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Implementation and Promotion of an IPM Strategy for Control of Eggplant Fruit and Shoot Borer in South Asia

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AVRDC
The World Vegetable Center

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Implementation and Promotion of an Integrated Pest Management Strategy for the Control of Eggplant Fruit and Shoot Borer (*Leucinodes orbonalis*) in Indo-Gangetic Plains of South Asia

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Executive Summary

Eggplant, *Solanum melongena* L., is one of the most commonly grown and economically important vegetables in South Asia. This sturdy crop is cultivated throughout the year, even during the hot-wet monsoon season when other vegetables are in short supply, and is one of the very few vegetables that are available at affordable prices for both the rural and urban poor. Eggplant is cultivated on small landholdings, and sale of produce harvested almost daily over a 5–6 month season serves as a valuable source of cash income to farmers. Besides income, eggplant is an important source of nutrition. It is a rich source of vitamins B_6, C, K, thiamin, niacin and pantothenic acid; minerals such as magnesium, phosphorus, potassium, manganese and copper; dietary fiber; and folic acid.

In recent years, cultivation of this vegetable has become increasingly costly and hazardous to farmers. This is due to the increase in use of chemical pesticides by farmers combating insect pests, especially eggplant fruit and shoot borer (EFSB), *Leucinodes orbonalis* Guenée. This insect, the larvae of which bore into shoots and fruits, is causing increasing levels of damage to eggplant yields, thus reducing farmers' incomes.

An integrated pest management (IPM) strategy that may control EFSB with minimal use of pesticides was developed during a DFID-funded project in Bangladesh, India, and Sri Lanka from 2000 to 2003. It involved 1) field sanitation, especially proper disposal of eggplant stalks, to prevent carryover of EFSB from previous season; 2) prompt excising and disposal of EFSB-damaged shoots, with larvae inside, throughout the season; 3) installation of traps baited with sex pheromone to attract and kill EFSB adult males; and 4) withholding of insecticide use for as long as possible to allow native natural enemies of EFSB to proliferate and help control the pest. Integration of all four approaches is essential for successful control of EFSB.

During the second phase of the project, from October 2003 through January 2006, the IPM strategy was implemented on farmers' fields via pilot project demonstrations in select areas of Bangladesh and India, and its use was promoted in both countries. The promotional activities included organization of farmers' field days on pilot project sites, dialog meetings between farmers and researchers, training of farmers, and the use of mass media to distribute information to a wide range of audiences. The promotion included production and distribution of informative brochures, leaflets, posters, and news releases in local languages, telecasting of a specially prepared documentary film, and interviews over radio and television to drive home the message of IPM, especially to farmers and consumers. Project activities also included working with small and medium enterprises (SMEs) in both countries to encourage commercialization of sex pheromone. Research was directed at understanding of sex pheromone related behavior of EFSB and economizing the use of sex pheromone, the only purchased input in the new IPM strategy.

A socio-economic study of farmers' eggplant production and protection practices and an assessment of the impact of the project activities in target and non-target areas were both carried out toward the end of the project in late 2005.

In Bangladesh, the project activities were coordinated by Bangladesh Agricultural Research Institute (BARI). Pilot projects were implemented in Jessore, Norsingdi, Bogra, and Pabna Districts. During two years, the pilot projects were implemented on nearly 139 ha of eggplant cultivation owned by 1,084 farmers.

In India, the pilot projects were implemented in Bhavnagar District of Gujarat by Anand Agricultural University (AAU), in Khurda District of Orissa by Orissa University of Agriculture and Technology (OUAT), in Ranchi District of Jharkhand by Ramakrishna Mission (RKM), in Birbhum District of West Bengal by Visva Bharati University (Shantiniketan), in Shillong District of Meghalaya and West Tripura District of Tripura State by ICAR Research Complex for North Eastern Hilly Region (ICAR-NEH), and in Varanasi and Mirzapur Districts of Uttar Pradesh by Indian Institute of Vegetable Research (IIVR), the institute that coordinated the project activities of the latter four institutions. During the two years, the pilot project activities were conducted over 186 ha of eggplant cultivation in numerous parcels of land owned by about 1,000 farmers.

In Bangladesh, BARI conducted 12 field days at various sites. One such field day was attended by the Minister for Agriculture of Bangladesh. In India, 25 field days at various pilot project demonstration sites were organized. Two such events, one each in Gujarat and Jharkhand, were attended by members of State Legislative Assemblies. The presence of elected officials at the gatherings attracted large crowds and received wide coverage in local media.

Several daylong training courses were conducted to train farmers in the use of sex pheromone and removal of pest-damaged shoots. Through such activities a total of 9,984 farmers were trained in both countries.

A documentary film, "How to control eggplant fruit and shoot borer: a safer IPM approach" was produced in English and then dubbed in Bengali, Gujarati, Hindi, Khasi, and Oriya languages. This 25-minute film was telecast over BTV (Bangladesh national TV) five times in Bangladesh and 13 times in India over Doordarshan, a national TV channel. Most vegetable farmers own television sets or have easy access to community television. This documentary was also shown to audiences of farmers and others on special occasions and was used extensively in training of farmers.

Three extension brochures, "How to Control Eggplant Fruit and Shoot Borer", "A Farmer's Guide to Harmful and Helpful Insects in Eggplant Fields" and "How to Use Sex Pheromone in Controlling Eggplant Fruit and Shoot Borer", were written in English at AVRDC and subsequently translated in Bengali, Gujarati, Hindi, Khasi, and Oriya by respective project sites. Nearly 22,000 copies of these brochures were distributed to farmers during field days, dialog meetings, and training sessions. BARI, AAU, and IIVR sites also mailed these brochures to farmers via local postal service. In addition, most sites printed illustrative posters depicting IPM themes. These posters were displayed in places such as tea shops, vegetable markets, pesticide and fertilizer shops, community halls, and suitable structures around vegetable fields and other such fixtures to draw farmers' attention.

Project activities, especially the observance of farmers' field days, to which media persons were especially invited, received wide attention. Such coverage included news articles, editorials, and special features in print media, as well as news stories, interviews with project scientists and farmers, and excerpts of the film documentary in electronic media.

A baseline survey evaluating the socio-economics of production and protection of eggplant was carried out in Bangladesh, Gujarat, West Bengal, Uttar Pradesh, and to some extent in Orissa. The impact of the project was subsequently assessed in Bangladesh, Gujarat, and West Bengal. The surveys included personal interviews with farmers using pre-tested questionnaires. Over two-thirds of vegetable farmers were literate, receiving at least primary school education. Over 95% of farmers recognized EFSB as the most serious pest and nearly all of them used only chemical insecticides to combat it. Very few eggplant farmers had knowledge of beneficial insects in the field, hence were unaware of harmful effects of pesticides on these beneficials. However, most farmers were aware of the harmful effects of these chemicals on humans and animals. Most farmers believed pesticides can control EFSB and increase eggplant yield. Farmers almost never followed governmental recommendations on the appropriate chemicals, dosages, and time intervals between spraying and harvesting. The most important source of information to farmers on the selection of chemicals and their dosages were pesticide shop keepers, rather than government extension agents. Despite heavy use of pesticides and other inputs, eggplant production in most sites was profitable. The profit margins, however, increased and pesticide use decreased significantly for those farmers who adopted IPM. An ex-ante evaluation of IPM using the economic surplus model revealed an internal rate of return (IRR) of 39% and benefit-cost ratio (BCR) of 3.25 in Bangladesh. In West Bengal, a similar study revealed an IRR of 38% and a BCR of 2.78.

At the end of the first phase of the project in 2003, three SMEs started selling sex pheromone of EFSB in India, compared to none at the beginning of the project in year 2000. By the end of 2005, nine Indian SMEs were selling this product. Four of these SMEs volunteered to inform us that their sales of pheromone lures nearly tripled from 74,000 in 2002 to 193,000 in 2004. All firms expected continued robust growth in demand for the lures in the near future. Eventually these companies will be leading promoters of IPM to control EFSB in the region.

1 Introduction

Eggplant, *Solanum melongena* L., a native plant species of South Asian origin, is an important vegetable in Bangladesh and India. It is grown on over 510,000 ha in India (FAO, 2004) and approximately 60,000 ha in Bangladesh (Bangladesh Bureau of Statistics, 2004). This crop is grown by small landholders, under management practices that range from low-input rainfed crops grown once a year to high-input irrigated crops that are grown twice or even thrice a year. Sales of eggplant from throughout the prolonged harvest season provide farmers with valuable cash income.

Besides income, eggplant is an important source of nutrition. It provides essential dietary nutrients such as vitamins B_6, C, K, thiamin, niacin and pantothenic acid, as well as minerals such as magnesium, phosphorus, potassium, manganese and copper. Eggplant is a good source of dietary fiber and folic acid, and is very low in saturated fat, cholesterol, and sodium. During the hot-wet monsoon season, when other vegetables are in short supply, eggplant at times is the only vegetable available at an affordable price to rural and urban poor. From a social equity point of view, this vegetable is especially important. It is liked by rich and poor, urban and rural, upper and lower classes, and is a social leveler in the class-conscious society of this part of the world.

In recent years, however, cultivation of this vegetable has become increasingly costly and hazardous to farmers as well as consumers. This is due to the increase in use of chemical pesticides by farmers for combating insect pests, especially eggplant fruit and shoot borer (EFSB), *Leucinodes orbonalis* Guenée. This pest is causing increasing levels of damage to eggplant yields, thus cutting into farmers' income.

To protect their eggplant crop, farmers have been relying exclusively on application of pesticides because alternative control measures, which might be as effective and as convenient to use, are not yet developed. Pesticide use is very intense because larvae, which hatch from eggs laid on eggplant leaves, must be killed before they bore inside shoots or fruits. Once inside these plant parts, larvae are inaccessible to the killing action of chemicals sprayed on the plant. Since neonate larva can enter a fruit or shoot within an hour after hatching, pesticides have to be applied frequently in order to have sufficient pesticide residues on the plant surface to kill the crawling larva. Due to various reasons, including the possibility that the pest is gradually developing resistance to the pesticides, the use of pesticides is on the rise. A survey conducted in Bangladesh in early 1993–1994 indicated that farmers spray their eggplant crop up to 84 times during the 6–7 month cropping season (BARI, 1995); another survey in the same area in 2002 revealed a frequency of 120 sprays in one season (Rashid et al., 2003). Similar abuse of chemicals is found in some intensive eggplant growing areas in neighboring India.

A three-year research and development project, funded by the Department for International Development (DFID) of the United Kingdom, was launched in April 2000 to develop a sustainable integrated pest management (IPM) strategy that is simple, economical, and effective in reducing EFSB damage with minimal use of chemical pesticides. Through intensive laboratory and field research in Bangladesh, India, Sri Lanka, Taiwan and the United Kingdom, an IPM strategy was developed that involved 1) field sanitation to prevent carryover of EFSB from the previous season; 2) prompt excising and disposal of EFSB-damaged shoots, with larvae inside, throughout the season; 3) installation of traps baited with EFSB sex pheromone to attract and kill adult males; and 4) withholding of insecticide use for as long as possible to allow native natural enemies of EFSB to proliferate and help control the pest. Integration of all four approaches is essential for successful control of EFSB.

This strategy, developed during first two years of the initial three-year phase of the project, was tested during the third year in limited pilot project studies on farmers' fields in Jessore District of Bangladesh, Gujarat and Uttar Pradesh States of India, and Central Province of Sri Lanka. Except in Sri Lanka, the pilot projects were successful in reducing pest damage below economically tolerable levels. Such success prompted three small and medium enterprises (SMEs) in India to commercialize the sex pheromone for sale at competitive prices (Alam et al., 2003). Socio-economic studies in Bangladesh showed that the IPM strategy reduced production costs by 34% compared to the traditional farmer practice of calendar-based pesticide application. The benefit-cost ratio with IPM was 5.3, as against 1.7 for the traditional practice. With such a precipitous drop in pesticide use, the IPM strategy, if adopted community-wide, is likely to be sustainable for decades.

Based on the success of this project, DFID funded a two-year extension of the project to expand implementation and promotion of IPM in Bangladesh and India. The major activities involved expanding areas under pilot projects on farmers' fields, followed by promotion of IPM by organization of farmers' field days, dialogs between farmers and researchers, training demonstrations to farmers in the use of sex pheromone, and use of multimedia to distribute information to wider audiences of various sectors of the population. The promotion also included production and distribution of informative brochures, leaflets, posters and news releases, telecasting of a specially prepared film documentary, and interviews over radio and television to drive home the message of IPM, especially to farmers and consumers. A socio-economic study of farmers' eggplant production and protection practices and an assessment of the impact of project activities in target and non-target areas were also carried out toward the end of the project. This bulletin summarizes activities undertaken and results obtained at four regions in Bangladesh and six states in India during the second phase of the project.

2 Scientific Basis of IPM Strategy

Knowledge of biology, host plants, nature of damage, mortality factors of the pest insect, agronomy and seasonality of the target crop, and local environmental conditions are essential for developing an IPM strategy for controlling any pest insect. Such knowledge helps in identification of weak points in the insect's life cycle that can be taken advantage of in combating the pest with relative ease and on a sustainable basis. Reliable details of the biology and host-range of EFSB were sketchy despite over 300 papers being published on various aspects of the pest. Much of this literature, generated mainly from South Asia, is confined to screening of pesticide chemicals to judge their comparative toxicity to the pest, irrespective of whether the chemicals have been approved for use on eggplant, and some research on screening of locally available eggplant varieties for resistance to the pest (AVRDC, 1995). A critical study of all available literature on EFSB and inference from such knowledge generated for related pest species, therefore, was utilized during the first phase of this project in developing an IPM strategy.

2.1 Biology of EFSB

Like other members of the order Lepidoptera, EFSB goes through four growth stages: egg, larva, pupa, and adult (Fig. 1). Details of the biology are described in an earlier publication (Alam et. al., 2003). This section will review how some vulnerable points in the biology of the pest can be exploited in developing a sound and sustainable IPM strategy in combating EFSB.

Egg. Adult females lay eggs on eggplant foliage. The number of eggs laid by an average female varies from 80 to over 250. Oviposition takes place during the

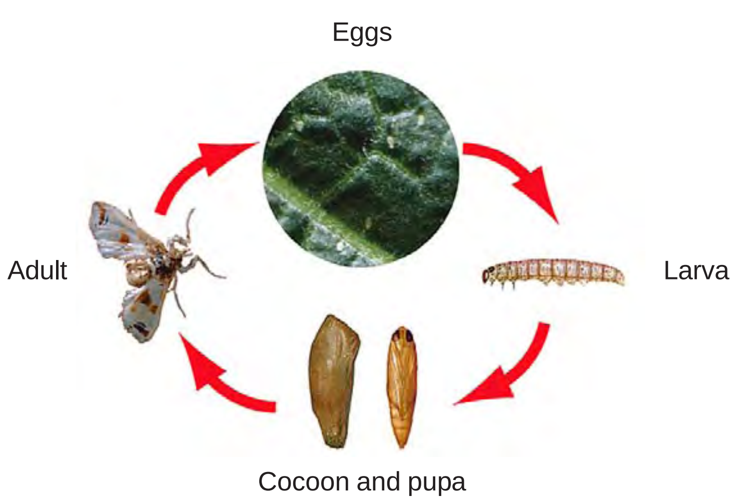


Fig. 1. *Life cycle of eggplant fruit and shoot borer*

night and eggs are laid singly on the lower surface of the young leaves, green stems, flower buds or calyces of the fruits. Eggs are flattened, elliptical, and 0.5 mm in diameter. Eggs hatch in 3–6 days. Since the eggs are tiny and laid singly, it excludes the possibility of an economical use of egg parasitoids—which are more effective when eggs are laid in masses or when individual eggs are relatively large—for combating EFSB. Although egg parasitoids are easy to rear and some SMEs in South Asia have been producing these natural enemies for commercial use, their use in combating EFSB is not practical.

Larva. Soon after hatching from eggs, young caterpillars search for and bore into tender shoots (Fig. 2), flower buds, or fruits (Fig. 3). When available, caterpillars prefer fruits more so than other plant parts. Larvae go through five instars. The entire larval period, which lasts 12–15 days in the summer and up to 22 days in the winter, is spent hidden within shoots or fruits. This cryptic habit of the pest reduces the chances that predators or environmental factors such as rain or strong wind would kill the EFSB larvae. Such a habit also reduces the possibility of parasitoids adapting to the pest larvae readily. There are only two noteworthy parasitoids species that attack EFSB larvae: *Trathala flavo-orbitalis* and *Eriborus sinicus* (Sandanayake and Edirisinghe, 1992; AVRDC, 1996). Both parasitoids are, however, oligophagous, i.e., they feed on more than one species of insect, EFSB being one of them. Species-specific natural enemies tend to be more effective and relatively safer for introduction in problem-plagued areas in combating a pest. Nonetheless, efforts should be made to create conditions under which these parasitoids will proliferate. This will necessitate reduction in pesticide use to avail this freely available natural resource in combating EFSB. Indeed, in certain areas of Bangladesh where pesticide use is minimal, *T. flavo-orbitalis* is very active and helps to reduce pest damage (Alam et al., 2003).

Pupa. Mature larvae come out of their feeding tunnels at night (Fig. 3) and pupate in tough silken cocoons among the fallen leaves and other plant debris on the soil surface near the stem of the host plant. The color and texture of the cocoon matches the surroundings (Fig. 1) making it difficult to detect them. Some studies indicate the presence of cocoons at soil depth of 1–3 cm. The pupal period lasts 6–17 days depending upon temperature; shorter period in summer, longer period in winter. This pupation habit excludes the possibility that any predator, parasitoid, or other agent can be employed that will kill this life stage readily.

Adult. Moths come out of pupal cocoons mostly at night. Young adults are generally found on the lower leaf surfaces following emergence from pupal cocoons. EFSB females are slightly larger than males. The abdomen of the female moth tends to be pointed and curls upward, whereas the male moth possesses a blunt abdomen. The moth is white but has pale brown or black spots on the dorsum of thorax and abdomen (Fig. 1). Wings are white with a pinkish or bluish tinge and are fringed with small hairs along the apical and anal margins. The forewings are ornamented with a number of black, pale and light brown spots.

The moth measures 20–22 mm across the spread of wings. The adults are short-lived; longevity of the male is 1.5–2.4 days and that of female 2.0–3.9 days. They mate either the same night they emerge from cocoons or 24 hours later. The pre-oviposition and oviposition periods are 1.2–2.1 and 1.4–2.9 days, respectively (Mehto et al., 1983).

There are no known natural enemies of EFSB adults. Since adults are small, hiding under the leaves within the plant canopy, and actively flying only at night, chances of predators being effective are meager. However, like most other Lepidoptera species, virgin females of EFSB produce a sex pheromone that attracts male moths for mating. Sex pheromones of several other insects have been identified, synthesized, and with the help of suitable traps, are routinely used in trapping and killing male moths, thus reducing their chances of mating and producing subsequent generations of that pest insect.

Sex pheromones of several species of insects are now commercially produced and used in combating numerous insect pests, especially in horticultural crops. Two research groups, one in China and one in Sri Lanka, have identified two chemicals that, when present in a specific proportion, form sex pheromone of EFSB (Zhu et al.,1987; Attygalle et al., 1988). However, field use of this sex pheromone was never developed. Our preliminary studies in Bangladesh showed that the pheromone lure of EFSB attracts male moths, which can be killed by using suitable traps. Therefore, use of sex pheromone was included as one component in the proposed IPM strategy.

