean | Bean fly<br>Pod borers | *Ophiomyia phaseoli*<br>*Maruca vitrata*<br>*Helicoverpa armigera* | Not Available<br>*N/A* |
| Cabbage | Caterpillar<br>— Diamond Back Moth | *Plutella xylostella* | *N/A* |
| | — Cabbage stem borer | *Hellula undalis*<br>*Chrysodeixis erisoma* | *N/A* |
| | Leaf webber<br>Army worm | *Crocidolomia pavorana*<br>*Plusia eriosoma* | *N/A* |
| | | *Spodoptera litura* | *N/A* |
| | Black cut worm | *Agrotis* spp.<br>*Bagrada* spp. | *N/A* |
| Tomato | Root-knot nematodes | *Meloidogyne* spp. | *N/A* |
| | Tomato fruit borer | *Helicoverpa armigera* | *N/A* |
| | Black cut worm | *Agrotis* spp. | *N/A* |
| Beet root | Root-knot nematodes | *Meloidogyne* spp. | *N/A* |
| | Leaf miner | *Liriomyza huidobrensis* | *N/A* |
| Brinjal | Shoot and pod borer | *Leucinodes orbonalis* | *N/A* |
| | Scales and mealy bugs | | |

| Crop | Common name | Name of insect | Crop loss |
|---|---|---|---|
| | Mites | *Tetranychus* spp. | *N/A* |
| | Leaf hoppers | *Amarasca* spp. | *N/A* |
| Cucurbits | Root-knot nematodes | *Meloidogyne* spp. | *N/A* |
| | Aulacophora beetles | *Aulacophora foveicollis* | *N/A* |
| | | *Aulacophora cincta*<br>*Aulacophora cruenta*<br>*Aulacophora lewisii* | |
| | Epilachna beetle | *Epilachna* spp. | *N/A* |
| | Paddle legged bug | *Leptoglossus* spp. | *N/A* |
| | Gall fly | *Lasioptera falcata* | *N/A* |
| | Fruit fly | *Bactrocera cucurbitae* | *N/A* |
| Okra | Shoot and pod borer<br>Red cotton bug<br>Leaf webber<br>Leaf hoppers<br>Field crops | *Earias vittella*<br>*Dysdercus cingulatus*<br>*Sylepta derogate*<br>*Amarasca* | *N/A*<br>*N/A*<br>*N/A*<br>*N/A* |
| Chilli | Chilli leaf curl complex | | *N/A* |
| | — hrips | *Scirtothrips dorsalis* | *N/A* |
| | — Aphids | *Aphis gossypii*<br>*Myzus persicae* | *N/A* |
| | White fly | *Bemisia tabaci* | *N/A* |
| | Mites | *Hemitarsonemus latus* | *N/A* |
| | Chilli pod borer | *Helicoverpa armigera*<br>*Spodoptera litura* | *N/A* |
| Onion | Onion Thrips | *Thrips tabaci* | *N/A* |
| | Common onion caterpillar | *Spodoptera litura* | *N/A* |
| | Onion caterpillar | *Spodoptera exigua* | *N/A* |
| | Leaf webber | *Antigrasta catalaunalis* | *N/A* |
| Mustard | Diamond Back Moth | *Plutella xylostella* | *N/A* |
| | Plant sucking bug | *Bagrada hillaris* | *N/A* |
| | Leaf eating beetle | *Phyllotreta spp.* | *N/A* |
| Ground nut | Red hairy caterpillar | *Amsacta albistriga* | *N/A* |
| | Leaf miner | *Stomopterx subsecivella* | *N/A* |
| Maize and Sorghum | Stem borer<br><br>Cob or grain borer | *Chilo partellus*<br>*Sesamia* spp.<br>*Helicoverpa armigera* | *N/A*<br><br>*N/A* |

| Crop | Common name | Name of insect | Crop loss |
|---|---|---|---|
| Pigeonpea | Pod borers | *Maruca vitrata*<br>*Lampides boeticus*<br>*Helicoverpa armigera* | *N/A* |
| | Pod fly | *Melanagromyza obtusa* | *N/A* |
| Potato | Potato tuber moth | *Phthorimaea operculella* | *N/A* |
| | White grubs | *Melolontha* spp.<br>*Anomala* spp. | *N/A* |
| | Mites | *Tetranichus* spp. | *N/A* |
| | Root eating ants | *Dorylus orientalis* | *N/A* |
| | Green peach aphid | *Myzus persicae* | *N/A* |
| | Potato cyst namatode | *Globodera rostochinensis* | *N/A* |
| | Leaf minor | *Liriomyza hudobrensis* | *N/A* |
| Cassava | Cassava scale | *Aonidomytilus albus* | *N/A* |
| Innala | Root-knot nematodes | *Meloidogyne* spp. | *N/A* |
| Sweet potato<br>Fruits | Sweet potato weevil | *Cylas formicarius* | *N/A* |
| Mango | Mango leafhopper | *Idiocerus clypealis* | *N/A* |
| | | *Idiocerus niveosparus*<br>*Amritodus brevistylus* | |
| | Mango fruit fly | *Bactrocera dorsalis* | *N/A* |
| | Mango seed weevil | *Stemochetus mangiferae* | *N/A* |
| | Leaf cutting weevil | *Deporous marginatus* | *N/A* |
| Pineapple | Mealy bugs | *Dysmicoccus brevipes* | *N/A* |
| Banana | Root/ Corm weevil | *Cosmopolites sordidus*<br>*Odoiporus longicollis* | *N/A* |
| Citrus | Leaf minor<br>Other pests | *Phyllocnistis citrella* | *N/A* |
| | Termites | *Hodotermes mossombicus* | *N/A* |
| | Snails &slugs | *Achatina* spp.<br>*Aplysia* spp.<br>*Deroceras reticulativm* | |

