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Development of an Integrated Pest Management Strategy for Eggplant Fruit and Shoot Borer in South Asia

Asian Vegetable Research and Development Center

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Development of an Integrated Pest Management strategy for the control of eggplant fruit and shoot borer (*Leucinodes orbonalis*) in South Asia

AVRDC
—The World Vegetable Center—

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Executive Summary

Eggplant, *Solanum melongena* L., a versatile vegetable, is one of the three most popular and economically important vegetables among small-scale farmers and low-income consumers of South Asia, especially during hot-wet summers when other vegetables are in short supply. During the past two decades this crop has been increasingly ravaged by an insect, eggplant fruit and shoot borer (EFSB), *Leucinodes orbonalis* (Guenée), the larvae of which bore inside eggplant fruit. Farmers have resorted to frequent sprays of pesticides to kill the larva before it enters the fruit. Such extensive use of pesticides cuts into profitability of eggplant production, makes eggplant more expensive to consumers, poses health hazards, and causes environmental pollution and resource degradation.

A regional collaborative research and development project, funded by the Department for International Development (DFID) of the United Kingdom, was undertaken in Bangladesh, India, and Sri Lanka to develop a sustainable IPM strategy and validate its utility in pilot project studies on farmers' fields. Research results indicated that prompt cutting and removal of pest-damaged shoots reduces pest damage to fruit if such practice is coupled with other community-wide means to reduce immigration of pest adults into the area. This latter point reinforces the need for a community-based approach where all farmers practice sanitation and destroy other sources of EFSB, such as old eggplant stubble stored in the field or near dwellings.

A landrace of eggplant, EG058, proved to be resistant to EFSB in India, Sri Lanka and Thailand, but not in Bangladesh. This material is a valuable source to breed pest-resistant eggplant cultivars in the former three countries.

A larval parasitoid of EFSB, *Trathala flavo-orbitalis,* is present in all three countries of South Asia and also in Thailand. However, its activity is adversely affected by the current use of pesticides. Wherever pesticides are used intensively the activity of the parasitoid is eliminated; in turn, wherever pesticides are used sparingly the activity of the parasitoid is restored, which helps in EFSB control.

A two component pheromone, which was discovered over a decade ago but was never field tested, attracted large numbers of male moths when traps were baited with 100:1 proportion of (*E*)-11-hexadecenyl acetate to (*E*)-11-hexadecen-1-ol.

An IPM strategy based on sanitation, withholding of pesticide use, and installation of pheromone traps was successfully tested in pilot project studies on farmers' fields in five districts of India and two of Bangladesh. These IPM practices were promoted among farmers, extension workers, non-governmental organizations, and small agribusiness enterprises through farmers' field days, distribution of promotional materials, newspaper articles, as well as television and radio features. Based on the results of IPM trials, EFSB sex pheromone is now commercialized by three small agribusiness firms in India.

Socio-economic studies of current EFSB control practices in Jessore District of Bangladesh indicated that 98% of farmers relied exclusively on the use of pesticides and more than 60% farmers sprayed their crop 140 times or more in the 6–7 month cropping season. Pesticide use was the costliest item and contributed to 32% of total cost of production. Production costs per hectare for IPM farmers were only Tk 67,025 compared to Tk 97,783 for non-IPM farmers in winter crops, and Tk 85,053 for IPM farmers compared to Tk 128,274 for non-IPM farmers in summer crops (58.39 Tk = 1 USD). Net income per hectare was Tk 91,020 for IPM farmers compared to Tk 57,257 for non-IPM farmers in winter crops, and Tk 214,002 for IPM farmers compared to Tk 36,786 for non-IPM farmers in summer crops. Successful adoption of IPM in eggplant cultivation will increase profits, protect the environment, and improve public health.

1 Introduction

Vegetables are an important source of vitamins, minerals, and plant proteins in human diets throughout the world. Vegetable cultivation is one of the more dynamic and major branches of agriculture, and from the point of view of economic value of the produce, it is one of the most important. Vegetables are rapidly becoming an important source of income for the rural population. At the same time, vegetable cultivation is becoming more costly due to the increasing use of purchased inputs such as pesticides and fertilizers to sustain production levels. These inputs are also a cause for concern due to their deleterious effect on human health and the environment.

Eggplant, *Solanum melongena*, is one such typical vegetable in that its cultivation helps to improve human nutrition and income generation, yet it also degrades the environment. Eggplant is especially important in South Asia (Bangladesh, India, Nepal, and Sri Lanka), where it is one of the three most important vegetable species. This region accounts for almost 50% of world's area under eggplant cultivation. In the hot-wet monsoon season when other vegetables are in short supply, eggplant is practically the only vegetable that is available at an affordable price for rural and urban poor. This vegetable is cultivated largely on small, family-owned farms where weekly sale of its produce brings in a ready cash income.

In recent years, an increasing amount of pesticides have been used in cultivating eggplant due to increasing damage by arthropod pests. Eggplant is infested by a plethora of insect pests throughout Asia. A survey of vegetable pests conducted by AVRDC—the World Vegetable Center indicated that EFSB is the most destructive pest in most major eggplant producing countries of South Asia. EFSB larvae tunnel inside plant shoots (or fruit if available), adversely affecting marketable fruit yield.

Currently farmers rely exclusively on the application of pesticides to control EFSB and to produce blemish-free eggplant fruit. Pesticide use is very intensive for killing the larvae before they bore inside shoots or fruits; once in the shoots or fruits, larvae are inaccessible to the killing action of surface applied chemicals. Since neonate larvae can enter fruits or shoots within only a few hours of hatching from eggs, pesticides have to be applied frequently in order to have sufficient toxic residues on the plant surface adequate enough to kill the crawling larvae. Surveys conducted in Bangladesh indicated that farmers spray insecticides up to 84 times during a 6–7month cropping season (Bangladesh Agricultural Research Institute, 1995).

The research and development activities to combat EFSB have largely been confined to screening pesticides to select the most effective chemical and determining the frequency of their use. At one time, researchers developed pesticide spray schedules that involved calendar spraying whether the pest was present or not (Atwal, 1976; Srivastava and Butani, 1998). This approach has led to increased dependence on pesticides and consequent adverse effects of higher costs of production, environmental pollution, destruction of natural enemies, and development of pesticide resistance in EFSB. The current pesticide use is not only non-sustainable but, if continued, it will adversely affect eggplant and other vegetable production. There was, therefore, an urgent need for developing alternative control strategies.

Host-plant resistance, biological control, sex pheromone, and mechanical control are some alternatives to the use of pesticides. Although numerous reports from India have indicated the availability of EFSB-resistant cultivars, these reports were based on testing of a few, rarely over a dozen, local commercial cultivars (Dhankhar, 1988). These results were never pursued further possibly because the level of resistance was inadequate to reduce pest populations. Some wild *Solanum* species showed high levels of resistance, but it proved to be impossible to incorporate the genes for resistance from wild species into commercial cultivars due to breeding incompatibilities (Dhankhar et al., 1982). Later research in Taiwan identified one eggplant accession possessing genetic resistance that can be exploited in breeding pest-resistant eggplant cultivars (AVRDC, 1999b). A report from Sri Lanka indicated the occurrence of a larval parasitoid, *Trathala flavo-orbitalis* (Cameron), which has potential for providing some degree of pest control (Sandanayake and Edirisinghe, 1992). Another larval parasitoid, *Eriborus sinicus*, was observed in Taiwan and presented an opportunity for biological control of the pest (AVRDC, 1996). A two-component pheromone of this pest was identified in late 1980s (Zhu et al., 1987; Attygalle et al., 1988), but its use in combating EFSB was never exploited. Integration of these control approaches, the only ones readily available, was needed in order to develop a safe and sustainable control strategy that would reduce farmers' dependence on toxic chemicals.

AVRDC, in consultation with national agricultural research and extension systems (NARES) of Bangladesh, India, and Sri Lanka, as well as the Natural Resources Institute in the United Kingdom (UK), proposed a 3-year collaborative research and development project entitled "Development of an Integrated Pest Management strategy for control of eggplant fruit and shoot borer (*Leucinodes orbonalis*) in South Asia" for funding by Department for International Development (DFID), UK. The project was approved by DFID in early 2000, officially inaugurated on 1 April 2000, and lasted until 31 March 2003. This document summarizes research and development activities undertaken in this project and results obtained. The project research included the possible use of mechanical barriers to reduce immigration of the pest from elsewhere to newly planted crops, sanitation of field by prompt cutting and destruction of pest-damaged plant shoots with larvae still feeding inside, multi-location testing of available sources of resistance within *S. melongena* germplasm to judge stability of resistance, development of a protocol for the use of sex pheromone in combating the pest, a survey of the occurrence of local parasitoids and their role in reducing pest populations, and understanding the socio-economics of eggplant production and protection.

The project research in Bangladesh was undertaken by Bangladesh Agricultural Research Institute (BARI), in India by Gujarat Agricultural University (GAU) and Indian Institute of Vegetable Research (IIVR), and in Sri Lanka by Horticultural Crops Research and Development Institute (HORDI). Backstopping laboratory research was done at AVRDC headquarters in Taiwan and field research at the Asian Regional Center of AVRDC (AVRDC-ARC) at Kamphaengsaen in central Thailand. After intensive and well-focused research in the first two years of the project, a cost-effective IPM strategy was developed that was successfully tested in pilot project trials during Year 3 on farmers' fields to demonstrate the utility of the approach.

2 Biology and Nature of Damage of EFSB

Eggplant fruit and shoot borer (EFSB) was first described as *Leucinodes orbonalis* by Guenée in 1854. It was designated as the type species of the genus by Walker in 1859. There are no known synonyms of *L. orbonalis*, but several other species of *Leucinodes* have been described. This insect belongs to family Pyralidae of the insect order Lepidoptera.

Biology

Egg. Adult females lay eggs on the foliage (Figure 1). The number of eggs laid by an average female varies from 80 to 253. Oviposition takes place during the 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. They are creamy-white soon after they are laid, but change to red before hatching. Eggs hatch in 3 to 6 days.

Larva. Soon after hatching from eggs, young caterpillars search for and bore into tender shoots near the growing point, into flower buds, or into the fruits. Caterpillars prefer fruits over other plant parts. Larvae go through at least five instars (Atwal, 1976) and there are reports of the existence of six larval instars. Larval period lasts 12 to 15 days in the summer and up to 22 days in the winter. Sandanayake and Edirisinghe (1992) studied the larval distribution on mature eggplant in Sri Lanka. They found first instars in flower buds and flowers, second instars in all susceptible plant parts, third and fourth instars in shoots and fruits, and fifth instars mostly in fruits. Larval feeding in fruit and shoot is responsible for the damage to eggplant crop. A full-grown larva measures 18 to 23 mm in length (Figure 1).

Pupa. Mature larvae come out of their feeding tunnels and pupate in tough silken cocoons among the fallen leaves and other plant debris on the soil surface near the base of eggplant plants. The color and texture of the cocoon matches the surroundings making it difficult to detect (Figure 1). Some studies indicate the presence of cocoons at soil depths of 1 to 3 cm. The pupal period lasts 6 to 17 days depending upon temperature.

Adult. Moths come out of pupal cocoons at night. Young adults are generally found on the lower leaf surfaces following emergence. EFSB females are slightly bigger than males. The abdomen of the female moth tends to be pointed and curl upwards, 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. Wings are white with a pinkish or bluish tinge and are ringed 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 to 22 mm across the spread of wings. Longevity of adults was 1.5 to 2.4 days for males and 2.0 to 3.9 days for females. The pre-oviposition and oviposition periods were 1.2 to 2.1 and 1.4 to 2.9 days, respectively (Mehto et al., 1983).

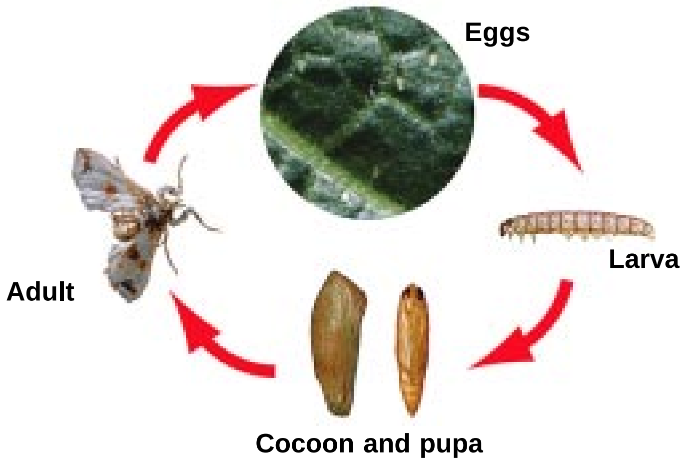

Figure 1. Life cycle of EFSB

Nature of damage

Within one hour after hatching, EFSB larva bores into the nearest tender shoot, flower, or fruit. Soon after boring into shoots or fruits, they plug the entrance hole with excreta. In young plants, caterpillars are reported to bore inside petioles and midribs of large leaves. As a result, the affected leaves may drop off (Butani and Jotwani, 1984).

Larval feeding inside shoots result in wilting of the young shoot (Figure 2). Presence of wilted shoots in an eggplant field is the surest sign of damage by this pest. The damaged shoots ultimately wither and drop off. This reduces plant growth, which in turn, reduces fruit number and size. New shoots can arise but this delays crop maturity and the newly formed shoots are also subject to larval damage.

Larval feeding in flowers—a relatively rare occurrence—results in failure to form fruit from damaged flowers.

Figure 2. Symptoms of EFSB infestation in shoot (left) and fruit (right)

Larval feeding inside the fruit results in destruction of fruit tissue (Figure 2). The feeding tunnels are often clogged with frass. This makes even slightly damaged fruit unfit for marketing. The yield loss varies from season to season and from location to location.

Damage to the fruits in India, particularly in autumn, is very severe and the whole crop can be destroyed (Atwal, 1976). EFSB is active throughout the year at places having moderate climate but its activity is adversely affected by severe cold.

EFSB is practically monophagous, feeding principally on eggplant; however, other plants belonging to family Solanaceae are reported to be hosts of this pest. They include tomato (*Lycopersicon esculentum*), potato (*Solanum tuberosum*), selected nightshades (*S. nigrum* and *S. indicum*), and turkey berry *(S. torvum).*

3 Mechanical Control

Measures of mechanical or physical control involve the use of physical force with or without the aid of special equipment. Mechanical control techniques give immediate and tangible results, even though they are time consuming. Some of the common practices include: handpicking of large larvae or adults; erecting mechanical barriers; cleaning of planted areas prior to, during or after the cropping season (also termed sanitation); and denying pests alternate sources of food. An experiment to this effect was conducted in which a combination of barrier and sanitation was utilized to minimize EFSB damage to eggplant crops.

This experiment was based on two premises. First, the EFSB adult is a relatively small moth and flies short distances when disturbed. Such insects, therefore, can be prevented from spreading from field to field by erecting suitable barriers. Second, larvae of EFSB bore inside tender eggplant shoots, especially before fruit set, and cause wilting of shoots. The insects inside these damaged shoots eventually develop into pest adults that spread and lead to future yield losses. Therefore, the combination of mechanical barriers and prompt destruction of freshly wilted shoots harboring pest larvae has potential in controlling EFSB effectively.

An experiment to this effect was conducted at BARI, GAU, HORDI, and AVRDC-ARC during initial stages of this project. A parcel of land was rototilled and worked into ridges and furrows depending upon local cultural practices. The area was divided into four 20-m × 20-m plots with a distance of 2.0 to 3.2 m between two adjacent plots. The plots were arranged in two rows in a quadrangle or in a single row rectangle depending upon the shape of the available land for the experiment. Five-week-old seedlings of local, EFSB-susceptible cultivars were transplanted in single rows on the top of each bed keeping a distance of 0.5 to 1 m between two adjacent plants depending upon local cultivation practices.

Immediately after transplanting, a 2-m-high nylon net (mesh size 16) barrier was erected around two plots located either diagonally in the quadrangular arrangement or in alternate plots in the rectangular arrangement. At the top of the barrier, 40 cm of netting was stretched and bent outward and downward at an angle of 80 to 85^{o} (Figure 3). This was done to restrict the movement of EFSB adults on the net crawling over the barrier and to provide shelter for predators such as mantids and spiders that could kill the EFSB adults. The bottom 15-cm of nylon net was buried in soil. The remaining two plots were maintained without barrier.

Once a week we observed all plants in one barrier plot and one open field plot and promptly excised and destroyed EFSB-damaged shoots containing pest larvae. The remaining two plots were kept undisturbed. When ready, we harvested marketable sized fruits, recorded weights of damaged and healthy fruits, and calculated percent damaged fruits and yield of marketable fruit. The frequency of observation of pest damage to shoot and fruit varied from 8 to 18 times in a season depending upon the location.