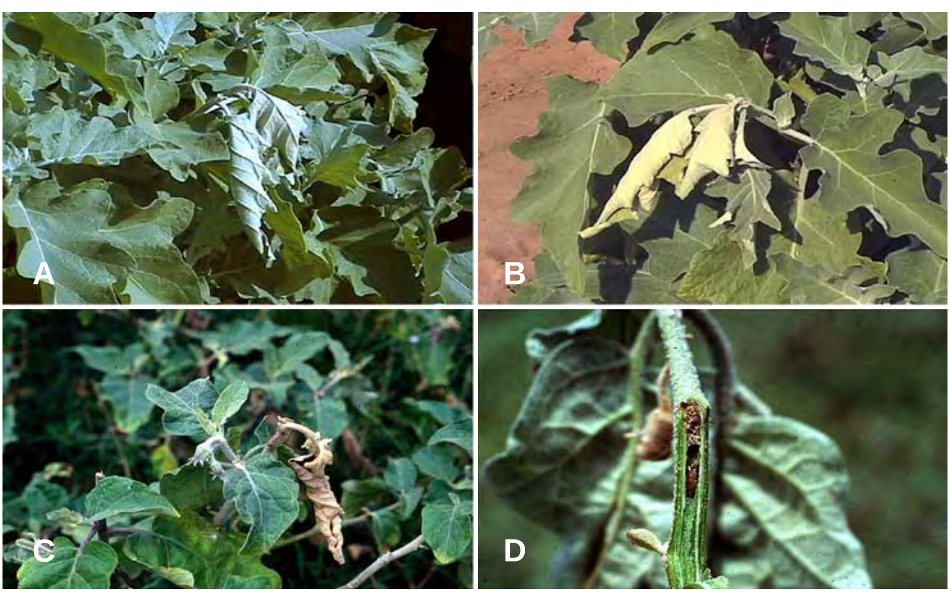


Fig. 2. *Progressive wilting (A, B) and eventual withering (C) of EFSB-damaged eggplant shoots due to feeding of larvae inside shoots (D)*

2.2 Nature of damage

EFSB larvae bore into the nearest tender shoot, flower or fruit within one hour after hatching. Soon after boring into the plant, they plug the entrance hole with excreta and remain concealed inside that plant part. Larval feeding inside shoots results in progressive wilting of the young shoot, a characteristic called "dead-heart" (Fig. 2). The presence of wilted, drooping shoots in an eggplant field is the surest sign of damage by this pest. The damaged part of the shoot invariably contains a larva feeding inside. Cutting and destruction of such shoots to kill the larva will reduce pest populations in the future.

Larval feeding inside the fruit prevents the fruit from being marketable (Fig. 3). At harvest, which is at least once a week in eggplant, chopping and disposal of such unmarketable fruits will reduce pest population and further damage to the crop.

Fig. 3. *EFSB larvae feeding inside eggplant fruit (left) and exit hole of full-grown larva in preparation for pupation in soil*

Destruction of damaged shoots and fruits once or twice a week depending upon the frequency of harvest does not take much effort, especially in comparison with spraying the entire field with pesticides. Such a practice guarantees killing of pest insects, which is not always true when one resorts to spraying of pesticides.

2.3 Host range of EFSB

EFSB is an endemic pest of eggplant in South Asia. It is practically monophagous, i.e., it feeds only on one crop, in this case, eggplant. However, occasionally other plants belonging to family Solanaceae are also reported to be the host of this pest. These include potato, tomato, as well as nightshades such as *Solanum nigrum*, *S. indicum*, and *S. torvum*. However, growth and development of EFSB on these plants is very slow. Given a choice, EFSB prefers eggplant to other hosts. Therefore, denying EFSB moths easy access to eggplant plants to lay their eggs upon is the first and surest way of controlling this pest.

2.4 Carryover of EFSB from season to season

Since EFSB is a specific pest of eggplant, and rarely feeds on other plants, it was believed that the infestation of a newly planted eggplant crop comes from the adults migrating from neighboring older eggplant crops or by adults emerging from the pupae in soil of the same field if no rotation is observed. These two sources of EFSB infestation remain important.

However, during the first phase of this project, we found a new source of the pest insect—dried eggplant stalks heaped around fields from the previous season's crop. Most farmers store these plants around their fields or dwellings (Fig. 4) and use the dried stalks as fuel for cooking. With the help of sex pheromone, we were able to detect EFSB adults coming out of stored dried stalks for up to 8 weeks after harvest of the old crop. This period is well beyond the normal pupal period, when adults must come out. Prolongation of the pupal or larval-pupal period in drying plant residues is an unusual phenomenon and needs further investigation.

This finding, however, poses a dilemma to the implementation of IPM. Prompt elimination of eggplant stubbles from old plantings will prevent carryover of EFSB from season to season and this will help reduce EFSB damage to new eggplant crops. However, farmers insist on keeping the plant stubbles as a fuel for cooking. Under such conditions, a suitable compromise needs to be worked out so that farmers will dispose off eggplant residues promptly after harvest. At times, un-

Fig. 4. *Dried eggplant stalks stored on bunds for use as fuel for household use while a new eggplant crop is raised nearby*

knowingly, farmers also grow their eggplant seedlings in the vicinity where the dry eggplant stubbles are heaped. It is likely that EFSB adults, emerging from the stubbles, will lay eggs on seedlings and the infestation will be carried into the eggplant field when the seedlings are transplanted.

2.5 The IPM strategy

Based on the above account of available information and research findings during the first phase of this project, we developed an IPM strategy, the details of which are described below:

1. Sanitation of planting area to make sure eggplant residues from the previous crop, which can harbor EFSB, are disposed off promptly or stored far away from areas planted in new eggplant crops.
2. Prompt excising and disposal of all EFSB-damaged shoots when wilted shoots become visible, and prompt disposal of damaged fruits. These operations need to be done throughout the season.
3. Starting with the first flush of flowering, installation of traps baited with sex pheromone of EFSB. These traps, placed just at the plant canopy level, are erected at the junction of a 10-m grid throughout the field. Lures inside the traps are to be replaced every 4–5 weeks. Traps can be purchased or even homemade.
4. Withholding of pesticide use for as long as possible. This allows the survival and proliferation of native predators and parasitoids that help in biological control of EFSB as well as other pests.

This IPM strategy, developed during the first two years of the project, was tested in pilot project studies on farmers' fields in Jessore District of Bangladesh, Gujarat and Uttar Pradesh States of India, and Central Province of Sri Lanka. The pilot projects were successful in reducing pest damage below economically tolerable levels. This strategy, therefore, was implemented in four major intensive vegetable growing areas of Bangladesh and in similar areas in six states of India during the second phase of this project.

3 Implementation of Pilot Projects

Implementation of pilot projects on farmers' fields was a major planned activity of the second phase of this project. The pilot projects were meant to demonstrate the utility of the IPM strategy in reducing EFSB damage, while reducing pesticide use and labor costs. Such pilot projects were also used to train farmers in field sanitation, the use of sex pheromones, and the prompt destruction of EFSB-damaged shoots.

Pilot project sites were also meant to be the venues for organizing field days, bringing together not only the participating farmers but also their neighbors as well as farmers from outside the community, thus helping to spread the IPM message. Based on the limited experience gained during the first phase of this project, farmers' field days proved to be suitable forums for having dialog between scientists and farmers. On occasions when elected officials attended such events, it led to dialog between them and farmers; such dialog could lead to the promotion of IPM at the government policy level.

These events would also attract the press, whose coverage of pilot project activities and the abuse of pesticides in eggplant production could spread the message of IPM nationwide. Our limited experience in the first phase also showed that attendance of local pesticide dealers during field days would entice them to stock sex pheromone lures and pheromone traps, which made these important tools of IPM strategy readily available to farmers at competitive prices.

3.1 Pilot project partners

The project had three major partners that implemented the project activities in South Asia:

1. Bangladesh Agricultural Research Institute (BARI), Gazipur, Bangladesh
2. Anand Agricultural University (AAU), formerly Gujarat Agricultural University, Anand, Gujarat, India
3. Indian Institute of Vegetable Research (IIVR), Varanasi, Uttar Pradesh, India

The two outside partners included:

1. Natural Resources Institute (NRI), University of Greenwich, Greenwich, UK
2. AVRDC – The World Vegetable Center, Shanhua, Taiwan.

BARI, AAU, and IIVR implemented the projects in Bangladesh and the two respective regions of India (Fig. 5). NRI provided technical expertise in the development and use of sex pheromone. AVRDC provided technical expertise in development of IPM and was the coordinating agency for this project.

IIVR had the mandate to implement the project in the northeastern, largely poor states of India while handling the implementation of the project in its home state, Uttar Pradesh. For the east-northeastern states, IIVR chose four sub-project partners to work with:

1. Orissa University of Agriculture and Technology (OUAT), Bhubaneswar, a state agricultural university in Orissa State.
2. Rama Krishna Mission (RKM), a non-government organization (NGO) active in Jharkhand State.
3. Institute of Agriculture, Visva Bharati University, Shantiniketan, a Central university in West Bengal State.
4. ICAR Research Complex for North Eastern Hilly Region (ICAR-NEH), an institute of Indian Council of Agricultural Research, Shillong, Meghalaya, which handles agricultural research and development in seven northeastern states, including Meghalaya and Tripura where the project was implemented.

Fig. 5. *Location of project activity coordinating centers in Bangladesh and India*

Each site had a project coordinator who was a regular staff member of the partner institution. The project coordinator was assisted by one or two project technicians who assisted in day-to-day research and other activities of the project.

3.2 Project sites

Selection of pilot project sites depended on the willingness of the farmers, especially a group of farmers, rather than isolated individuals, to join the project. Efforts were made to include farmers whose eggplant cultivation was contiguous. It was believed that the larger the area being included, the more likely the impact of IPM would be evident. However, at times it became difficult to convince all farmers in a community to join the project's activities. Nevertheless, participation by a majority of farmers was seen to benefit all farmers by lowering pest populations within the community.

As far as possible, pilot projects were set up in the areas of excessive pesticide use. In many of the intensive vegetable growing areas of Asia, pesticide use is excessive and farmers obviously have adequate resources to use pesticides. Many of these farmers expressed interest in trying alternative methods that would reduce their costs of production.

Pilot projects were also set up in marginal areas, where eggplant is grown only once a year as a rainfed crop, where EFSB damage is significant and, despite limited resources, farmers are resorting to pesticide use. These sites were located mainly in Jharkhand and Orissa States of India, where farmers, largely tribal, are especially poor.

Although eggplant in Bangladesh and India can be grown throughout the year, summer is the major eggplant growing season in central, southern and western states of India. In winter, due to the availability of a large number of competing species of vegetables, eggplant cultivation is less in these states. Due to the local preference for this vegetable, however, in specialized areas of Bangladesh and in the Indian States of Tripura and West Bengal, eggplant is grown throughout the year. Pilot projects at such locations, therefore, were organized irrespective of season.

Most of the pilot projects were located in clusters of villages. The locations of pilot projects in various townships in four regions of Bangladesh and six states of India are shown in Figs. 6 and 7, respectively.

3.2.1 Bangladesh

BARI chose four major project sites, one each in Jessore, Norsingdi, Bogra and Pabna districts, to implement pilot projects (Fig. 6). In Jessore, pilot projects were implemented in Mominnagar, Sikandarpur and Gaidghat villages at a total of seven plantings during winter and summer cropping seasons; this project encompassed a total of 72.6 ha of eggplant cropland owned by 492 farmers. In Norsingdi, where eggplant is grown only in winter, pilot projects were implemented annually in Balabo village on a total of 13.7 ha owned by 130 farmers. In Bogra, BARI did a similar exercise in three villages on a total of 6 plantings encompassing 43.8 ha owned by 397 farmers. BARI also implemented a pilot project in Goishpur village of Pabna during summer of 2004 on a total of 8.8 ha of cropland owned by 65 farmers.

Fig. 6. *Location of major project sites in Bangladesh*

3.2.2 India

In Gujarat, in the post-rainy “rabi” season from October 2003 to February 2004, AAU set up pilot projects in four villages in Bhavnagar District on 13 parcels covering a total of 3.0 ha (Fig. 7A). In the rainy “kharif” season (June–October), AAU established pilot projects in 17 villages on 123 parcels covering a total of 33.2 ha. This was followed by a similar demonstration in 16 villages on 71 parcels covering 17.8 ha. In 2005 rainy season, AAU conducted its largest pilot project demonstration in its history, encompassing 41 villages on 267 parcels covering 64.0 ha of cropland. Toward the end of 2005, when project activities were terminating, AAU set up pilot project trials in two villages on 12 parcels of eggplant cropland covering 5.3 ha.

In Orissa, OUAT conducted a total of four pilot project demonstrations over eight villages during four seasons in Khurda District of Orissa (Fig. 7B). It covered an area of 9 ha in the rainy season and 12 ha in the post-rainy season and included fields of 132 eggplant farmers.

In 2004, RKM conducted pilot projects in Ranchi District of Jharkhand (Fig. 7C) in 8 villages covering a total of 3.7 ha; in 2005, similar activities were conducted in five villages covering a total of 7.3 ha.

In West Bengal, Shantiniketan conducted pilot projects during both rainy and post-rainy seasons in 10 villages covering a total of 14 ha of eggplant production in Birbhum District (Fig. 7D).

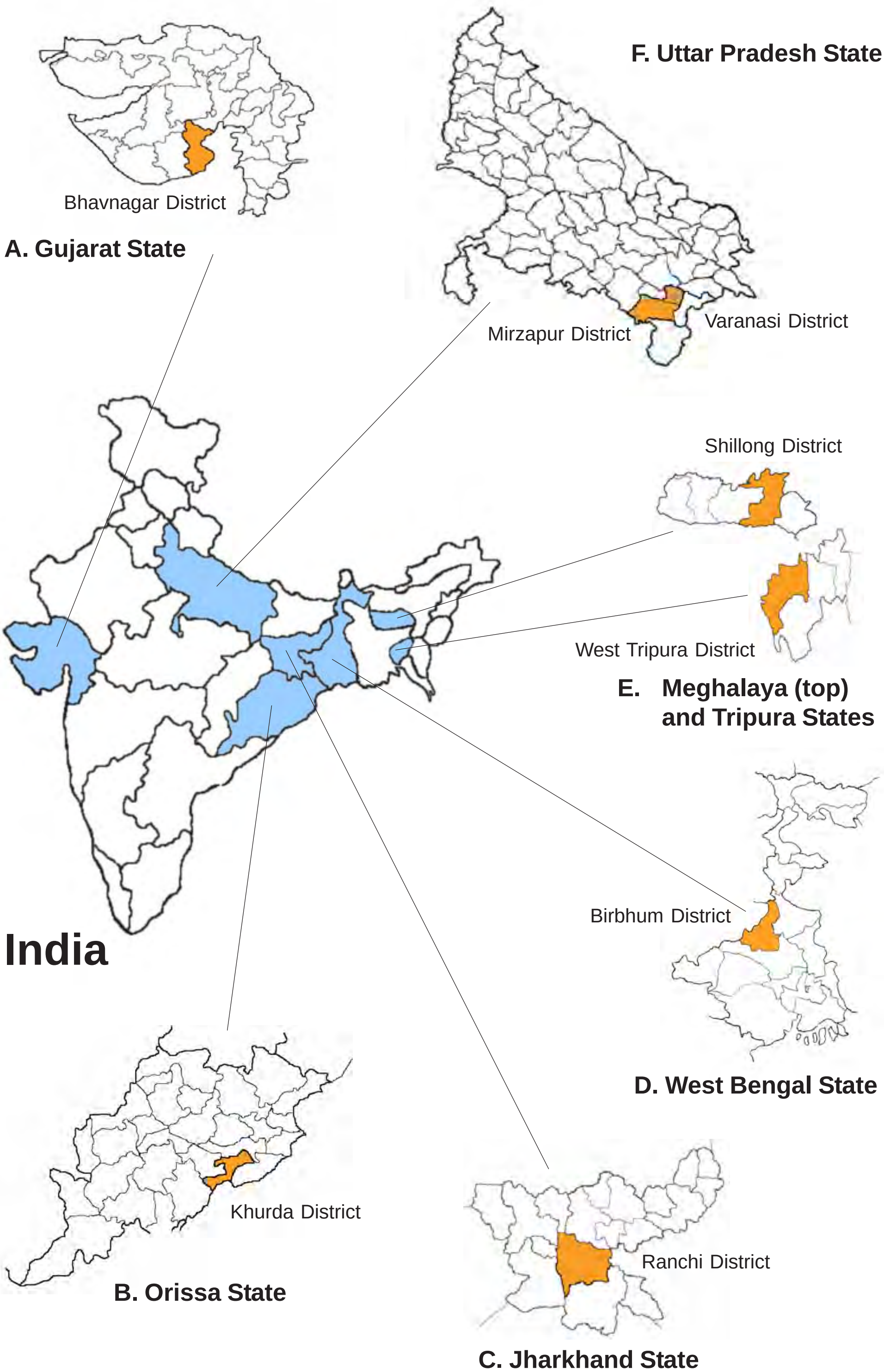


Fig. 7. *Location of major project sites in India*

In Meghalaya, during 2004, ICAR-NEH conducted one pilot project demonstration over 2.5 ha in Mawlasnai village in Shillong District (Fig. 7E). When project activities were subsequently moved to neighboring Tripura State, ICAR-NEH conducted two additional pilot projects, initially in Hawaibari and Teliamura villages over 2.2 ha, and later at Mohanpur and Lankamura villages in West Tripura District (Fig. 7E) covering 2.8 ha of eggplant cultivation.

In its home state of Uttar Pradesh, IIVR conducted five pilot project studies in five villages in Mirzapur and Varanasi Districts (Fig. 7F). It covered a total of 9.5 ha owned by 81 farmers scattered in those villages.

In both Bangladesh and India, because of the publicity generated at the end of the first phase of this project, individual farmers and farm leaders from places far away from the pilot project sites urged coordinators to conduct similar pilot projects in their area. Site coordinators obliged, but organized these activities on a much smaller scale or limited activities to conducting daylong trainings to motivate farmers to adopt IPM strategy.

3.3 Pilot project modalities

All farmers in the proposed pilot project areas were contacted well ahead of each planting season. They were explained the details of pilot project implementation and sought their consent in voluntarily joining the project. They were allowed to use their own variety of eggplant and their own ways of raising seedlings, planting, fertilizing, and other cultural practices—except the use of insecticides to control insect pests. If they must use insecticides, they were requested to seek help of the site coordinators to select the most suitable chemical. In most cases, spraying of neem, an extract of seeds of *Azadirachta indica*, was recommended. Neem, a safer alternative to chemical pesticides, is commonly used for the control of a broad spectrum of pests on many crops in India.

Once the farmers agreed to join the project, the local project staff explained to them the overall operation of the project and reasons for doing each activity during each specific period, beginning with sanitation of the field and surrounding areas before planting. Starting with the first flush of flowers, project staff prepared installation of pheromone lures in the fields. The staff demonstrated the assembly of the traps, installation of traps in a 10-m grid in the field, adjusting the trap height periodically to keep the traps at plant canopy level, and monthly replacement of pheromone lures.

At the very first appearance of EFSB-damaged shoots, project staff explained to the farmers why shoots wilt and upon excising a damaged shoot showed them EFSB larvae feeding inside that plant part. This convinced farmers the need to cut and destroy the damaged shoot along with larvae inside. We explained to farmers how the destruction of such larvae will reduce pest populations and future damage to the fruits. Project staff supervised and helped farmers to do weekly excising of such damaged shoots throughout the season.

At harvest, we recorded the yield of healthy and damaged fruits and convinced the farmers to discard the damaged fruits, bury them in soil or feed them to cattle, but do not leave them around the fields. At the end of the season the farmers were explained the need for prompt destruction of the freshly uprooted plant residues.

Such demonstrations were supplemented by distribution of extension brochures in local languages, which explained the details of this IPM strategy. For organization of field days, these farmers not only willingly allowed to use their fields for the purpose, but were of immense help in communicating with fellow farmers on the merits of the project's activities.

Many of the farmers heard of the successful control of EFSB by our IPM strategy through publicity in newspapers, news magazines, and telecasts. Our offer of free sex pheromone lures and traps helped project staff to convince farmers not to use pesticides. Seeing the pheromone traps erected and maintained by the project staff in their fields convinced the farmers on the seriousness of our efforts. Further, actually seeing the moths being trapped and eventually killed in the pheromone-baited traps was a powerful facilitator, which strengthened the farmers' belief in the IPM strategy.