**Pests of Sugarcan**

| Crop | Common name | Name of insect | Crop loss |
|---|---|---|---|
| | Sugar cane | 12-20% | |
| Important pests | Sugarcane plant hopper<br>Parasitic nematodes<br>Sugarcane Wooly Aphids(SWA) | *Pyrilla perpusilla*<br><br>*Ceratovacuna lanigera* | <br>*N/A*<br>*N/A* |
| Important occasional pests | Termites<br><br><br><br><br>Inter node borer<br>Shoot borer | *Odontotermes redemanni* (Wasman)<br>*Odontotermes ceylonicus* (Wasman)<br>*Odontotermes horni* (Wasman)<br>*Chilo sacchariphagus* (Kapur)<br>*Sesamia inferens* (Walker) | *N/A*<br><br>*N/A*<br><br>*N/A*<br><br>*N/A*<br>*N/A*<br>*7%* |
| Pest of minor Importance | Pink mealy bug<br>Scale insects | *Saccharicoccus sacchari*<br>*Aclerda takahashi*<br>*Saccharolecanium kurgerii* | *N/A*<br>*N/A*<br>*N/A* |

**TRENDS OF INSECTICIDE USE**

Integrated pest management (IPM) in Sri Lanka dates back to 1984 the time FAO Inter Country Programme for rice IPM was initiated. From this period until the end of the project in 2002, the programme evolved gradually in content and methodology to finally make it a farmer empowerment programme with the adoption of Farmer Field School (FFS) approach. This approach was an impetus for both farmers and trainers alike to study the complex nature of the crop environment in real situations and understand the agro-ecosystem for the purpose of better decision making on pest related problems. Thus it became easier to convince the farmers on the wrong use of insecticides and the adverse effects of such insecticide applications. This brought about a radical change among trained farmers on use of insecticides for pest problems.

Before IPM, the farmers in high potential rice growing areas in the dry zone used as much as 5-7 times of insecticide applications per season while in the wet zone where rice is grown mainly for subsistence, farmers used around three applications per season. But during training, the studies done at each FFS site before and after each training season through out the country as well as a broad scale study done after the project period shows very clearly that insecticide use on rice has been reduced by 81% resulting in savings on agrochemical inputs.

Further more due to IPM training, the Agricultural Extension Officers who used to directly recommend insecticides for pest problems have changed their attitudes to look at problems from a point of view of IPM and advise farmers. Apart from rice, IPM was tested for other crops like chilli and vegetables as well. Chilli is a crop that is been sprayed with insecticides heavily, almost every week especially for leaf curl problem. But it proved that, insecticide applications for chilli could be reduced by 50% or more through the adoption of IPM, similarly trials carried out on some vegetables show same trends. But the extension of IPM for other field crops and vegetables is slow as there is no project to support as in the case of rice. It is hard to estimate the reduction of insecticide use at national level due to several reasons.

- Insecticides used in the country are often common to all crops.Therefore, it is difficult to isolate the amounts of insecticides used on each crop per season.
- It is not possible to gather information with regard to actual sales during a season or they are not available.
- Importation data do not show a significant reduction in annual imports of insecticides.

However, locally there seems to be a trend that most farmers are quite knowledgeable about natural enemies and the consequences of insecticides on the environments. As such there is a decline in insecticide use. Especially, spraying at early stages of the crop, brown plant hopper (BPH) damage that was a threat in late nineties has been lessened considerably now and it could be attributed to less spraying of insecticides as a result of IPM though debatable.

**ON-GOING IPM PROGRAMME**

Sri Lanka has a long history of IPM. Extension of rice IPM was first implemented in 1984 using the training and visit (T&V) extension system. Message-based technology was transferred to farmers by contact farmers through fortnightly meetings, using small demonstration plots. However, even though contemporary conditions were optimal the effect was limited. The flexibility of the (T&V) system was tested when the contact farmer concept was replaced with a Group concept, which allowed for a more intensive kind of service meant to deal with complex issues. Group of farmers from the same paddy tract followed periodic training classes over a period of several years. They applied the technology uniformly in their tract of roughly ten hectares while the group was given access to credit and input facilities. This approach is called the Block Demonstration. Educational principles on IPM were incorporated in the curriculum in 1985. Initial results were positive but thereafter, the programme was scaled up very fast with large numbers of extension officers and farmers being trained by 1987. Unfortunately, the content and quality of training were being compromised; training of trainers course were short and had followed a trickle-down process for officers at several levels. Loss of motivation and quality resulted from the rapid expansion.

- Since the FAO-inter country programme on IPM for rice ended in 2002, several provincial councils with own funding continued to conduct IPM Farmer Field Schools for rice in districts. At the same time, the Plant Protection Service of the Department of Agriculture carried out trials to test the feasibility of IPM FFS approach for vegetable crops like beans, brinjal, tomato, sweet potato, cabbage, chilli and cucurbits. In this case, though the technology adopted to reduce pesticide use was a success, gathering farmers for half a day as in rice FFS was difficult due to the following reasons.

1. The owner farmers were not available instead paid labour was present in the field when trainers visited. They cannot devote time for training.
2. Vegetables are labour intensive crops. Hence time is a limiting factor for farmers as they have to attend to activities such as irrigation, weeding, fertilizing, harvesting and marketing etc. continuously.
3. Most farmers who own vegetable cultivations are part time farmers. They are the decision makers but are not available during training.

Therefore careful planning is necessary such as identifying real farmers, obtaining farmer agreement on suitable days, time and their participation etc. before commencing training.