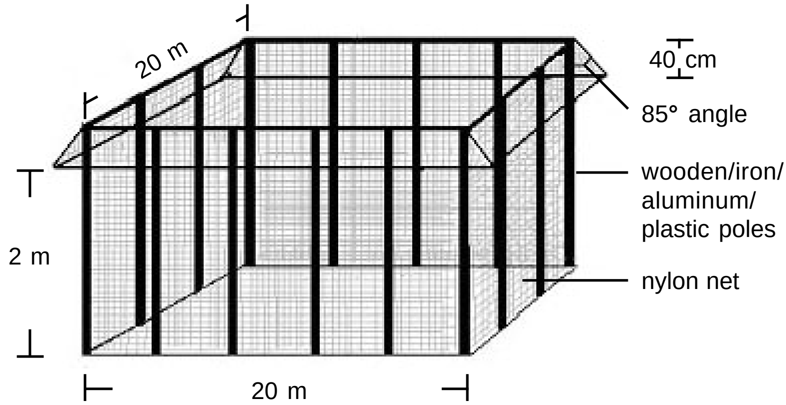

Figure 3. Design of barrier net erected around eggplant plot

The results of the experiment at all four locations are summarized in Table 1. The use of barriers combined with prompt destruction of pest-damaged shoots reduced damage to shoots by an average of 62.7% over locations, which was significantly less damage than by using either the barrier or sanitation alone. Without a barrier, even if one removed damaged shoots promptly, the source of insects flying in from other fields to the experimental area remains unchecked. Suitable barriers can reduce migration and lower the infestation of the crop. That is why the combination of barrier and sanitation gave greater reduction in pest damage to shoots. However, the 2-m-high barrier was not able to completely block migration of EFSB adults.

The EFSB damage to fruits was not as dramatically reduced compared to that of shoots. This is due to the fact that when fruits are formed, the majority of newly hatched larvae prefer to feed on fruits than shoots. As such, removal of damaged shoots only marginally affects the pest damage to fruits. As surmised earlier, the 2-m-high net itself is not adequate to prevent migration of adults into the experimental area. As a result, although combination of barrier and sanitation reduced pest damage to eggplant fruit, the damage reduction to fruits is not as dramatic as the reduction in damage to eggplant shoots.

Table 1. Effect of mechanical barrier and sanitation on the damage of EFSB to eggplant shoots and fruits at four locations in Asia[1]

Treatment	BARI		GAU		HORDI		AVRDC-ARC		Mean reduction (%)[3]
	Damaged plants in shoots								
	Damage (%)	Reduction[2] (%)	Damage (%)	Reduction[2] (%)	Damage (%)	Reduction[2] (%)	Damage (%)	Reduction[2] (%)	
Barrier + Sanitation	8.6	55.6	13.3	52.4	0.6	57.6	2.8	85.0	62.7 ± 15.1 a
Barrier only	16.8	12.9	18.3	34.5	0.8	47.2	11.5	39.2	33.5 ± 14.7 b
Sanitation only	16.1	16.7	17.6	37.3	1.0	27.8	7.3	61.3	35.8 ± 19.0 b
Check	19.3		28.0		1.4		18.9		
	Damaged fruits								
	Damage (%)	Reduction[2] (%)	Damage (%)	Reduction[2] (%)	Damage (%)	Reduction[2] (%)	Damage (%)	Reduction[2] (%)	
Barrier + Sanitation	44.3	40.8	6.6	52.7	44.3	15.6	41.4	24.43	33.4 ± 16.6 a
Barrier only	51.3	31.5	8.4	39.8	41.3	21.3	37.7	21.2	28.5 ± 9.0 a
Sanitation only	66.9	10.6	12.0	13.7	50.0	4.8	50.1	8.4	9.38 ± 3.8 b
Check	74.8		13.9		52.5		54.7		

[1]BARI = Bangladesh Agricultural Research Institute, Bangladesh; GAU = Gujarat Agricultural University, India; HORDI = Horticultural Crops Research and Development Institute, Sri Lanka; and AVRDC-ARC = Asian Vegetable Research and Development Center-Asian Regional Center, Thailand

[2]Reduction in damage compared to check where neither barrier nor sanitation was used

[3]Each location was considered as a replicate for statistical analysis. Mean separation by Duncan's multiple range test, $P \leq .05$

Since the 2-m-high barrier net is not adequate to completely stop migration of EFSB adults into the protected area, the net height has to be increased. However, it appears that such barrier nets may not be economical or convenient to use in most Asian countries, especially those that are prone to typhoons or cyclones.

The results of this multi-location experiment, however, show that a reduction in damage can be achieved if one undertakes suitable measures to substantially reduce migration of EFSB adults and practice sanitation by promptly excising EFSB-damaged shoots. This points to the need for a community approach that encourages all farmers in a community to undertake stringent sanitation measures during the entire season. If some farmers do not follow this practice, insects initially will attack their crop and EFSB adults from their fields will fly to neighboring fields and cause damage. Old crop debris should be disposed of promptly to reduce carryover of EFSB after the last harvest.

Carryover of EFSB from season to season

EFSB is a specific pest of eggplant. It was initially believed that a newly planted eggplant crop becomes infested via EFSB moths that either emerge from pupae in the soil or migrate from neighboring eggplant crops. These two sources of EFSB infestation remain important. However, we identified a new source of the pest insect: eggplant stalks from previous crops. Most farmers store these plants around their fields or dwellings (Figure 4) and use the dried stalks as fuel for cooking.

In order to confirm this finding, we covered one large heap of dry plant stalks with 16-mesh nylon net. Before closing the net tightly around the heap, we placed two pheromone-baited traps inside the heap. Two similar traps were erected in an open area next to this heap and additional two traps were erected 250 m away. This experiment was done during off-season, March–April, when eggplant is not commonly grown in Gutal village in central Gujarat (potato is commonly grown during the winter off-season). The numbers of EFSB adults caught in the traps were recorded once a week during March–April 2002.

Figure 4. A heap of dried eggplant stalks near farmers' dwellings in central Gujarat, India; note the eggplant seedlings raised in the vicinity of the stalks

On average, more than three EFSB adults were caught in pheromone traps every week inside the covered heap of dry eggplant stalks compared to less than one EFSB adult caught in the vicinity outside the netted heap (Table 2). Substantial numbers of adults were also trapped farther away from the heap. This data indicate that EFSB adults are from the eggplant stalks. The adults caught in the traps placed farther away are most likely from other open heaps in the neighborhood since all farmers save the eggplant stubble as a fuel.

In another study in the same area, GAU scientists were able to trap large numbers of EFSB adults (5.5 to up to 19.5 per trap per week) in pheromone-baited traps placed in potato fields during December to January, when potato is usually grown in the region. No potato plants were damaged by the pest, although this insect is reported to attack potato elsewhere in India (Nair, 1967). There was no standing eggplant crop but the area was dotted with heaps of dried eggplant stalks.

This finding poses a dilemma to implementation of EFSB IPM. Prompt elimination of eggplant stubble from old plantings will prevent carryover of EFSB from season to season and this will help reduce damage of this pest to new eggplant crops. However, farmers insist on keeping the plant stubble as a fuel for cooking. A suitable compromise needs to be worked out. At times farmers also grow their eggplant seedlings in the vicinity of the dry eggplant stubble heaps (Figure 4). It is likely that EFSB adults, emerging from the stubble, will lay eggs on the seedlings and the infestation will be carried into the field when the seedlings are transplanted. This possibility cannot be ruled out and needs further investigation.

Table 2. Catches of EFSB moths in sex pheromone traps placed inside a net-covered heap of dry eggplant stubble and outside in open field in central Gujarat, India[1]

Week	Inside net	Open field nearby	Open field away[2]
1	1	0	7
2	3	2	4
3	5	1	1
4	4	0	1
Mean	3.25	0.75	3.25

[1]Mean of two traps spaced 40 m apart; measured weekly during March to April 2002

[2]250 m away from enclosed heap

4 Host-Plant Resistance

Insect-resistant cultivars have been successfully developed and used in numerous field crops including rice, wheat, sorghum, and soybeans. These cultivars can be used alone or in combination with other control measures in an IPM program. Advantages of the use of pest-resistant varieties include low cost, easy transferability to farmers' fields, no danger to humans and domestic animals, and compatibility with all other control practices. Several attempts have been made in South Asia to develop cultivars resistant to EFSB, but after 40 years of efforts, no commercial cultivar has been developed with appreciable level of resistance. Because of the obvious usefulness of this pest control technology, this approach must be further pursued.

In repeated tests at AVRDC in Taiwan, a landrace of eggplant, code numbered EG058, was consistently rated as moderately resistant to EFSB damage both in shoots and fruits (AVRDC, 2000). Since EFSB is far more damaging in South Asia than Taiwan, this accession was tested at all project sites during the early stages of the project. The test accessions included EG058 and a known susceptible accession, EG075. Seeds of these accessions were provided by AVRDC and scientists at each site were advised to test these accessions with one or two local popular cultivars.

At each site the test accessions were transplanted in randomized complete block design with three or four replications. The crop was grown according to local cultural practices but no pesticide was applied. Beginning at the initiation of flowering, the number of plants damaged by EFSB in shoots was recorded weekly. When fruits developed to marketable size, they were harvested weekly and numbers of healthy and damaged fruits were recorded. At times the number of plants showing fruit damage was recorded and in all cases there was positive correlation between the percent total fruit damage and percent plants showing damaged fruit.

The results of evaluation of EFSB damage to shoots and fruits are summarized in Table 3. Except for the BARI location, EG058 was significantly less damaged than the susceptible check EG075, and in most cases, local check commercial cultivars. The reasons for EG058 showing susceptibility in Bangladesh are hard to fathom. Based on data of other studies, pest population pressure in Bangladesh is distinctively higher than other locations throughout the year. It is unlikely that EFSB in Bangladesh is a distinctly different strain because EFSB in Bangladesh responds to the same sex pheromone lure that is effective elsewhere and a larval parasitoid *Trathala flavo-orbitalis* attacks EFSB at all locations equally effectively. We think it is due to influence of local environment on both host and the pest. Accession EG058 represents an important source of resistance to breed EFSB-resistant cultivars, albeit outside Bangladesh.

During the course of study, we also found a new source of resistance in Turbo, a commercial F_1 hybrid cultivar grown by farmers in Thailand. In two identical tests in Thailand and Taiwan, this cultivar was consistently less damaged than the susceptible check. Turbo has green rind, succulent flesh, and good quality fruits. It is, however, an F_1 hybrid currently available in Thailand only. Its commercialization in other countries, if the fruit type is acceptable to local taste, will go a long way toward reducing EFSB damage and pesticide use. At the same time, introducing purple fruit color in Turbo could make this cultivar popular in countries where purple color is preferred.

Based on its consistently lower EFSB damage in all AVRDC trials, EG058 was used at AVRDC in a breeding program to develop EFSB-resistant eggplant. The breeding progeny has been screened for EFSB resistance both at AVRDC in Taiwan and at GAU in India. The 10 least damaged progeny with good fruit quality have been selected for multi-location trials in the region.

Table 3. EFSB damage to eggplant shoots and fruits of various eggplant accessions at four locations in South and Southeast Asia[1]

Accession	BARI	GAU	HORDI	AVRDC-ARC
	% damaged shoots			
EG058	50.9 b[2]	5.4 a	13.0 a	9.8 a
EG075	53.3 b	13.8 c	36.0 b	29.6 b
Jessore local	38.1 a			
Doli		8.2 b		
Morbi		15.7 c		
SM164			28.0 b	
Turbo				10.1 a
	% damaged fruits			
EG058	56.8 b	3.5 a	17.2 a	39.3 a
EG075	58.7 b	11.5 c	48.3 b	90.5 b
Jessore local	37.7 a			
Doli		4.6 b		
Morbi		7.3 b		
SM164			17.3 a	
Turbo				42.5 a

[1] BARI = Bangladesh Agricultural Research Institute, Bangladesh; GAU = Gujarat Agricultural University, India; HORDI = Horticultural Crops Research and Development Institute, Sri Lanka; and AVRDC-ARC = Asian Vegetable Research and Development Center-Asian Regional Center, Thailand

[2] Mean separation in column sections by Duncan's multiple range test, $P \leq 0.05$

5 Biological Control

Most insect pests have natural enemies, which can be other arthropods, or entomopathogens such as fungi, bacteria, viruses, or nematodes. Under natural conditions these natural enemies keep the pest populations under reasonable control. As many as sixteen parasitoids, three predators, and three species of entomopathogens have been reported as natural enemies of EFSB from all over the world (Khorsheduzzaman et al., 1998). However, they do not seem to play any significant role in keeping EFSB damage under reasonable control (Srivastava and Butani, 1998), especially in South Asia. The sole exception is a study from Sri Lanka where Sandanayake and Edirisinghe (1992) reported a high level of parasitism of EFSB larvae by a parasitoid, *Trathala flavo-orbitalis* (Cameron) (Hymenoptera: Ichneumonidae). This parasitoid has been reported to be present in India (Naresh et al., 1986) and Bangladesh (Alam and Sana, 1964), however, its contribution to pest control was rarely documented and does not appear to be significant. Since biological control is an important component in IPM and very little information is available on the role of biological control agents in combating EFSB in the region, we made greater efforts to identify local natural enemies and study their potential role in pest control. Monitoring of seasonality of pest and parasitoids, therefore, were major research activities of the project period.

This experiment was done at all five project sites. In addition to surveying parasitoid species and the extent of parasitism on pesticide-free eggplant crops grown on the experimental farms, some sites also conducted natural enemy surveys on farmers' fields where insecticides were routinely used to understand the potential contribution of natural enemies.

HORDI, Sri Lanka

A survey of parasitoids was conducted on the HORDI experimental farm at Gannoruwa, Peradeniya, where eggplant was grown on an 820 m^2 parcel of land throughout two years from January 2001 to December 2002. No insecticide was used. Marketable sized fruits were harvested weekly and 50 EFSB damaged fruits were maintained in insect rearing cages. When marketable sized fruits were not available, small fruits showing EFSB damage were collected. The numbers of pest and parasitoid adults that emerged from these fruits were recorded and mean percent parasitism during each month was calculated. Data on rainfall and mean and maximum temperatures were obtained from the weather station at Gannoruwa.

Results of the 2-year survey are summarized in Figure 5. *Trathala flavo-orbitalis* (Figure 6) was the only parasitoid found at Gannoruwa. The parasitoid was active throughout the year. Its parasitism of EFSB larvae ranged from 9.5% to almost 39% with an average of 23%. This level of parasitism is substantial considering the fact that parasitism rarely exceeds 10% elsewhere. It must be pointed out that no insecticide was used and the planted area was isolated from major eggplant growing areas. Neither rainfall nor temperature affected the level of parasitism. Host density, as judged by the percent of EFSB damaged fruit, also did not have any significant correlation with the extent of parasitism.

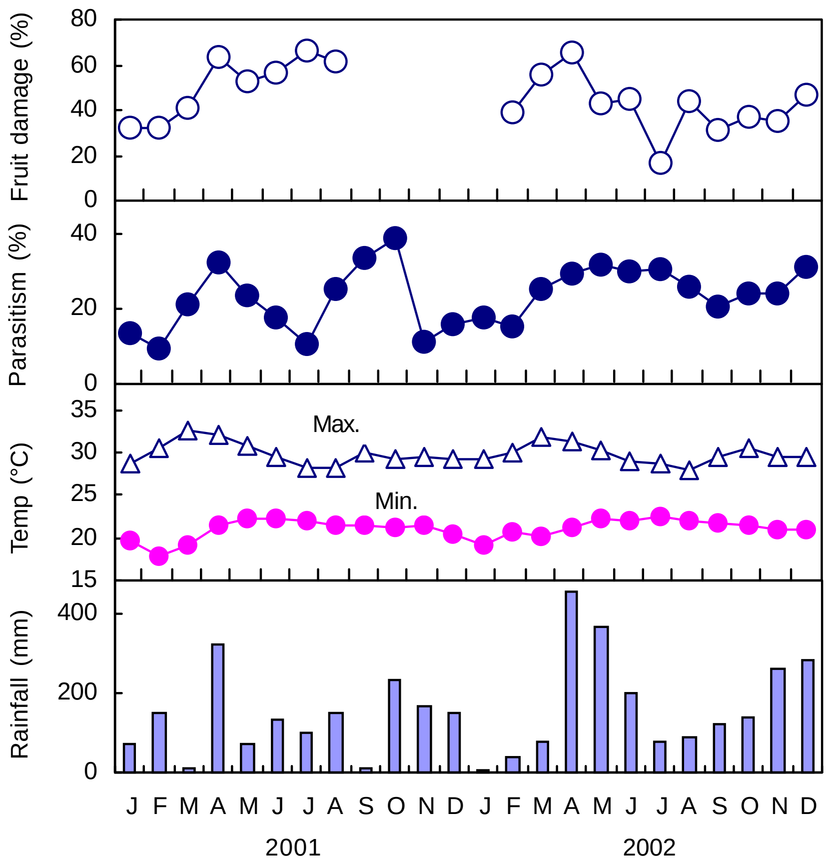

Figure 5. Seasonality of EFSB damage and Trathala flavo-orbitalis *parasitism of EFSB at Peradeniya, Sri Lanka*

Figure 6. Adult of Trathala flavo-orbitalis *(Sun et al., 1995)*

Efforts were made to raise *T. flavo-orbitalis* under laboratory conditions for possible introduction of this ichneumonid in EFSB-problem areas where it does not exist or even possible inundative releases to combat the pest locally if the parasitoid rearing proves to be economical. EFSB larvae were raised on a meridic commercial diet of a polyphagous insect, *Spodoptera exigua*, fortified with eggplant fruit powder (AVRDC, 1999a). Five fifth-instar larvae feeding inside diet blocks were exposed in a plastic jar to one gravid parasitoid female for oviposition. Very few, 8%, of larvae inside the diet were parasitized. However, when eggplant leaves and one fresh fruit were also placed in the plastic jars, parasitism of larvae inside the diet block increased to 62%. Placing of either fruit or leaves was less successful (Table 4). Presence of fresh host-plant parts obviously stimulated searching of EFSB larvae for oviposition by *T. flavo-orbitalis,* possibly due to the chemical signals from the host plant.