4 Backstopping Research

Among various components of the IPM strategy, only the use of sex pheromone entails purchased inputs. Other components—sanitation of field before planting, prompt cutting of EFSB damaged shoots, and withholding of insecticide use—are simple and can be practiced by farmers without much expense or labor input. Therefore, during the second phase of the project, research efforts were targeted at reducing the cost of both the pheromone lures and traps, leading more farmers to use this safer method of pest control. The research included 1) basic understanding of pheromone-related reproductive biology of EFSB; 2) selection of better material to dispense the pheromone chemical so that the chemical is released in adequate quantities to catch all male moths attracted to the pheromone; and 3) reducing the cost of traps by incorporating locally available and inexpensive materials.

Understanding of reproductive biology, such as when the EFSB adults emerge from pupae in the soil, how soon after emergence do they start mating, and how often adults mate in their lifetimes, are important in the economical use of sex pheromone. Ideally, the synthetic sex pheromone should attract males before they are attracted to the females who produce natural pheromones in the field. The longer the period between adult emergence from pupae and the physiological maturity of adults for mating, the better the chances that a synthetic sex pheromone will trap the male moths before mating.

The selection of a suitable material that will release the pheromone chemicals uniformly, in sufficient quantity, and over an extended period of time is key. Such release of pheromone chemical will result in attracting the maximum number of male EFSB moths and lead to the most economical control of the pest. Improving trap designs to capture as many male moths that are attracted to the lure is important. At the same time, the cost of such traps should be affordable. The use of locally available, inexpensive materials in making the traps will reduce costs. Further, if such traps can be made by farmers, it increases the availability of this pest control tool whenever one wants. All these factors economize the overall use of sex pheromone. Research efforts, therefore, were targeting to all these points during the project period.

4.1 Mating and oviposition timing study

A previous study showed that EFSB adults start emerging from pupae in the soil soon after sunset and this continues over the next 4 hours. In this study, the timing and frequency of their mating followed by egg laying was investigated. Male and female adults that emerged within a span of 2 hours were put together in an acrylic cylinder containing a branch of eggplant shoot. Insects were observed hourly and times of initiation and duration of mating were recorded. From this data, the premating period—the time between adult emergence and mating—was calculated for both males and females.

After mating, males were removed and females were transferred to an oviposition chamber, which consisted of a 30-cm-long and 15-cm-diameter acrylic chamber, lined inside with rough tissue paper on which EFSB readily lays eggs. An eggplant branch with leaves was placed inside this structure along with a cotton plug dipped in honey. Insects were observed hourly and times of initiation of egg laying were recorded. The pre-oviposition period—the time between adult emergence from pupae and initiation of egg laying—was calculated.

The earliest mating began at 2100 HR and lasted, occasionally, up to 0500 HR the next day. Most frequent matings, however, occurred between 2200 and 0100 HR (Fig. 8). The vast majority of adults started mating within 0–3 hours after emergence from pupae, however, some did mate the next day. In most cases, if adults emerged before 2100 HR, they mated the same night; insects emerging after 2100 HR, mated the following night. The mean pre-mating period for 20 pairs was 9.25 ± 10.43 hours and the median was 2 hours.

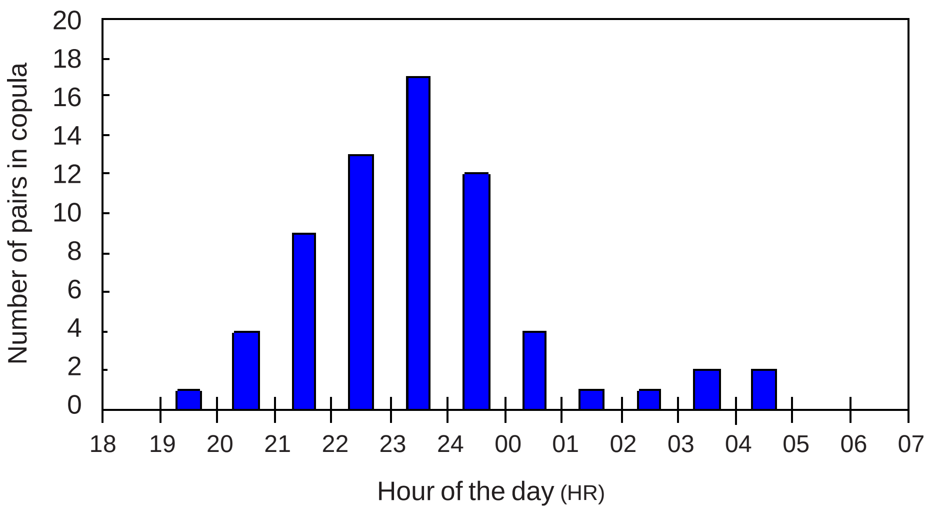


Fig. 8. *Diurnal timing of mating in EFSB*

The mating of insects soon after emergence, especially of males, has implications in the use of sex pheromones for mass trapping males. When the pre-mating period in males is short, the pheromone chemical intended for trapping males must be present in high enough concentration from sunset to sunrise, so that emerging males will be attracted to the pheromone-baited traps and be killed. Since pupae reside in soil, the freshly emerged sexually mature males are likely to hover over the soil surface, below the plant canopy, especially in a mature eggplant field. The pheromone, which traditionally is placed at the crop canopy level or slightly above, may not seep down to the soil level to attract newly emerged males, especially if one plants an eggplant variety that is tall and has thick crop canopy. Under such circumstances, one may need to adjust trap height to below crop canopy.

In a study of mating frequency, in 13 pairs that we observed for two consecutive nights, only one male mated twice with different females, all others mated only once. The rate of mating (% adults mating) was unaffected by presence of host-plant within the mating chamber. The duration of such mating also did not differ whether host-plant was present or absent. The duration of mating in 20 pairs lasted 1.9 ± 0.8 hours.

EFSB females started laying eggs usually the following night after they emerged from pupae. Oviposition usually began at 1900 HR and lasted until 0200 HR. The pre-oviposition period ranged from 18 to 49 hours, with a mean of 33.9 ± 12.3 hours. There was no specific trend between timing of mating and initiation of egg laying.

4.2 Effect of sex pheromone on timing and success of mating

Two freshly emerged female adults were placed in each of two 16-L clear plastic containers. In one container, a sex pheromone lure containing 3 mg of pheromone chemical was placed while the other container was kept as a check without pheromone. The containers were closed tight and placed 2 m apart in a dark room. Starting at sunset, once every 10 minutes, the insects were observed for 2 minutes to record the timing and duration of "calling" or pheromone release behavior of female adults. The calling behavior includes raising and shaking of the abdominal tip. A similar test with newly emerged male adults was conducted to record the timing of their response to pheromone, which includes rapid movement of antennae, fluttering of wings, and short flights.

In another study, the effect of Z-analog of the natural E-analog pheromone in mating success was investigated. In one 16-L container, a lure baited with 3 mg of Z-analog pheromone and in a similar container a lure baited with E-analog pheromone were placed. In each container, a pair (1 male + 1 female) of adults was introduced. The containers were closed tight and placed in a dark room and the timing of mating was recorded for two consecutive nights. On the third night, males were discarded and females placed in an oviposition chamber described earlier for egg laying. The number of eggs laid and number of those hatched into larvae were recorded for 72 hours.

Results of the effect of sex pheromone on calling behavior of females and males are depicted in Fig. 9. Females placed in a chamber without sex pheromone initiated calling behavior at 1930 HR, the normal time for such behavior; however, in the presence of sex pheromone the timing was delayed to 2100 HR or even later. It is not certain how this delay will eventually affect mating success because males seem to remain sexually active well beyond 2100 HR. In the case of males alone, absence of pheromone did not show any pre-mating behavior activities. In the presence of pheromone, males exhibited typical pre-mating behavior starting 2100 HR to well past midnight.

In the presence of synthetic sex pheromone, newly emerged pairs of EFSB failed to mate whereas in the absence of it, all pairs mated successfully (Table 1). Although unmated insects did lay eggs, albeit few, all such eggs were infertile because these eggs did not hatch into larvae. Mated females laid substantial numbers of eggs and over 75% of the eggs hatched into larvae. Thus, synthetic pheromone used in high concentration prevents successful mating. One can use this pheromone to bring about mating disruption, a pest control method often practiced in orchard crops. Identical mating disruption was observed when Z-analog was used (Table 1). Unlike E-analog, Z-analog does not attract any EFSB males; however, this analog is able to disrupt mating in EFSB. In places where Z-analog is cheaper than the normal pheromone, this analog can be used economically.

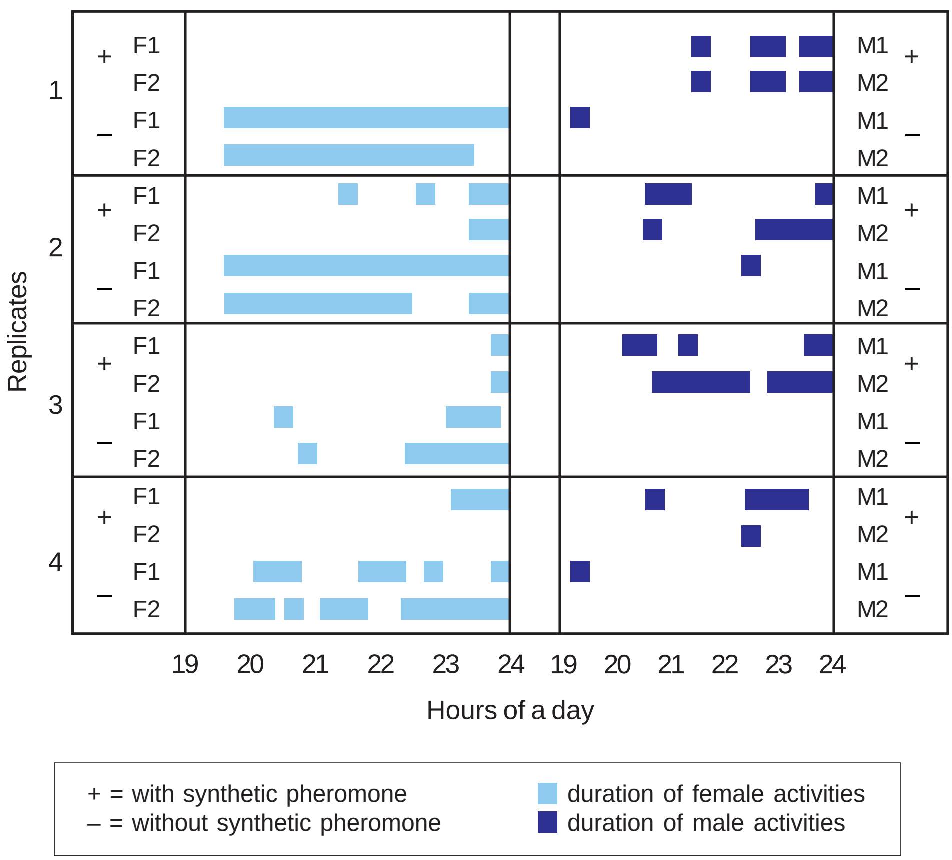


Fig. 9. *Effect of presence of synthetic sex pheromone in calling behavior of EFSB female (F) and pre-mating behavior of EFSB male (M)*

Table 1. *Mating success and egg production of EFSB mating pairs in the presence and absence of EFSB sex pheromone, and its Z analog*

Treatment	Insect pairs	Eggs laid	Larvae emerged	Egg hatch (%)
Without pheromone	1	155	119	76.8
	2	140	125	89.3
	3	216	149	69.0
With pheromone	1	11	0	0
	2	18	0	0
	3	22	0	0
Without Z-analog	1	98	69	70.4
	2	49	46	93.9
	3	133	122	91.7
	4	81	63	77.8
With Z-analog	1	27	0	0
	2	1	0	0
	3	6	0	0
	4	0	0	0

4.3 Effect of sex pheromone components on biological activity

In a series of tests, possible effects of minor component of EFSB sex pheromone, (*E*)-11-hexadecenyl alcohol (E11-16:OH), on sex pheromone related behavior and mating in both male and female adults was studied. In nature, E11-16:OH does not attract EFSB males at any concentration from 10 to 500 µg, whereas the major component (*E*)-11-hexadecenyl acetate (E11-16:Ac), alone attracts the insects, especially at higher concentrations. The addition of a mere 1% of E11-16:OH, however, synergizes the effect of E11-16:Ac in attracting male EFSB moths at much lower pheromone concentrations. In all tests, 30 µg of E11-16:OH, which is equal to the amount of this chemical in standard 3 mg of pheromone lure, was used. Similar tests were also conducted with Z analog of the minor component.

No significant difference in the pre-mating behavior of male or female EFSB adults was observed in the presence or absence of E11-16:OH. Mating success was also not affected by presence of either E11-16:OH or Z11-16:OH. Insects mated successfully and laid a statistically similar number of fertile eggs in both the presence and absence of these sex pheromones. Egg hatching, however, was reduced drastically when a mixture of 30 µg of E and 30 µg of Z analogs was used. The minor component, therefore, does not seem to have effect on mating or oviposition, on its own.

4.4 Characterization of pheromone release rate dynamics of commercial lures

An ideal pheromone lure should release an adequate quantity of pheromone chemical uniformly over a period of time that will attract the maximum number of male moths present in the field at a given time. Such a lure will be an effective pest control agent. However, such a release rate is influenced by, besides the chemical and physical properties of the pheromone chemical itself, the physical and chemical properties of the dispenser on which pheromone chemicals are loaded for use in the field. Pheromone lures of EFSB and other insects prepared and sold in India are manufactured with a range of polymer dispensers from crude rubber tubing to natural rubber septa.

Controlled release trials were undertaken in a wind tunnel to assess the effect of polymer matrix on release of three related compounds: (Z)-11-hexadecenyl acetate, (Z)-11-hexadecenyl alcohol, and (Z)-11-hexadecenal (Z11-16:Ald). The first two compounds have the same release characteristics as the two pheromone components of EFSB. The chemical Z11-16:Ald is the major component of the pheromone of the economically important polyphagous pest *Helicoverpa armigera*. In the first study, dispensers made from various substrates and loaded with a known amount of pheromone chemical were included. They were placed in a wind tunnel maintained at 27 °C with a wind speed of 5 km/hour and the release of chemicals was monitored over a period of time. In the second study, commercial lures from various vendors in India, irrespective of type of dispenser or the quantity of pheromone loaded, were studied for the rate of release of the chemicals in a similar wind tunnel experiment. These studies were supplemented by field experiments by Anand Agricultural University (AAU) in Gujarat, where the commercial lures were compared for their effectiveness over a period of time. AAU also compared various commercial and locally designed and assembled traps for their efficiency in trapping EFSB adults.

Approximately 50 samples of each formulation were placed in a wind tunnel and two samples of each formulation removed at 0, 1, 2, 3, 6, 10, 14, 17, 21, 27 and 30 days after commencement of the experiment. Samples removed from the wind tunnel were labeled and held at –20 °C until the end of the experiment when residual pheromone was analyzed by gas chromatography. Half-life—the time for 50% reduction in the pheromone concentration—was calculated.

Comparison of various dispenser materials. The results (Table 2) clearly demonstrated that changing the polymer matrix can have a profound effect on release rate (as measured by half-life in days). Low density polyethylene (LDPE) vials provided a relatively fast release matrix for the compounds tested, with Z11-16:Ac releasing at a significantly slower rate than either Z11-16:OH or Z11-16:Ald. However, there was no significant release from the high density polyethylene (HDPE) vials as previously used by Pest Control India (PCI). The half-life for PCI vials was greater than 100 days for all compounds.

Table 2. *Release of pheromone components from different polymer matrices*

Compound	Polymer	Half-life (days)		
		Z11-16Ald	Z11-16OH	Z11-16:Ac
NRI vial	LDPE[1]	24.5	28	43
PCI vial	HDPE[2]	>100	>100	>100
NRI septa	Natural rubber	44	108	120
Green septa	Natural rubber	n/a	n/a	n/a
Brown septa	Natural + nitrile rubber	42	n/a	>100
Red septa	Nitrile rubber	29	>100	>100
Clear septa	Silicon rubber	26	112	150

[1, 2] Low density and high density polyethylene, respectively.

The release rates of compounds from natural rubber septa were slower than from the vials and comparable with those from silicon rubber septa (Table 2), although the release of Z11-16:Ald was almost twice as fast from the synthetic rubber compared to the natural rubber, suggesting thereby that the latter would not be such an effective polymer matrix for the pheromone of *H. armigera*. Similarly, synthetic nitrile rubber alone released Z11-16:Ald as fast as the LDPE vials but the EFSB pheromone components were released much more slowly. The blend of natural and synthetic rubber produced release rates comparable to natural rubber.

The differences in release rates observed with the various polymer matrices are due to the chemical composition of the polymers. Natural rubber is composed of polyisoprene molecules whereas synthetic nitrile rubber (NBS) is a co-polymer of acrylonitrile and butadiene, which would be expected to be more polar in nature. Other commonly available polymers in India include SBR, a styrene butadiene co-polymer, as well as “triblock” co-polymers, also known as styrene-butadiene-styrene (SBS) and styrene-isoprene-styrene (SIS) rubbers, which would be expected to have even higher polarity and hence release compounds such as Z11-16OH more slowly than non-polar LDPE.

Comparison of various commercial lures. Several SMEs in India have commercialized sex pheromone of EFSB. However, the amount of pheromone chemical and type of dispensers they use vary considerably. As a result, the effectiveness of these lures also varies considerably. This poses a problem for farmers looking for the best product. NRI has been assisting SMEs in India to develop quality products at affordable prices to ensure that the technology achieves sustainable impact beyond the project cycle.

In this study, the release of E11-16Ac from lures produced by seven companies (Fig. 10) was determined. The results (Fig. 11A) show that three of the lures released the pheromone quicker than NRI lures and four released the pheromone too slowly. On this basis, three of the company lures would be expected to catch higher numbers of moths than the NRI lure over the period of exposure (six weeks). However, this data is based on the percent loss from the original quantity of phero-

Fig. 10. *Types of dispensers used by various Indian SMEs to load sex pheromone of EFSB; the dispenser at the right hand bottom corner, made from low density polyethylene (LDPE), is often used by NRI and was included as a check*

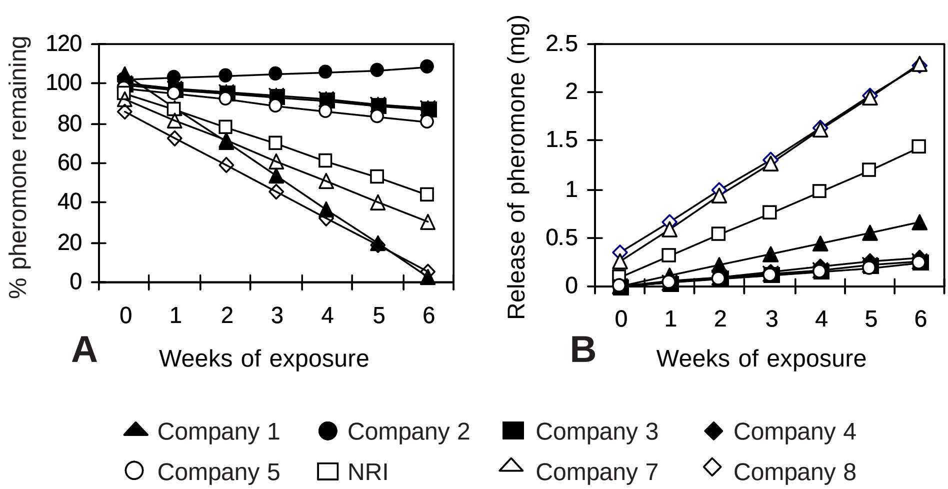


Fig. 11. *Comparison of release rates of pheromone chemicals (A), and cumulative release of pheromone chemicals (B) from various lures obtained from vendors in India*

mone used in loading the lure, which differed among the companies, and takes no account of the quantity used in loading of pheromone.