- The Mahaweli Authority of Sri Lanka (MASL) is an organization responsible for major irrigated settlement schemes in the country. Rice is the main crop grown in these areas. MASL was a key participant of the IPM programme for rice and a large number of their extension field staff was trained during that period. Thus, IPM has become an integral component in their agriculture programme. Therefore, IPM programmes are continuing in those areas with own funds.

- The Research Institute of the Department of Agriculture (DOA) is also carrying out research as well as field testing of IPM low country vegetables such as gerkin, egg plants, capsicum, tomato, okra, bittergourd, snakegourd and ridge gourd. These IPM programmes were developed and Implemented under farmers field conditions using the following techniques:

- Destruction of crop residues,
- Soil treatment,
- Conservation of natural flora and fauna surrounding the croping area
- Delaying of pesticide sprays.
- Obtaining of vigorous crops by using recommended agronomic practices.
- Manual destruction of pests and diseased plant parts, and
- Utilization of native natural enemies.

- Export crops, mainly spices, cocoa and coffee come under the purview of the Department of Export Crops (DEC). DEC promote IPM widely among farmers for the management of coffee berry borer, cardamom stem and capsule borer and cinnamon woodborer moth. Field level Extension officers of the DEC disseminate the technology to the farmers. Farmers very rarely use insecticides in coffee and cinnamon to control pests but insecticides were used in cardamom to control stem and capsule borer. The department is encouraging them to practice IPM.

The Tea Research Institute of Sri Lanka (TRISL) recommendations include Integrated Management of diseases (IDM), insect and nematode pests (IPM) and weeds (IWM), good agricultural practices (GAPS) and good manufacturing practices (GMPS) in relation to avoid or minimize crop damages by various pests and subsequent contaminations to meet the internationally accepted guidelines in respect of pesticide handling and use. The commitments in adherence to TRISL recommendations by Sri Lankan tea growers have resulted in both successful management of tea pests and achieving the description of Sri Lankan teas as *"the cleanest in the world as far as pesticide residues are concerned"* by the Technical Sub Committee in the International Market on Tea of the International Organization for Standardization (ISO) repeatedly since 1997.

- The Sugarcane Research Institute also conducts several programmes for developping IPM programmes

In 1985 after one year of establishment of the Sugarcane Research Institute, the Pest Management Division commenced studies towards an integrated pest management programme to limit the excess use of insecticides. These research programmes incorporated with the following components;

**Studies on pests**

Basic studies on identification of pests, their parasitoids and alternate hosts; biology, reproductive biology and the damage were studied in detail. The effect of the climatic factors on the pest and the natural enemy populations were also studied in plantations of different regions to support the control programmes.

**Control strategies**

Except for live wood termites of sugarcane, environmental friendly and farmer affordable methods were studied instead of chemical insecticide control methods. After identification of pests, their natural enemies and the alternate hosts, the biology of the recorded insect pests and parasitoids were completed during 1985-1995, enabling the determination of suitable stages of the pest life cycles for control. The information on damage levels by insect and nematode pests completed during 1985-1999 helped for consideration of the suitable time for control measures. The necessary background for suitable control measures were provided by the climatic data collected for the same period together with the fluctuations of pest population densities. The forecasting schedule based on the above observations. For examples, the forecasting model for *P. perpusilla* showed two population peaks per every year just before the monsoonal rainy seasons. Also higher level of damage by termites was observed after a continuous dry spell of five weeks or more.

**IMPLEMENTATION OF IPM PROGRAMME**

The introduction of the parasitic moth *Epiricania melanoleuca* (Fletcher) was successful for the control of the serious plant hopper pest *Pyrilla perpusilla* throughout Sri Lanka. Through the recommendations of agronomic and manual methods, the infestations of the shoot borer *Sesamia inferens* populations were maintained below the pest status. Manual methods of detrashing of old leave successfully reduced the infestations of the pink mealy bug *Saccharicoccus sacchari* and the scale insects *Aclerda takahashi* and *Saccharolecanium kurgerii*. The strengthening of the resistant varieties spectrum for the inter node borer has been identified as a most useful strategy and variety screening programmes for the pest are now in progress. Faculty of Agriculture of the University of Peradeniya and Ruhuna University also conduct research activities for the development of IPM The faculty Of Agriculture, the University of Ruhuna has conducted a number of research to develop pest management practices for cinnamon, including management of seedling pest complex, the leaf mites and other sucking and wood boring caterpillars. The research outcome has reviewed by Rajapakshe and Wasantha Kumara. The methods include cultural practices like covering the plant base with soil; and use of pheromones and safer insecticides. At present, research programmes are being conducted in collaboration with the Department of Export Agriculture to develop effective management method against clearwing moth.

The faculty has conducted a number of research programmes in collaboration with the Department of Agriculture to improve our knowledge on rice pest management. These experiments include identification of spider fauna in rice ecosystems, the predatory behavior of jumping spiders and orb web spiders. The abundance and diversity of spiders is low in wet zone rice fields. Biology and behavior of Argiope, an orb web spider, common in rice fields were studied. These research findings are yet to be published. Experiments were conducted to understand the biotype development of BPH on Bg 379-2, in collaboration with the DOA. It was revealed that some populations of BPH are virulent on Bg 379-2 (a resistant variety). Experiments were conducted to develop IPM against low-country vegetables in collaboration with DOA. The results have been published as a book for farmer use.

Field experiments were conducted in collaboration with DOA to determine the host weeds of parasitoids of vegetable pests. These experiments indicted the importance of some wild weeds in enhancing the parasitoids in vegetable ecosystems. The faculty also has conducted research to develop IPM methods for post harvest pests of legumes and rice. The methods include use of botanicals, pheromones for rice moth.