The rearing of *T. flavo-orbitalis* proved to be laborious and costly in terms of labor use and electricity consumption in maintaining the rearing room temperature at 26 ± 2°C. Such rearing produced 58% males and 42% females. Preponderance of males will further reduce the utility of laboratory-reared insects in practical control of the pest, if one decides to use the parasitoid to control EFSB locally.

Table 4. Influence of presence of eggplant leaves or fruits on the parasitism of artificial diet-reared EFSB larvae by T. flavo-orbitalis

Treatment	Parasitoid adults emerged per five larvae
Larvae in diet block	0.67 c[1]
Larvae in diet block + 1 leaf	1.13 b
Larvae in diet block + 1 fruit	1.20 b
Larvae in diet block + 1 leaf + 1 fruit	3.07 a

[1]Mean separation by Duncan's Multiple Range Test at $P \leq .05$

GAU, Gujarat, India

A survey was conducted to evaluate EFSB damage to eggplant crops, the occurrence of parasitoids, and extent of their parasitism of EFSB larvae. In general, pesticide use for EFSB control in central Gujarat is only marginal, five to six sprays per season, and the GAU team preferred to carry out this survey on farmers' fields in widely spaced areas to estimate the extent of parasitism and its contribution to EFSB control. The survey was carried out during the normal eggplant-cropping season (April to December) from August 2000 to August 2002 at several villages in Kheda and Anand districts in central Gujarat. Some observations were also carried out on the experimental farm of GAU at Anand Campus.

EFSB damage to eggplant fruits varied considerably. Pest damage was the highest during July to August and it tapered off gradually after that. There was very little fruit damage during November to December toward the end of the season (Figure 7). This trend in pest damage is likely due to high summer temperatures, hovering in mid 30s hovering in mid 30s during July to August and cooling off to 20 to 25°C in November to December (Figure 7). At the peak period the pest damage in many areas exceeded 60% of total fruits whereas in December barely 5% fruits had EFSB damage. *Trathala flavo-orbitalis* was the only parasitoid found in central Gujarat and its parasitism of EFSB in some fields reached as high as 55% in August. However, in some neighboring areas it was below 10%. The level of parasitism coincided with the population of the pest—high during August to September and low during subsequent months. In general, higher levels of EFSB damage coincided with higher parasitism. However, as was found in Sri Lanka, there was no significant correlation between the EFSB damage and parasitism. Under prevailing conditions in Gujarat, it appears unlikely that this natural enemy alone will be able to give adequate control of the EFSB.

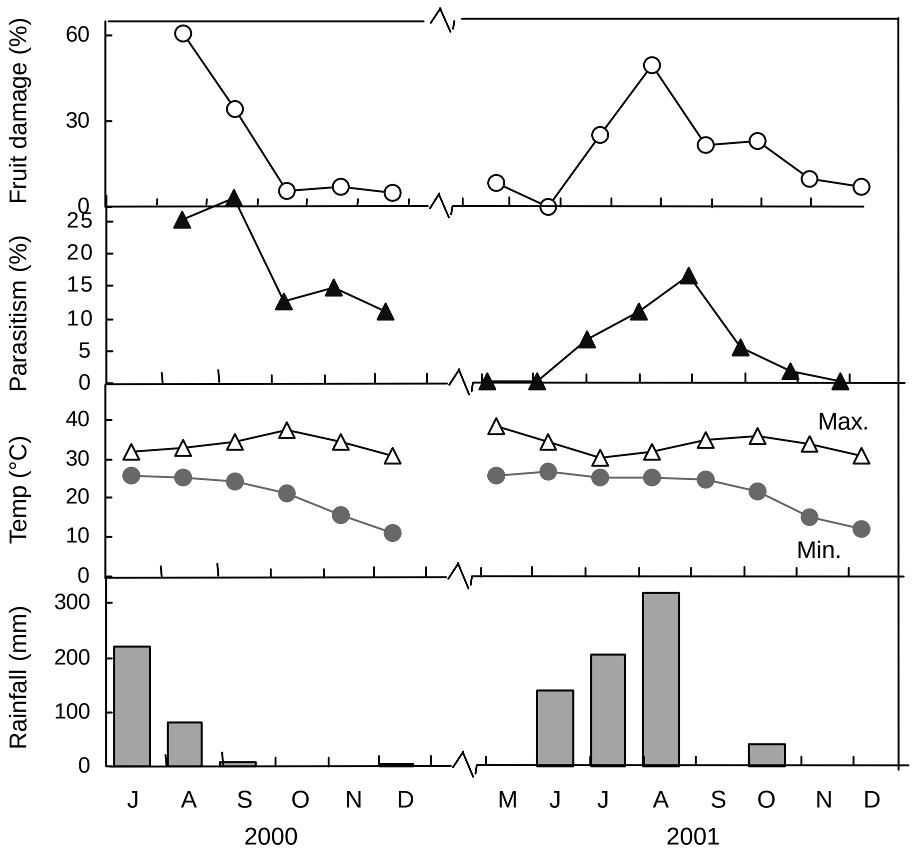

Figure 7. Seasonality of EFSB damage and Trathala flavo-orbitalis *parasitism of EFSB in central Gujarat, India*

IIVR, Uttar Pradesh, India

Surveys of natural enemies and their parasitism of EFSB were carried out from September 2001 to January 2003 on the IIVR experimental farm where pesticide use is restricted. A parcel of land measuring 0.10 to 0.12 ha was planted once every three months. Once a week, all marketable sized fruits were harvested and larvae from damaged fruits were reared on freshly harvested eggplant fruit until adult emergence. The number of parasitoids and EFSB adults emerging from the host were recorded and percentage parasitism was calculated. At this stage the identity of each parasitoid species was established.

Throughout the survey period, *T. flavo-orbitalis* was the predominant parasitoid. Its parasitism peaked at 9.2% EFSB larvae during the second half of October 2001 (Figure 8). From second half of November 2001, activity of this parasitoid ceased but a new parasitoid, *Goryphus nursei* (Cameron) (Hymenoptera: Ichneumonidae), was found parasitizing the EFSB larvae. This ichneumonid was not previously recorded as a parasitoid of EFSB. This species remained as the sole parasitoid of EFSB until the second half of January 2002, a period that coincides with relatively low temperatures in the Varanasi area (Figure 8). However, its peak parasitization during this brief period was only 7.0%. Once temperatures started increasing in April 2002, there was a gradual increase in parasitism, this time by *T. flavo-orbitalis*. Parasitism peaked at 12.0% during the third week of April, fell to around 4–5% until second week of December 2002 when it peaked again at 13.0%. However, parasitoid activity dropped completely during the second half of December through the end of January 2003 when the experiment was discontinued. This period coincided with the lowest temperature in the Varanasi area. Unlike the first year, the parasitism by *G. nursei* was not found during the second year of this experiment, although a few individual wasps of this species were found hovering around plants in this area. Unusually low temperatures during the winter of 2002–2003 may have reduced activity of *G. nursei.* It probably has other hosts in this area.

The overall parasitism of EFSB is lower in the Varanasi area than elsewhere in the region. This is despite the fact that no pesticide was used in cultivating the eggplant crop. It is unlikely that the parasitoid alone will be able to keep the pest population under check and supplementary control measures that are compatible with biological control need to be introduced.

BARI, Bangladesh

The experiment on the abundance of *T. flavo-orbitalis* was done in pesticide-sprayed and pesticide-free eggplant fields at three locations: Gazipur in central Bangladesh, Jessore in the southwest, and Rangamati in the Raikhali Hills in the southeast, from July 2001 to June 2002. Selection of these locations was based on varying histories of pesticide use. In Jessore, farmers spray pesticides daily or every alternate day; in Gazipur at weekly intervals; and in Rangamati, once every two weeks. Non-sprayed eggplant fields were maintained at the nearest BARI research stations in all three areas. Once every month, 30 shoots and 30 fruits infested with EFSB were collected

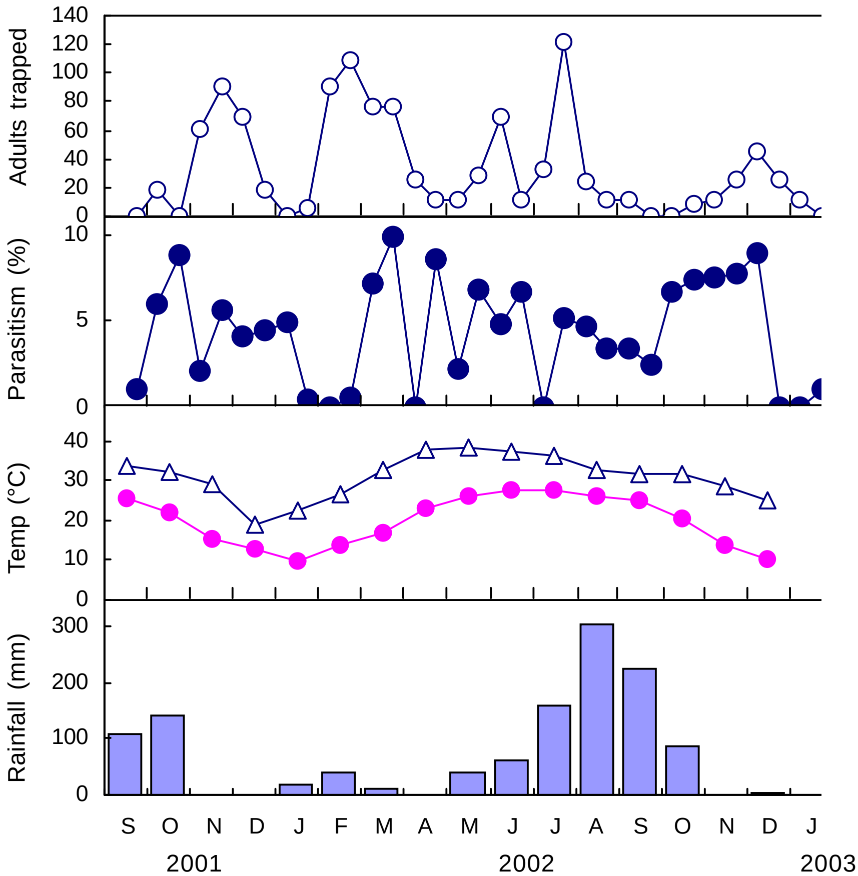

Figure 8. Seasonality of EFSB damage and Trathala flavo-orbitalis *parasitism of EFSB in Varanasi area, India*

from each of the three non-sprayed fields and three customarily sprayed farmers' fields from each region. Pesticides used by farmers varied from time to time and it was not possible to get reliable information. The collected fruits and shoots were kept in the laboratory until pupation. Pupae extracted from damaged plant parts were observed and the number of *T. flavo-orbitalis* and EFSB adults emerging from the pupae were recorded. All the data were subjected to analysis of variance (ANOVA). Means were compared by the test of least significant difference (LSD).

In pesticide-free eggplant fields during the winter season, the EFSB population was low and the pest was not found at Gazipur, especially during January to February. In Jessore, some infestation occurred during this period. Results at Gazipur and Jessore indicated that the population of *T. flavo-orbitalis* is dependent upon the density of its host, EFSB (Figure 9). A significant and positive correlation between the number of EFSB and the parasitoid was observed at both locations (Gazipur, r = 0.87, $P \leq .05$; Jessore, r = 0.71, $P \leq .05$). Such correlations were not found in three previously described locations; this may be due to the relatively high pest population levels and rates of parasitism in Bangladesh. The population of *T. flavo-orbitalis* increased gradually in both locations during the yearlong experimental period. During August 2000, when the study was initiated, the average number of *T. flavo-orbitalis* reared from the field-collected shoots and fruits was 4.3 at Jessore and 7.0 at Gazipur. After 12 months of withholding pesticide use, the number of parasitoids from the same number of damaged shoots and fruits increased to 40.7 and 61.7 at Jessore and Gazipur, respectively. This was reflected in increasing levels of parasitism of EFSB by *T. flavo-orbitalis.*

The level of parasitism increased by about threefold after one year of eggplant cultivation without pesticide spraying. The parasitism rate during August and September 2001 was considerably higher in both locations (39.3 and 44.3% at Gazipur and 44.9 and 48.9% at Jessore). If this level of parasitism can be sustained over larger areas throughout the year, it would reduce the pest population on a sustainable basis, thus reducing the need for pesticide use in combating EFSB.

Emergence of *T. flavo-orbitalis* from samples collected from pesticide-sprayed fields at all three locations was very low or non-existent although researchers were able to collect 30 EFSB-damaged shoots and fruits at each observation interval. In Jessore, no *T. flavo-orbitalis* emerged from either infested shoots or fruits (Figure 10). In Gazipur, the parasitoid emerged from infested fruits but not shoots. In Rangamati,

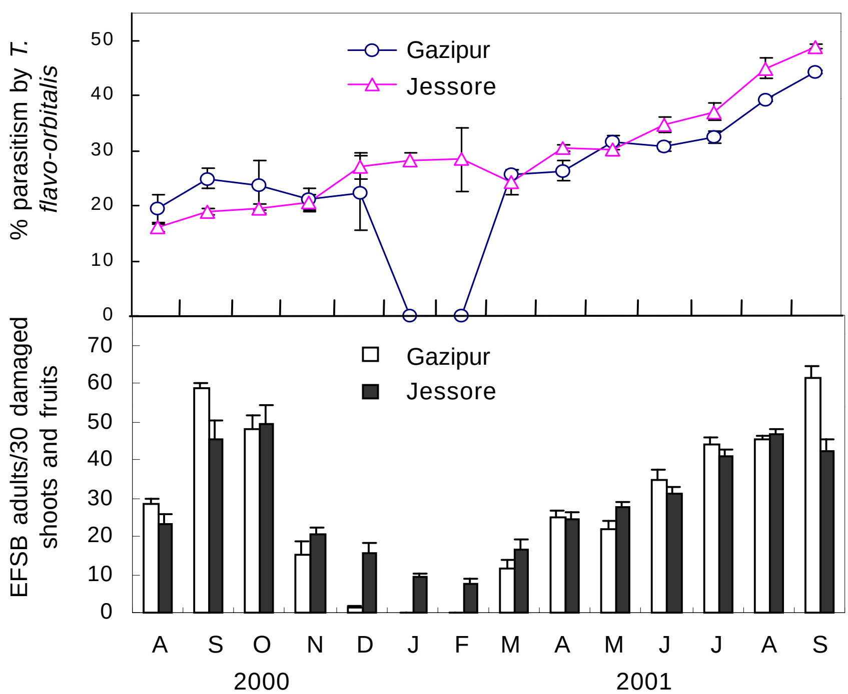

Figure 9. Abundance of EFSB and its parasitism by Trathala flavo-orbitalis *in continuously cropped, pesticide-free eggplant fields at two locations in Bangladesh*

some parasitoids emerged from both fruits and shoots. As expected, considerable numbers of *T. flavo-orbitalis* emerged from the infested fruits and shoots of non-sprayed fields from all locations. The numbers of *T. flavo-orbitalis* adults emerging from shoot or fruit were similar, although the number was marginally higher for shoot than fruit.

These results demonstrated the existence of *T. flavo-orbitalis* in all regions of Bangladesh, however, indiscriminate use of pesticides is highly deleterious to the parasitoid; the higher the spray frequency, the lower was the parasitoid population. Pesticide use in eggplant cultivation in Jessore region clearly verifies this. No specimens of *T. flavo-orbitalis* were recorded from the infested shoots and fruits from farmers' eggplant fields in Jessore, obviously because of the indiscriminate use of pesticides (Rashid et al., 2003). On the contrary, the parasitoid was available on the non-sprayed fields in the same location. The parasitoid population exists even in sprayed areas where pesticide use is moderate or low as is the case for Gazipur and Rangamati, respectively.

AVRDC-ARC, Thailand

Eggplant is an important vegetable in Thailand but very little is known about EFSB damage to the crop in the country. We monitored occurrence of this pest and its major parasitoids to assess the extent of crop damage and the possible role of its natural enemies, especially parasitoid *T. flavo-orbitalis* on control. This research was done on the experimental farm of AVRDC-ARC, Kamphaengsaen, in Nakhonprathan Province of Thailand.