By expressing the data as cumulative release of pheromone (Fig. 11B), the data demonstrates that only two commercial lures released pheromone at a higher rate than the NRI lures (companies 4 and 8). These lures would be expected to catch higher numbers of moths than the NRI lures. Nevertheless, the results from field work conducted at AAU (Table 3) suggested that lures from companies 4 and 8 were not as attractive as the NRI lure. This result indicates that the attractiveness of lures as indicated by trap catch is not directly related to the release rate of the major component of the pheromone, E11-16:Ac, and that release of both components in the correct 100:1 ratio may be more important than hitherto appreciated.

Table 3. *Relationship between pheromone release and EFSB male moth catch in commercial EFSB lures*

Company/organization	Pheromone release over 6 weeks (mg)	No. moths caught per trap/night
Company 1	–0.42	7.7
Company 2	0.17	1.6
Company 3	0.72	11.7
Company 4	2.31	11.5
Company 5	0.24	27.5
National Resources Institute	1.44	24.1
Company 7	0.32	2.2
Company 8	2.29	2.7

4.5 Studies on the aging of commercial pheromone lures on trapping efficacy

Commercial lures obtained from seven Indian companies along with the standard lure from NRI were placed into sleeve traps erected in an empty field on the campus of AAU, Anand. The lures were allowed to remain outdoor or "age" for 1 to 6 weeks from 24 August to 5 October 2004 (Fig. 12). During this aging period, the maximum temperature ranged from 27.0 to 36.4 °C and minimum from 19.0 to 26.5 °C. There were only three rainy days and a total of 10 mm of rainfall during the six weeks. Daily wind velocity varied from

Fig. 12. *Aging of sex pheromone lures baited in the traps in an open field at AAU, Anand, Gujarat*

0.2 to 4.3 km/hour and except for the three overcast days, sunshine duration ranged from 3.5 to 10 hours per day. At the end of each week, five lures of each of eight units were brought back to the lab, sealed in aluminum foil containers, and stored in refrigerator until use. At the end of 6 weeks, three fresh lures as well as three aged ones for each of the designated aging durations, and of each company and NRI were tested in the eggplant field for their efficacy in attracting EFSB male moths. Each lure was baited in an individual sleeve trap erected slightly above plant canopy with a distance of 10 m between two adjacent traps. There were 56 treatment combinations (8 companies × 7 aging periods) and 3 replicates arranged in a randomized complete block design. This experiment was done in Zaria village in Bhavnagar District of Gujarat. The number of moths trapped in each trap was recorded every morning for six consecutive days.

Results of this test are summarized in Fig. 13. As expected, all lures lost effectiveness and such loss was proportional to the aging period. However, lures from Margo attracted consistently higher numbers of EFSB moths compared with all other companies. The effectiveness of Margo lures was comparable with standard lures loaded with 3 mg of pheromone, supplied by NRI. Lures from all other companies, except Indore Biotech, Agriland Biotech and Ganesh Biocontrol, lost efficacy within one week; Indore's lures were as good as Margo's for the first three weeks; whereas Agriland and Ganesh products had comparable effectiveness for only two weeks.

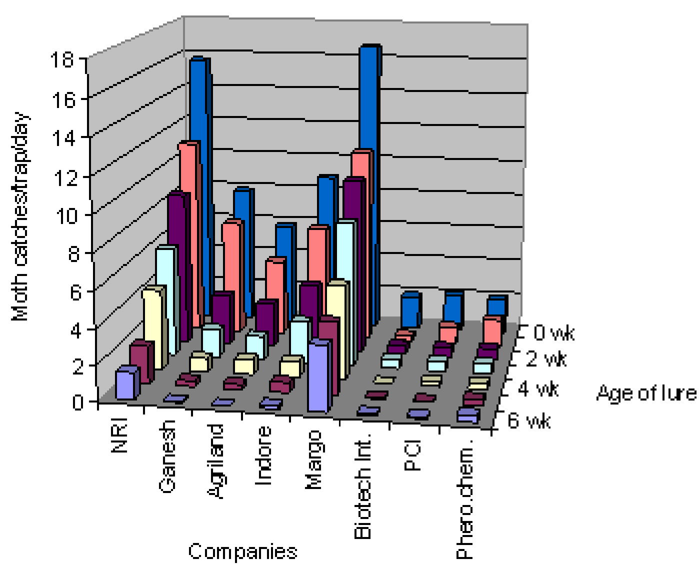


Fig. 13.*Effects of aging of sex pheromone lures, obtained from various Indian vendors, on attracting EFSB males*

Duration of effectiveness depends on the purity and the quantity of the pheromone chemical used in loading each lure. All companies but PCI used chemicals supplied by one source. However, getting reliable information from the companies on the quantity of chemical they used in loading lures was difficult to come by. For pheromone use to be competitive with chemical control measures, the optimum duration of effectiveness, similar to one obtained with NRI lures, should be four weeks.

In another study, the effect of storage temperature on shelf life of lures packed in aluminized sachets was studied using *Helicoverpa armigera* pheromone, which is approximately twice as volatile as that of EFSB. Lures loaded with 2 mg of pheromone chemical were stored at –20 °C, +5 °C and +20 °C for six months and the chemical retained in the lures at the end of storage period was analyzed. The results (Table 4) confirmed that pheromone release was essentially stopped at –20 °C with only 1% loss. Much higher losses of pheromone occurred under refrigerated and ambient room temperatures. The vendors need to store pheromone lures of EFSB in freezers until sold to the users.

Table 4. *Effect of storage conditions on pheromone lures in aluminized sachets*

Temperature	Storage unit	Pheromone (mg)	Percentage loss	Loss per day (μg)
–20 °C	Freezer	1.98	1.0	0.11
+5 °C	Refrigerator	1.75	12.5	1.37
+20 °C	Room	1.31	34.5	3.78

4.6 Efficiency of EFSB lures marketed in India

There are as many as nine SMEs in India currently selling sex pheromone of EFSB throughout the country. All these companies started commercialization of the product only after the utility of sex pheromone in combating EFSB was demonstrated in the early years of the first phase of this project. These companies are using different materials for manufacture of the dispensers, loading dispensers with different quantities of pheromone chemicals, and utilizing different procedures in loading the pheromone. Generally various types of polyethylene or rubber are used as the carrier for the sex pheromone. Considering the varying physical properties of different materials under different weather conditions, the performance of sex pheromone lures could vary with manufacturer. Therefore, a field experiment was carried during autumn of 2004 in Bhavnagar District of Gujarat to evaluate EFSB pheromone lures marketed by different companies in India. Lures obtained from eight local companies and NRI were included in this evaluation. Each lure was baited in a sleeve trap and the traps were erected 10 m apart making sure the lure is just above the crop canopy. There were nine treatments, each treatment representing an individual vendor, three replications, and plots were arranged in randomized complete block design. Lures were replaced with fresh ones after every three weeks. The numbers of EFSB adults trapped were recorded once every week for 10 weeks.

The data on moth catches pooled over time revealed that the lures of Indore Biotech and NRI performed best (Table 5) and were at par with each other and differed significantly from the lures of the rest of the companies. The next best lures were from Ganesh Biocontrol, Margo Biocontrols, Agriland Biotech and Pest Control (India) Ltd., which were at par with each other. The lures of A.G. Bio Systems and Basarass Biocontrol (India) Pvt. Ltd. were at par and comparatively less effective but significantly more effective than that of Biotech International Ltd., the least effective lure. The variation in moth trapping efficiency of lures marketed by different companies might be due to differences in the type of dispenser, quality, and quantity of sex pheromone. Thus, constant field evaluation at different locations and monitoring of lures manufactured and marketed by different companies is necessary for quality control.

4.7 Evaluation of pheromone traps for capturing EFSB

During the first phase of this project, various readily available traps developed for other pest insects as well as a few indigenously designed ones were tested for their suitability for trapping EFSB males. We tested a funnel-type sleeve trap, which consists of a detachable flat top over a funnel receptacle with a long plastic bag attached to the tapering end of the funnel hanging downwards. This trap, which is readily available and used widely in India in trapping of *Helicoverpa armigera* in cotton, proved to be superior to most others. However these traps are not easily available in all areas of the country and are also costlier. An attempt was therefore made to minimize these constraints and develop a simple, easy to make, and economical trap made from locally available empty mineral water or soft drink bottles, which otherwise go to waste. These traps were evaluated at AAU for their efficiency in trapping EFSB males in comparison with a few readily available and modified design traps. The following types of traps were utilized:

1. Water trough traps. A 2-L capacity plastic round jar was used to prepare the water trough traps. Two (15 × 7 cm), three (9 × 7 cm) or four (6 × 7 cm) rectangular windows were cut open in the wall of jar, 3–4 cm above the bottom, for entry of moths into the trap. The lure was kept hanging inside the jar just above the soapy water added to a depth of 2–3 cm at the bottom.

2. Funnel traps from plastic bottles. A simple and locally made trap was prepared from an empty mineral water/soft drink bottle. After removing the screw cap the top section of the bottle was cut at the end of funnel-shaped portion (Fig. 14). The funnel-shaped cut portion was then placed in an inverted position over the remaining portion of the bottle and secured by tape. Finally, the lowest 2-cm portion of the bottom was cut and fixed in the inverted position in the hollow cut portion of the bottle. This bottom portion could be detached and attached when needed to remove dead moths collected in the main body of the bottle (Fig. 14).

Table 5. *Number of moths caught per trap, by week, of various traps manufactured/marketed by various companies in India*

Enterprise	Week									
	1	2	3	4	5	6	7	8	9	10
Indore Biotech	14.33 ab	11.00 ab	10.00 a	10.33 a	8.67 a	8.67 a	12.00 a	8.00 a	10.00 a	10.50 a
Natural Resources Institute	18.00 a	12.33 a	10.00 a	7.67 abc	9.00 a	8.33 ab	12.00 a	8.33 a	8.33 ab	10.23 ab
Ganesh Biocontrol	11.67 b	9.00 ab	7.00 abc	7.67 abc	6.67 ab	8.00 ab	9.00 a	7.00 ab	10.67 a	8.50 ab
Margo Biocontrols	12.00 b	7.00 ab	7.33 ab	10.00 a	6.67 ab	8.33 a	8.67 a	9.33 a	8.67 ab	8.60 ab
Agriland Biotech	10.67 bc	8.33 ab	6.33 bc	8.00 abc	5.00 bc	6.33 bc	9.67 a	7.00 ab	7.33 ab	7.80 a
Pest Control (India)	10.33 bc	6.67 b	9.00 ab	9.67 ab	6.67 ab	7.67 bc	8.67 a	7.00 ab	6.33 ab	7.70 bc
A.G. Bio Systems	6.67 cd	6.67 b	6.67 abc	5.00 bc	3.33 c	4.67 bc	7.00 ab	3.00 c	4.00 bc	5.20 bc
Basarass Biocontrol	5.33 d	6.33 b	4.33 cd	4.33 cd	2.67 c	4.00 c	4.00 b	3.33 bc	4.33 bc	4.27 c
Biotech International	2.33 e	2.00 c	2.33 d	2.00 d	0.67 d	0.33 d	4.00 b	2.00 c	2.67 c	1.83 d
Mean	09.42	2.78	6.22	7.18	5.48	6.25	8.33	6.11	6.92	7.18
SE ± Treatment	0.25	0.29	0.19	0.28	0.19	0.24	0.29	0.27	0.33	0.23
CD (5%)	0.76	0.86	0.56	0.85	0.56	0.73	0.88	0.82	1.00	0.71
CV (%)	14.01	17.97	12.37	18.53	13.85	17.20	17.90	19.34	22.32	16.52

Standard sleeve trap of Agriland was used and lures were changed at three-week intervals.
Means in the same column followed by same letters are not significantly different at 5% level.

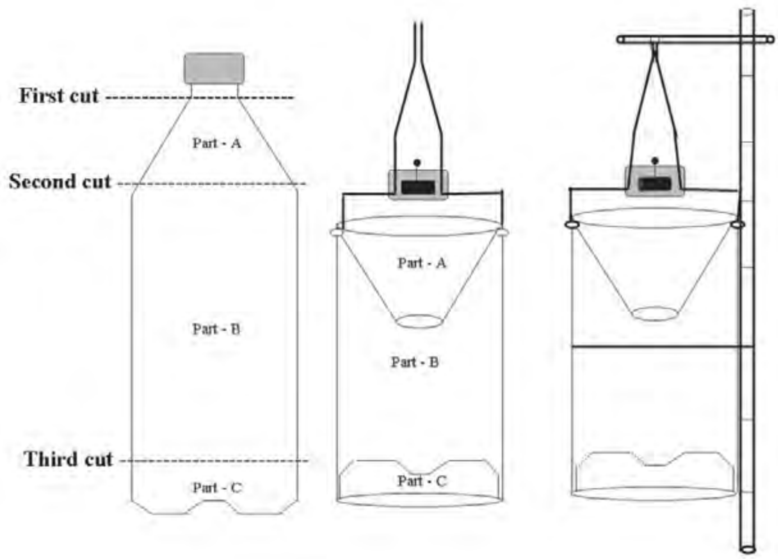


Fig. 14. *Design and assembly of "Anand Phero-trap" made from discarded plastic bottles*

The lure was hung inside the bottle cap and tied to the trap in such a way as to have it suspended 0.5–1 cm above the upper edge of the funnel.

3. Modified sleeve traps. Standard sleeve traps with 2–3 pegs were modified by trimming down the size of the top to only the central 2-cm-diameter disk. This disk was attached over the funnel by only one peg; remaining pegs were cut and discarded. The modified top was then attached to the original funnel bottom. The lure was fixed into original socket under the modified top. Reducing the size of the top as well as removal of extra pegs, it was thought, would reduce obstacles for the entry of attracted moths into the funnel, thus potentially increasing the number of moths trapped.

4. Standard sleeve traps. Standard funnel-type sleeve traps manufactured by Agriland Biotech Ltd. and Ganesh Biocontrol Systems were used as a check.

The results summarized in Table 6 revealed that the bottle trap worked best at catching EFSB moths. The standard sleeve trap was the next best effective, which was at par with the modified Ganesh trap with 3 pegs and water trough trap with two windows. The bottle traps have since been named the Anand-Phero trap by AAU. In addition to its superior trapping efficiency, use of this trap overcomes the need for a long plastic bag, which sometimes gets torn by birds or rodents or even jackals trying to feed on the moths found inside the transparent bag. Moreover, the Anand Phero-trap is cheaper, long lasting and can be prepared by farmers themselves using empty plastic bottles. Such use of discarded plastic bottles also helps to reduce environmental pollution.

Table 6. *Number of moths caught per trap, by week, in locally designed and commercial traps*

Trap design	Week 1	2	3	4	5	6	7	8	9	10
Water trough trap w/ 2 rectangular windows	9.67	4.67	3.67	10.00	13.33	12.67	8.00	9.33	7.67	6.67
Water trough trap w/ 3 rectangular windows	6.33	5.00	4.67	7.67	11.00	6.67	6.00	9.33	8.00	1.33
Water trough trap w/ 4 rectangular windows	4.33	3.00	5.33	4.67	9.00	6.33	3.33	4.67	8.00	2.00
Funnel trap from 1-L polyethylene bottle	19.00	10.00	12.00	17.67	20.33	17.00	10.67	14.33	15.33	11.67
Funnel trap from 1.5-L soft drink bottle	16.67	10.33	9.00	18.33	18.00	15.67	11.33	13.67	12.00	13.00
Sleeve trap with modified top w/ 3 pegs	13.00	7.67	8.67	14.00	15.33	12.67	8.33	11.33	11.00	10.33
Sleeve trap with modified top w/ 1 peg	5.00	3.67	3.67	11.67	11.00	9.67	6.33	8.33	8.67	7.00
Standard sleeve trap of Ganesh	8.00	4.67	9.33	10.33	16.67	14.00	9.33	11.33	7.67	6.00
Standard sleeve trap of Agriland	6.00	7.00	8.00	13.33	15.67	13.00	9.00	8.00	8.67	7.33
S E ± Treatment	0.28	0.26	0.33	0.52	0.37	0.34	0.40	0.41	0.29	0.28
CD (5%)	0.83	0.79	0.97	NS	NS	1.01	NS	NS	NS	0.85
CV (%)	15.72	18.18	21.21	26.43	16.68	16.94	24.24	22.49	15.81	18.69

Lures supplied by NRI were used and were changed at four-week intervals.
NS: Not significant.

5 Promotion of IPM

Organization of farmers' field days at pilot project sites, training of farmers in the use of sex pheromone and other IPM practices, open dialog meetings between farmers and scientists, production and screening of a film documentary in local languages, news releases, newspaper and magazine articles, radio and television talk shows, interviews with the press, posters, wall writings, and the production and distribution of specialized brochures and leaflets formed the bulk of this project's IPM promotion activities. These tools were used liberally to spread the message of IPM among vegetable farmers, extension workers, consumers, and policy makers to promote this IPM strategy.

5.1 Farmers' Field Days

The major purpose of field days was to show the community of farmers how the project farmers, who are their neighbors and in some cases relatives, are reducing EFSB damage to their eggplant by adopting our IPM strategy instead of routinely using chemical pesticides. This type of farmer-to-farmer demonstration is much more effective than mere lectures by specialists on IPM. A typical farmers' field day, conducted always at the pilot project implementation site, consisted of an advance announcement of the date, time, and location of the field day event followed by inviting all vegetable farmers within the community as well as neighboring ones to attend. Inviting reporters from newspapers, farm magazines, radio stations and television stations to cover the event was an important part of the preparation of field days. On most such occasions, efforts were made to invite local, regional, or even national political leaders to attend the field days. Attendance of such personalities drew larger crowds of farmers as well as the press and this, in turn, generated more publicity for the project activities. In the future, these political leaders may help to promote the adoption of IPM-friendly policies at the policy making level. The field days also drew attention to the misuse of pesticides practiced by vegetable farmers, which is causing increasing concern among consumers and environmentalists. Besides on-spot demonstrations of procedures involved in IPM strategy, such events provided an opportunity to distribute brochures, leaflets, flyers and other promotional materials. Such events also promoted dialog between farmers and researchers, which was mutually beneficial.

Organization of farmers' field days began in the earnest during the first cropping season in spring of 2004, six months after initiation of the project in October 2003. This delay was largely due to cool weather from November through February, which was not suitable for eggplant production in most parts of the Indian subcontinent, although some farmers plant this vegetable throughout the year. The field day activities undertaken by various sites are described below:

5.1.1 Bangladesh

BARI organized four field days in Jessore, five in Bogra, two in Norsingdi, and one in Pabna pilot project sites. The field days held in four villages in Jessore were organized on 5 June, 3 October, 25 November 2005 and 7 January 2006. The first field day on 5 June 2005 at Kazura Bazar, a pilot project village, was attended by over 515 farmers. In addition to local farmers, select farmers from Bogra, Norsingdi, and Pabna sites also participated in this daylong event. A special invitee, the Bangladesh Minister for Agriculture, Mr. M.K. Anwar, attended the event (Fig. 15). The Minister's presence attracted a large contingent of press, government officials, scientists from various research organizations, and representatives of non-governmental organizations (NGOs). This, as expected, generated lots of publicity in both print and electronic media. In an open dialog with the Minister, farmers lobbied for speedy registration of sex pheromone of EFSB so that they can easily purchase and use the pheromone whenever needed. As required, BARI provided all technical data and requested to register the pheromone to the Department of Agricultural Extension (DAE), the government body that handles registration of all pest control agents. In late 2005, Bangladesh parliament passed a law that will facilitate registration and use of sex pheromone and similar other chemicals for pest control in the country. DAE and other agencies are now working on details to enforce the law.

Fig. 15. *Farmers' field day in Jessore, Bangladesh, attended by Mr. M.K. Anwar, Minister for Agriculture (see arrow); attendance of events by VIPs attracted more farmers and the press, which helped spread the IPM message*

The second field day, attended by 120 farmers, was held in Mominnagar. The third field day was attended by 130 farmers in Gaidghat and the last field day was attended by 150 farmers in Moniramput.

