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Evaluation of Pheromone Trap Settings for Managing Brinjal Shoot and Fruit Borer (*Leucinodes orbonalis*) in Brinjal

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Abstract - An experiment was conducted to find out among 9 trap settings the most appropriate site for trap placement in the Brinjal field based on Brinjal shoot and fruit borer trapping efficiency, shoot and fruit infestation, healthy and total fruit yield, and BCR. The efficiency of different trap setting positions varied significantly. Trapping efficiency observed the T_1 ensured the minimum shoot and fruit infestation 10.02% and 20.95%, respectively, minimum infested fruit yield (4.75 ton/ha), maximum healthy and total fruit yield (26.72 and 31.47 ton/ha) and the maximum BCR (1.70), which was followed by T_2 and T_4. The minimum trapping efficiency of T_9 treatment led the maximum shoot and fruit infestation 13.89% and 29.26%, respectively, maximum infested fruit yield (7.59 ton/ha), minimum healthy and total fruit yield (17.74 and 25.32 ton/ha) and the minimum BCR (1.00). A correlation between the number of BSFB adults trapped from the most efficient trap setting and the shoot and fruit infestation recorded and found a linear positive correlation between number of BSFB adults trapped and shoot infestation ($r = 0.781$) and fruit infestation ($r = 0.810$). The effect of pheromone trap positions observed in this study may be attributed to the easy accessibility of the lures and traps, when they are placed at the canopy.

Key words - *Leucinodes orbonalis*, Brinjal, Pheromone trap
Abbreviations - BSFB, Brinjal shoot and fruit borer, BCR, Benefit cost ratio

Introduction

Integrated management practice banking on removal of Brinjal shoot and fruit borer infested shoots and fruits, mass trapping with sex pheromone and judicious use of pesticides to allow proliferation of natural enemy population and it is useful as a low cost sustainable management practice for managing BSFB minimizing the yield loss of Brinjal. Integrated Pest Management (IPM) gave effective control of shoot and fruit borers, as well as the highest benefit cost ratio (Duara *et al*., 2003). To address this serious issue, AVRDC, "The World Vegetable Center" developed, validated, and promoted an IPM strategy for the control of EFSB in South Asia from 2000-2005 (Alam *et al*., 2003, 2006).

This IPM strategy includes using sex pheromones to trap and kill male adults (Cork et. al., 2001, 2003), The combination of different control measures was more successful than the sole one, which influenced the farmers for the application of different control measures (Alam *et al*., 2003). The use of sex pheromone become prospective alternative to sole use of chemical pesticides, and efforts are underway to find-out better means of harvesting the maximum benefit through its proper and efficient use. The term sex pheromone is the substances secreted to the outside by an individual and perceived by a second individual from the same species, in which they release a specific behavioral reaction, recognition among others (Cork *et al*., 2001; Karlson and Luscher, 1959). It was observed that the main component of the female sex pheromone of *L. orhonalis*, was identified as (E)-l 1-hexadecanyl acetate (Zhu *et al*., 1987). It was synthesized in the laboratory and tested in the field where more males were captured in traps baited with 300-500 mg of the compound than by 6 live females.

The virgin females of the BSFB secrete pheromone, which attracts male for mating (Gunwardena *et al*., 1989). The compound has been effectively used for pest management and monitoring adult population, mating disruption and attacking and killing the target pest in the trap (Bottrell, 1979). The field traps baited with virgin female moths of the Brinjal shoot and

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fruit borer, *Leucinoodes orbonalis* Guenee, attracted both marked and wild males (Das and Islam, 1984). However, in the study areas a large number of sample farmers were reported to use sex pheromone traps as practices for controlling BSFB. The sex pheromone traps were set differently by different farmers and as many as eight combinations trap settings, in respect of its placement site in the plot and the crop canopy were reported, and the efficiency of the sex pheromone vis-a-vis farmers practices using sex pheromone traps greatly varied. Although there are recommendations regarding the pheromone trap settings, the wide variations in their practice and also in the efficiency evoked the necessity for their further on-station evaluation under supervised condition.

Under the above perspective, the present study was undertaken with the following objectives; to evaluate the BSFB trapping efficiency of all trap settings identified through the survey along with the prescribed trap settings under supervised condition; to identify the most appropriate site of sex pheromone trap setting in the Brinjal plot based on the BSFB trapping efficiency, infestation reduction, fruit yield and BCR in Brinjal; and to determine the correlation between the numbers of BSFB adults trapped in the best trap setting and the infestation level in Brinjal.