A 16-m × 40-m parcel of land was rototilled and after basal fertilizer application, the land was worked into ten 1.6-m × 40-m beds. One-month-old seedlings of an EFSB-susceptible accession, EG075, were transplanted in each bed, maintaining a distance of 1 m between adjacent plants. The crop was raised by traditional cultural practices including timely weeding, irrigation, and fertilization practices. No pesticides were used to control arthropod pests or diseases. Starting within two weeks after transplanting, we observed each plant weekly for pest damage in the shoot and recorded the number of damaged plants irrespective of the number of shoots damaged in individual plants. Damaged shoots containing larvae were excised and brought to laboratory. Excised larvae were transferred to freshly harvested eggplant fruit for completion of larval development followed by pupation and emergence of adults of the pest or parasitoid. The percent parasitism was calculated. Once a week, marketable sized fruits were harvested and the number of EFSB damaged and healthy fruits were recorded. The damaged fruits were maintained in insect-rearing cages and the numbers of adults of parasitoid and EFSB were recorded and the percent parasitism was calculated.

During 2001, four such plantings were transplanted: one each on 13 February, 4 May, 10 July, and 5 October 2001. Incidence of EFSB and extent of its parasitism were recorded. Each planting was maintained for 18 weeks after transplanting. Bi-

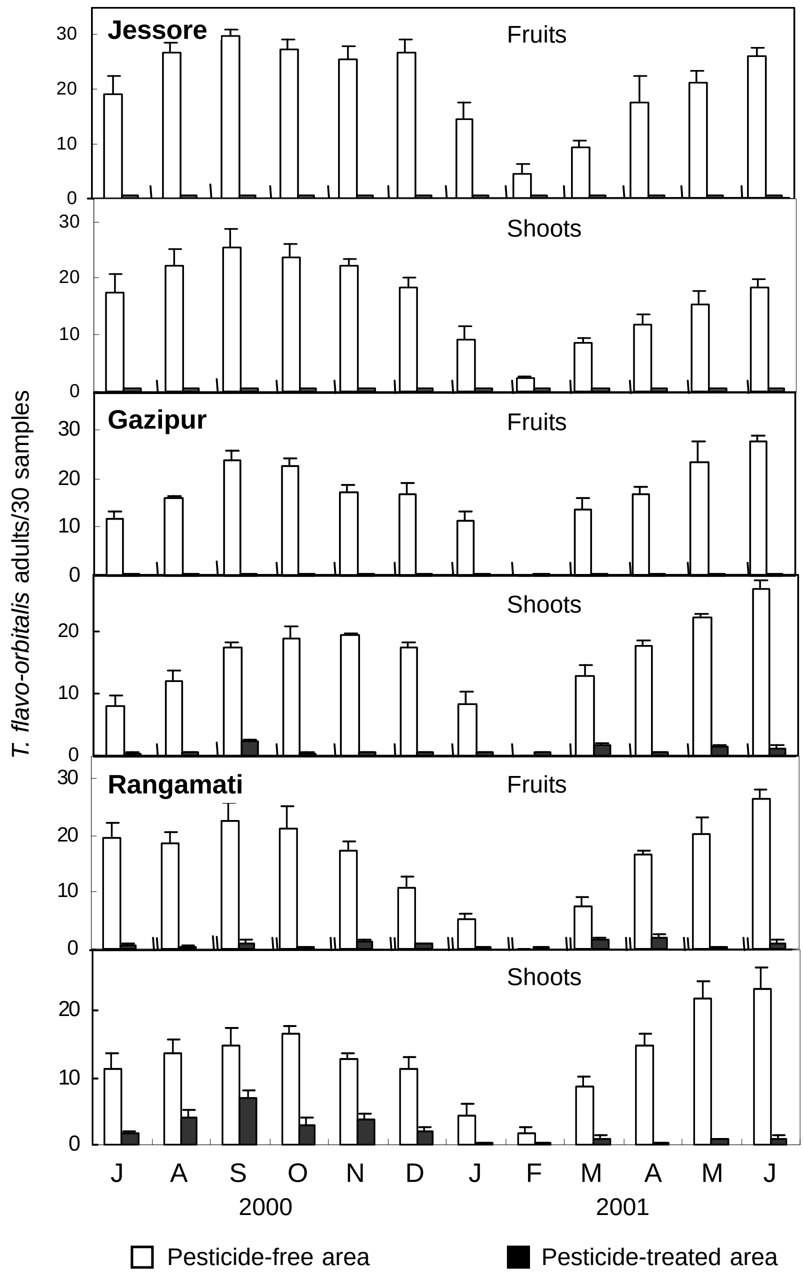

Figure 10. Trathala flavo-orbitalis *emergence from EFSB-damaged shoots and fruits collected from pesticide-free and pesticide-treated eggplant fields in three regions of Bangladesh*

weekly mean minimum and maximum temperatures and monthly rainfall data were obtained from the local weather station.

The results of the monitoring of EFSB damage and its parasitism mainly by *T. flavo-orbitalis* are summarized in Figure 11. The pest was prevalent throughout the year. Its damage in shoots became noticeable usually within four to five weeks after transplanting and increased gradually through the rest of the season averaging around 20% plants damaged at each observation. In general, shoot infestation declined when plants started to bear fruits; however, this was not the case for the EFSB epidemic in central Thailand. Plant damage in the shoots increased gradually every week until final harvest. The highest pest damage in the shoots was during July to September.

The parasitoids, which were confined mainly to larvae present in damaged shoots, were prevalent from June to December. Except for one occasion in mid-August, when parasitism reached 49%, parasitism rarely exceeded 25% of larvae. Onset of parasitism in damaged shoots occurred from the second week after onset of pest damage to four weeks after such event. Plant age did not affect the number of larvae in shoots parasitized.

Pest damage to fruits was present at every weekly harvest with highest damage occurring in August when it ranged from 57 to 97%. Fruit damage was generally less during April to May. There was no consistent correlation between level of damage in shoots and fruits. This is probably due to the preference of EFSB larvae to fruits over shoots after fruit set.

Despite heavy pest damage to fruits, and occurrence of parasitism in shoots, except for two weekly observations on 13 and 20 May, EFSB larvae in fruit were free of parasitoid attack throughout the year. Reasons for this lack of parasitism in fruit is difficult to understand, but could be due to the bulky large fruits of EG075, the accession we used for this experiment. In bigger fruits, EFSB larvae can go deeper inside the large fruit beyond the reach of ovipositors of *T. flavo-orbitalis*. At the same time, tender shoots of eggplant are thin and succulent enough for females of *T. flavo-orbitalis* to pierce with its ovipositor and lay eggs inside larval body.

Temperature appeared to have a positive correlation to level of pest damage. High damage to eggplant crops in July, August, and September coincided with higher air temperatures in Kamphaengsaen during these months. At the same time, low temperatures during January to March had the opposite effect on pest damage. EFSB, being a tropical insect, prefers warmer weather.

Besides *T. flavo-orbitalis,* two specimens each of *Pristomerus testaceus* Merl. and *Elasmus corbetti* Ferriere, and one of *Euagathis* sp. were recovered from the EFSB larvae during the year. The first two species were found in July to August and the latter in December.

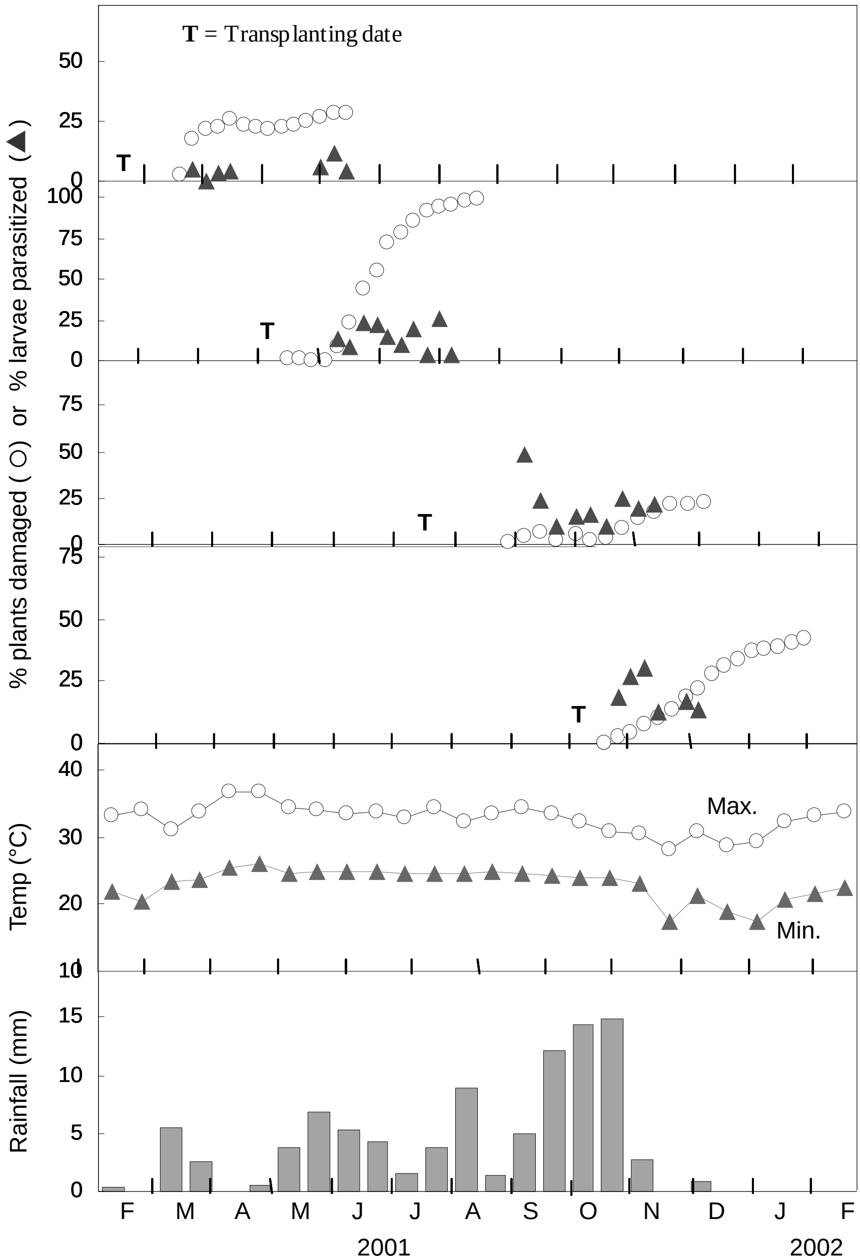

Figure 11. Infestation of EFSB and its parasitism mainly by Trathala flavo-orbitalis *for four plantings of eggplant grown at Kamphaengsaen, Thailand*

6 Sex Pheromones

Sex pheromone chemicals are increasingly used to control insect pests of vegetables and fruits. Zhu et al. (1987) working in China identified (*E*)-11-hexadecenyl acetate (E11-16:Ac) as the major component of the female sex pheromone of EFSB and suggested that it was attracting male moths in the field, although no data was provided. Subsequently, Attygalle et al. (1988) confirmed the presence of E11-16:Ac in virgin females using insects from Sri Lanka. In addition they found trace amounts of (*E*)-11-hexadecen-1-o1 (E11-16:OH). However, they too did not conduct any field studies to ascertain the importance of either of these two compounds. AVRDC obtained pure chemicals and tested mixtures of varying proportions of E11-16:Ac and E11-16:OH in selected locations in Asia. Results of field studies in Bangladesh and later in India indicated that high concentrations of E11-16:Ac alone or low concentrations of mixtures of E11-16:Ac and E11-16:OH (10:0.5 or 10:1) attract large numbers of male moths to pheromone-baited traps (Figure 12) (AVRDC, 1996; Praveen Kumar and Sundara Babu, 1997; Srinivasan and Sundara Babu, 2000). These results formed the basis for inclusion of sex pheromone as one of the components of IPM of EFSB in this project.

Initial studies undertaken in UK by Natural Resources Institute (NRI) under this project confirmed presence of large amounts of E11-16:Ac and trace amounts of E11-16:OH in the extracts of ovipositors of female insects sent from Taiwan and India. NRI's other studies in India indicated that a combination of 100:1 of E11-16:Ac and E11-16:OH attracts significantly greater number of male moths than other combinations (Cork et al., 2001). Additional studies were conducted at BARI, GAU, and IIVR to optimize the use of sex pheromone for use in IPM of EFSB on farmers' fields.

Figure 12. EFSB male adults caught in sex pheromone-baited trap

Optimization of trap design

Depending upon local availability, various types of traps were tested at three sites (Figure 13). GAU tested the standard delta trap and two plastic funnel traps commercialized by two local companies in India. IIVR tested three traps: a funnel trap, delta trap, and a locally made water-trough trap similar to the one used by BARI. BARI tested delta, open delta, funnel, uni, *Spodoptera*, and locally designed water-trough traps. Lures loaded with 3 mg of sex pheromone were used. Traps were placed in EFSB-infested eggplant fields just above the crop canopy. The number of male EFSB adults trapped were recorded at regular intervals over varying lengths of time reaching to up to 5 weeks.

Figure 13. Pheromone traps of various designs tested in sex pheromone studies; from top left and clockwise: delta trap, winged trap, water-trough trap, and funnel trap

At GAU, the delta trap consistently caught more EFSB male adults than the other trap designs, Phero and the Nomate. The latter two were essentially funnel traps of similar design and caught similar numbers of insects. However, the sticky surface of delta traps needed to be replaced quite often making its use inconvenient and costlier than funnel traps. Researchers at the GAU site, therefore, preferred funnel traps for further studies, especially in the pilot IPM projects on farmers' fields. Long-lasting funnel traps are commercially produced in India and are reasonably priced.

At IIVR, funnel traps consistently trapped more EFSB adults than delta or water-trough traps. Weekly moth catches for funnel, delta, and water-trough traps were 18.25, 6.03, and 2.75 moths per trap, respectively. IIVR, therefore, decided to use funnel traps in all of their subsequent studies.

Several sets of tests were conducted at BARI to select an efficient trap that was cost effective and locally available. In their final test, BARI scientists compared the efficacy of delta, open delta, funnel, and water-trough traps. The traps were maintained in eggplant fields for 10 days and the number of adults trapped recorded every alternate day. The results are summarized in Table 5.

Among the four traps, the open delta caught significantly greater numbers of EFSB males than other traps (Cork et al., 2003). There were no significant differences between the numbers of EFSB moths trapped among the remaining three traps. Among these traps, only the water-trough trap can be fabricated locally when needed at an affordable price. All others have to be imported from abroad and their costs are higher. BARI scientists therefore decided to use the locally fabricated water-trough trap. This trap consists of a 3-liter capacity, 22-cm tall rectangular or round clear plastic container (Figure 13). A triangular hole is cut in any two opposite sides starting 3 to 4 cm from the bottom. Soapy water of 3 to 4 cm 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 it is 2 to 3 cm above the surface of the soapy water.

Preference of moths to certain types of traps is a function of the behavior of that species. The aim of any pheromone trap should be to trap the maximum number of adults at any given time. However, for the sake of economy, both GAU and BARI preferred traps that gave less than optimum control of the pest. At the same time it is puzzling that in tests at IIVR, significantly more EFSB males were trapped in funnel traps than in delta traps in each of two tests they carried out.

Table 5. Influence of sex pheromone trap design on catches of male EFSB moths in Jessore, Bangladesh

Trap design	Moths/trap/night
Delta	0.44 ± 0.50 a[1]
Open delta	2.34 ± 0.32 b
Water-trough	0.60 ± 0.42 a
Funnel	0.52 ± 0.04 a

[1]Data are means of 5 replicates, each replicate maintained for 10 nights. Means followed by the same letter are not significantly different at $P \leq .01$ by Newman-Keuls multiple range test on log (X+1) transformed data

Trap height study

It is important to know how high the sex pheromone-baited traps should be erected in the field to enable the maximum number of male moths to be caught. Optimal trap height for EFSB is influenced by the flying habit of the pest and whether it is flying in from other fields or originates from pupae within the same field.

Trap height studies were performed at GAU, IIVR, and BARI. The heights tested ranged from 0.5 m to 2 m above the soil surface. In some cases instead of soil surface, the height of crop canopy was used as a reference height and traps were placed at the level of crop canopy as well as above and below the height of the crop canopy. The results in terms of number of male moths trapped varied considerably.

In Gujarat, where this test was conducted at three locations (Anand, Chaklasi, and Chhani), pheromone-baited delta traps were placed at 0.5, 1.0, and 1.5 m above the soil surface in a field of eggplant of unspecified height. The numbers of insects trapped were recorded weekly for up to 7 weeks. The pooled data of three locations indicated that the higher the traps above the soil surface, the smaller was the number of moths trapped. The average number of moths trapped per trap per week was 4.09 at 0.5 m height, 2.46 at 1.0 m height, and 1.57 at 1.5 m height. In two out of three locations the number of insects trapped at the 0.5 m height was significantly greater than at the 1.5 m height. The number of insects trapped at the 1.0 m height was not significantly different from those trapped either at 0.5 m or 1.5 m heights.

At IIVR, the crop canopy of unspecified height but of fruiting mature plants was considered as the reference point to decide the height of the pheromone trap. The traps were placed at plant canopy level, 25 cm below canopy, and 25 cm above plant canopy. The trap height was adjusted once a week to the height of the crop. The number of male adults trapped was recorded daily from 50 to up to 110 days after transplanting. Average daily moth catches of 30.58 in traps installed 25 cm above crop canopy was significantly higher than the number of moths trapped either at crop canopy, 20.22, or 25 cm below crop canopy, 12.78.