Between April 2004 and May 2005, BARI organized five field days in Bogra District. These events were attended by a total of 350 farmers. Two such events in Norsingdi and one in Pabna attracted a total of 380 farmers. Some of the pilot project implementation activities, including field days, were in collaboration with NGOs, such as MCC (Mennonite Central Committee), PROSHIKA (acronym of Bengali name of a local NGO), MPUS (Montri Polli Unnaya Sagastra or Friendly Rural Development Association), government organizations such as OFRD (On Farm Research Division of BARI) as well as Syngenta, a private enterprise. These organizations were very helpful in getting a wide array of farmers to participate in the field day events.

5.1.2 Gujarat

All pilot project activities carried out by AAU were confined to Bhavnagar District of Gujarat State. AAU conducted six field days during 2004–2005. The dates, locations, and the number of farmers and others attending the field days are listed in Table 7. The highlight of each of the AAU-organized field days was the attendance of the Vice Chancellor, the de facto head of the university, and the Director of Research, at these events. Both officials came with a contingent of faculty members. The presence of so many specialists gave way to lively dialogs between farmers and AAU scientists, which covered all aspects of cultivation of eggplant, besides other vegetable industry problems (Fig. 16). On such occasions, the project recognized farmers who faithfully followed IPM by offering a shawl, which was tied around shoulders of the recipient by a VIP. This is a local tradition of Gujarat. Almost all field days were also attended by representatives of Gujarat State Directorate of Horticulture. The Directorate has now included lures and traps in the list of items to be subsidized in order to promote IPM in the State. In addition to inviting reporters of print, radio and television media, AAU was active in getting representatives of agricultural marketing societies, pesticide companies, and SMEs that commercialize bio-pesticides and sex pheromones to attend the field days. The attendance of these representatives was especially useful to all concerned in getting to know the difficulties farmers encounter in the use of sex pheromone, which is a new tool for combating insect pests.

Table 7. *Details of farmers' field days organized by AAU in Bhavnagar District of Gujarat State, India*

Date	Place	No. of farmers attending
3 February 2004	Khadsaliya	350
9 June 2004	Krushanapura	400
25 September 2004	Vavdi	300
24 February 2005	Bhadli	450
11 June 2005	Hathab	500
5 December	Bhadi	350

Fig. 16. *AAU scientists and IPM farmers share information with participants (left); following farm visit, farmers attend open forum discussion (center); at which time greetings of IPM farmers is done by VIP attending the field day (right) in Bhavnagar District, Gujarat, India*

The field day at Vavdi village on 25 September 2004 was also attended by Mr. Sunilbhai Oza, a local MLA (Member of Legislative Assembly or State Parliament). This generated wide publicity in newspapers and electronic media and helped AAU to drive home the message of available alternatives to chemical pesticides in growing vegetables. AAU also availed the field days to distribute brochures, leaflets, and other promotional materials (see Section 5.3.2 for details).

5.1.3 Orissa

In Orissa, OUAT conducted two major field days, on 2 June 2004 (Kaluchuapatna Village) and 29 September 2004 (Nidhipur Village). These field days were attended by about 100 farmers each. OUAT also conducted two dialog meetings with farmers, the first on 23 March 2005 (Siko Village) and the second on 31 October 2005 (Pindamula Village). The total attendance at these events was approximately 150, and 200, respectively. During field days, farmers had the opportunity to interact with specialists from OUAT, including professors and research administrators (Fig. 17), as well as the project coordinators from IIVR and AVRDC. For dialog meetings, only farmers in the community were invited for the question-and-answer session with project staff to understand farmers' problems and inform them of the latest developments in EFSB IPM. Similar to other sites, besides demonstration of IPM procedures, there was active dialog among farmers as well as between farmers and research specialists. Field day activities were covered by print, radio and television media.

Fig. 17. *OUAT scientist explains IPM procedure to farmers at field day in Khurda District, Orissa, India*

5.1.4 Jharkhand

RKM is well recognized all over India for its work on improving welfare of the rural poor, most of whom are farmers. RKM conducted two pilot project studies in Angara, and one each in Murhu and Burmu blocks in Ranchi District of Jharkhand. They organized three field days, one each on 21 August 2004, 25 October 2004, and 6 September 2005. These events held in Iteh, Baburamdih, and Pachpade villages of Ranchi District were attended by 336, 212, and 218 farmers, respectively. The field day at Iteh was attended by Mr. Ramchandra Naik, local MLA, which attracted a large group of farmers. The major emphasis of RKM in promoting IPM was on daylong training of farmers, and several of such trainings were conducted during 2004 and 2005. Details of the training activities are covered in Section 5.2.3.

5.1.5 West Bengal

Main pilot project activities by Shantiniketan were carried out in several villages in Birbhum District of West Bengal. These villages are among a block of villages adopted by Shantiniketan for their Institute of Agriculture's extension and student training activities. The major portion of IPM promotion activities linked to pilot projects involved training farmers.

In addition, Shantiniketan conducted two field days, one each in 2004 and 2005. The first field day was scheduled for 14 August 2004 in Kankutia Village but due to heavy rains on previous evenings, the eggplant planting was submerged; field day activities, including dialog between farmers and Sriniketan Agriculture faculty, were done the next day in Sriniketan Community Hall. About 160 farmers from eight villages participated in the dialog with the Vice Chancellor, faculty of the Institute of Agriculture, and other staff of the University.

A year later, the second field day was held in the same village on 21 August 2005. It was attended by the Vice Chancellor, faculty of the Institute of Agriculture, and nearly 300 farmers. Both field days were attended by the Director of the Department of Agriculture of the West Bengal State, who promised to continue promotion of the IPM, with government funding, in other districts of West Bengal following termination of the DFID funding for the project. Both field days were covered by print and broadcast media.

5.1.6 Meghalaya-Tripura

ICAR-NEH Shillong initially conducted pilot project studies at Mawlasnai Village in Meghalaya State. However, due to heavy monsoon rains from June to October and the onset of cool winter soon after that until March, eggplant cultivation was much less profitable in Meghalaya than in neighboring states, especially Tripura. Therefore, after the first season, the pilot project implementation was moved to Tripura, with minimal activities maintained in Meghalaya.

Like in neighboring Bangladesh, eggplant is the most important vegetable in Tripura and pesticide use in combating EFSB is very high. Tripura is a hilly state and agriculture is feasible in narrow valleys. Landholdings are small and the average eggplant field rarely exceeds 200 square meters. The project activities administered by ICAR-NEH, Shillong, were conducted through Tripura Station of ICAR-NEH, located in the outskirts of the state capital, Agartala. During the first crop season, ICAR-NEH conducted one field day on 29 May 2004 that was attended by about 70 local and neighboring village farmers (Fig. 18). For the rest of the project period, they conducted pilot projects at Teliamura, Lankamura, and Hawaibari villages in West Tripura District. Dialog meetings with farmers were held 11, 12 and 31 March and 1 April 2004 at these villages. Three field days, one each on 18 and 19 August 2004 and on 28 February 2005, were organized at Hawaibari, Lankamura, and again at Lankamura, respectively. A total of 250 farmers

Fig. 18. *Farmers' field day activities in West Tripura District of Tripura State, India*

attended the three events. For the last farmers' field day on 28 February 2005, ICAR-NEH invited the Director of Horticulture of Tripura State to attend the meeting. The Director assured farmers and project staff that the State Department of Horticulture will continue IPM promotion activities after DFID funding for the project is terminated in January 2006. Dialog meetings with groups of farmers continued until the end of November 2005.

Because of the communication difficulties in this largely tribal area, organization of large-scale field days proved to be difficult. The main language in Tripura is Bengali, therefore, the brochures, leaflets and other promotional material produced by Shantiniketan were distributed during dialog meetings and field days.

5.1.7 Uttar Pradesh

In Uttar Pradesh, IIVR conducted pilot project implementation in a cluster of villages in Mirzapur, Varanasi, and Chandauli Districts of that state. IIVR organized four field days in 2004, one each on 21 June (Araziline and Sultanpur Villages), 31 July (Basavn Village), 27 September (IIVR Campus), and 3 November (Basavn Village). A total of 630 farmers attended these events. In addition to demonstration of IPM procedures and distribution of extension brochures, IIVR organized open dialog between farmers and the IIVR scientists. In 2005, IIVR opted for Rane Village in Varanasi District for project implementation and instead of a field day, they organized a series of dialog meetings between farmers and the project staff.

5.2 Training of farmers

Training of farmers in IPM of EFSB involved the following activities:

1. Demonstration of the use of sex pheromone, including assembly of pheromone trap, how and when to erect the traps in the field, how often to change the lures, and upkeep of traps and lures.
2. Emphasis on prompt cutting and proper disposal of EFSB-damaged shoots, as often as possible, but at least once a week starting from first flowering. Proper disposal of damaged shoots and fruits was also demonstrated.

3. Improvement in general field sanitation with emphasis on removal of sources of EFSB infestation before planting a new crop. These EFSB sources are old plantings still present in the field, stacks of harvested plants scattered around or stored carefully for use as a fuel for cooking.
4. Withholding the use of any chemical insecticide to control insect pests unless absolutely necessary was especially emphasized.
5. Emphasis was placed on the need to have a community approach in following all of the above steps to reduce pest populations and how such an approach will benefit the society.

Training was aided by a specially-produced film documentary which illustrated details of biology of the insect, how it moved from one eggplant field to other, and principles and procedures involved in adopting the IPM. This documentary entitled "How to control eggplant fruit and shoot borer: A safer IPM approach" was produced early in 2004 in English and was dubbed in all local languages, including Bengali, Gujarati, Hindi, Khasi and Oriya. The training was also supplemented by three brochures originally produced in English by AVRDC staff and translated into the above five languages by project site staff. These brochures included:

1. How to Control Eggplant Fruit and Shoot Borer (15 pages)
2. A Farmer's Guide to Harmful and Helpful Insects in Eggplant Fields (21 pages)
3. How to Use Sex Pheromone for Controlling Eggplant Fruit and Shoot Borer (21 pages)

Although each site did some form of training of farmers, especially during field days, training to promote IPM was a major activity in Bangladesh, Gujarat, Jharkhand and West Bengal. Each training session lasted one full day. All training was done by project staff in local language and on pilot project fields or at times in a hall or classroom facilities available nearest to such fields. Details of training by concerned sites are described below:

5.2.1 Bangladesh

Training was started in Bangladesh from the initiation of the project once BARI decided to conduct pilot projects in Jessore, Bogra, Norsingdi, and Pabna Districts. The training was conducted at all sites at intervals throughout the project period. A total of 1,087 farmers were trained through 23 one-day training sessions during the first two years (Fig. 19). BARI also conducted a special training for 275 field staff of the

Fig. 19. *BARI scientist trains farmers in Norsingdi, Bangladesh*

Department of Agricultural Extension, Sub-District Agricultural Officers, additional Agricultural Officers, and Block Supervisors. These staffs were to take over training of farmers outside the project areas especially after the project is terminated.

5.2.2 Gujarat

AAU organized 2 one-day training courses, one each in Ramdhari Village (10 June 2005) and Navajuna Rajapara Village (22 September 2005). Through these courses, AAU trained a total of 295 farmers.

5.2.3 Jharkhand

Farmers' training, in which rural RKM has considerable experience through their decades-long developmental activities, was a major part of RKM's project promotion activities (Fig. 20). From January 2004 to November 2005, RKM conducted 62 one-day courses and trained 7,049 farmers in IPM strategy to combat EFSB.

Fig. 20. *RKM staff train farmers on IPM principles (left) and assembling of sex pheromone traps (right) in Jharkhand, India*

5.2.4 West Bengal

The Institute of Agriculture at Sriniketan has long established a tradition of working with farmers for the institute's extension activities including training of their students. From January 2004 to November 2005 they conducted 36 one-day training classes and trained 1,553 farmers in IPM of EFSB (Fig. 21).

Fig. 21. *Shantiniketan staff train farmers on the use of sex pheromone traps in West Bengal, India*

5.3 Production and distribution of IPM promotional materials

Various audiovisual aids, such as a film documentary, brochures, leaflets, posters, wall writings, thematic puppet shows, press releases, radio and television talk shows, press interviews and advertisements were utilized to drive home the message of IPM. Among these, the film documentary and brochures were first produced in English at AVRDC and later dubbed or translated into local or regional languages. All other items were produced by local site coordinators.

5.3.1 Film documentary

The script for a film documentary entitled "How to control eggplant fruit and shoot borer: A safer IPM approach" (Appendix 1), was written by AVRDC staff. After competitive bidding, Y-Media, a family-run company in New Delhi, India, won the bid and produced this 25-minute documentary. The original English commentary was dubbed into Bengali, Gujarati, Hindi, Khasi, and Oriya, the local languages in various states of India and Bangladesh. AVRDC maintains the original copy and copyright but allows interested parties to use its English or local-language dubbed version for non-commercial purposes. This documentary (Fig. 22) was used by various project sites for telecast on local stations' farming programs, and shown to farmers and other audiences during field day or specially appointed days, and in training of farmers. Some sites distributed CDs of the documentary to NGOs and government agencies for use in training.

Fig. 22. *Tapes and CDs of a documentary on IPM of EFSB were produced in local languages and telecast over TV channels in Bangladesh and India as well as screened during farmers' meetings and training*

<u>*Bangladesh*</u>. BARI modified the documentary slightly to fit its local scene. It was telecast five times (12 and 16 February, 14 and 18 May, and 12 December 2005) under "Praikirti and Poribash" (Nature and Environment) on BTV (Bangladesh TV), the only nationwide TV channel in the country (Fig. 23). Excerpts of the documentary were also shown on RTV, a privately-owned channel on 5 January 2006. BTV also telecast the entire documentary under their new program *Mati O Manush*, a farm program, on 22 January 2006. Each program was watched by an estimated audience of 200,000 farmers throughout the country. The documentary was shown 62 times to groups of farmers and extension workers at various project sites. The screening was also conducted for the benefit of IPM courses conducted by DAE in collaboration with DANIDA (Danish International Development Agency), and two local organizations, NCDP (National Crop

Fig. 23. *Stills from telecast of Bengali version of documentary on BTV in Bangladesh*

Diversification Project) and IHAN (Integrated Horticulture and Applied Nutrition Project).

Fig. 24. *Screening of documentary in a village in Bhavnagar District, Gujarat, India*

Gujarat. The documentary was dubbed in Gujarati and telecast on Doordarshan, the national TV channel, four times: 15 March, 1 June, 19 August, and 26 September 2005. It was shown 15 times to select groups of farmers and others and was viewed by a total of 1,022 persons (Fig. 24). AAU also distributed 102 CD copies of the documentary to progressive farmers, Krishi Vigyan Kendras (Agricultural Technology Centers), state agricultural extension functionaries, pesticide/pheromone dealers, seed companies, commercial nursery growers, and local cable TV operators for use in their farm programs. AAU also took advantage of local farmers' liking for puppet shows and organized one such show depicting IPM themes (Fig. 25). This attracted a large crowd, which also viewed the IPM documentary that followed the puppet show.

Fig. 25. *Puppet show depicting theme of IPM in Bhavnagar District, Gujarat, India*

Orissa. The Oriya version of the documentary was telecast on the Bhubaneswar station of Doordarshan on 16 January 2005. OUAT was not able to use the documentary during field days or farmers' meetings due to the remoteness of the largely tribal villages where electricity is either not available or supply is not assured. Field day events of OUAT were covered on private television channels.

Jharkhand. RKM did not get the documentary telecast on any channels, however, it was shown in five villages. The screening was attended by a total of 565 farmers. The documentary in Hindi was telecast in neighboring Uttar Pradesh and benefited Jharkhand farmers because Hindi is a common language in both states.

West Bengal. Shantiniketan made extensive use of the documentary in training and promotion of IPM in West Bengal. The film was shown 12 times to groups of farmers as a part of motivational training. A total of 535 farmers viewed the documentary. The documentary was also shown during the Shantiniketan annual gathering featuring cultural activities participated by people from neighboring towns and village. About 2,000 farmers viewed the documentary. Shantiniketan managed to get the Bengali version of the documentary telecast over the local station of Doordarshan four times from November to December 2004.

Fig. 26. *Screening of documentary on TV set during farmers' meeting in West Tripura District of Tripura State, India*

Meghalaya-Tripura. ICAR-NEH screened the documentary dubbed in Khasi language during a farmers' meeting in Mawlasnai village in Meghalaya State. The documentary was telecast on Doordarshan's Shillong station on 23 August, 8 and 30 September, 18 and 29 October, 16 November, and 6 December 2005. In Tripura, the documentary was telecast monthly from September

2004 to January 2005, the main eggplant growing season in the district, over the Agartala Station of Doordarshan. Tripura farmers were also able to view the documentary on BTV from neighboring Bangladesh. The documentary was also shown during farmers' meetings on 18 August in Lankamura and 19 August 2004 in Teliamura (Fig. 26). Thirty-seven farmers in the former and 65 farmers in the latter meeting viewed the documentary.

Uttar Pradesh. The Hindi version of the documentary was telecast from Varanasi Station of Doordarshan, the national channel, on 2 and 9 November 2004. This telecast was also viewed in neighboring states, including Jharkhand, Bihar, and Madhya Pradesh. The documentary was shown to more than 360 farmers from two villages and on the IIVR station itself to a stream of visitors and farmers from July to August 2004. It was also screened on the IIVR campus to a group of Directors of All-India Radio Stations in Uttar Pradesh and neighboring Uttaranchal State. This generated much interest and resulted in a flood of enquiries. IIVR project staff also found many farmers away from the pilot project area practicing IPM in managing EFSB.

5.3.2 Brochures and other printed materials

Three brochures written by AVRDC staff were the mainstay of the project's promotional activity via print media at all sites. These brochures entitled "How to Control Eggplant Fruit and Shoot Borer","A Farmers' Guide to Harmful and Helpful Insects in Eggplant Fields", and "How to Use Sex Pheromone for Controlling

Fig. 27. *Brochures produced by AVRDC, published on its web site, and subsequently translated in Bengali, Gujarati, Hindi, Khasi, and Oriya for local use in South Asia*

Eggplant Fruit and Shoot Borer" (Fig. 27), were written in simple terms and served as templates for translation and further simplification of the content in several local languages: Bengali, Gujarati, Hindi, Khasi, and Oriya (Fig. 28). The original English versions are posted on the AVRDC web site <www.avrdc.org> in downloadable format for anyone to access and print copies. In addition, some sites produced leaflets on specific topics in local languages for distribution during field days or during other farmers' gatherings. Each site also produced posters for posting at often-frequented locations by farmers, such as tea shops, pesticide dealer shops, vegetable markets, and similar locations.

Fig. 28. *Locally produced brochures formed an important part of IPM promotion*

Bangladesh. BARI printed a total of 7,500 copies of three brochures translated in Bengali. These brochures were distributed to farmers during field days, motivational trainings, or during other personal contacts. A total of 2,650 copies were distributed in this manner. BARI also mailed copies of brochures by postal service directly to individual farmers. Our survey during the first phase of this project indicated that nearly 73% of the vegetable farmers in Bangladesh have received primary or higher levels of education (Rashid et al., 2003) and are literate enough to understand brochures written in simple text and using numerous illustrations. We also observed in Bangladesh and elsewhere that farmers consider anything received by mail to be as important as the mail from distant family members. If educated, they read such mail themselves or had educated neighbors, schoolchildren or village school teachers read it for them. BARI mailed 4,850 copies of the brochures in this manner.

BARI printed and distributed 2,500 copies of two types of specially prepared posters depicting various steps in IPM of EFSB. These posters were distributed to various agencies such as government agricultural offices, NGOs, DAE offices, and BARI research stations for posting in important places easily seen by farmers. These posters were posted around village markets, tea shops, pesticide and other agricultural goods shops, schools, and similar structures often seen by farmers.

Gujarat. AAU distributed 8,650 copies of three extension brochures during the second and third year of the project. Distribution was done during field days, farmers' training, and special event exhibits of project activities. AAU also mailed 1,350 copies of the brochures by local postal service with the hope that farmers will read them and adopt the new IPM strategy to manage their EFSB pest problem (Fig. 29). Copies of the brochures were also sent to Gujarat State Departments of Agriculture, NGOs, and other extension functionaries. In addition, AAU produced and distributed 4,000 copies of a leaflet, which was an abridged version of the brochure on IPM practices to combat EFSB. AAU produced a farming calendar which listed detailed packages and practices for production and protection of healthy eggplant crops and timing of adopting various management practices. Four thousand copies of this wall calendar were distributed among farmers in 2004 and 2005. AAU also produced posters on EFSB themes and pasted them along roadsides, vegetable markets, tea shops, and similar other public places around project villages.