Materials and Methods

The material used in this experiment was Brinjol and the experiment comprised nine treatments set-up in a Randomized Complete Block Design (RCBD) with three replications. The whole field was divided into three blocks of equal size having 2 m space between the blocks and each block was again subdivided into 27 plots (3 m × 3 m) with 2 m space between the plots. The 9 treatments, in fact, comprised different sites for placement of the trap, which were as follows: T_1 : Pheromone trap placed at plant canopy and in the centre of the plot, T_2: Pheromone trap placed at plant canopy and at the edge of the plot, T_3 : Pheromone trap placed at plant canopy and at nearer to edge of the plot, T_4 : Pheromone trap placed above plant canopy and in the centre of the plot, T_5 : Pheromone trap placed above plant canopy and at the edge of the plot, T_6 : Pheromone trap placed above plant canopy and at nearer to edge of the plot, T_7 : Pheromone trap placed below plant canopy and in the centre of the plot, T_8 : Pheromone trap placed below plant canopy and at the edge of the plot, and T_9 : Pheromone trap placed below plant canopy and at nearer to edge of the plot.

The following parameters were considered for evaluating the effectiveness of each treatment:

Adult Catch

The adult BSFBs caught in each of the traps were counted twice a week throughout the cropping season and were recorded against each treatment and replication in the data sheets. The mean of three replications was considered as the number of adults trapped per treatment at each observation.

Shoot infestation

The total number of shoots and the number of infested shoots were recorded from 5 plants at weekly basis.

Shoot infestation was calculated in per cent using the following formula:

$$\text{\% Shoot infestation} = \frac{\text{Number of infested shoots}}{\text{Number of total shoots}} \times 100$$

Fruit infestation and yield

Data on the number of healthy and infested fruits were harvested from 5 sample plants per plot and recorded at each harvest. Harvesting was done at 7 days interval. 12 harvests were done throughout the fruiting season. Percent fruit infestation at each harvest was calculated using the following formula:

$$\begin{array}{r}\text{\% Fruit infestation}\\ \text{(by number)}\end{array} = \frac{\text{Number of infested fruits}}{\text{Number of total fruits}} \times 100$$

For calculating over-all percent fruit infestation, data on the number of healthy and infested fruits and their weights per plot were recorded separately from 5 sample plants at each harvest. Fruits were harvested at 7 days interval. 12 harvests were done throughout the fruiting season. Rate of fruit infestation at each harvest was calculated using the following formulae:

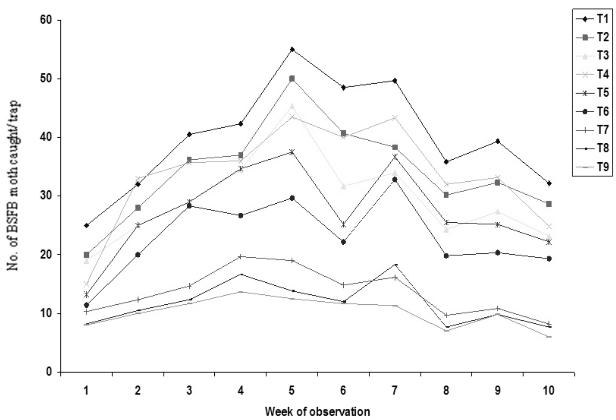

Fig. 1. Number of BSFB adult moth caught per trap at different plant canopy observed weekly. T_1 : Pheromone trap placed at plant canopy and in the centre of the plot, T_2: Pheromone trap placed at plant canopy and at the edge of the plot, T_3 : Pheromone trap placed at plant canopy and at nearer to edge of the plot, T_4 : Pheromone trap placed above plant canopy and in the centre of the plot, T_5 : Pheromone trap placed above plant canopy and at the edge of the plot, T_6 : Pheromone trap placed above plant canopy and at nearer to edge of the plot, T_7 : Pheromone trap placed below plant canopy and in the centre of the plot, T_8 : Pheromone trap placed below plant canopy and at the edge of the plot, and T_9 : Pheromone trap placed below plant canopy and at nearer to edge of the plot.

$$\underset{\text{(by number)}}{\%\text{ Fruit infestation}} = \frac{\text{Number of infested fruits}}{\text{Number of total fruits}} \times 100$$

$$\underset{\text{(by weight)}}{\%\text{ Fruit infestation}} = \frac{\text{Weight of infested fruits}}{\text{Weight of total fruits}} \times 100$$

For obtaining healthy fruit yield and infested fruit yield, the weights of healthy fruits and infested fruits were summed up plot-wise by 5 representative plants and then transformed into per plant healthy fruit yield and infested fruit yield. The plot yields of healthy and infested fruits were obtained transformed into healthy fruit yield and infested fruit yield in ton per hectare. Sum of the healthy fruit yield and infested fruit yield is finally expressed as the total yield in ton per hectare. Benefit-cost analysis was expressed in terms of benefit -cost ratio (BCR).

Statistical Analysis

Statistical Analysis was done by least significant difference (LSD). Data represents the mean value of 3 replications; each replication is derived from 10 plants per treatment.