A much more detailed work on this topic was done at BARI site where pheromone baited traps were erected in at 0.5, 1.0, 1.5, and 2.0 m above soil level. These heights corresponded to 1.0 m below, 0.5 m below, at crop canopy, and 0.5 m above crop canopy, respectively. Four winged traps, each representing a replicate, were placed at each height. A distance of 15 to 20 m was maintained between treatments and 50 m between replicates. The numbers of moths trapped were recorded daily for 24 nights. Moth catch was significantly influenced by trap height in relation to that of the crop canopy (Table 6). Traps placed at the level of crop canopy (1.5 m above soil surface) caught significantly more moths than the traps erected at 0.5 m above or below the crop canopy. Traps located 1 m below the crop canopy (0.5 m above soil level) caught as many moths as those 0.5 m above or below crop canopy.

Table 6. Effect of sex pheromone trap height on catch of male EFSB moths in Jessore, Bangladesh[1]

Trap height above soil surface (m)	Trap height with respect to crop canopy (m)	Moths/ trap/night
0.5	- 1.0	1.23 $\pm$ 0.26 a[2]
1.0	- 0.5	0.92 $\pm$ 0.23 a
1.5	0	2.17 $\pm$ 0.59 b
2.0	0.5	0.92 + 0.16 a

[1]Winged trap, 4 replicates, 24 nights, November 2000

[2]Means followed by the same letter in a group are not significantly different $P = 0.015$ by Newman-Keuls multiple range test on log (x + 1) transformed data

Results of trap height tests from the three different locations varied considerably. This is more likely due to the varying sources of EFSB being trapped. If the insects are coming in from outside, which is usually but not exclusively the case in the initial stages of infestation, they are likely be flying well above the soil surface or even above crop canopy. In such cases, traps placed at a higher level, at or above crop canopy, are more likely to trap these insects. However, as the season progresses, substantial numbers of adults are likely to come from the pupae from local infestation. The adults emerging from such pupae are likely to be trapped in traps nearer to the soil. Basic studies at AVRDC revealed that neonate adults become sexually mature immediately, in some cases within an hour, after emergence from pupae starting at dusk. Since pupae emerge from the soil surface, the neonate adults could very well be below the plant canopy and the pheromone chemical has to be there to trap sexually mature males before mating. This phenomenon leaves the question of appropriate trap height in doubt.

In a related study conducted only at BARI, the influence of different materials used to dispense the pheromone was studied. Sex pheromone, 3 mg, was dispensed in white rubber septa, polyethylene vials (wall thickness of 1.5 m), or black rubber septa. Winged traps baited with individual dispensers were placed in the field for 24 nights and the numbers of EFSB male adults trapped were recorded daily. Polyethylene vials caught significantly more adults than either black or white septa (Cork et al., 2001). This information proved useful in economizing use of pheromone. For all subsequent studies, pheromone chemicals were dispensed in polyethylene vials rather than traditionally used rubber septa. This information has been shared with potential entrepreneurs interested in commercializing the EFSB sex pheromone in South Asia.

Study on mating and oviposition of EFSB

Initial studies with synthetic sex pheromone indicated that despite its effectiveness in attracting large numbers of adult males, EFSB can still cause substantial damage to crops where sex pheromone-baited traps are installed. In order to improve pest control efficiency of the pheromone, we conducted some basic studies on the sex pheromone-mediated mating behavior of this insect as well as oviposition that follows successful mating.

All insects used in this study came from a laboratory colony maintained at AVRDC alternatively on artificial diet (AVRDC, 1999a) and fresh eggplant fruit. In a study of periodicity of adult emergence from pupae, we confined individual pupae in 30-ml clear plastic containers and observed them once every hour until all pupae emerged into adults. We made this observation on 45 pupae in 2001 and 284 pupae in 2002. In a mating periodicity and duration study, we placed one male and one female that had emerged within 2 to 4 hours, into 15-cm-diameter and 30-cm-long acrylic cylinders, dubbed “mating chambers”. A cotton plug dipped in honey and a live seedling of eggplant was placed inside the chamber as food and possible mating stimulation source, respectively. We observed the adults every hour and noted the number of insects in copula. In a mating frequency study in 2001, we placed single pairs of newly emerged males and females together and after their mating ended, we removed each mated female and replaced it with another virgin female of 0–4 hours age inside the mating chamber and observed the insects once every hour. In 2002, one unmated male with three to four virgin females and one virgin female with three to four unmated males of 0–4 hours age were confined in mating chambers. Insects were observed every hour and the duration and frequency of mating were recorded. In a study of initiation of oviposition, immediately after mating was over, we placed the pair in an oviposition chamber. The oviposition chamber was essentially the same as the mating chamber except that the inner side of the acrylic cylinder was lined first with a layer of rough paper followed by a layer of 32-mesh nylon net. Insects were observed once every 2 hours to record the time when they started laying eggs.

EFSB adults started emerging from pupae around sunset, 1900 hours, and continued until 0200 hour the next day (Figure 14). Males tended to emerge slightly earlier than females and the duration of emergence time of males was longer than that of females. However the peak of emergence of both sexes was 2000–2200 hours.

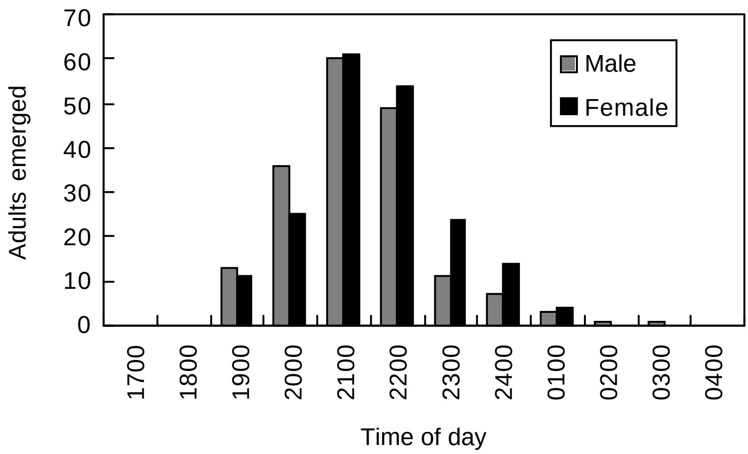

Figure 14. EFSB adult emergence periodicity

The earliest mating occurred at 1900 hours, almost soon after adult emergence from pupae, and initiation mating lasted until 2400 hours. Very few matings began after midnight. Some matings that began before 2400 hours lasted well beyond midnight. The peak mating period was 2100 to 2300 hours. Duration of mating lasted 1.90 $\pm$ 0.78 hours with a range of less than 1 hour to up to 3 hours. The average pre-mating period was 9.25 $\pm$ 10.43 hours ranging from 1 to 28 hours. A substantial majority of adults started mating 0–3 hours after emergence from pupae, however, some mated the next night. The adults that emerged before 2100 hours mated that same night, but those that emerged after 2100 hours mated on the next evening. No male moths mated more than once in the 2001 study, but 1 of 13 males mated twice in the 2002 study. Oviposition begins at the earliest at 19 hours after mating and at the latest 49 hours after mating. The average post mating pre-oviposition period was 33.93 $\pm$ 12.27 hours.

Tests of sex pheromone as a component of IPM

The role of sex pheromone as a component of IPM in reducing damage of EFSB to eggplant was studied on experimental farms or carefully supervised farmers' fields at GAU, IIVR, and BARI sites. In repeated tests in Sri Lanka, lures prepared out of various combinations of the two-pheromone chemicals and baiting them in traps of various designs failed to attract any significant number of male EFSB adults. This was especially surprising considering the fact that the two-component sex pheromone was detected first in female EFSB from Sri Lanka (Attygalle et al., 1988). This failure limited the potential use of sex pheromone in Sri Lanka, and in particular its scope for use in the pilot project studies in that country.

At GAU, experiments were conducted at two sites, one each at Gutal and Borsad villages in Anand District. Twenty pheromone-baited delta traps were installed in each of three 0.2 ha parcels of eggplant cultivated area in each village. A distance of 10 m was maintained between two adjacent traps. The numbers of adults trapped were recorded weekly. Three similar size check plots located away from the pheromone-installed plots were used. When ready for harvest, marketable sized fruits from 100 randomly selected plants in both pheromone-installed and check plots were picked once a week and numbers of EFSB-damaged and healthy fruits and percent damaged fruits were computed. Marketable fruits from entire plots were harvested and fruit yields per plot and per hectare were calculated. Male EFSB were trapped throughout the season at both sites (Table 7).

Table 7. Effect of sex pheromone-baited traps on EFSB damage to eggplant shoots, fruits, and yield at two locations in Gujarat, India

Items	Locations	
	Gutal	Borsad
No. moths trapped/week[1]		
(in pheromone-treated fields)	4.3	1.8
Shoots damaged (%)		
Pheromone	-[2]	16.1 ± 4.8
Check	-	29.2 ± 2.6
t		4.52*
Fruits damaged (%)		
Pheromone	27.4 ± 2.2	15.1 ± 0.5
Check	49.6 ± 1.2	31.3 ± 2.2
t	3.90*	11.32**
Marketable yield (t/ha)		
Pheromone	18.8 ± 1.8	23.6 ± 2.8
Check	9.1 ± 1.1	16.4 ± 0.7
t	3.07*	1.28[NS]

[1]From 2nd week of July to 3rd week of August 2001 at Gutal and from 2nd week of September to 2nd week of November 2001 at Borsad

[2]No observations made

The installation of pheromone-baited traps significantly reduced EFSB damage to shoots at Borsad (observations were not taken in Gutal). The traps significantly reduced EFSB damage to fruits at both sites. As a result, marketable yield was more in pheromone-treated plots than in check plots at both sites. The yield difference was statistically significant at Gutal village but not at Borsad village. Overall it was evident that the use of sex pheromone will assist in reducing EFSB populations and damage to eggplant crops.

In experiments at IIVR, sex pheromone was used in conjunction with sanitation—prompt cutting of pest damaged shoots with larvae feeding inside—to find the effectiveness of sex pheromone in reducing pest damage to eggplant. In 2001, this experiment was conducted at the IIVR experimental farm and on farmers' fields. In 2002, it was conducted only on the IIVR experimental farm.

In 2001, at each of two locations, IIVR and Adalpura village, six 28-m x 28-m plots were planted to eggplant variety Pb. Sadabahar in August. The plots were spaced 50 m apart. At IIVR three plots were kept undisturbed without any treatment whereas in each of remaining three plots a series of nine pheromone-baited funnel traps were erected at a distance of 10 m between two traps; trap height was adjusted at 15–25 cm above plant canopy. Starting 25 days after planting, EFSB damaged shoots were clipped and destroyed once a week. At weekly harvest, after recording the yield and number of damaged fruit, the unmarketable damaged fruit were discarded promptly. The number of EFSB adults trapped was recorded once a week. Identical pheromone and sanitation treatments were followed on farmers' fields in Adalpura, however, farmers were allowed to use the eggplant variety of their choice and also allowed to spray pesticides because they were unwilling to do away with these chemicals.

The results are summarized in Table 8. The number of EFSB male adults caught ranged from less than 1 per trap per week during the second week of January 2002, to over 227 during the last week of November at IIVR. A similar trend in moth catch was observed on farmers' fields in Adalpura. The average weekly moth catch differed only slightly between two sites, 60.2 at IIVR to 67.5 at Adalpura. This average level of moth catch throughout the season is considered quite substantial and contributed to reduction in pest population.

The fruit damage by EFSB was significantly reduced in pheromone-treated and sanitation plots than in check fields (Table 8). As a result, the marketable fruit yield was greater at both sites in pheromone-treated plots than in check plots. Use of sanitation may have contributed to the reduction in pest damage in pheromone-installed plots. However the experiment was done in the open field in a predominantly eggplant growing region, where migration of pest adults from elsewhere into experimental areas could not be prevented. As a result, as observed elsewhere with barrier net studies, contribution of sanitation-only treatment in reducing pest damage was expected to be minimal. Similar trends in fruit damage and marketable yield were observed when the experiment was repeated in 2002 on the experimental farm at IIVR.

In Bangladesh, replicated small-scale mass trapping trials were undertaken at two villages, Monirampur and Haibatpur, near the BARI's Regional Agricultural Research

Table 8. Effect of sex pheromone and removal of infested shoots on the control of EFSB at two locations in Uttar Pradesh, India

Items	IIVR	Adalpura
No. of adults trapped/plot/week (in treatment fields)	60.2 ± 57.1	67.5 ± 68.8
Fruit damaged (%)		
Pheromone + removal	22.9 ± 2.7	24.6 ± 3.4
Check	39.9 ± 4.0	34.4 ± 3.3
t	6.47*	5.15*
Marketable yield (t/ha)		
Pheromone + removal	19.9 ± 1.8	19.5 ± 1.9
Check	14.5 ± 1.2	16.1 ± 1.7
t	3.66*	1.89^{NS}

^{NS,*,**}Nonsignifiicant, or significant at $P \leq .05$ or .01, respectively

Station, Jessore, between July and September 2001. In Monirampur, trial plots of about 0.5 ha were demarcated from a contiguous area of about 7 ha of mature eggplant, while in Haibatpur the trials were initiated just after transplanting in an area of mixed vegetable cropping in plots of 0.5 to 1 ha. In each trial three plots were selected for mass trapping and three were maintained as checks, with plot to plot distance of at least 100 m. Delta traps were positioned in rows with 10 m spacing within and between rows in treatment plots. Trap catch data were collected from five traps placed in each check plot and five traps randomly selected in each treatment plot, with traps separated by at least 15 m in a plot. Infested shoots were initially removed from IPM plots by researchers when the trials were established and once weekly thereafter by farmers. Eggplant fruits were harvested and estimates of percent damaged shoots and fruit recorded weekly. Samples of 200 shoots and 50 fruits per plot were taken in the mature crop at Monirampur and 20 shoots and 10 fruits per plot initially in Haibatpur rising to 200 shoots and 160 fruits per plot as the crop matured. Weekly percent shoot and fruit damage data for check and IPM plots were maintained. Pheromone trap catch data were also maintained.

Removal of larvae from damaged shoots and trapping out of adult male moths in pheromone traps resulted in a significant reduction in pheromone trap catches in all IPM plots over the periods of observation (Figures 15A and D) compared to check plots. However, the effect was not observed for the first few weeks of the trials suggesting that males were initially replaced by newly emerged adults from pupae already present in the soil and immigration. Larval damage levels in shoots in IPM plots were similarly reduced over time compared to the check plots (Figures 15B and E). However, there was a difference in the time it took for a significant difference in percent damaged shoots between treated and check plots to be observed in each trial. Higher initial damage levels in the mature crop meant that even after a single pick of infested shoots there was a significant reduction in damage (Figure 15B) which was not observed until Week 6 in the young crop (Figure 15E). Similarly, significant differences in the level of infested fruit were observed in treated and check plots in both trials. However, even though a significant difference in percent damaged

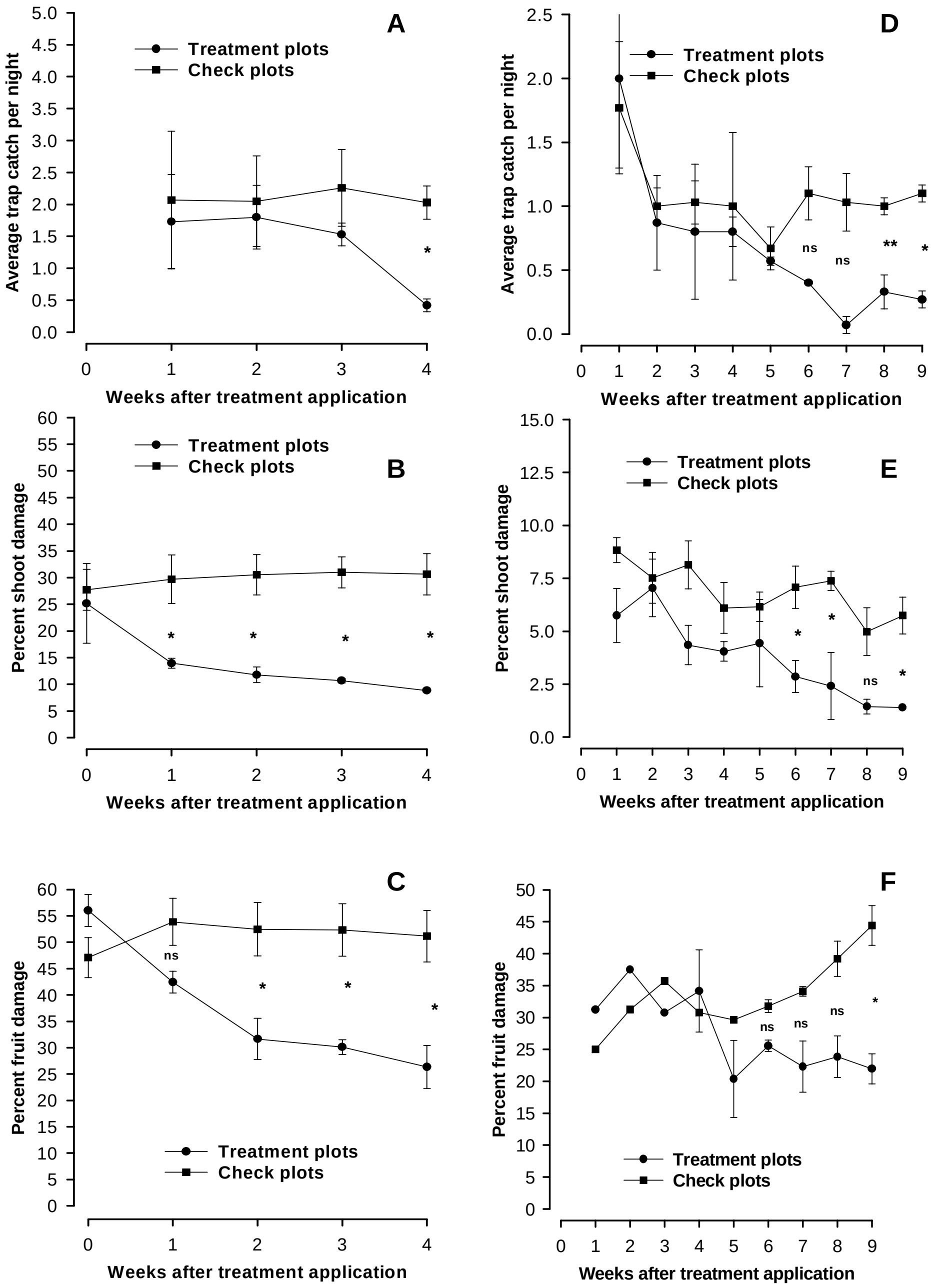

Figure 15. Assessment of replicated small-scale EFSB mass trapping trials in old (A–C) and young (D–F) eggplant crops showing averages of pheromone trap catch (A, D), percent shoot damage (B, E), and percent fruit damage (C, F); data from paired treatment and check plots were analyzed by Student's t *test and expressed as:* ns *not significant, * significant at the 5% level, and ** significant at the 1% level; data expressed as percentages were converted to arcsine for statistical analysis (Source: Cork et al., 2003)*

fruit was first observed between treated and check plots in the mature crop by Week 2 (Figure 15C) it was not until Week 9 that a similar difference in damaged fruit became apparent in the young crop (Figure 15F). These results, like results obtained at GAU and IIVR, indicated that the sex pheromone can be effective in reducing EFSB damage to eggplant crop.