Fig. 29. *The postal service was utilized to send promotional materials to farmers*

Orissa. OUAT printed 750 copies of the three brochures in Oriya language. In addition, they also prepared one leaflet explaining in simple terms various steps in IPM of EFSB. All brochures and leaflets were distributed to farmers and others during farmers' field days and dialog meetings.

Jharkhand. RKM distributed 1,500 copies of the three brochures printed in Hindi to project farmers, their neighbors, and farmers participating in daylong training courses. RKM also produced a three-page leaflet in Hindi on IPM of EFSB. A total of 2,000 copies of that leaflet were distributed in five regional and one central farmers' gatherings they organized in Jharkhand. RKM produced two types of posters depicting various steps in IPM of EFSB. Five hundred copies of these posters were distributed to different NGOs, vegetable and fruit markets, and RKM's service organization that serves farmers and other rural society sectors. RKM also used walls of public buildings, market structures, or similar unclaimed structures along the road or marketplaces to write messages of IPM. These messages were written in poetic verses, to send the message of IPM to farmers and the general public (Fig. 30).

Fig. 30. *Messages were written on walls along roads or farmer-frequented places to promote IPM; shown here are writings in Jharkhand (left) and Gujarat (right)*

West Bengal. In addition to Bengali translation of three brochures, Shantiniketan also produced two leaflets on the use of sex pheromone and three posters depicting various themes of IPM of EFSB. These promotional materials were distributed to farmers during field days and training classes not only within the project's implementation area but in other areas of West Bengal where project members were often invited to give demonstrations of the IPM strategy. A total of 2,660 brochures, 2,530 leaflets, and 1,130 posters were distributed. Posters were displayed in areas frequented by vegetable farmers (Fig. 31).

Fig. 31. *IPM thematic poster in Bengali posted on tree in area near eggplant fields*

Meghalaya – Tripura. During the first year of the project when the activity was confined to Meghalaya only, ICAR-NEH published a translation of the first IPM brochure in Khasi, the predominant language in Meghalaya and distributed copies among project farmers, their neighbors and others who attended field days and farmers' meetings. When the project implementation was moved to Tripura, a Bengali translation of the three brochures printed by the Shantiniketan site in West Bengal was distributed. ICAR-NEH mailed 200 copies of brochures to farmers by local postal service in addition to giving brochures to participants during field days and dialog meetings with farmers.

Uttar Pradesh. IIVR published translation of three brochures in Hindi. During the first printing, IIVR shared some copies with RKM in Jharkhand, which is also a Hindi-speaking state. However, later RKM printed additional copies for their own use. IIVR distributed over 500 copies of each brochure to farmers during field days and dialog meetings and those eggplant farmers visiting IIVR campus. They also mailed 300 copies to farmers by local postal service.

5.4 Print and electronic media coverage of project activities

All project sites availed the presence of various forms of print and electronic media in the region to convey the message of IPM in combating EFSB and indirectly pointed out the danger posed by the current abuse of chemical pesticides. These approaches included print press releases, press briefings, press coverage of farmers' field days, and farmers' training, advertisements, radio and television talk shows, and press interviews. These activities at each site are summarized below:

5.4.1 Bangladesh

Project activities were featured 31 times in print media, mainly daily newspapers during 2004–2005 (Table 8). Activities were featured as news articles, editorials, and special features in Bengali as well as English languages. The English papers included *The Daily Star*, *The Financial Express*, *The Independence* and *Bangladesh Today*. The Bengali newspapers included *The Inquilab*, *The Prothom Alo*, *Dainik Dinkal*, *Dainik Ittafaq*, *Daily Ranner*, *Daily Lok Samaj*, *Dainik Janakantha*, *Gramer Khabor*, *Sangbad* and *Lokgon* (Fig. 32). Most of these papers have nationwide circulation. BARI organized two special news confer-

Table 8. *List of news articles published on EFSB IPM project activities in Bangladesh*

No.	Date of publication	Newspaper (language)	Remarks
1	26 May 2004	The Daily Star (English)	News article
2	16 June 2004	The Daily Star (English)	News article
3	16 June 2004	The Inquilab (Bengali)	News article
4	17 June 2004	The Prothom Alo (Bengali)	News article
5	20 June 2004	The Prothom Alo (Bengali)	Editorial comment
6	25 June 2004	The Prothom Alo (Bengali)	Special feature
7	18 June 2004	The Financial Express (English)	News article
8	17 June 2004	Dainik Dinkal (Bengali)	News article
9	18 June 2004	The Independence (English)	News article
10	16 September 2004	Dainik Ittafaq (Bengali)	Sub-editorial
11	26 October 2004	Amar Desh (Bengali)	Sub-editorial
12	9 February 2005	Daily Star (English)	News article
13	9 February 2005	Daily Ranner (Bengali)	News article
14	9 February 2005	Daily Puraby (Bengali)	News article
15	9 February 2005	Daily Lok Samaj (Bengali)	News article
16	17 February 2005	Bangladesh Today (English)	News article
17	6 June 2005	Dainik Janakantha (Bengali)	News article
18	6 June 2005	Gramer Khabor (Bengali)	News article
19	6 June 2005	The Inquilab (Bengali)	News article
20	6 June 2005	Dainik Dinkal (Bengali)	News article
21	1 August 2005	Sangbad (Bengali)	News article
22	5 August 2005	Lokgon (Bengali)	Feature
23	18 September 2005	The Inquilab (Bengali)	News article
24	21 September 2005	Dainik Dinkal (Bengali)	Editorial comment
26	13 November 2005	The Daily Runner (Bengali)	News article
27	15 November 2005	Naya Diganta (Bengali)	News article
28	19 November 2005	Daily Janakantha (Bengali)	News article
29	20 November 2005	Prathom Alo (Bengali)	News article
30	5 December 2005	Daily Star (English)	News article
31	27 December 2005	Manob Zamin	News article


যশোরের বন্দবিলায়
কীটনাশকবিহীন সবজি চাষে
কৃষকদের অসামান্য সাফল্য
The Daily Star
Goodbye pesticides

Fig. 32. *Clippings of news items featuring EFSB IPM activities in various newspapers of Bangladesh*

ences in Jessore, one each on 7 June 2004 and 7 February 2005. The farmers' field day presided over by the Minister for Agriculture was featured as news items on BTV, the national TV channel.

5.4.2 Gujarat

Pre- and post-event press notes for project activities such as demonstration of IPM strategy, farmers' field days, farmers' trainings, and others were published in leading newspapers, news magazines, and newsletters in the Bhavnagar area as well as in Central Gujarat. Such news items were featured on at least 43 occasions from November 2003 to the end of 2005. Most of the newspapers or magazines were in local Gujarati language and included *Sandesh*, *Saurashtra Samachar*, *Divya Bhaskar*, *Naya Padkar*, *Gujarat Samachar*, *College Flash*, *Krishigovidhya*, *Aaj Kal*, *Aas Pas*, *Krishidarshan*, *Akila*, *Pagdandi*, *Sardar Gurjari* and *Divya Bhaskar* (Fig. 33). In addition, AAU site project staff wrote four articles in Gujarati for popular magazines specializing in farming affairs: *Krishi Viswa*, *Krishi Sandesh*, *Krishijivan* and *Krishigovidya*. AAU staff also organized a special press briefing to both print and electronic media and distributed CDs of the film documentary and all published literature. Each field day activity was covered either during the evening news or the farming program. AAU staff also gave two talk shows, one each on Doordarshan and E-TV in Gujarati, on the importance of IPM strategy in managing EFSB.


આણંદ કૃષિ યુનિવર્સિટી દ્વારા વાવડી ખાતે ખેડૂત (રીંગણી) દિનનું કરાયેલ આયોજન
આણંદ કૃષિ યુનિ. દ્વારા વાવડી ખાતે તા. ૨૫મીએ યોજાશે ખેડૂત રીંગણી દિન

Fig. 33. *Clippings of news items featuring EFSB IPM activities in various newspapers of Gujarat, India*

5.4.3 Orissa

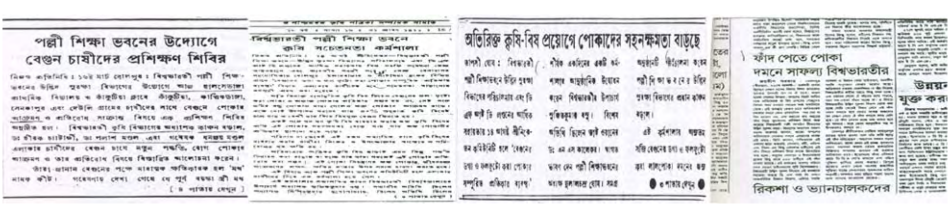
OUAT was active in publicizing the project via inviting media persons to attend field days, giving interviews, writing popular articles, and even advertising. The latter approach was followed to publicize the mandate of the project in local language newspapers. All three of OUAT's field days were featured in newspapers such as *Sambad* and *Pragatibadi*, which are published in the Oriya language. Doordarshan and E-TV taped the proceedings of a field day and used it at a later date in their farming programs. The project coordinator published an article on operation of the project in farm magazine *Krusak Bandhu Annapuna* in the initial stages of the project. Another article with a similar theme was published in Oriya in the OUAT Extension Bulletin *Chasira Sansar*.

5.4.4 Jharkhand

Initially RKM advertised the starting of our project and various planned activities in the local Hindi magazine *Divyayan Samachar* and repeated a similar advertisement one year later. The advertisement sought consumer awareness and farmers' participation in the project. Farmers' field day activities as well as some motivational training of farmers were covered in local newspapers such as *Aaj*, *Prabhal Khabhar* and *Ranchi Express*. The motivation training activities were also covered on the local channel of E-TV. This TV channel also covered the farmers' field days.

5.4.5 West Bengal

The project activities, especially farmers' training and field days organized by Shantiniketan, have been covered widely by local newspapers such as *Krishi Kalyan*, *Birbhumer Katha*, *Dainik Chandravaga* and *Visva-Bharati Chronicle*; regional newspapers such as *Burdwan Joti*, *Dainik Stateman*, *Sambad* and *Pratidin*; and even national newspapers such as *Anandabazar Patrika*, *Ganasakti*, and *Bartaman* (Fig. 34). Electronic media sources Doordarshan and E-TV recorded these events and telecasted them from time to time in their farming programs *Krishi Darpan* (Doordarshan) and *Annadata* (E-TV). Jhalak, a local TV channel in Bholpur, also covered a field day activity on their daily news telecast.


পল্লী শিক্ষা ভবনের উদ্যোগে
বেগুন চাষীদের প্রশিক্ষণ শিবির

অতিরিক্ত কৃষি-বিষ প্রয়োগে পোকাদের সহনক্ষমতা বাড়ছে

ফাঁদ পেতে পোকা
দমনে সাফল্য বিশ্বভারতীর

রিকশা ও ভ্যানচালকদের

Fig. 34. *Clippings of news items featuring EFSB IPM activities in various newspapers of West Bengal, India*

5.4.6 Meghalaya – Tripura

Because of the remoteness of the mountainous project area, small-size plantings, and widely scattered villages, ICAR-NEH was not able to get print or electronic media persons to attend field days. However, a press release from a field day event in Meghalaya was printed in the local Shillong newspaper *Shillong Times* and a field day event in Tripura was printed in the local Agartala newspaper *Tripura Times*.

5.4.7 Uttar Pradesh

Project activities conducted by IIVR in its home state, Uttar Pradesh, were covered regularly through the project period starting with 2003 and ending in late 2005. News items related to project activities such as field days, farmers' dialogs, and farmers' training were published a total of 24 times in Hindi and English language editions of local, regional, and national newspapers and news magazines *Times of India*, *Hindustan*, *Dainik Jogaran*, *Amar Ujala*, *Aaj*, *The Pioneer*, *Krishak Dunia* and others (Fig. 35). Thirteen episodes on the importance of vegetables and safe management of EFSB were aired in Hindi biweekly on the farming program *Krishi Jagat* from Varanasi station of All India Radio during February–March 2005.


अमर उजाला

वाराणसी

'नाइट्रोजन से पौधों पर कीटों का प्रकोप अधिक'

हिन्दुस्तान

वाराणसी

कीटों को खेत में मारें नहीं, जाल में फं

THE PIONEER

140TH YEAR PUBLISHED FROM DELHI, LUCKNOW AND BHOPAL

PHEROMONES PLAY A VITAL ROLE IN CONTROL OF PESTS

Fig. 35. *Clippings of news items featuring EFSB IPM activities in various newspapers of Uttar Pradesh, India*

6 Socio-economics of Protection of Eggplant in South Asia

Because of the economic importance of the crop and increasing severity of damage by EFSB, farmers in South Asia rely on application of pesticides to protect their eggplant crop. The widespread and ever increasing use of pesticides in vegetable production is occurring all over Asia, resulting in well-known consequences to health, environment, cost of production, resurgence of pest insects, and resource degradation. In some cases, it is not the pest—but the pesticides used in combating the pest—which have become the bigger problem. Current pest control practices in combating EFSB in the region fall into this category. A socio-economic study of eggplant crop protection, therefore, was undertaken at major project sites in Bangladesh and India to find out the causes behind such pesticide use and assess the possible impact that adoption of the IPM strategy may have on reducing pesticide use and production costs.

6.1 Methodology

Two institutes, AAU and IIVR, carried out baseline surveys of eggplant production and protection in Gujarat and Uttar Pradesh States of India, respectively. BARI conducted a baseline survey in Jessore District of Bangladesh earlier during the first phase of this project (Rashid et al., 2003). During the second phase, BARI also conducted a similar survey in Jessore as well as Norsingdi Districts, in conjunction with an assessment of the impact of project activities. BARI's results are presented in the impact assessment section of this chapter.

For baseline surveys, each site chose a group of villages with long histories of eggplant cultivation. A minimum of 100 farmers were to be interviewed by each site for gaining information on their eggplant production and protection practices. An objective-oriented, structured questionnaire, modified from previous such studies in Bangladesh (Rashid et al., 2003), was used to identify different pest problems, pest management practices, patterns of input use, and economic returns associated with eggplant cultivation. Due to the lack of professional economists at several sites, no statistical model, similar to one used by Rashid et al. (2003), was adopted to identify pesticide misusers or factors that lead to pesticide misuse. However, because of the similarity of socio-economic conditions in Bangladesh and India, the published information from Rashid et al. (2003) served as a reference to judge factors that led to pesticide misuse in this study. The data for West Bengal site is published as a companion bulletin (Baral et al., 2006) and similar information for Bangladesh will be published elsewhere. The information generated at Gujarat and Uttar Pradesh sites is discussed in this chapter.

6.2 Socio-economic characteristics of farmers

Initially all sites agreed to adhere to a common questionnaire; however, while interviewing farmers, individual sites modified the questionnaire, at times significantly, to suit local conditions. As a result, it is difficult to present data from these sites in a common table or figure for comparison purposes. Therefore, salient features of the socio-economic characteristics of farmers and their eggplant production and protection practices to grow eggplant in Gujarat and Uttar Pradesh are summarized separately in the following two sections:

6.2.1 Gujarat

A random sample of 174 farmers, each having three or more years of experience in eggplant cultivation, was selected by AAU in Bhavnagar District of Gujarat State. Individual farmers were interviewed personally by the project staff.

All farmers in the survey were males. Among them, 30.5% were illiterate, 53.5% received only primary education, 15.5% no more than secondary education, and less than 1% received college or university education. Over 85% of the farmers were 31 to 50 years old, well within their productive age as laborers. Their experience in farming ranged from 5 to over 15 years. Over 90% of the farmers cultivated eggplant for more than six years; among these farmers, over one-third of them have been eggplant growers for over 15 years. Some of these farmers have become specialized eggplant producers, which enables them to get some of the highest yields of this vegetable in India. The average landholding was 2.6 ha, with a range of less than 2.0 to more than 6.0 ha. Nearly 80% of farmers owning less than 2.0 ha of land were vegetable growers, out of which 99% grew eggplant.

Practically all farmers, 173 out of 174, used their own seeds from previous eggplant crops to grow new crops and all of them raised their own eggplant seedlings for transplanting. This farmers' practice of using their own variety of eggplant, which is commonly practiced all over the country, is related to the local preferences of consumers. Such practice will make it difficult to introduce new eggplant varieties, and institutions that are attempting to produce Bt-transgenic eggplant varieties to control EFSB will be hard-pressed to convince such farmers to use new varieties. Most Bhavnagar farmers (72.4%) preferred to grow eggplant during June to October, which is a rainy season in India. Bhavnagar and the whole of Saurastra Region of Gujarat rarely receive rains after October until next June. Most farmers rotate their eggplant crop with other crops; only 17.8% grew eggplant after eggplant.

Based on the symptoms of pest damage, the vast majority of farmers (94.3%), considered EFSB to be the most important pest insect, although 44% of them could not identify the insect specimen correctly before the initiation of the project. Over 93% of farmers suffered yield losses of over 25% by this pest. Most farmers were unaware of the beneficial insects in their eggplant field and considered most of them to be damaging. Only 1 out of 174 farmers had previously received any training in pest control practices.

All but two farmers felt application of pesticides reduced pest damage by up to 50%. One hundred and fifty-three out of 174 farmers (88%) used only insecticides and the remaining farmers used insecticides coupled with clipping of damaged shoots to combat EFSB. Most of the farmers, 137 out of 174 (79%), started spraying pesticides from one month after transplanting and over 95% of them applied more than 40 pesticide sprays per season, which lasts 5–6 months. For advice on insecticide use, the farmers used information from multiple sources, but 85% of them relied on the local pesticide dealers and only 10% sought information from government extension officers. Pesticide dealers have a vested interest in selling more pesticides and such dependence on their information may lead to abuse of the chemicals. Pesticide use was more intense from July to October, a period when temperature, humidity and pest populations are high. The most commonly used equipment to spray pesticides was a hand-operated knapsack sprayer. As a protective measure, most farmers covered at least their faces with cloth while applying pesticides.

Among the 174 farmers, 129 (74%) believed pesticide use increases the crop yield; others were not sure. The average cost of production in Bhavnagar was Rs.170,000/ha (US$1 = Rs.44). Pesticide use amounted to 38.8% of the total cost of production. The average fruit yield in the project area was 44.8 t/ha, which is almost three times the national average yield for India. The net return ranged from Rs.50,000 to over Rs.200,000/ha, with an average of Rs.141,000/ha.

After final harvest of the crop, more than 70% of Gujarati farmers saved plant residues and stacked them around their field for use as fuel for cooking; some farmers, however, burned the stubbles after they were adequately dry. Those who wanted to use the dry stalks for fuel maintained the material for more than six weeks before starting to use them. This habit, practiced elsewhere in India and Bangladesh, contributes to carryover of EFSB infestation from season to season, and helps to exacerbate the pest problem.

6.2.2 Uttar Pradesh

In Uttar Pradesh (UP), IIVR conducted a similar socio-economic survey with 88 farmers in eggplant growing areas of Varanasi and Mirzapur Districts. All farmers were interviewed in person by the project staff. All surveyed farmers were males. Most of the farmers, 88%, were relatively young, less than 50 years old, and relatively better educated than their Gujarati counterparts. Only 9% of the UP farmers were illiterate, 13% received only primary education, two-thirds received no more than secondary education, and 11% were college graduates. Experience in farming ranged from 6 to over 20 years, and nearly 60% of farmers had been growing eggplant from 6 to over 20 years. Two-thirds of farmers possessed only 1 ha of land, and more than 71% of them grew eggplant on 0.2 ha parcel of land.

These farmers were progressive vegetable growers and over 55% of them used hybrid varieties and over 90% of them purchased seeds from market. This is in stark contrast to the situation described earlier for Gujarat. All UP farmers practiced crop rotation, mostly with other vegetables, to grow their eggplant crop.