The faculty in addition has conducted a number of surveys in the southern Sri Lanka to determine the effectiveness of FFS in implementing IPM programme. Research activities of the University of Peradeniya Faculty of Agriculture have been focused on several themes: Promotion of biological control as a component of IPM, use of botanicals as an alternative to synthetic chemicals and use of different wave frequencies to alter insect behavior. Research activities in biological control over the last few years focused on assessing the parasitoid communities of vegetable pests. Parasitoid community of leafminer, *Liriomyza* spp. Role of coccinellid predators in controlling vegetable pests assessment of locally available coccinellid species in relation to ecological system and their efficacy and role of babler bird in controlling leaf eating caterpillars in cabbage were being examined. Value of flowering plants as floral resources providers in the field or in field boarders is examined in terms of biological diversity associated with plants. Fitness of parasitoid, eg.*Cotesia plutella* and *Diaeretiella rappae* in relation to floral resourses is being examined. Extensive survey of mango leafhoppers in mango revealed an additional member in the leafhopper complex, which had been unnoticed for years. *Idioscopus nagpurensis* (Pruthi) was first reported in Sri Lanka. In accordance with the IPM objectives, use of botanicals in managing green house insects on tomato and bell pepper is being examined. Population dynamics of whiteflies and aphids together with other insects were examined to formulate effective physical methods such as sticky traps. In addition, use of sound waves with different frequencies to alter the insect behavior is another novel approach that can be incorporated to IPM and it has been attempted in the Faculty of Agriculture.

**Innovations**

**Training outcome.** A study on the impact of participatory IPM training was conducted and innovative outcomes of Farmer Field School (FFS) training were observed. Farmers reported how they started producing their own quality seed, tested out new planting methods to reduce the reliance on herbicides, began applying cattle and poultry manure to the field, and initiated marketing of pesticide-free rice. They also reported how they extended their new knowledge to vegetables, fruits and legumes, and used traditional of new methods of pest management. The trainers had guided some of these outcomes whereas others originated from farmers. The results also demonstrate how the increased profits, recorded in the broad-scale study, eased poverty. Profits were used to build new houses, to improve or diversify agricultural production (purchase of two-wheel tractor, cows and poultry, cultivation of legumes), and provided new business opportunities (three-wheel taxi, sewing machine, refrigerator for yoghurt, grinding machine, vegetable sales outlet, shop, pesticide-free rice marketing unit).

**Integrated Pest and Vector Management (IPVM) Project.** After the IPM programme, a new project was initiated in the country, incorporating mosquito vector management into IPM programme. During IPM it was revealed that mosquito larvae thrive abundantly in paddy fields and that they are vectors of diseases like Japanese encephalitis and malaria that pose a health threat to farmers, affecting the livelihood situation of rural communities. The pressure of these diseases through lost working days and cost of clinical treatment is substantial in the dry zone of Sri Lanka. However, the management of vectors in rice ecosystems has been a neglected component in the control of vector borne diseases. Synergies between IPM and vector management operate on several fronts. Alternate wet-dry irrigation of rice fields reduces the incidence of rice pests, improves plant root development and effectively reduces the emergence of adult mosquitoes. Moreover, if farmers refrain from applying insecticides early in the season, they not only reduce the chance of pest damage but also reduce mosquito populations.

Therefore, incorporating vector management into the IPM programme was very effective. The project required the involvement of several departments like the Department of Agriculture, Department of Health and Mahaweli Authority of Sri Lanka due to its multidisciplinary nature. This was a unique experience, integrating agriculture with health for providing a better service and upgrading the livelihoods of rural communities. Otherwise, they were working in isolation within their own framework. The IPVM programme was implemented in Sri Lanka successfully from 2002 to 2007 with funding from Global IPM Facility followed by UNEP.

**IPVM Clubs.** To sustain the programme and motivate community action by farmers' alumni groups, farmer clubs were formed. However, it did not seem to function without further assistance from the facilitators. Since the farmers were poor, they did not have a proper foundation to build up. Therefore as a trial, when the IPM project ended an IPM club was formed in the Buttala area of Monaragala district and they were given a donation of about US$ 250 to start a revolving fund. This club was given the freedom to plan their own programme and carry on. They used this money to provide credit to members to purchase good seed paddy at a higher price and started growing insecticide free rice. In addition, other activities such as training fellow farmers on IPM, providing advice on pest management issues etc. were also begun. Gradually, they progressed and were able to build up the capital to nearly US$ 750 in about 4 years time. Now, they collect a membership fee from its members of which a portion goes to a savings account of each member. Credit is now provided free of interest to members.

Taking the experience of this club , two more similar clubs were also formed under the IPVM Project this year in the same district and each club was donated a sum of USD 500 from the project funds. Prior to the formation of new clubs, arrangements were made for the new groups to visit the farmer club, interact with them, see and learn for themselves the success story. Among the three clubs, one is a women's club. Farmers had never been taken into confidence before and funds were never given entirely for them to manage without supervision by Govt. officials before. This is an instance where trust between officials and farmers come into play. On the other hand, instead of paying incentives to individual farmers to attract them, it is worthwhile to donate that money to a group of farmers and that would be another way of empowering them.