Based on these results and farmers interest in using sex pheromone for combating EFSB in India, three small agri-business companies have already commercialized the sex pheromone. They are Agriland Biotech Limited of Vadodara, Ganesh Bio-Control System of Gondal (Gujarat), and Pest Control India, Mumbai (Figure 16). The competition has now reduced the price of pheromone lures to an affordable level.

Figure 16. Three commercially available EFSB sex pheromone lures in India; from left to right, products from Agriland Biotech, Pest Control India, and Ganesh Bio-Control

7 Socio-economics of Eggplant Protection in Bangladesh

Management practices to combat EFSB in Asia are limited to frequent sprays of pesticides. The widespread and increased use of pesticides for vegetable production is occurring all over Asia and such use in Bangladesh has been documented (Sabur and Mollah, 2000). The Pesticides Association of Bangladesh (1999) reports that seven times more pesticides are used in eggplant production (1.41 kg/ha), compared to rice production (0.2 kg/ha). Meanwhile, inappropriate pesticides, incorrect timing of application, and improper dosages all have resulted in high pesticide costs with little or no appreciable reduction in target pest populations. Studies in rice production show that any gains in crop yields from the use of pesticides are completely offset by the health costs related to pesticide exposure (Rola and Pingali, 1993).

A socio-economic research study on eggplant protection was, therefore, undertaken in Bangladesh, and more specifically in Jessore District. This district is considered as the “vegetable basket” of the country and where pesticide use is very high. The survey documented existing pest problems, farmers’ management practices, patterns of input use, and economic returns associated with eggplant cultivation. A baseline understanding of the socio-economic factors that influence perception of pest management practices of eggplant was achieved, followed at the end of the project by an investigation of the potential impact of adoption by farmers of IPM technologies developed in this project. Because of the similarities in agro-ecological conditions of vegetable cultivation as well as overall socio-economical conditions among the countries in South Asia, it was presumed that the information generated in Bangladesh could very well be applicable elsewhere in the region.

Methodology

Two areas in Jessore where eggplant is cultivated intensively, Barinagar and Chowgachha, were selected for this study. A total of 100 farmers were interviewed during July 2000 to February 2001 and again in December 2002 to February 2003. Objective-oriented, structured questionnaires were used to identify different pest problems, pest management practices, patterns of input use, and economic returns associated with eggplant cultivation. Pre-tested survey instruments were used for the collection of data. The pesticide misuse analysis used a logit model in which a dependent variable takes a value of 1 if there is pesticide misuse and 0 otherwise (Rashid et al., 2003). Misuse of pesticides was defined as application of chemicals in a higher or lower than the recommended dose and frequency, mixing of more than one pesticide per application, or use of unregistered or banned product. Descriptive statistical methods were used to analyze the survey data (Rashid et al., 2003), including the computer-based statistical package SPSS.

Socio-economic characteristics of the eggplant farmers

The socio-economic characteristics of the eggplant growers in two Jessore area townships are presented in Table 9. Farming is the occupation for the vast majority (93%) of the inhabitants in the study area. Most farmers (62%) are not involved in any other income generating activity.

Farmers were grouped into six categories according to their level of education. Only 27% of farmers had not attended school. A high proportion of the farmers (39%) had received five years of formal schooling, whereas about 21% of the farmers studied class VI to X. About 7% and 4% had passed Secondary School Certificate (SSC) and Higher Secondary Certificate (HSC) examinations, respectively. Only 2% had university level education (Table 9).

Half of the farmers were in the age group of 30 to 40 years. The average farm size per household was 1.12 ha. About 26% of the total land was allocated to vegetable

Table 9. Socio-economic characteristics of eggplant farmers in Barinagar and Chowgachha townships, Jessore, Bangladesh

Traits	Barinagar	Chowgachha	Average
Major occupation (% of farmers)			
Farming	94	92	93
Business	4	6	5
Service	2	2	2
Education level (% of farmers)			
None	26	28	27
Up to class V	40	38	39
Class VI to X	18	24	21
Secondary School Certificate	8	6	7
Higher Secondary Certificate	6	2	4
University graduate	2	2	2
Age (% of farmers)			
Below 30 years	16	10	13
30 to 40 years	50	50	50
41 to 50 years	24	30	27
Above 50 years	10	10	10
Average farm size (ha)			
Owner cultivated land	0.64	1.60	1.12
Family size (number)			
Adult male	3	3	3
Adult female	3	2	3
Child (below 13 yrs.)	2	2	2
Total	8	7	8
Other			
Member of farmers' associations (%)	4	2	3
IPM training received (%)	10	2	6

cultivation, of which 12% was occupied by eggplant. The two most used cropping patterns were eggplant-based: rice-eggplant-eggplant and potato-eggplant-eggplant. The average family size was eight persons (three adult males, three adult females, and two children). Only 3% of the farmers were members of farmers' associations and only 6% had received training in pest management.

Insect pests and their management

Every farmer considered EFSB as the most damaging insect pest. EFSB damaged 31% and 33% of the eggplant crop in 1999 and 2000 crop years, respectively. This is despite repeated spraying of pesticides in the survey areas. Nearly all farmers (98%) relied solely on spraying of pesticides for the control of EFSB; the remaining 2% used a combination of sanitation, which consisted of prompt removal of damaged shoots, and pesticide sprays. The majority of farmers (82%) began spraying their crop at the first sign of damage and continued thereafter on a routine basis.

Jessore farmers used a variety of insecticides belonging to different chemical groups. The most popular chemicals were quinalphos, an organophosphate; and carbosulfan and cartap, both carbamates. Other insecticides used by farmers were malathion, monocrotophos, cypermethrin, and esfenvalerate. Among the insecticides used, only cypermethrin is registered for use against EFSB (Plant Protection Wing, 1999). All other presently used insecticides are not registered against EFSB, although there are 11 insecticides registered for EFSB control in Bangladesh.

The farmers were frequently changing insecticides because no one insecticide could control EFSB. But farmers were not spraying one insecticide at a time; generally they were mixing one powder insecticide with one liquid insecticide and then spraying the mixture formulation. Theovit was the only fungicide used by the farmers in Jessore region. It was applied in highest quantity, 1.87 kg/ha, at each spray interval.

The interval between spray applications mostly depended upon the season. In the rainy season (June to September) farmers sprayed their eggplant crop every day while in winter the interval was more than 5 days (Figure 17). As a result, 35% of the total application was done as daily sprays. About 60% of growers applied pesticides more than 140 times a season. In the rainy season most farmers harvested and marketed their eggplant on the same day they sprayed pesticides. During winter, however, 3 to 4 days lapsed between pesticide applications and the harvest. The recommended re-entry period of pesticides used by the farmers is at least 7 days.

Most farmers (65%) reported that they received advice on the selection of chemical and their dosages from pesticide sales agents, 18% from neighbors, 8% from relatives, and remaining 9% from extension workers. This indicates that the retailers of pesticides are an important factor of pesticide use in Bangladesh. On the other hand this also indicates that the pesticide dealers do not have proper technical knowledge about insect control in eggplant. Furthermore, these persons are obviously motivated by profits from pesticide sales. Extension workers in the area either do not have proper technical expertise or communication skills, as evidenced by their lack of influence on farmers.

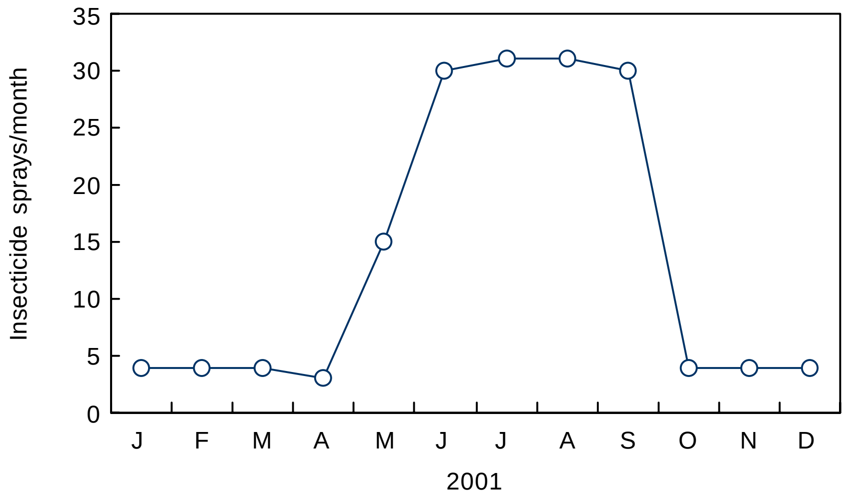

Figure 17. Frequency of insecticide sprays per month for the control of EFSB in Jessore, Bangladesh

Health hazards associated with pesticide use

Very few farmers used protective clothing or other safety measures during pesticide application; 74% did not observe any safety measures. Only 6% covered their faces with cloth during application to minimize breathing of the chemicals. Only 11% covered their bodies, 5% covered their heads, and only 3% used gloves or socks to cover their hands and legs. No farmer used protective eyewear during pesticide application. Almost all farmers experienced sickness related to pesticide application, e.g. physical weakness or eye infection or dizziness, but only 3% were hospitalized due to complications related to pesticide use.

Farmers' awareness on pesticide use issues

Seventy-four percent of farmers believed that pesticide applications are harmful to farm laborers and 71% felt that pesticide applications are injurious to the health of the people in general. Approximately 72% of farmers expressed the view that pesticides pollute water and 43% believed that pesticides pollute the air. Only 21% of farmers viewed that pesticides pollute eggplant crops and 11% believed that pesticides cause harm to natural enemies of EFSB. Most farmers believed that pesticide applications do more damage to the environment compared to other farming practices.

Pesticide use model

Results of the logit analysis are presented in Table 10. The initial model has a log-likelihood value of -75.59 and McFadden R^2 of 0.234. A McFadden R^2 value of between 0.2 and 0.4 is typical for logit models (Sonka et al., 1989). The model's chi-squared

Table 10. Socio-economics determinants of pesticide misuse in Jessore, Bangladesh

Variable	Description	Coefficient	Std dev.	Level of signif.	Probability of misuse
Constant		3.159			
AGE	Age of farmer	-0.004	12.350	0.089	0.000
FEY	Farming experience	-0.895	0.391	0.056	-0.140
EDUCN	Level of education[1]	-0.781	0.654	0.066	-0.108
TRAINING	Attended IPM training[2]	-0.965	0.471	0.059	-0.150
VISAGT	Visited with ag technician[2]	0.723	0.374	0.077	0.117
TENSTAT	Land tenure status[3]	-0.111	0.392	0.590	-0.002
MEMBER	Member of farm association[2]	1.591	0.701	0.018	0.233
LABOR	Number of family labor	0.112	1.210	0.221	0.003
IRRIG	Irrigated land[2]	0.312	0.392	0.315	0.002
AREA	Total eggplant area	-0.263	0.690	0.716	-0.006
BORROW	Received credit[2]	1.223	0.310	0.191	0.215
COOP	Member of cooperative[2]	-1.801	0.322	0.058	-0.293
COST	Importance of cost when selecting pesticides[4]	-0.329	0.612	0.211	-0.050
AGTECH	Importance of ag techs when selecting pesticides[4]	0.351	0.591	0.312	0.008
PESTDEAL	Importance of pesticide dealers when selecting pesticides[4]	-1.805	0.432	0.004	-0.264
CHEMCO	Importance of chemical co. reps when selecting pesticides[4]	0.337	0.662	0.477	0.005
NBOR	Importance of neighbor when selecting pesticides[4]	0.120	0.893	0.525	0.003
NENEMY	Understand natural enemies[2]	-0.792	0.254	0.253	-0.131
WAQUAL	Pesticides may harm water[2]	-0.182	0.418	0.810	-0.005
IMPACT	Pesticides harmed water or family on farm[2]	0.785	0.392	0.291	0.119

McFadden R^2 = 0.234
Log likelihood = -75.59
Chi-squared = 49.15, P-value = 0.0197
Correct prediction (%) = total: 79.89, misusers: 91.88, non-misusers: 43.89

[1] Rated as 1 = no schooling; 2 = primary schooling (1–6 years); 3 = high school (7–10 years); 4 = college (11 or more years)
[2] Rated as 1 = yes; 0 = no
[3] Rated as 1 = owner/operator; 0 = otherwise
[4] Rated as 1 = extremely important; 2 = very important; 3 = somewhat important; and 4 = not important

value is 49.15, which is significant at $P = 0.019$. Of the 100 total observations, 80% were predicted correctly, with 92% misuses and 44% proper users being predicted correctly.

The only variable significant at the 1% level was the importance of information from pesticide dealers when deciding which pesticide to use. As farmers reduce the importance of information from pesticide dealers, the probability of misusing pesticides decreases by 26%.

Among other variables, it was unexpected to find that membership in a farmer's association increases the probability of pesticide misuse by 23%; this was significant at the 5% level. As a farmer's experience in farming and level of education increases, the probability that he/she misuses pesticides decreases. Training in IPM has the effect of reducing the probability of misuse by 15%. Contrary to expectations, a visit by an agricultural technician to discuss pest management increases the probability that a farmer will misuse pesticides by 12%, while receiving credit from a cooperative reduces the probability of pesticide misuse by 29%. These variables were all significant at the 10% level. The effect of TV and radio upon farmers when they select pesticides was negligible and therefore not shown in the analysis.

Costs and returns

Average production cost per hectare of eggplant is calculated at Tk 177,513 (58.39 Tk = 1 USD) (Table 11). Pesticide cost, the single highest cost item, constitutes 32% of total cost of production followed by triple superphosphate fertilizer, 20%, and human labor 20%. Total cost included 24% material cost and 76% non-material cost.

On average, farmers obtained gross income of Tk 310,297/ha from eggplant cultivation. Average net income was Tk 132,784/ha and benefit to cost ratio was 1.75, indicating farmers earned substantial profits from eggplant cultivation.

Socio-economic impact of IPM trials

The data for impact assessment were collected from the fields of three farmers who volunteered to host our pilot project at Monirampur village in Jessore District. Three categories of farmers were defined: *IPM farmers* were defined as those who used recommended practices developed by this project (weekly clipping of infested shoots, using pheromone traps, and withholding of insecticide sprays), *non-IPM farmers* followed the traditional practice of regularly spraying to control pests, and *IPM + spray* farmers followed the project's recommended IPM practices and sprayed pesticides on their crops. The latter group was developed after many farmers expressed interest in the project's technologies yet were not willing to stop spraying completely.