Results and Discussion

The relative effectiveness of 9 treatments comprising pheromone trap settings at various positions has been assessed in terms of number of BSFB adults caught as well as percent shoot and fruit infestation along with the healthy fruit yield and total yield of Brinjal. The trap setting positions evaluated differed significantly among treatments, which are presented below:

BSFB trapping efficiency of pheromone trap settings

The different positions of the trap setting performed differently in respect of catching or trapping the BSFB adults. The sex pheromone used in the trap is sex-specific and caught or attract the male adults of the BSFB. The number of adults caught in traps placed at different positions varied significantly and followed the similar trend throughout the crop season. As shown in Fig. 1, the highest numbers of BSFB adults were caught in T_1 (Pheromone trap placed at plant canopy and in centre of the plots) throughout the crop season as evident from the highest number of catch at each observation, the highest catch being 55 at 3rd observation while the lowest was 38 at 8th observation. This was followed by T_2 (Pheromone trap placed at plant canopy and at edge of the plots) and T_4 (Pheromone trap placed above plant canopy and in centre of the plots), the highest number of catch being 50 and 43.5 respectively and the lowest being 28.67 and 24.83 respectively. The catch of adults in other trap setting positions was moderate while it was shown very low in T_7, T_8 and T_9, and the highest was found 19.67, 16.67, and 13.67 respectively. It revealed that the traps placed at or above plant canopy and placed in the center of the plot was more efficient in trapping adult male BSFB than those placed below canopy and at the edge/near to edge and even center of the plot. The BSFB larvae hatched-out from fertilized egg laid by BSFB females, cause infestation to the shoots and fruits of BSFB, and the oviposition of fertilized eggs is influenced by the successful mating of the females with males. The sex pheromone trap attracts the males, traps and disrupts the mating, which ultimately reduces the fertilized egg oviposition vis-a-vis larval as well as adult population of BSFB, and consequently the shoot and fruit infestation get reduced.

The trapping of adult BSFB has two implications; one is the monitoring of the adult BSFBs for using the value as a basis

Table 1. Effect of different settings positions of pheromone traps on infestation and yield of Brinjal

Treatments	Shoot Infestation(%)	Fruit infestation (%)	Healthy fruit (%)	Fruit yield (ton/ha)		
				Total	Healthy	Infested
T_1	10.02 d	20.95 bc	84.88 a	31.47 a	26.72 a	4.75 b
T_2	11.05 cd	23.22 ab	76.78 bc	27.42 bc	20.99 b	6.43 ab
T_3	12.08 abc	25.48 ab	74.52 bc	26.95 bc	20.06 bc	6.89 ab
T_4	11.85 bcd	15.12 c	79.05 ab	28.17 b	22.28 b	5.89 ab
T_5	11.67 bcd	26.75 ab	73.25 bc	26.81 bc	19.59 bc	7.22 a
T_6	10.95 cd	22.92 ab	77.08 bc	27.15 bc	21.03 b	6.12 ab
T_7	12.78 abc	24.75 ab	75.25 bc	28.14 b	21.20 b	6.94 ab
T_8	13.08 ab	26.00 ab	74.00 bc	26.04 bc	19.27 bc	6.77 ab
T_9	13.89 a	29.96 a	70.04 c	25.32 c	17.74 c	7.59 a
$LSD_{(0.05)}$	1.769	7.256	7.556	2.408	2.943	1.967
CV (%)	7.44	9.85	10.15	5.89	7.91	8.42

of insecticide application (i.e., the economic threshold) and another is the management of the BSFB through mating disruption, the later one is evident from the less number of adults catch in the subsequent later observations following the traps set in the field. However, the number of adult caught at the two extremes of the crop period as seen in Fig. 1 was less than the middle stage, which may be explained from two views such as at the very initial stage of the crop the population of BSFB was originally low while the second one is that the continuous trapping of the adults through the pheromone trap gradually reduced the natural population, which ultimately became the lowest at the later stage of the crop. Therefore, the more efficient trap setting is the BSFB adults and it would be in managing the BSFB for reducing the infestation.

Shoot and fruit infestation

The pheromone trap setting positions significantly influenced the shoot infestation by BSFB as shown in Table 1. The lowest shoot and fruit infestation 10.02% and 20.95% respectively was recorded from T_1 treatment that comprised pheromone trap placed at plant canopy and in the centre of the plot which was statistically identical (10.95% and 22.92%) with those of T_6 treatment comprising pheromone trap placed above plant canopy at nearer to edge of the plot and T_2, 11.05% and 23.22% respectively comprising pheromone trap placed at plant canopy and at edge of the plot.

In Gujarat, India it was observed that the higher the traps above the soil surface, the smaller were the number of BSFB mot hs trapped and the minimum shoot infestation (Jhala and Patel, 2003).