Like in Gujarat, based on damage symptoms, all farmers considered EFSB to be the most destructive pest. Over 93% of them, however, were not able to identify the larvae or adult of EFSB. This is understandable because EFSB larva is an internal feeder, rarely seen outside the shoot or fruit, and the adult is nocturnal. Nearly 60% of farmers reported EFSB damage of 25% and above to their crops, at times exceeding 75%. All farmers applied pesticides to combat the pest but a substantial number, 75 out of 88 (85%), also incorporated clipping of damaged shoots along with pesticide application. Only 3% of farmers were exposed to any IPM training.

Over 90% of farmers reported that they apply pesticides when they see damage in the field; 75% of them begin spraying within one month after transplanting. The vast majority of farmers, 76 out of 88 (86%), sprayed their crop twice or thrice a week. Nearly all farmers followed the advice of their pesticide sales agent, and not that of their government extension agent, when it came to the selection of chemical and frequency of application. This situation is similar to what is happening in Bangladesh (Rashid et al., 2003) and Gujarat.

Most UP farmers (80%) used foot pumps rather than knapsack sprayers to apply pesticides, 74% used protective clothing while applying pesticides, and nearly all washed their hands using soap after spraying of pesticides. These farmers are thus safety conscious.

Eight-five of the 88 farmers (97%) stated that they harvest their eggplant within 2 days after spraying. This considerably increases the probability that farmers will be exposed to pesticide residues in the field. Farmers were not aware of the natural enemies or adverse effect of pesticides on the natural enemies. Two-thirds of farmers, however, were aware of the harmful effects of pesticides to humans and farm animals.

Nearly 97% of farmers believed that pesticide use can reduce pest damage up to 50%; a similar number believed pesticide use increased eggplant yield, and 88% of them thought pesticide application is profitable. Such perception may lead to abuse of chemicals. IIVR found that 90% of farmers sprayed more frequently than recommended, 43% used excessive dosages, and nearly 60% used illegal mixtures of pesticides.

UP farmers produced an average yield of 35.8 t/ha, which is twice the national average for India. Their average cost of production was Rs.54,357/ha. Plant protection expenses amounted to Rs.28,280/ha or 52% of the total cost of production. The average net return of the majority of farmers (73.8%) ranged from Rs.50,000 to Rs.250,000.

After the final harvest of the crop, more than 93% of the farmers saved plant residues or stubbles to be used for fuel purposes. This habit, like that of Gujarati farmers, contributes to carryover of EFSB infestation from season to season, thus exacerbating the pest problem.

Detailed survey data of these studies are available at the AVRDC library as well as at the libraries of AAU for Gujarat data and IIVR for Uttar Pradesh data.

6.3 Impact Assessment

It is too early to see the full impact of the project activities; however, during the last two months of the project, a survey was conducted at selected sites to assess the change of attitude of farmers toward the use of pesticides and adoption of IPM strategy. This allowed us to compare their attitude before the project with their attitude two years later after experiencing IPM promotional activities. Two Indian institutes, AAU and IIVR, also surveyed SMEs on their sale of sex pheromone lures over the past three years. The sale of these lures is an indication of the impact of IPM activities.

6.3.1 Bangladesh

BARI selected project sites at Jessore and Norsingdi to study the socio-economic impact of the project activities. Jessore is considered a “vegetable basket” of Bangladesh because it produces vegetables throughout the year and is a major supplier of these commodities to the rest of the country. Norsingdi is an intensive vegetable growing area and is a significant supplier of winter vegetables to Dhaka. During the second phase of this project, nearly 500 farmers in Jessore area were involved in eggplant cultivation using IPM strategy while in Norsingdi, 130 farmers were involved in such activity. For winter cultivation, BARI chose 25 IPM and 25 non-IPM farmers at both sites, while for summer, similar numbers of farmers were selected at Jessore only (eggplant is not grown widely in Norsingdi during summer). Farmers in Jessore had two years of experience in using IPM strategy, whereas those in Norsingdi practiced IPM for only one year.

Survey procedure. The pre-designed, pre-tested questionnaire was used to gain information and interviews were conducted in person with each farmer during September–October 2005. A computer-based statistical package, SPSS, was used for data analysis and *t* statistics were employed to find significant differences between various parameters of IPM and non-IPM farmers. The Cobb-Douglas production function (Heady and Dillon, 1972) was used to find the effect of selected independent variables on farm productivity of IPM and non-IPM farmers in the study area. The economic surplus model was used to estimate the benefits from adoption of IPM strategy. The internal rate of return (IRR) was calculated relating total social benefit (TSB) minus an input cost change, if any, in each year to the research expenditure.

Pest management practices. All farmers in study areas considered EFSB as the most destructive pest of eggplant. They have been using pesticides in combating this pest for the past several years. However, IPM farmers had reduced their pesticide use in both cropping seasons (Table 9). They sprayed their winter crop only 21 times and summer one, 33 times. In contrast, those farmers who did not adopt IPM sprayed their winter crop 90 times and summer crop 110 times during the 5–6 month season. More importantly, despite the reduction in pesticide use, IPM farmers' winter crops had only 30% of fruits damaged by EFSB whereas non-IPM farmers had 75% of fruits damaged by the pest. A similar and striking difference was found in summer crops as well. As expected, summer crops suffered much greater pest damage than winter crops.

In view of such benefits, when asked about their intention of increasing area under eggplant in the future, 55% of the IPM farmers indicated their desire to increase their eggplant crop by an average of 0.32 ha per farmer. The reason for this desire was higher yields, higher income, and lower costs of production. Others did not want to increase their eggplant production because of scarcity of sex pheromone lures, lack of suitable area for additional eggplant cultivation, inadequate capital, and the perception that IPM is labor intensive. Our survey, however, revealed that labor use by IPM farmers was 15–20% less than by non-IPM farmers (Table 9). The Bangladesh Government has recently passed a legislation allowing use of sex pheromone and similar chemicals for pest control in the country; as a result, pheromone lures will be readily available, which will reduce farmers' fear of scarcity of pheromone lures.

Input use in eggplant cultivation. In general, other inputs, such as chemical fertilizer, organic manure, seedlings, irrigation power, draft power for tillage, and

Table 9. *Status of pesticide use for IPM adopter and non-adopter farmers in Jessore and Norsingdi regions of Bangladesh*

	Winter crop		Summer crop	
Items	IPM-adopters	IPM-non adopters	IPM-adopters	IPM-non adopters
No. pesticide sprays/season	21	90	33	110
EFSB damaged fruits (%)	30	75	41	80
Damaged-fruit by weight (%)	18	55	22	65
Pesticide use[1]				
Liquid (ml/ha)	1,147	8,512	1,540	8,483
Granular (kg/ha)	16	54	24	95
Human labor, days/ha				
Family	122	145	141	166
Hired	115	158	150	174
Total	237	303	291	340

[1]Irrespective of types of chemicals or active ingredients

human labor were relatively less on IPM farms than on non-IPM ones (Table 10). It seems that IPM adopters became more conscious of the inputs they were using for raising eggplant and are using these inputs more diligently than before. This will further contribute to a reduction in overall cost of production. The cost of production on a full-cost basis, was Tk56,298 and Tk65,220/ha for IPM users and non-IPM users, respectively, in the winter season, and Tk65,073 and Tk104,988 for the same categories of farmers in the summer season (US$1 = Tk67). There was a

Table 10. *Cost of production (Tk) of eggplant under IPM and non-IPM practices in Jessore and Norsingdi regions of Bangladesh*

	Winter crop		Summer crop	
Items	IPM-adopters	IPM-non adopters	IPM-adopters	IPM-non-adopters
Human labor[1]				
Family	9,760	11,600	11,280	13,320
Hired	9,200	12,680	12,000	13,960
Total	18,960	24,280	23,280	27,280
Draft power				
Family	235	302	215	380
Hired	280	350	286	279
Total	515	652	501	659
Tractor/power tiller	2,490	2,940	2,840	3,230
Seedlings	5,250	5,900	5,300	5,750
Manure (cow dung)	903	913	733	814
Fertilizers				
Urea	1,050	1,560	840	1,860
Triple super phosphate	3,224	4,355	3,240	3,859
Muriate of potash	1,778	3,080	2,198	4,032
Gypsum	90	125	170	470
Sulfur	100	600	300	400
Total	6,242	9,720	6,748	10,621
Pesticides[2]				
Liquid	1,961	19,765	3,519	19,979
Granular	2,125	1,961	3,510	15,699
Total	4,086	21,456	7,029	35,678
Irrigation	2,940	3,794	2,504	3,404
Rental value for land	13,970	13,832	15,016	15,340
Interest on capital	942	1,343	1,123	2,212
Cost				
Full cost	56,298	85,220	65,074	104,988
Variable cost	31,626	58,055	37,655	74,116
Cash cost	31,391	57,753	37,440	73,736

Bangladesh Taka (US$1 = Tk67).

[1]Labor cost was 11% and 25% for spraying under IPM and non-IPM practitioners, respectively.

[2]IPM practitioners use sex pheromones lures and traps. Pheromone lures are not yet available in Bangladesh. Cost of lures and traps expected to be around Tk8000/season/ha.

stark difference between IPM adopters and non-adopters when it came to the cost of pesticides and labor input for applying these chemicals. This difference contributed to the differences in the costs of production between the two categories of farmers. Even if one factors in the cost of pheromone lures and traps, estimated at Tk8,000/ha/season, the difference in the cost of production between IPM adopters and non-adopters will still be significant. Both variable costs as well as purchased input costs were drastically reduced by IPM users compared to non-users.

Profitability of eggplant production. There were significant differences between actual yield of eggplant obtained by IPM users and non-users (Table 11). Equally important was the reduction in actual yield from potential yield if EFSB did not affect the crop. In summer, when pest population pressure is high, the yield loss of non-IPM users was nearly 40%, whereas for IPM users it was only 15%. The higher yield of IPM users fetched them higher gross returns compared to non-IPM users (Table 12). The average gross margin was Tk155,261/ha for non-IPM users and Tk264,517/ha for IPM users on variable cost basis and the gross margin was equally high on cash cost basis. Other benefit-cost indicators, such as benefit-cost ratio (BCR), return on labor, and return on irrigation were higher for IPM adopters than non-adopters.

An ex-ante evaluation was made to estimate the benefits of IPM technology using the economic surplus model for years 2003–2015. Using base parameters, the internal rate of return (IRR) was estimated at 39% for the IPM research and extension. This indicates that, on average, each Tk100 invested will give a return of Tk39 per year from the year it was invested (2003) until year 2014–2015. Such rate of return on investment in research is a very good return. The BCR of 3.25 also indicated much higher benefits in such investment.

Table 11. *Observed and expected yields of eggplant for IPM adopters and non-adopters in Jessore and Norsingdi regions of Bangladesh*

	Winter crop		Summer crop	
Yield	IPM-adopters	IPM-non adopters	IPM-adopters	IPM-non adopters
Observed (kg/ha)	38,058**	28,318	40,710**	26,070
Expected[1] (kg/ha)	42,470	42,892	47,920	42,970
Reduction (%)	10.39	33.92	15.04	39.33

**Difference in observed yields of IPM-adopters and non-adopters in respective season significant at 1% probability level

[1]If not affected by EFSB

Table 12. *Profitability of eggplant cultivation for IPM adopters and non-adopters in Jessore and Norsingdi regions of Bangladesh*

	Winter crop		Summer crop	
Items	IPM-Adopters	IPM-non adopters	IPM-adopters	IPM-non-adopters
Cost of cultivation (Tk/ha)				
Full cost	56,298	85,220	65,074	104,988
Variable cost	31,626	58,055	37,655	74,116
Cash cost	31,391	57,753	37,440	73,736
Yield (kg/ha)	38,058	28,318	40,714	26,070
Gross return (Tk/ha)	290,515	236,738	307,798	205,953
Gross margins (Tk/ha)				
Over variable cost	258,889	178,683	270,143	131,837
Over cash cost	259,124	178,985	270,358	132,217
Net return (Tk/ha)	234,217	151,518	242,724	100,965
Rate of returns				
Over variable cost	9.19	4.08	8.17	2.78
Over cash cost	9.25	4.10	8.22	2.79
Return on labor (Tk/day)	1,172	670	1,008	468
Return on irrigation				
Per Tk invested	89	48	109	40

6.3.2 India

The impact assessment study in India was confined to changes in various parameters of EFSB control practices and attitudes toward the new IPM strategy, before initiation and after completion of the project. This work was done mainly in Gujarat and to a lesser extent in Uttar Pradesh and Orissa.

In Gujarat, AAU chose 174 farmers randomly from the project area and surveyed their pesticide use pattern before the project implementation and two years later after completion of the project. Some of these farmers participated in the pilot project implementation but only for one season. AAU rotated the pilot project demonstrations among villages.

The most striking impact of IPM promotion in Gujarat was the reduction of pesticide use from before to after the project. Prior to the project, 146 farmers used to spray their eggplant crop more than 50 times, and a substantial number of them over 80 times per season (Fig. 36). After IPM implementation, only 27 farmers sprayed their crop more than 50 times, and none more than 70 times.

From the same survey, when information was collated for weekly frequency of pesticide use during each month of the year, the effect of IPM on reduction in pesticide abusers (those who spray more than once a week) was striking (Fig. 37). Farmers who used to spray once or even twice a day, especially in July and Au-

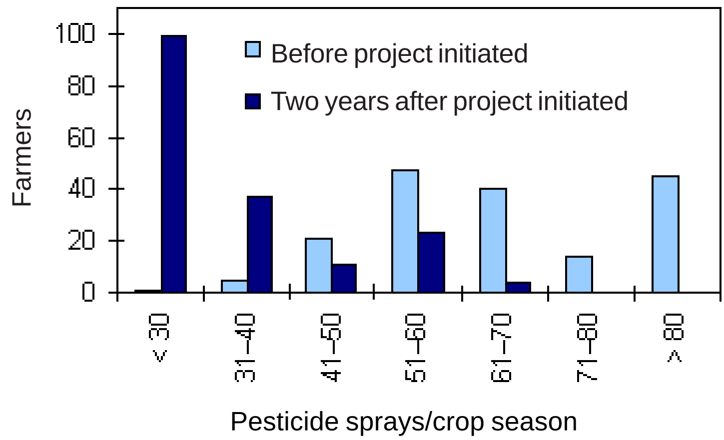


Fig. 36. *Seasonal load of pesticide use for the control of EFSB before and after implementation of EFSB IPM project in Bhavnagar District of Gujarat, India*

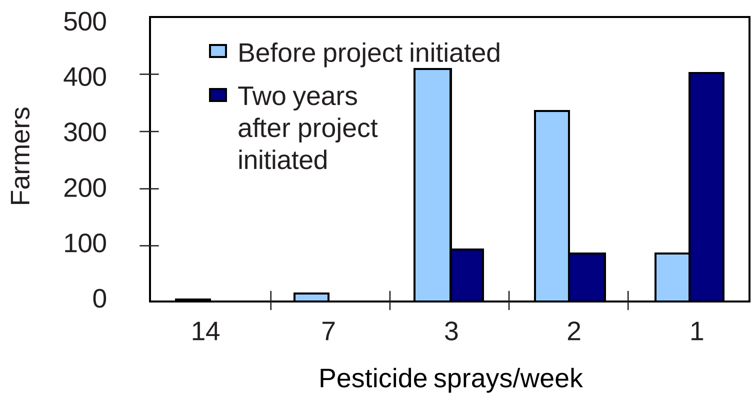
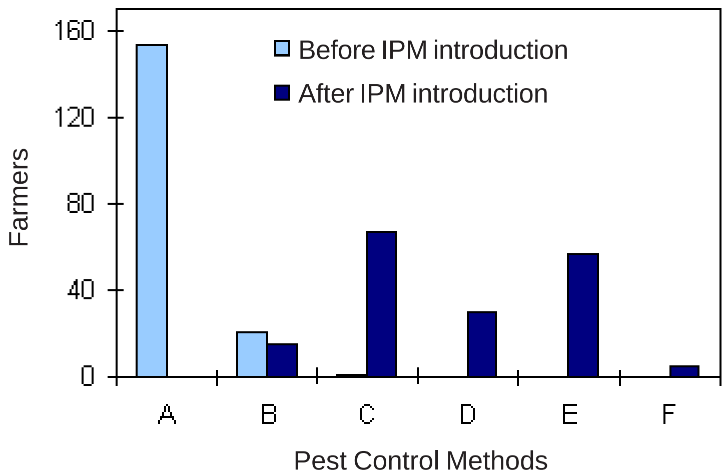


Fig. 37. *Frequency of weekly pesticide sprays for the control of EFSB before and after implementation of EFSB IPM project in Bhavnagar District of Gujarat, India*

gust, discontinued such practice completely. There was also a drastic reduction in farmers who used to spray their crop twice or thrice a week. Consequently the number of those using pesticide once a week—considered "judicious" by prevailing local standards—increased nearly fivefold.

Many of those farmers that reduced pesticide use started using integrated approaches to manage their EFSB problem. For example, prior to IPM promotion activities, 153 out of 174 farmers (88%) used only pesticide to combat EFSB, but after IPM promotion, none of the farmers relied solely on pesticides in managing their pest problems (Fig. 38). They reduced their pesticide use considerably and initiated an integrated approach involving pesticides, sex pheromone, cutting and proper disposal of pest-damaged shoots, culling and disposal of damaged fruits, and prompt disposal of plant residues after the crop is uprooted after the final harvest.



A: Pesticides only
B: Pesticides + damaged shoot cutting
C: Damaged shoot cutting + damaged fruit picking
D: Pheromone use only
E: Pheromone + damaged shoot clipping + prompt disposal of plant residue after final harvest
F: Proper disposal of plant residue after final harvest

Fig. 38. *EFSB management practices of eggplant farmers before and after implementation of EFSB IPM project in Bhavnagar District of Gujarat, India*

Gujarati farmers, like their Bangladeshi counterparts, after subjected to IPM promotion activities, not only drastically reduced their input in pesticide use, but also other items, especially purchased inputs such as fertilizers, albeit moderately (Table 13). As a consequence, the total cost of production was reduced by 30% from Rs.169,743 to Rs.118,693/ha. Although the cost of pesticides, after IPM introduction, was reduced by 40%, because of the substantial reduction in other cost items, such as labor input, the contribution of cost of pesticides toward overall cost of production reduced only marginally from 38.8% to 33.3% during this period. In both cases, pesticide use still remained the single costliest item. The average net return to farmers increased from Rs.141,037 to Rs.224,000/ha (Table 14). The number of farmers making less than Rs.150,000 or less per hectare was reduced from 60 to 13, but the number of those making more than Rs.150,000 increased

Table 13. *Cost of production of eggplant prior to and after introduction of IPM in Bhavnagar District of Gujarat, India*

Cost items	Rs./ha/season	
	Pre-IPM	Post-IPM
Human labor	40,004	26,002
Machine power	8,341	8,064
Animal labor	4,032	3,634
Seed	1,185	934
Farmyard manure	20,079	19,835
Cow dung/oil cake manure	65	50
Urea	9,843	9,299
Ammonium sulfate	745	697
Diammonium phosphate	6,156	6,029
Triple superphosphate	1,564	1,434
Muriate of potash	1,794	1,717
Liquid fertilizer/micronutrients	108	72
Growth regulators/hormones	1,455	1,131
Sprayer machine	270	251
Pesticides	65,905	39,543
Irrigation	8,255	7,713
Total	169,743	118,693

US$1 = Rs.44

Table 14. *Net return to eggplant growers prior to and after introduction of IPM in Bhavnagar District, Gujarat, India*

Net return (Rs/ha/season)	Number of farmers	
	Pre-IPM	Post-IPM
Up to 50,000	11	1
50,00–100,000	21	4
100,000–150,000	28	8
150,000–200,000	104	64
Above 200,000	10	97
Mean net return (Rs/ha)	141,037	224,000

from 114 to 161. The number was especially impressive for those making over Rs.200,000 or more; it jumped from 10 farmers before the project to 97 after the introduction of the project. So farmers who were making less money before the project, increased their income substantially because they adopted IPM in managing the pest. Like in Bangladesh, the introduction of IPM has brought substantial economic benefit to eggplant farmers.