The IPVM clubs were formed in villages where FFS training were conducted so that farmers themselves could continue the activities they learnt at the FFS while disseminating that knowledge to other farmers. Besides, they could also maintain good relations developed during their training with government officials and have continuous interactions with those organizations for the betterment of the community. To give a start a sum of US$ 500 was donated to each club to build up a revolving fund, which they would use to help the members in their agricultural activities. Reduced application of insecticides enables IPM farmers to increase bee colonies and earn more profit

## INSTITUTIONAL ARRANGEMENT FOR IPM

The powers vested with the central government were devolved to provinces in 1989. With that some of the activities like agricultural extension, controlled centrally had to be devolved to provinces. This gave rise to two entities, National Ministry of Agriculture and Provincial Ministry of Agriculture. Under each ministry, there is a Department of Agriculture to deal with the subject of agriculture. The central Department of Agriculture has a wide scope of activities such as research, seed production, seed certification and plant protection, pesticide registration, agricultural extension etc while the Provincial Department of Agriculture (PDOA) has only agricultural extension under its control. Therefore, the PDOA has to depend on the DOA for all other services. The MASL under the National Ministry of Agriculture is another organization responsible for agricultural development in the country. The new settlement schemes irrigated by the river Mahaweli, established mainly for rice cultivation but being diversified to some extent, now comes under the jurisdiction of MASL.

Figures 1 and 2 show that though each organization have own administrative structures for management, there is a constant interaction with each other and they are inter–dependant. They are bound to carry out national agricultural programmes. At the same time, they are free to plan and implement their own programmes. Consequently, agricultural extension in the country is shared by all three organizations, the DOA, PDOA and MASL. DOA is in charge of about five areas within districts that come under major irrigation schemes. These are areas irrigated by rivers flowing through several provinces, which were retained with the central government during devolution. PDOA is responsible for agricultural extension in districts that come within the purview of the province. MASL perform extension activities in Mahaweli systems that come under it. Figure 2 shows the way DOA interact with PDOA. The Plant Protection Service (PPS) is a national level, servicing unit providing technical support on plant protection matters to extension services apart from other mandated activities. Therefore, it has direct contact with all these organizations and access to different levels in each organization.

PPS has been coordinating IPM and IPVM programmes in the country through out and it has the capacity and experience to train, manage and implement and monitor IPM programmes. PPS is, therefore, the main coordinating body in the DOA that is responsible for carrying out IPM programmes with DOA, PDOA and MASL. The direct implementation of IPM falls within the purview of extension services of DOA, PDOA and MASL. There are trained extension personnel in each organization to train farmers on IPM. They are in the category of Subject Matter Officers (SMO) and Agricultural Instructors in the case of DOA and PDOA and Field Assistants (FA) in the case of Mahaweli Authority. Meanwhile the research arm of the DOA is carrying out experiments to develop pest resistant crop varieties and other techniques that could be used in IPM programmes.

**Figure 1. Institutional arrangements for IPM extension – Department of Agriculture Mahaweli Authority of Sri Lanka.**

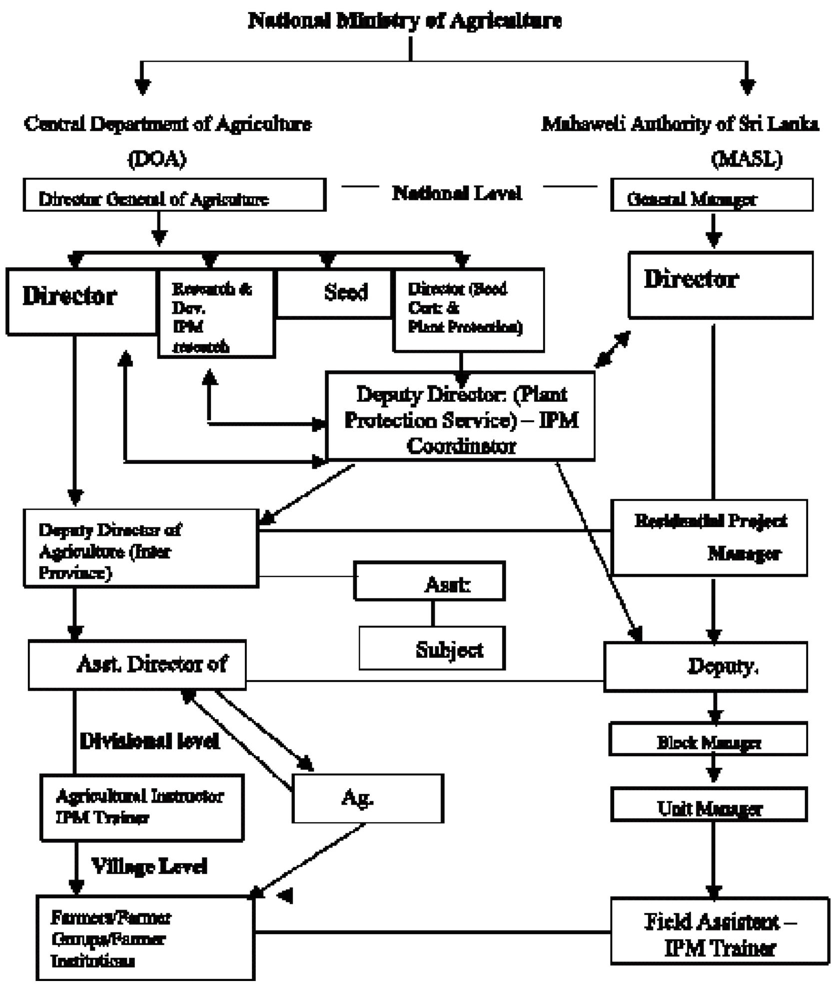
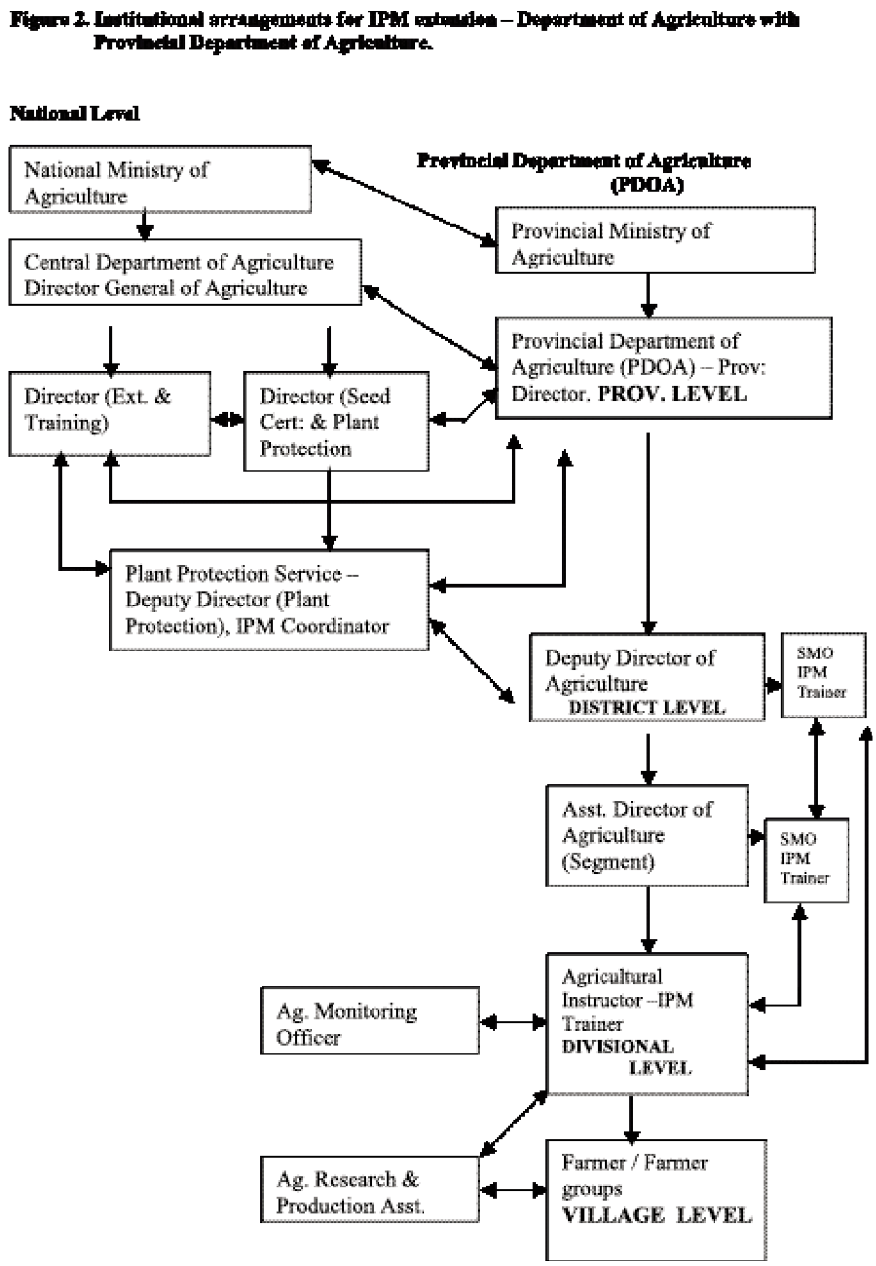