IPM practices required the least amount of human labor. On average, each hectare of eggplant production required 337 man-days for IPM farmers and 432 man-days for non-IPM farmers in the winter trial. In the summer trial, each hectare of eggplant production required 453 man-days for IPM farmers, 515 man-days for non-IPM farmers,

Table 11. Costs and returns for eggplant production in Barinagar and Chowgachha townships, Jessore, Bangladesh

Items	Barinagar (Tk/ha)	Chowgachha (Tk/ha)	Average (Tk/ha)	Total costs (%)
Service costs				
Human labor	34 000	35 000	34 500	19.4
Animal labor	5 900	4 400	5 150	2.9
Power tiller	1 482	1 902	1 692	1.0
Sprayer machine	553	500	527	0.3
Subtotal	41 935	41 802	41 869	23.6
Material costs				
Seed cost	5 187	6 669	5 928	3.3
Inorganic fertilizer	52 503	49 398	50 951	28.7
Urea	7 110	6 222	6 666	3.8
Triple superphosphate	35 916	34 284	35 100	19.8
Muriate of potash	9 477	8 892	9 185	5.2
Pesticide	59 725	52 982	56 354	31.8
Manure	2 371	2 223	2 297	1.3
Irrigation	1 482	2 078	1 780	1.0
Rental value of the land	14 820	14 820	14 820	8.4
Interest on capital	3 594	3 436	3 515	2.0
Subtotal	139 682	131 606	135 644	76.4
Total production costs	181 617	173 408	177 513	100.0
Gross income	305 666	314 927	310 297	-
Net income	124 049	141 519	132 784	-
Benefit to cost ratio	1.70	1.80	1.75	-

58.39 Tk = 1 USD

and 600 man-days for IPM + spray farmers (Table 12). Between IPM and non-IPM farmers, the variation in input use was substantial for human labor, pesticides, and inorganic fertilizers and soil amendments.

IPM practices were less costly due to savings from pesticide expenditures. Costs were calculated on full cost and cash cost basis. In this analysis, cash cost was calculated for the items that were hired or purchased. Full cost was calculated for both the family supplied and hired or purchased inputs such as family labor and the opportunity cost of land. Rental value of land covering the crop season was included in full cost analysis. Average production costs per hectare were Tk 67,025 for IPM and Tk 97,783 for non-IPM farmers in the winter trial (Table 13). Average production costs per hectare were Tk 85,053 for IPM, Tk 128,274 for non-IPM, and Tk 107,276 for IPM + spray farmers in the summer trial.

Farmers using IPM practices generated higher returns and net profits. On average, farmers obtained gross returns of Tk 158,045 for IPM and Tk 155,040 for non-IPM farmers in the winter trial. Average gross returns were Tk 299,055 for IPM, Tk 165,060 for non-IPM, and Tk 301,658 for IPM + spray farmers in the summer trial.

Table 12. Input use and costs for eggplant cultivation under different EFSB management regimes in Jessore, Bangladesh[1]

	Winter trial				Summer trial					
	IPM		Non-IPM		IPM		Non-IPM		IPM + spray	
Input use	Qty.	Tk.	Qty	Tk.	Qty.	Tk.	Qty.	Tk.	Qty.	Tk.
Human labor (man-days):										
Family	105	5 250	134	6 700	223	11 150	295	14 750	315	15 750
Hired	232	11 600	298	14 900	230	11 500	220	11 000	285	14 250
Total	337	16 850	432	21 600	453	22 650	515	25 750	600	30 000
Animal labor (pair-days):										
Family	4	400	5	500	8	800	9	900	7	700
Hired	5	500	6	600	6	600	6	600	8	800
Total	9	900	11	1 100	14	1 400	15	1 500	15	1 00
Tractor/power tiller	-	2 978	-	3 179	-	3 127	-	3 232	-	3 091
Seed cost	-	2 558	-	2 568	-	2 495	-	2 512	-	2 537
Cow dung (kg)	2 003	436	2 088	445	-	1 514	-	1 012	-	918
Urea (kg)	518	3 367	756	4 914	600	300	746	4 476	952	5 712
Triple superphosphate (kg)	552	7 176	763	9 919	1 447	17 364	1 501	18 012	1 690	20 280
Muriate of potash (kg)	182	1 638	201	1 809	255	2 805	331	3 641	214	2 354
Sulfur (kg)	12	108	18	162	-	-	-	-	-	-
Gypsum (kg)	175	612	286	1 001	-	-	-	-	-	-
Insecticide	-	-	-	27 740	-	-	-	42 076	-	10 200
Sex pheromone lures	-	7 675	-	-	-	7 675	-	-	-	7675
Irrigation	-	8 307	-	8 342	-	5 723	-	8 462	-	5 905
Rental value for the land	-	13 461	-	13 461	-	15 384	-	15 384	-	15 384
Interest on operating capital	-	959	-	1 543	-	1 316	-	2 217	-	1 720
Total costs:										
Full cost basis	-	67 025	-	97 783	-	85 053	-	128 274	-	107 276
Cash cost basis	-	46 955	-	75 579	-	56 403	-	95 023	-	73 722

[1]All data are on a per hectare basis; 58.39 Tk = 1 USD. *IPM farmers* were those who used recommended practices developed by this project (clipping of infested shoots and using pheromone traps) and withheld pesticide sprays, *non-IPM farmers* followed the traditional practice of regularly spraying to control pests, and *IPM + spray* farmers followed the project's recommended IPM practices and sprayed pesticides on their crops

Average net incomes were Tk 91,020 and Tk 57,257 for IPM and non-IPM farmers respectively in the winter trial. Average net incomes were Tk 214,002 for IPM farmers, Tk 36,786 for non-IPM farmers, and Tk 194,382 for IPM + spray farmers in the summer trial. The average net income of non-IPM farmers in summer trials was very low as compared to IPM and IPM + spray farmers; these farmers spent much more on pesticides and still suffered marketable yield losses from pest infestation.

The benefit cost ratio of IPM farmers was higher than non-IPM farmers for both season's trials indicating that IPM farmers earned more profits from eggplant cultivation than non-IPM farmers (Table 13).

Table 13. Costs and returns of EFSB management practices for eggplant cultivation in Jessore, Bangladesh[1]

	Winter trial		Summer trial		
Parameters	IPM	Non-IPM	IPM	Non-IPM	IPM + spray
Full cost basis	67 025	97 783	85 053	128 274	107 276
Cash cost basis	46 955	75 579	56 403	95 023	73 722
Variable cost	53 564	84 322	69 669	112 890	91 892
Yield (kg/ha)	31 609	31 008	39 874	22 008	40 221
Gross return	158 045	155 040	299 055	165 060	301 658
Gross margin	104 481	70 718	229 386	52 170	209 766
Net return	91 020	57 257	214 002	36 786	194 382
Benefit to cost ratio					
Full cost basis	2.4	1.6	3.5	1.3	2.8
Cash cost basis	3.4	2.1	5.3	1.7	4.1

[1]All costs and returns in Tk on a per hectare basis; 58.39 Tk = 1 USD. *IPM farmers* were those who used recommended practices developed by this project (weekly clipping of infested shoots, using pheromone traps, and withholding of insecticide sprays), *non-IPM farmers* followed the traditional practice of regularly spraying to control pests, and *IPM + spray* farmers followed the project's recommended IPM practices and sprayed pesticides on their crops.

8 Pilot Project Demonstration and IPM Promotion

After initial limited-scale testing of the project's IPM strategy (cutting and removal of pest-damaged shoots, using pheromone for mass trapping, and conservation of natural enemies by withholding pesticide use), pilot projects were undertaken by each site to demonstrate the utility of this strategy on farmers' fields. In addition to working closely with farmers on whose fields the pilot projects were undertaken, farmers' field days were organized to spread the message to wider groups of vegetable farmers, community leaders, media personnel, government plant protection policymakers, extension workers, and NGO staff. In some instances, field days were utilized to train farmers by way of on-site demonstration and provision of easy-to-understand educational materials in local languages.

GAU site

Pilot projects were undertaken at Gutal and Dharampura villages in Kheda District (Figure 18) during May to September 2002. At each site, two plots, each measuring 0.7 ha, were selected. In one plot the IPM strategy was executed and in the other plot the farmers were allowed to do their normal pest control practices, which involved use of pesticides only. For the IPM strategy, 70 pheromone-baited funnel traps were erected 30 cm above crop canopy starting 4 weeks after transplanting until final harvest. Pest-damaged shoots were cut off at weekly intervals. Pheromone lures were replaced once every 4 weeks. Data were recorded weekly on the number of moths trapped in the IPM field and the numbers of EFSB-damaged shoots and fruits in 100 randomly selected plants in both plots. During harvest, marketable fruits were harvested from four 5-m x 5-m parcels from each field and the number of damaged and healthy fruits were recorded. Damaged fruits from IPM as well as check fields were held in laboratory until larvae inside these fruits pupated and adults of either EFSB or the parasitoid *T. flavo-orbitalis* emerged. Based on the number of adults emerged, the percentage parasitism was calculated.

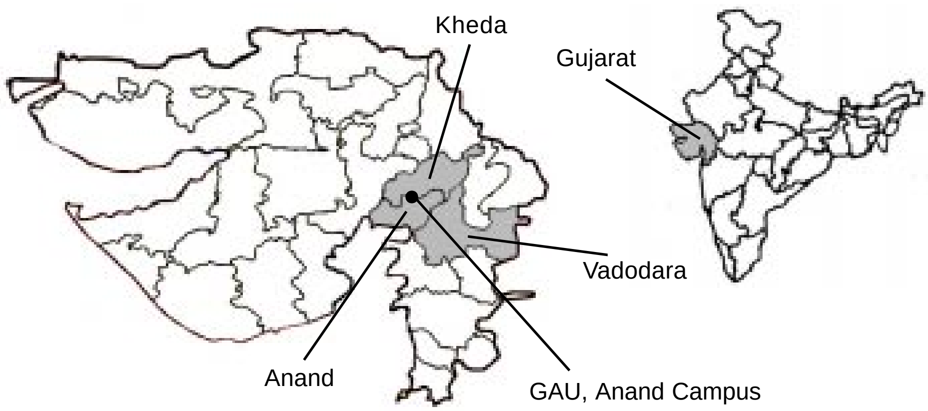

Figure 18. Map of Gujarat State of India showing location of Anand, Kheda, and Vadodara Districts where research and pilot projects were undertaken

The summarized data on number of moths trapped, fruit damage, marketable yield, and level of parasitism for both locations are presented in Table 14. The moth catch and damage to fruits and shoots were the highest during the warmer months of July and August. The parasitism of EFSB by *T. flavo-orbitalis* was also highest during this period.

We could not find any significant correlation between the number of moths trapped and the percent fruit damage either for the same dates of observation or any earlier consecutive dates of moth catch or later consecutive dates of fruit damage. Thus moth catch data cannot be used for predicting pest damage under central Gujarat conditions. Similarly there was no significant correlation between fruit damage and parasitism.

The use of IPM substantially reduced pest damage to shoots and fruits and increased the yield compared to the farmers' practice of using pesticides alone in combating EFSB. IPM practices marginally improved the parasitism of EFSB by *T. flavo-orbitalis*; however, overall parasitism was still relatively low.

IPM promotional activities. In addition to pilot project studies at Gutal and Dharmapura, GAU organized method-cum-result demonstrations of IPM at three

Table 14. Effect of IPM strategy on control of EFSB, crop yield, and parasitism of EFSB in two villages in Gujarat, India

IPM items	Location: Gutal	Location: Dharampura
Moths trapped/week for 18 weeks	12.35	3.22
Shoot damage (%)[1]		
IPM field	1.62	0.39
Check field	2.84	0.83
% reduction in IPM	42.90	53.01
Fruit damage (%)[2]		
IPM field	9.42	11.87
Check field	27.15	26.83
% reduction in IPM	65.31	55.71
Marketable yield (t/ha)[3]		
IPM field	26.12	27.13
Check field	14.71	17.16
% increase in IPM	77.60	58.80
Parasitism (%)[4]		
IPM field	6.07	10.72
Check field	5.71	9.29
% increase in IPM	6.30	15.39

[1]Average of 17 weekly observations at each location

[2]Average of 11 and 12 weekly observations at Gutal and Dharampura, respectively

[3]Total of 10 and 13 weekly harvests at Gutal and Dharampura, respectively

[4]Average of 10 and 12 weekly observations at Gutal and Dharampura

additional locations: Latipura and Relaipura in Vadodara District and Navli in Anand District (Figure 18). At the latter three locations, meant only for demonstration of IPM, no detailed observations on pest damage, yield, or parasitism were recorded. GAU organized three farmers' field days, one each on 14 June 2002 (Dharampura), 8 October 2002 (Latipura), and 31 December 2002 (Relaipura) to explain and demonstrate to the farmers the practice and utility of IPM strategy. The field days were attended by an average of over 380 farmers at each occasion. Persons from local and national print and broadcast media, agri-businesses, NGOs, extension workers, and GAU staff attended these events. GAU also organized two 1-day training courses at its headquarters at Anand for farmers from Navli and Chaklasi villages. The first training course, held on 1 February 2003, was attended by 61 farmers and the second training course, held on 5 February 2003, was attended by 30 local farmers.

During field days and training courses, copies of IPM promotional publications in the forms of leaflets, brochures, and training manuals, published in local language (Gujrati) and one in English, were distributed among participants. The project activities were featured in ten newspaper articles, two radio broadcasts on All-India Radio, two telecasts in Gujrati language on E-TV, and five telecasts on Doordarshan, the national television channel.

IIVR site

Two villages, Bhopapur and Kanaksarai, in intensive vegetable growing areas in Varanasi District (Figure 19) were selected to demonstrate the utility of IPM in combating EFSB.

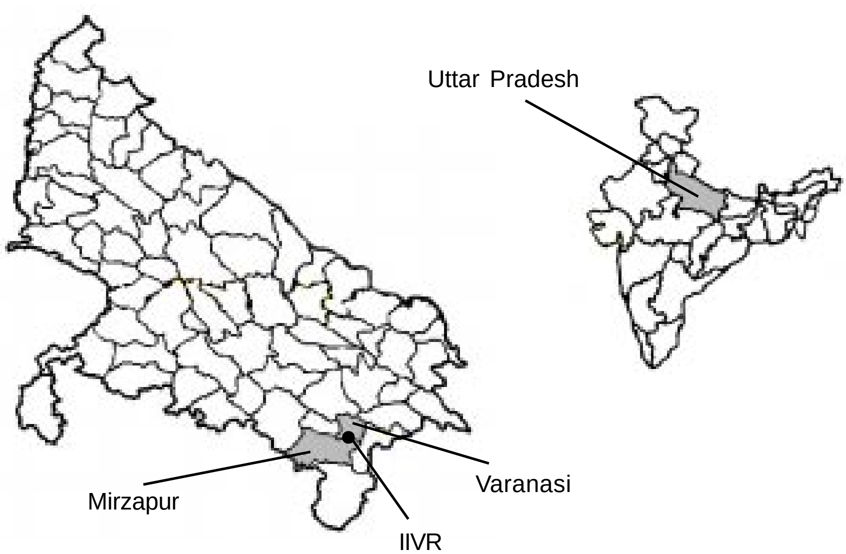

Figure 19. Map of Uttar Pradesh State of India showing location of districts where research and pilot projects studies were undertaken

Bhopapur. This village is located about 25 km north of Varanasi city. Four farmers' fields were selected for this study. Pheromone installation and sanitation was practiced by three farmers: Mr. Haricharan Maurya (2262 m^2 of land in eggplant cultivation), Mr. Jawahar Maurya (784 m^2), and Mr. Chowthi Maurya (884 m^2), whereas the fourth farmer, Mr. Shiv Murat (625 m^2), did not adopt these practices. Although they are small land-holding farmers, they use modern production practices such as planting hybrid varieties, applying organic as well as inorganic fertilizers, and using pesticides. Eggplant is a major vegetable in this area and sale of produce is an important source of income for these farmers. All farmers were allowed to use their own methods of raising the crop including application of pesticides. Plots were separated by at least 50 m from each other. Crops were transplanted from 2 May to 6 June 2002. All farmers used hybrid eggplant cultivars developed by a private seed company in India. Plastic funnel traps, baited with 3 mg of sex pheromone each, were installed in the first three farmers' fields starting 20 to 25 days after transplanting. A distance of 10 m was maintained between two traps. Trap height was adjusted to just above plant canopy. Pheromone lures were changed once every month. Clipping of damaged shoots was done at weekly intervals. Data on weekly moth catch and periodical pest damage to fruit whenever farmers harvested their crop, were recorded.

Kanaksarai. This pilot project site village is located 22 km west of IIVR and 40 km to the southwest of Varanasi city in Mirzapur District. Five fields belonging to four farmers were selected. On four fields, farmers practiced IPM and the fifth was left as a check. Farmer Mr. Subhash Yadav had 1800 m^2 of land under eggplant cultivation, farmer Mr. Gulab Chandra had one parcel of 1100 m^2, and another one of 800 m^2, farmer Mr. Ramdhani Yadav had 400 m^2, and farmer Mr. Rambali Yadave had 1000 m^2. The first three farmers practiced IPM, the latter did not. All plots were located at least 50 m away from each other. All farmers used a local cultivar that produces round purple fruits. All farmers transplanted their eggplant crop between 12 to 22 July 2002. The pheromone-baited funnel traps were set at 10-m distance throughout the field on IPM practitioners and damaged shoots were excised once a week on the eggplant crop owned by these farmers. Pheromone lures were changed once a month.