The social benefit in terms of food safety, improving human health, and quality of environment will be an additional bonus, the value of which is difficult to calculate at this stage. If the IPM is promoted nationwide with the same zeal as was done while implementing the project, it will not only offer these benefits, but will also reduce the cost of eggplant in the market, thereby providing consumers with economic benefits from the public investment in research and extension.

Sale of sex pheromone lures in India. Use of sex pheromone is an important component of our new IPM strategy to combat EFSB. It is the only purchased input item in the new strategy. At the initiation of the first phase of this project in April 2000, sex pheromone was not commercially available anywhere. However, after pheromone-baited lures showed consistently high efficacy in trapping EFSB males, it enticed local SMEs in India to commercialize the product. At the end of the first phase in March 2003, three SMEs started selling the product. Soon afterwards, several more got into the business. At the end of 2005, a total of nine such firms were selling pheromone lures of EFSB throughout India (Table 15). In Gujarat, where five out of nine firms are located, the combined sales of two pioneering

Table 15. *List of SMEs that have commercialized sex pheromone of EFSB in India*

No.	Enterprise	Headquarters
1	Agriland Biotech Pvt. Ltd.	Vadodara, Gujarat
2	A.G. Bio Systems Pvt. Ltd.	Secunderabad, Andhra Pradesh
3	Basarass Biocon (India) Pvt. Ltd.	Chennai, Tamil Nadu
4	Bio-tech International Ltd.	Vadodara, Gujarat
5	Ganesh Biocontrol Systems	Gondal, Gujarat
6	Indore Bio-tech Inputs & Research (P). Ltd.	Indore, Madhya Pradesh
7	Margo Biocontrols Pvt. Ltd.	Bajwa, Gujarat
8	Pest Control (India) Ltd.	Mumbai, Maharashtra
9	Pheromone Chemicals	Hyderabad, Andhra Pradesh

SMEs, Agriland Biotech and Genesh Biocontrol Systems, had tripled from 5,278 units in 2002–2003 to 16,529 in 2004–2005.

For the entire country, we were not able to get complete data for all companies, but four companies that volunteered the information showed tremendous growth in the sale of pheromone lures. Their total sales increased from 74,100 units in 2002 to 134,200 in 2003 and 193,400 in 2004. All companies expect continued strong demand for the lure in the near future. This bodes well for the future of IPM of this pest in India. This is primarily because these companies, rather than the government, will promote IPM. Such efforts will be much more effective in the region, which is known for its non-existent or inefficient farm extension service.

It will be worthwhile if a more exhaustive impact assessment of this project is done by a team of economists and entomologists 3–4 years hence. By that time farmers in Bangladesh too will have access to sex pheromones from private sources within the country.

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Appendix:
Script of Film Documentary

(text in italics may be adjusted depending on nationality of audience)

Food, more than anything else, is the basic requirement for mankind. Without food we cannot survive. Cereals such as rice and wheat form the bulk of our food. They fill our stomach and provide energy for our activities. However, man cannot live on rice alone because rice by itself is not a complete food. It lacks nourishment for the development of human body and mind, and for fighting diseases. That is where the vegetables come in. Vegetables are mankind's richest source of plant proteins, vitamins, mineral and crude fiber, all of which are essential for the growth and development of our body, and for fighting diseases. Everyone wants to be strong and healthy. Vegetables not only provide nutrients to build our body, they also provide taste and variety, which helps us to eat and digest staples like rice. This makes us healthy and energetic. Eating vegetables, therefore, is as essential as rice.

Vegetables come in different sizes, shapes, and colors. Some are leaves, some fruits, while others are roots, and even flowers. They are grown in large fields, small plots, backyard gardens, under nethouses and plastic houses, throughout the year. Their daily sales give farmers ready cash income. In general, the vegetable farmers make more money than the rice farmers.

Amongst a large number of vegetables grown in *Bangladesh / India*, brinjal or eggplant is the most popular, and can be found in the market at reasonable prices throughout the year. It is cooked in various delicious cuisines. *Nationwide, Bangladeshis consume more brinjal than any other single vegetable commodity / Brinjal is one of the top five most popular vegetables consumed in India*. However, this versatile, always available, and humble vegetable is getting increasingly poisoned, and becoming dangerous to eat. This is because the *Bangladeshi / Indian* farmers are using too many pesticides, and far too often, on their brinjal crop to control various pests, especially the most damaging one, the brinjal fruit and shoot borer. *Bangladeshi / Indian* farmers use more pesticides to kill this pest than any other pest affecting agriculture in the country. *In Bangladesh, the pesticides used per hectare on brinjal is 7 times more—1.4 kg/ha—than on rice, which consumes a mere 200 g/ha / Indian farmers use substantially more pesticides to control brinjal fruit borer than most other vegetable pests.* These pesticides, many of them imported, wasting valuable foreign exchange, are readily available in the region. Although most pesticides are registered to be used on specific crops, many farmers use them for all the crops. Thus, certain hard pesticides registered for non-food crops such as cotton, get applied on vegetables like brinjal, cabbage or tomato, endangering people's health.

Excessive use of the pesticides means farmers spending more and more money to buy them, besides more time to spray them on the brinjal crop. These pesticides are harmful to the insects as well as the people. When a farmer sprays pesticides in the field—in most cases, without wearing any protective clothing—he is automatically exposed to toxic chemicals. He breathes these chemicals through his nose, and absorbs them through the skin taking them further inside his body. His eyes, too, get harmed by the chemicals. Several farmers have been sickened and hospitalized, and few have even died, due to the pesticide exposure. The chemicals sprayed on the brinjal can remain on the fruit for several days. People buy and eat these contaminated fruits and are harmed gradually. During the rains, the pesticides from brinjal field are washed to the streams and rivers or leached underground into the well water that people drink. More than that, the pesticides are silent killers of the friendly insects—the so-called predators and parasitoids. Some of these friendly insects, when alive, feed on brinjal fruit borer, thus rendering help to the farmers to protect his crop. These beneficial insects are the true friends of farmers, but by spraying excessive amounts of pesticides, *Bangladeshi / Indian* farmers are destroying this god-given help. The destruction of predators, in fact, worsens the brinjal fruit borer problem. This has to stop for the good of the farmers and *Bangladeshi / Indian* people who love to eat their brinjal.

However, the help is on its way.

The scientists in Bangladesh and India, and at the World Vegetable Center in Taiwan, have now developed a new way to control the pest without killing the friendly insects, or harming the people, or even poisoning the soil and water. This new technique can control the brinjal fruit borer easily without the use of any pesticides, and is, in fact, cheaper than the use of pesticides. To apply it, however, we need to first understand:

- how does the brinjal fruit borer survive and multiply in nature;
- how does it come to the farmers' brinjal field;
- how does it damage our brinjal crop; and
- where does it go when there is no brinjal in the field?

1. How does this borer survive and multiply?

Every insect, including the brinjal fruit borer, undergoes four different stages or "avatars" in its lifetime: the egg, the larva, the pupa, and the adult. The female adult or the moth, which does not damage the plant, lays its eggs, up to 60 of them, on brinjal leaves. Soon after laying the eggs, the moth dies. Each egg soon hatches into a tiny larva. This tiny, almost transparent, larva cannot survive outside the plant and searches for a soft spot either in the tender shoot or the brinjal fruit. Upon finding a suitable spot, the larva makes a tiny hole and enters inside. It feeds and makes tunnels inside the shoot or the fruit for almost two weeks continuing to feed and growing bigger and bigger. It is only this avatar that damages the brinjal fruit. After two weeks, the mature larva makes a small hole from inside the fruit to the outside, and exits, descending finally to the soil below.

In the soil it crawls just underneath the surface and covers itself with a special coat, to change into the next avatar called the pupa. This pupa, in turn, is covered by a tough soil-like material called the cocoon. Inside the cocoon, in one week's time, the insect changes its shape and size completely, getting ready to enter the new avatar of adult or moth.

Soon after coming out from the cocoon, which usually happens 2–3 hours after the sunset, the moth hops short distances amid branches under the cover of the top brinjal leaves. The male moth searches for the female and mates with her during the same night it comes out of the pupa. The male moth soon dies and the female flies away looking for a suitable brinjal field to lay fresh eggs and start the next life cycle.

2. Where does the fruit borer come from to your field?

The brinjal fruit borer feeds and lives mainly on the brinjal crops. It comes to your crop in one or more of four different ways:

First, in a newly planted brinjal crop, the fruit borer moths can fly in from a neighboring older or abandoned brinjal crop that has already been damaged. This is the most important source of brinjal fruit borer coming to your field. Since moths can fly from one field to another, it is important that all farmers in a community work together to keep the fruit borer under control so that there are fewer and fewer pest adults to move from field to field.

Second, the brinjal seedlings that are used for transplanting a new crop can sometimes be carrying the eggs or tiny larvae, especially if one uses slightly older seedlings raised in an open field near a pest-damaged old brinjal crop or the heaps of dried plant stubbles from the last season's crop.

Third, if the previous crop grown in the same field or a field nearby was also brinjal, the fruit borer pupae from the previous crop, resting within the soil, will become adults and infest the new crop in the same field or in the neighboring ones.

Fourth, if the old uprooted brinjal plants are stored nearby or discarded around the area, the pupae from underneath such plant debris can develop into adults, which fly into a new brinjal field to lay the eggs and start a new infestation.

The fruit borer infestation from all the four sources can be stopped if all the farmers in a community work together. Such cooperation will not only remove the threat of the damage by this pest, but also the danger and the costs of toxic pesticides. Each and every farmer must cooperate for the good of the community.

3. When and how does the fruit borer cause damage?

The fruit borer moth itself does not cause any damage. The larvae coming out of its eggs cause the real damage by feeding inside the brinjal fruit. The fruit borer moth usually begins laying eggs when the crop starts to flower. No control measures are needed before the flowering. Any pesticides used before the flowering, in a hope to control the pest, are wasteful. Such sprays will kill only the friendly natural enemies of the fruit borer. This will backfire and the fruit borer damage will increase.

Initially, when the brinjal fruits have not yet developed, all the larvae go to the tender shoots and feed inside them. The first symptom of such damage is the freshly wilted shoot tips. Later when the plants start bearing fruits, most larvae prefer to feed inside the tender fruits. Larvae do not like the old, over-mature fruits. They sometimes feed on the flowers too, which reduces the fruit set and lowers the fruit yield. But that is not very common.

When a larva becomes mature, it leaves the fruit or shoot by making a hole outside and descends to the soil for pupation. These exit holes are clearly visible in the fruits, but may not be obvious in a shoot because of its hairiness. After an infestation begins, the pest damage can continue until the last harvest.

4. Where does the borer go when there is no brinjal crop in the field?

If there is no brinjal in the field, the borer moth has nowhere to go. Most of them will die, and a tiny fraction may fly to potato, if the crop is nearby. But eventually, all of them would die.

The fruit borer eggs cannot survive long, since the larvae developing inside the eggs must come out within a week or 10 days. And without brinjal plant to feed on, the larvae would starve and die.

One of the more suitable hiding places for the insect, in all its avatars, is the old plants left standing in the field after the last harvest, because the farmer may have no time or interest in using that area again for cultivation. Sometimes, in the unused empty areas or along the bunds, brinjal plants maybe present along with other weeds, without ever being planted or taken care of by the farmer. The fruit borer may take refuge among these as well.

The fruit borer pupae, however, are the toughest amongst all four stages of this insect, and seem to survive longer without ever being detected. The pupae can remain in the soil, where the last brinjal crop was grown, for 2 weeks or even 4 during the cooler winter months. After this, the borer moth must come out. And if there are no brinjal plants around, these adults also perish.

The safest place for this pest to hide in its toughest form—the pupa—seems to be the dried brinjal plants stored by the farmers in the field or around their houses, to be used as fuel for cooking. Somehow, the borer pupae seem to survive much longer among these dried stubbles than in the open field soil. In the next season, when the farmer plants his brinjal crop, the borer moths emerging from these pupae start the pest epidemic.

Hence, if we deny this borer all these hiding places, the pest will have nowhere to go, and could easily be eliminated, leaving the brinjal crop healthy and the farmers happy. However, this too requires cooperation of all farmers in the community.

How do the farmers control the fruit borer now? Most farmers spray their brinjal crop with pesticides to protect it from the fruit borer damage. Farmers use these chemicals indiscriminately, often mixing several pesticides, using wrong chemicals, and at wrong dosages. Many farmers spray their crop two or more times a week, and sometimes even every day!

Such pesticide use is expensive, and damaging to the human health and the environment. Indiscriminate pesticide use allows the borer to become tolerant to these chemicals. Eventually, it becomes impossible to kill the pest again economically with the same chemicals.

How then to control the fruit borer safely and economically? Here are four easy steps to do that:

Step 1. Sanitation before planting

Since the old dried plants can harbor the pest, it is important to get rid of the dried plant stubbles heaped around the field. If you do not want to get rid of these dried plants, then transplant your crop away from these heaps. This will ensure that the moths from these heaps will not reach the new crop to start the damage. At the same time, one should not plant a new brinjal crop in an area that was planted to the same crop in the preceding season. However, if one must plant brinjal after brinjal, keep a period of at least one month after the harvest of the last crop before planting a new crop in the same land. In this way, whatever the borer pupae that might have been left in the field from the earlier crop, would have become moths and gone away or died. Cleaning the surroundings free of old brinjal plants will remove the source of the borer that might attack your crop. As they say "well begun is half done". Such cleanliness will take care of half of the pest problem even before you plant your crop.

Step 2. Sanitation after planting

Before the plants start fruiting, the brinjal fruit borer larvae feed inside the tender shoots. These damaged shoots are readily visible as dried tops of branches. Cut and destroy these larvae-infested shoots immediately. This will prevent the larvae from becoming pupae and adults, and spread the pest epidemic.

Do not drop the excised shoots in the field. They must be destroyed away from the field, preferably by burning or burying 20 cm deep in the soil, or shredding them into tiny pieces so that the larvae are killed or deprived of food. If not destroyed in this manner, the larvae in the shoots can pupate in the soil, become moths, and infest new plants.

The pruning of damaged-shoots is especially important early in the season. Once the fruiting begins, most larvae will prefer to enter the fruits rather than the shoots. Newly infested fruits are difficult to detect. Therefore, destroying the larvae early in the season, harboring in the damaged shoots, will help to check the build-up of the pest population before it causes greater damage when the fruits are formed.

Continue cutting the damaged shoots at least once a week until the final harvest. This cutting will not harm the plant. Cutting them once a week does not take much time since the damaged shoots are easily seen usually in the top portion of brinjal plant, and can be snapped easily by a scissor or knife. In fact, it takes much less time to cut the damaged shoots than spraying the crop with pesticides. Any infested fruits found during the harvest should also be culled and destroyed immediately.

After the final harvest, the old plants should be uprooted and burned promptly since they may harbor fruit borer larvae, which could set off a future pest infestation.

Step 3. Use sex pheromones to trap and kill male moths

Sex pheromones are chemicals produced and released in the air by the females of the fruit borer moth. The normal function of the pheromone is to attract the males towards the females for mating. It is only after mating that the female moth starts laying eggs and spreads the pest epidemic.

The pheromone of fruit borer moth is now synthesized and produced in the factory. It is available in the market in India, and soon in Bangladesh. To use the sex pheromone in the field, one needs two items: the chemical (or the pheromone) lure and a suitable trap. The pheromone sample poured in a porous plastic tube or a tiny rubber cup is called the lure or bait, and is placed inside a trap. The pheromone smell from the lure released continuously in the air attracts the male adults of borer moth. Once near the lure, they fall into the trap and eventually die. The pheromone lures and the traps—both are necessary. In the field, such traps are tied to a stick and erected just above the brinjal plant height. The male moths—active only at night—come and get caught in the trap practically throughout the night. One lure usually has enough chemical to last up to 4 weeks. The trap can last for the whole season and even into the next. After 4 weeks the old lure has to be discarded and replaced with a new one.

The traps of various designs are available in the market or can be prepared locally. Delta and winged traps are commonly used for trapping most of the common insects. The pheromone lure is attached underneath the top of the trap, one lure per trap, which protects the lure from the sun and the rain. The bottom surface is coated with sticky glue in which the male moths attracted to the lure are trapped and killed. These traps can be used continuously in the field for 3–4 weeks depending upon the weather. During the rains or heavy winds, they can get damaged and need to be replaced. During dry weather, the strong winds blow soil and dust particles on to the sticky surface. This reduces the stickiness and efficiency of the trap in killing the insect. In that case, the sticky bottom surface has to be replaced with a new one frequently. This may not be economical.

A plastic funnel trap, developed for trapping the tomato fruitworm or cotton bollworm, is also effective in trapping the brinjal fruit borer adults. This trap, commercially available in India, is made from sturdy and inexpensive plastic material and does not need a sticky surface. The lure is attached underneath the top cover, just above the mouth of the funnel. The adults attracted to the pheromone lure slip through the smooth surface of the funnel into a long plastic bag which is tied to the lower end of the funnel. This trap can last throughout the season and could even be used in the subsequent seasons.

A simple, water-trough pheromone trap has been developed by the Bangladeshi scientists. It consists of a 3-L capacity, 22-cm tall, rectangular or round, clear plastic container. A triangular hole is cut on two opposite sides. Soapy water of 3–4 cm in height is maintained inside the trap throughout the season. The pheromone lure is hung through the center of the lid inside the trap in such a way that the lure is 2–3 cm above the water level.

It is the smell of the pheromone seeping from the lure that attracts the male fruit borer moths. They enter the trap, fly around the lure, and fall into the soapy water and die. The soapy water inside the trap must be replenished often to make sure the trap is never dry, or else the moths will not get killed. This trap can last at least through one season.

No matter what type of pheromone trap or lure is used, the sex pheromone is released for up to 4 weeks. The traps should be erected in the field starting 3–4 weeks after transplanting, to coincide with the flowering of the last harvest. A distance of 10–15 m should be maintained between traps in the field. The traps are hung in such a way that the lure is just above the plant canopy. This will require that the traps be moved higher as the plants grow taller.

Step 4. Reduce the use of pesticides

The indiscriminate use of the toxic, broad-spectrum pesticides is not giving satisfactory control of the brinjal fruit borer any more. In addition, these pesticides are killing the natural enemies of the fruit borer. The natural enemies, which were always present in the farmers' fields, were controlling the pest satisfactorily in the past when the pesticides were not readily available. One of the most notable parasitoids or predators of the brinjal fruit borer in the brinjal fields in Asian countries is a tiny wasp called *Trathala*. This wasp lays its eggs inside the body of brinjal fruit borer larvae still feeding inside the fruit or shoot. When the wasp eggs hatch, the wasp larvae crawl inside the fruit borer larvae and eat the larvae from within. At the end, the fruit borer larva is killed and the wasp larvae form their own pupae, and eventually the parasitoid adults come out. This stops the next generation of the pest, but allows the population growth of the natural enemies. This increased parasitoid population keeps the pest under check as long as the farmer does not use any pesticides. The wasp is harmless to the humans.

The broad-spectrum chemical pesticides sprayed to kill the fruit borer larvae will also kill these beneficial insects. This is the biggest disadvantage of the use of pesticides in combating fruit borer. Only if selective, preferably biological pesticides such as neem products are used, *Trathala* and many other parasitoids will survive and be able to kill the fruit borer larvae. Reducing the use of pesticides will allow common predators, such as the spiders, the ants, the earwigs and the mantids to survive and kill the fruit borer and other pests. These natural enemies are important assets of the vegetable farmer and should be protected by reducing, or if feasible, eliminating the use of broad-spectrum chemical pesticides.

If one must apply pesticides to combat the brinjal fruit borer or other pests, then only the locally recommended and still effective ones and preferably biological products should be used. It is extremely important to adhere to all the three steps to ensure a sustainable control of brinjal fruit borer, so that the people of *India / Bangladesh* can continue to enjoy the taste of their brinjal, season after season.

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