**Figure 2. Institutional arrangements for IPM extension – Department of Agriculture with Provincial Department of Agriculture.**



**PRIVATE SECTOR INITIATIVES IN IPM ACTIVITIES AND THEIR FUNDING SOURCES**

There are several NGO s who have been actively involved in IPM training in Sri Lanka. The SEEDS division of the National Level of NGO Sarvodaya had been conducting IPM activities with their own funds. The Rural Enterprise and Agricultural Projects (REAP) in the district of Matale and IFAD funded projects in Anuradhapura, Kurunegala, and Moneragala are showing interest in the FFS approach. Some of these projects are funding small programmes on IPM for vegetables and other field crops. Most of the programmes are carried out by the help of PDOA.

## GOVERNMENT COMMITMENT ON IPM ACTIVITIES

The successive governments' since1994 has accepted IPM as an important programme and has positively stated in their national policy declarations that IPM should be a part of national agricultural programmes.
Examples:

- In 1994, when the new government came into power the President in her policy declaration stated that IPM would be a component in its agricultural programmes to curb misuse and adverse effects of pesticide use.
- The Ministry of Agriculture in its publication in 1999 on national strategy for sustainable agriculture in rain-fed areas; under IPM 6 states, "Considering the benefits accruing to individual farmers as well as the country as a whole, the importance and the scope for expansion of IPM in this country cannot be ignored" and as the basic approach has mentioned organizing farmer groups and adoption of Farmer Field Schools (FFS).
- Under the present government in its latest programme to promote local food production has again stressed that programmes such as IPM would be promoted to protect the environment and produce food safe for consumption. "Api Wawamu, Rata Nagamu"(Lets grow, Develop the country) 2007 – 2010, Ministry of Agriculture & Agrarian Services
- The Director General of Agriculture has circulated a letter in September 2007, requesting the Heads of divisions in DOA to implement a programme drawn up for the development of agriculture in the country by the Ministry of Agriculture Development and Agrarian Services in consultation with the Heads of Departments connected to Agriculture, Professors and Lecturers of universities etc. In this programme special emphasis is given to IPM which stresses that more interest should be paid to this aspect.