At both Bhopapur and Kanaksarai, EFSB was present throughout the season as evidenced by presence of EFSB adults in pheromone-baited traps as well as pest damage to the fruit. The numbers of moths trapped and fruit damage were higher during warmer summer months until October but declined thereafter. Substantial differences in fruit damage were found between IPM practitioners and non-practitioners (Table 15). At Bhopapur the crop in three IPM practitioners' fields suffered an average of 33% fruits damage, whereas on the non-practitioner's field it was almost double that. Similarly at Kanaksarai, fruit damage was 16% on the IPM practitioner's farm, whereas on non-practitioners' fields it was almost 40%. Such fruit damage resulted in direct economic yield loss to farmers because damaged fruits were not marketable.

Adoption of IPM by these farmers will affect profitability of their eggplant cultivation. The only purchased input for IPM users will be sex pheromone lures and the traps. Both items are now commercialized by several small companies in India and the cost of adopting IPM, as shown from studies in Bangladesh, is much less than continued dependence on pesticide use, which is costly and not sustainable.

Table 15. Moth catch and pest damage to eggplant crops on IPM practitioners' and non-practitioners' fields in two villages in Uttar Pradesh, India

Village	Farmers	Farm size (m^2)	Moth catch total[1]	Damaged fruits (%)[1]
Bhopapur, Varanasi District				
I	IPM practitioner	2262	1297	42.2
II	IPM practitioner	784	723	28.9
III	IPM practitioner	884	610	27.8
IV	IPM non-practitioner	625	-	59.7
Kanaksarai, Mirzapur District				
I	IPM practitioner	1800	520	15.4
II	IPM practitioner	1100	222	20.5
III	IPM practitioner	800	157	13.1
IV	IPM practitioner	400	91	14.6
V	IPM non-practitioner	1000	-	40.0

[1]Data are means of 10 observations for Farmer I, 13 observations for Farmer II, 18 observations for Farmer III, and 17 observations for Farmer IV in Bhopapur village, and 5 observations for each of Farmers I, II, and III, 6 observations for Farmer IV, and 12 observations for Farmer V in Kanaksarai village

<u>IPM promotion activities</u>. IIVR organized a field day on 3 January 2003 at the Bhopapur village pilot project site. Over 400 farmers in addition to local government extension agents, media personnel, and researchers attended the field day. IIVR researchers demonstrated the use of sex pheromone and emphasized the need and care in cutting and prompt destruction of pest-damaged shoots. They also distributed copies of an extension brochure, written in Hindi, which illustrated the principles and practices of IPM of EFSB. Other promotional materials distributed included souvenir caps and T-shirts printed with slogans carrying message of IPM of EFSB. In an open dialog forum, IIVR staff answered all queries related to production and protection of eggplant in the region and availability of pheromone lures and traps. The project activities were featured in three local newspaper stories in Hindi language. The field day activities were broadcast over Varanasi station of All India Radio; E-TV also featured the use of sex pheromone in controlling EFSB on their farming program "Annadata" or food giver.

BARI site

Two sets of pilot projects, one each in winter and summer, were undertaken in Bangladesh to test and promote the newly developed IPM technologies.

<u>Winter trials</u>. Winter trials were set up on farmers' fields in two districts: Jessore District where pesticide use is intensive and Noakhali District where pesticide use is limited (Figure 20). At Jessore, 1.5 ha of eggplant fields belonging to three farmers in the vicinity was selected. These three fields were designated IPM1, IPM2, and

IPM3. The crop received only two insecticide sprays, one just after transplanting and one 60 days after transplanting. Pheromone-baited water-trough traps were set up 10 m apart throughout the field. At the same time, weekly removal of pest-damaged shoots was instituted from the first day such damage became visible until the final harvest. An equal amount of land cultivated to eggplant, located across the road from IPM fields and where farmers relied on frequent sprays of chemical pesticides was set aside as a check. The IPM trial at Jessore started in February and lasted until the second week of July 2002.

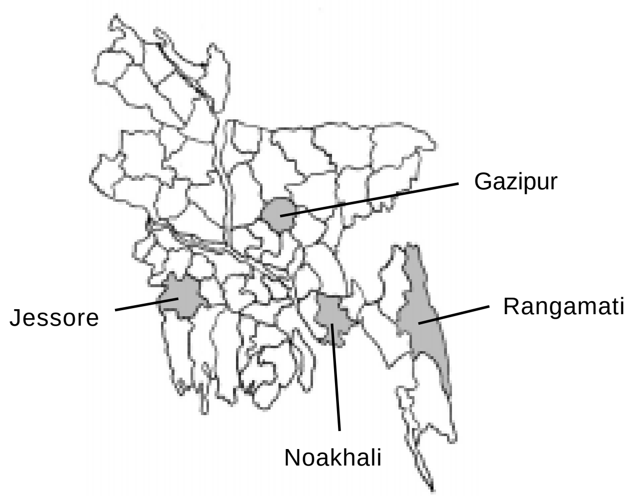

Figure 20. Map of Bangladesh showing location of research sites in Gazipur, Jessore, and Rangamati, and pilot project districts in Jessore and Noakhali

The Noakhali IPM trials, done in collaboration with the Mennonite Central Committee (MCC), started during the last week of June. No insecticide was used on IPM fields. The field plots were small (200 to 300 m^2) and isolated. Prompt weekly removal of pest-damaged shoots and installation of pheromone-baited, locally made, water-trough traps were undertaken soon after transplanting. Control plots, where farmers were allowed to continue their own practices of pest control, usually by insecticides, were selected in the same area. It must be pointed out that the overall pesticide use for vegetable production is much less in Noakhali than in Jessore.

At Jessore, infestation of fruits in IPM plots during initial harvest was high but reduced to 22% after five harvests, especially in the parcel of land that was situated farthest from the check field (Figure 21, IPM3). The initial high infestation in all three IPM plots was mainly due to the presence of old eggplant stubble heaped around farmers' dwellings, not too far from the IPM plots. These stubble, as demonstrated earlier at GAU, are a source of EFSB during the off-season. Adults flying in from these heaps probably attacked nearby IPM plots but not the check plots, which were farther across the road. Once the infestation stabilized, the combined effect of sanitation and sex pheromone reduced pest damage in all three IPM plots. This phenomenon pointed out the need for a community-wide approach to destroy all sources of insects, especially old abandoned plantings or dry stubble that carryover the pest from one season to the next. At Jessore, the predator and parasitoid diversity and numbers were very low. There were outbreaks of jassids, whiteflies, and red spider mites initially in the pesticide-treated area, which eventually spread to nearby IPM plots. No *T. flavo-orbitalis* specimens were recovered from IPM or check plots.

No significant difference was observed in total yield as well as damaged and healthy fruit yields between IPM and check plots (Figure 22); however, the check plots were sprayed every 3 to 4 days, whereas IPM fields were only sprayed twice all season.

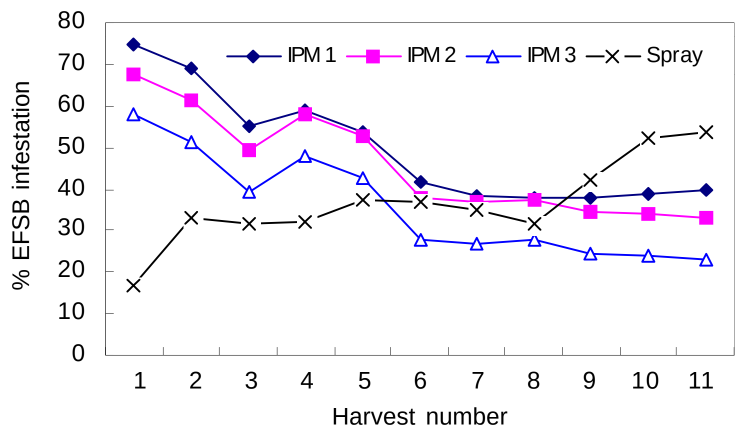

Figure 21. Fruit infestation in the IPM and spray (check) plots at Monirampur pilot project site in Jessore, Bangladesh

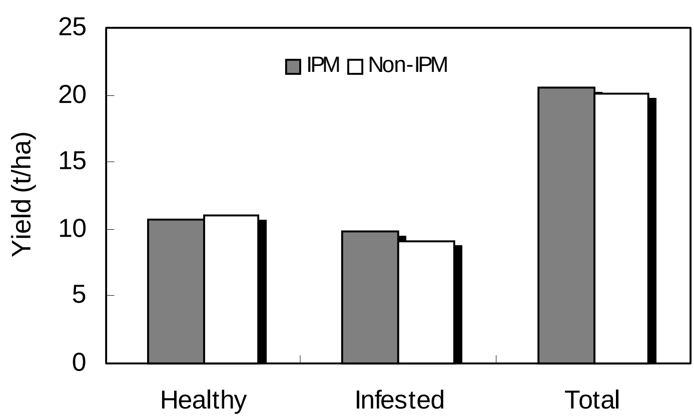

Figure 22. Healthy, infested, and total eggplant fruit yields in IPM and non-IPM (spray only) plots at Monirampur, Jessore, Bangladesh

At Noakhali, the pest damage to both shoot and fruits was substantially lower in IPM plots than in check plots (Figure 23). Even in shoots where damage was generally low, IPM plots always had less damage than check plots. The fruit damage in IPM plots was much less in Noakhali than at Jessore. No unusual outbreak of jassids or whiteflies were observed in that area. Specimens of *T. flavo-orbitalis* were recovered from IPM plots but not from check plots.

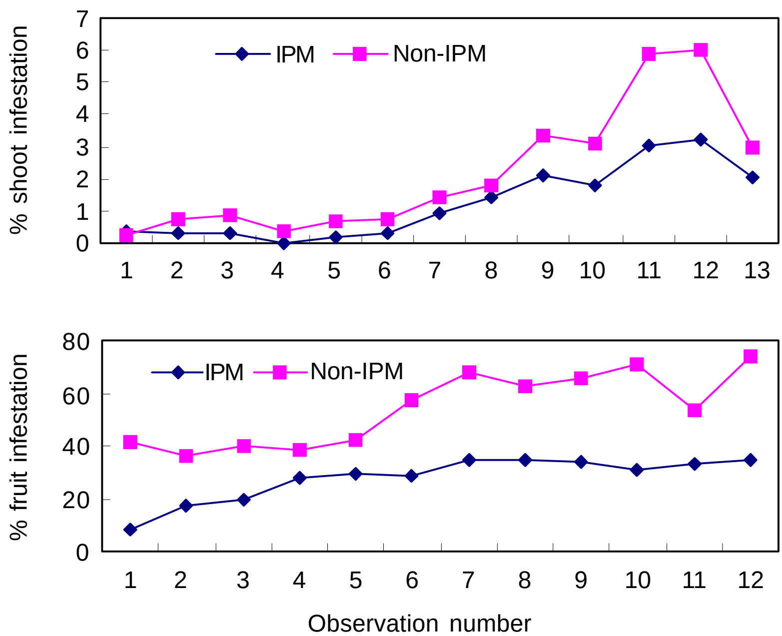

Figure 23. Shoot and fruit infestation in the IPM and non-IPM (spray only) plots during winter IPM trials at Noakhali, Bangladesh

Overall, the winter IPM trials suggested that insecticide application in the early stages of crop growth can induce an increase in populations of pests such as jassids and whiteflies while at the same time reduce populations of EFSB's natural enemies.

Summer IPM trials. IPM trials during summer were set up on farmers' fields at Jessore. The treatments in summer trials, which began in June 2002, were the same as the winter trials except that an additional treatment of mass trapping by sex pheromone (MT) combined with pesticide sprays, similar to ones used routinely by Jessore farmers, was added. The IPM treatment involved withholding of all pesticide use, weekly clipping of damaged shoots, and installation of sex pheromone for mass trapping of male adults. Each treatment had three replicates.

The results of the fruit damage are summarized in Figure 24. The fruit infestation in IPM plots was much less, in most cases significantly so, than in pesticide spray (check) plots where chemical pesticides were sprayed every 2 days.

In the initial stages there was no significant difference in fruit infestation between the IPM + spray and check treatments, but in later harvests the damage in IPM + spray treatment was significantly less than in check. Later in the season, which coincided with cooler weather of December and January, the overall pest population was low and the differences in pest damage in three treatments narrowed considerably. There was no significant difference between the total yield of IPM and IPM + spray treatments (Figure 25), however, both were significantly higher than yields obtained from plots treated with pesticides alone. Significantly higher yields of healthy fruits and lower yields of pest-damaged fruits were obtained in IPM plots only.

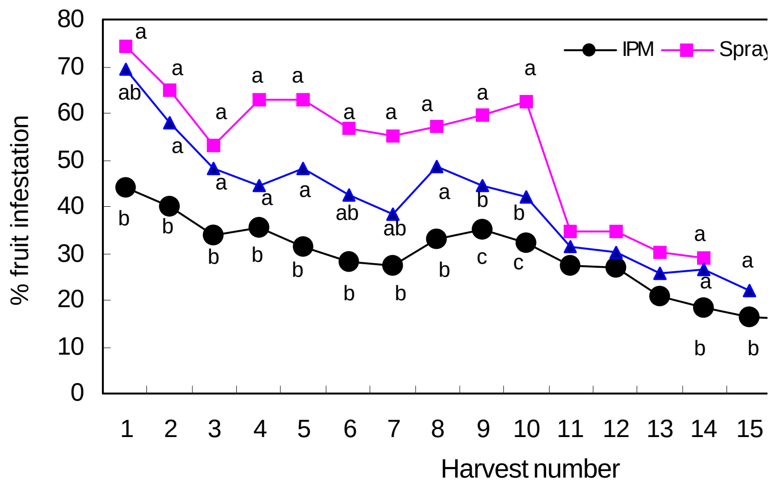

Figure 24. Infestation of fruits in the IPM, IPM + spray, and spray only (check) plots during summer trials at Jessore, Bangladesh; at each harvest date, dissimilar letters indicate signficant difference (P $\leq$ .05) between treatments

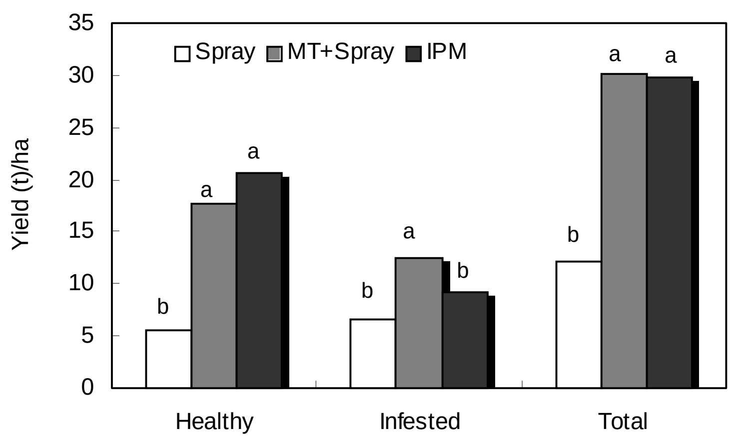

Figure 25. Healthy, infested, and total eggplant yields in IPM, IPM + spray, and spray only (check) plots during summer trials at Jessore, Bangladesh

IPM promotion activities. Four training workshops were conducted during November 2001 to March 2002. Attendees included farmers, government extension workers, local and international NGO members, pesticide industry personnel, university and BARI researchers, representatives from donor organizations, and officers of the Directorate of Agricultural Extension (DAE), the agency responsible for registration of pesticides in Bangladesh. Through these workshops, attendees were kept informed of pest problems, current pesticide misuse, and strategies for controlling EFSB through the use of IPM.

The first training workshop, held on 27 November 2001 at BARI headquarters at Joydebpur, Gazipur, was attended by 60 participants from government and NGOs, pesticide industries, and agricultural research organizations. The second training workshop was held at Noakhali on 2–3 January 2002 for MCC's field workers and their IPM trial farmers. A total of 65 individuals attended these workshops. The third training workshop was held again at BARI, Joydebpur, Gazipur for district-level plant protection specialists of the DAE. This workshop on 4–5 March 2002 was attended by 70 participants. A final training workshop was held at BARI in Jessore on 31 March 2002. A total of 55 DAE personnel from Jessore region attended the meeting.

A farmers' field day was organized toward the end of winter IPM trials on a farm in Jessore on 10 June 2002. One hundred farmers attended the event. A special feature of this event was the presence of Bangladesh's Minister for State of Agriculture Mr. Fakhrul Islam Alamgir. His presence attracted both print and electronic media and gave the project wider publicity. At all occasions, copies of a brochure containing detailed information on principles and practices of IPM of EFSB, printed in Bengali, were distributed among the participants.

The project activities were featured five times in local Jessore newspapers and twice in nationally circulated dailies between June to September 2002, the period of pilot project studies. The project was featured twice on national television channel BTV. It was featured in the 2 May 2002 issue of New Agriculturist magazine published in the United Kingdom. The project activities were also highlighted in two issues of BARI newsletters.

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