Though such interest has been shown, no concrete steps have been taken so far to come up with a systematic programme to implement a nation-wide programme on IPM by the government or the Central Agriculture Department in keeping with the government policies. During the 1960s when pesticides were vigorously promoted under the green revolution by the government there was a clear cut and a systematic programme to educate farmers on the use of these chemicals. Today's misuse and adverse effects are a result of such campaigns and that has been taken over and is been continued to date by the pesticide companies. It is, therefore, an urgent necessity today to launch an equally strong programme to get farmers converted to IPM from dependence on pesticides. The only programme in existence at present at central government level is the Integrated Pest and Vector Management (IPVM) programme implemented with very limited foreign funding. The provincial councils and the Mahaweli Authority are very much interested in continuing the IPM programme and have been allocating their own funds towards IPM. Both organizations expect to expand the implementation of its IPM activities in the near future. However, the availability of State government funds for IPM training in the Inter-Provincial areas is also not quite certain.

## FUTURE PLAN OF ACTION

Every season, twice a year, National Agricultural Programmes are drawn up by DOA with the participation of the National Ministry of Agriculture, PDOA and MASL. It is a bottom up process where planning is initiated at the village level.

### Planning process

**National Level.** *(Pre-Seasonal Planning Meeting) coordinated by National Ministry of Agriculture and Department of Agriculture*

**Participants**: Ministry representatives

| | | |
|---|---|---|
| **DOA** -Director General | **Provincial DOA–** | **Mahaweli Authority** |
| Director -Extension and Training (Agri: Development) | Provincial Directors | Director |
| Director -SCS and PP Centre | District Deputy Directors | Dputy. Resident Project managers |
| Director – Seed production | | (DRPM Agriculture) |
| Director – Projects and Planning | | |
| Directors – Research Centres | | |

**Provincial Level -** Provincial Technical Working Group Meeting (PTWG)

**Participants**

| | | |
|---|---|---|
| Inter Provincial Districts - | Districts under provinces - | Mahaweli Systems |
| **District Deputy Directors** | **Provincial Deputy Directors** | **Dputy. Resident Project** |
| **Asst. Directors of Agriculture** | **Asst. Directors of Agriculture** | **Managers (DRPM Ag)** |

| | | |
|---|---|---|
| **Subject Matter Officers** | **Subject Matter Officers** | **Agricultural Officers** |
| **Directors of Regional Research Centres** | | |
| **Research Officers** | | |
| **Plant Protection Service staff**<br>Asst. Directors (Training)<br>Registrar of Pesticides | | Asst. Directors (Training) |

**Segment Level** – Planning meetings

Organise individually by Assistant Directors of both Inter Provincial districts and Provincial districts with the Subject Matter officers and Agricultural Instructors of the segment to plan the seasonal programme. Similarly Resident Project Managers for Agriculture of Mahaweli Systems hold their meetings with the Agriculture Officers and Field Assistants to plan their programmes.

**Village level** – Planning meetings

Agricultural Instructors of districts and Agricultural Officers of Mahaweli Blocks along with their Field Assistants meet with farmers' organizations and other allied departmental officials meet with members of farmer organizations at the village level to discuss and finalize the seasonal programmes for their own areas.

In this process of planning, the Plant Protection Service, the main coordinating body for IPM in the Department of Agriculture, will assist through its staff to include IPM in Inter-provincial, Provincial and MASL extension plans. They will also provide training to develop new IPM trainers as well as technical guidance during implementation.

Finding funds for implementation will be the responsibility of each organization once the programme is approved at the national level unless otherwise projects for funding are available. For monitoring of the programme it is proposed to set up two committees. A Steering Committee at the Director General Level and an Implementation Committee at the Plant Protection Centre which will comprise of Provincial Directors, Representatives from Extension & Training Division of the DOA and MASL. These committees will review the progress periodically during implementation.

**SUGGESTIONS AND RECOMMENDATIONS**

1. A national strategy for participatory IPM is an urgent requirement.

2. An IPM programme for vegetables is a felt need at present; as such, funds for a long term project on vegetable IPM will help develop one that will find answers to many an existing problem in pest control. This will also help minimize excessive use of pesticides in food crops.

3. Aggressive propaganda by pesticide companies is a threat to IPM activities. Hence, an equally strong campaign by government should be launched to counteract such propaganda.

4. Formation of a steering committee and an implementation committee is essential to monitor and carry out the programme successful.

5. There is need to increase various cadre of trainers for vegetables IPVM activities. A training of trainers course (TOT) is needed.

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**Appendix 1: Persons engaged / involved in IPM activities with their mailing Address and contact numbers**

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**Appendix-2 Photographs of IPM activites**

IPM field day

Yield data collection by farmers at IPM FFS site

IPM  Awareness programme for school ehildren

Field activity Trainers on IPVM-TOT Training programe

Group dynamic at TOT Training

Preparation of Trials by FFS farmer groups

**Appendix-2 Photographs of IPM activites**

Field exercise by TOT trainers

Discussion on Field experiment with TOT trainer

Sampling of mosquito larvae

Discussion on Field experiment with TOT trainer

Field day at IPM FFS site

Farmers and Officers gathered in vegetable IPM – FFS
Field day funded by REAP project

## Appendix-2 Photographs of IPM activites

Ballot Box test at FFS

Group dynamic at TOT training

Defoliation trial in FFS site

Field observation by farmers at vegetable IPM – FFS at Walmoruwa

Milling of pesticide free rice by IPM farmers (community IPM)

# ANNEXURE 1. ABBREVIATIONS AND ACRONYMS

| | | |
|---|---|---|
| AEZ | : | Agro Ecological Zones |
| AIC | : | Agriculture Information Centre |
| APP | : | Agriculture Perspective Plan |
| ASC | : | Agricultural Service Centre |
| BAFRA | : | Bhutan Agriculture, Food and Regulatory Authority |
| BSMRAU | : | Bangbandhu Sheikh Mujibur Rahman Agricultural University |
| BTK | : | Bacillus thuringiensis |
| BW | : | Bacterial Wilt |
| CBO | : | Community Based Organization |
| CIB | : | Central Insecticide Board |
| CIDA | : | Canadian International Development Agency |
| CIL | : | Central Insecticidal Laboratory |
| CIPMCs | : | Central IPM Centres |
| CNR | : | College of Natural Resources |
| COTI | : | Countries other than India |
| CSO | : | Chief Scientific Officer |
| DAC | : | Department of Agriculture and Cooperation |
| DAO | : | District Agriculture Officer |
| DEC | : | Department of Export Crops |
| DFID | : | Department for International Development |
| DOA | : | Department of Agriculture |
| DPPQ&S | : | Directorate of Plant Protection, Quarantine and Storage |
| DST | : | Department of Science and Technology |
| EC | : | European Commission |
| ETL | : | Economic Threshold Level |
| FA | : | Field Assistant |
| FAO | : | Food and Agriculture Organization of the United Nations |
| FFS | : | Farmers' Field School |
| FP | : | Farmers' Practice |
| FYM | : | Farm Yard Manure |

| | | |
|---|---|---|
| FYP | : | Five-Year Plans |
| GAP | : | Good Agriculture Practice |
| GDP | : | Gross Domestic Product |
| GIS | : | Geographic Information System |
| GOI | : | Government of India |
| GMP | : | Good Manufacturing Practice |
| GNH | : | Gross National Happiness |
| GOB | : | Government of Bangladesh |
| HCB | : | Hexachlorbenzene |
| HCN | : | Hexachlorocyclohexane |
| HRC | : | Horticulture Research Centre |
| HVC | : | High Value Commodity |
| IAAS | : | Institute of Agriculture and Animal Science |
| ICAR | : | Indian Council of Agricultural Research |
| ICM | : | Integrated Crop Management |
| ICP | : | Inter Country Project |
| IDM | : | Integrated Diseases Management |
| IHDP | : | Integrated Horticulture Development Project |
| INTERFISH | : | Integrated Rice and Fish Project |
| IPC | : | Integrated pest control |
| IPM | : | Integrated Pest Management |
| IPMDP | : | Integrated Pest Management Development Project |
| IPMCRSP | : | Integrated Pest Management Collaborative Research Support Programme |
| IPVM | : | Integrated Pest and Vector Management |
| IRRI | : | International Rice Research Institute |
| ISO | : | International Organization for Standardization |
| IT | : | Information technology |
| IWM | : | Integrated Weed Management |
| MASL | : | Muhawell Authority of Sri Lanka |
| MoA | : | Ministry of Agriculture |
| MOAC | : | Ministry of Agriculture and Cooperatives |

| | | |
|---|---|---|
| MRL | : | Maximum Residue Level |
| MT | : | Metric Ton |
| NAEP | : | New Agricultural Extension Policy |
| NAP | : | National Agriculture Policy |
| NARC | : | Nepal Agricultural Research Council |
| NARS | : | National Agricultural Research System |
| NCPC | : | National Crop Protection Centre |
| NEs | : | Natural Enemies |
| NGO | : | Non Government Organization |
| NIP | : | National IPM Policy |
| NOPEST | : | New Options for Pest Management |
| NPPC | : | National Plant Protection Centre |
| NPPO | : | National Plant Protection Organization |
| NPV | : | Nuclear Polyhedrosis Virus |
| NRI | : | Natural Resources Institute |
| NWFP | : | Northwest Frontier Province |
| NTFs | : | Non-timber Forest Products |
| ODA | : | Overseas Development Agency |
| OFRD | : | On-Farm Research Division |
| OP | : | Organophosphate |
| PAB | : | Pesticide Association of Bangladesh |
| PBW | : | Pink Bollworm |
| PODA | : | Provincial Department of Agriculture |
| POPs | : | Persistent Organic Pesticides |
| PPD | : | Plant Protection Directorate |
| PPO | : | Plant Protection Officer |
| PPS | : | Plant Protection Service |
| PPW | : | Plant Protection Wing |
| PRO | : | Pesticide Regulation Officer |
| PSO | : | Principal Scientific Officer |
| PTAC | : | Pesticide Technical Advisory Committee |
| QCRS | : | Quality Control and Regulatory Services |

| | | |
|---|---|---|
| RC | : | Registration Committee |
| R&D | : | Research and Development |
| REAP | : | Rural Enterprise and Agricultural Project |
| RED | : | Research and Extension Division |
| REID | : | Research, Extension & Irrigation Division |
| RMA | : | Royal Monetary Authority |
| RNR | : | Renewable Natural Resources |
| SAARC | : | South Asian Association for Regional Cooperation |
| SABL | : | Safe Agro Bio-tech Limited |
| SAC | : | SAARC Agriculture Centre |
| SAU | : | State Agricultural University |
| SDC | : | Swiss Agency for Development Cooperation |
| SMO | : | Subject Matter Officer |
| SMS | : | Subject Matter Specialist |
| SPPS | : | Strengthening Plant Protection Services |
| SSO | : | Senior Scientific Officer |
| T&V | : | Training and Visit |
| TA | : | Technical Assistance |
| TCA | : | Trichloro Acetic Acid |
| TG | : | Technical Grade |
| TOF | : | Training of Facilitator |
| TOT | : | Training of Trainer |
| TRISL | : | Tea Research Institute in Sri Lanka |
| TYIP | : | Three-Year Interim Plan |
| UK | : | United Kingdom |
| UNCED | : | United Nations Conference on Environment and Development |
| UNDP | : | United Nations Development Programme |
| USAID | : | United States Agency for International Development |
| WHO | : | World Health Organization |
| WTO | : | World Trade Organization |
| WWMP | : | Wang Watershed Management Project |