The highest shoot and fruit infestation was 13.89% and 29.96% respectively and recorded from T_9 treatment that comprised pheromone trap placed below plant canopy and at nearer to edge of the plot, which was statistically identical with the treatment T_8 comprising pheromone trap placed below plant canopy at the edge of the plot (13.08% and 26%, respectively), followed by T_7 treatment comprising pheromone trap placed below plant canopy at center of the plot (12.78% and 24.75% respectively). Components of IPM such as application of Neem cake, 247 kg/ha at transplanting, installation of sex pheromone trap at 45 days interval significantly reduced the shoot and fruit infestation on Brinjal when compared with non IPM plots (Raht *et al*., 2005). It was reported that there are two methods; one is the clean cultivation with removal of infested shoots and fruits, and the other is the application of synthetic organic chemicals at 7-15 days interval, which still remains main weapon (Nair, 1986).

Healthy fruit and yield

The effect on shoot and fruit infestation, the different pheromone trap setting positions in the field showed significant variations in healthy fruits production in Table 1. The highest healthy fruit (84.88%) and healthy fruit yield (26.72 ton/ha) were recorded from T_1 treatment comprising pheromone trap

Table 2. Cost and benefit analysis for different settings of pheromone traps in Brinjal cultivation

Treatments	Production cost (Tk /ha)	Yield		Gross return(Tk.)	Net return (Tk.)	Benefit cost ratio
		Healthy	Infested			
T_1	215500	26.72	4.75	581900	366400	1.70
T_2	215500	20.99	6.43	484100	268600	1.25
T_3	215500	20.06	6.89	470100	254600	1.18
T_4	220500	22.28	5.89	504500	284000	1.29
T_5	215500	19.59	7.22	464000	248500	1.15
T_6	215500	21.03	6.12	481800	266300	1.24
T_7	215500	21.2	6.94	493400	277900	1.29
T_8	215500	19.27	6.77	453100	237600	1.10
T_9	215500	17.74	7.59	430700	215200	1.00

placed at plant canopy and in the centre of the plot, which was statistically identical with the T_4 treatment (79.05% and 22.28 ton/ha) comprising pheromone trap placed above plant canopy and in the centre of the plot. On the other hand, the same treatments resulted in the lowest infested fruit yield (5.89 ton/ha). This was followed by T_6 treatment comprising pheromone trap placed above plant canopy and at nearer to edge of the plot (77.08% and 21.03 ton/ha, respectively), which was statistically identical with those of T_2 treatment comprising pheromone trap placed at plant canopy and in the centre of plot (76.78% and 20.99 ton/ha respectively). In case of T_7 treatment comprising pheromone trap placed below plant canopy and in the centre of the plot was found 75.25% and 21.20 ton/ha respectively. On the other hand, the lowest healthy fruit (70.04%) and healthy fruit yield (17.74 ton/ha) were recorded from T9 treatment comprising pheromone trap placed below plant canopy and at nearer to edge of the plot, which was statistically identical with those of treatment T_5 comprising pheromone trap placed above plant canopy and at the edge of the plot.

Total fruit yield

The above effects on shoot infestation, fruit infestation and healthy fruit yields, the different setting positions of pheromone trap in the field showed significant variations in fruit yield per hectare in Table 1. The highest (31.47 ton/ha) fruit yield was recorded from the T_1 treatment comprising pheromone trap placed at plant canopy and in the centre of the plot, which was statistically comparable (28.17 ton/ha) with the T_4 treatment consisting of pheromone trap placed at plant canopy and in the centre of the plot. Moreover, the lowest (25.32 ton/ha) fruit yield was recorded from T_9 treatment comprising pheromone trap placed below plant canopy at nearer to edge of the plot, which was statistically similar (26.04 ton/ha) with that of the treatment T_8 comprising pheromone trap placed below plant canopy and at the edge of the plot. The pheromone trap, having the best setting position provided best performance and maintained shoot and fruit infestation level at 10.02% and 20.95%, respectively thus loosing at least 4.75 ton/ha yield in the form of infested fruit yield.

Benefit and cost ratio

Benefit cost ratio calculated based on cost incurred and the return received from the sale of produces was significantly different from different treatments in Table 2. The highest BCR (1.70) was recorded from T_1 while it was the lowest (1.10) obtained from T_9 treatment. BCR was quite encouraging, the total healthy fruit yield could be still increased significantly if additional management practice was adopted, which is evident from a substantial quantity of infested fruit yield. It was observed that combination of mechanical and chemical practices gave the highest benefit cost ratio than untreated control and sole one (Maleque *et al*., 1998).

The effect of pheromone trap positions observed in the present study and may be attributed to the easy entrance of the lures and traps, when they are placed at the canopy. It is to be noted that the adult moths of BSFB are trapped in the pheromone trap only at the night because of their nocturnal behavior, and the traps below the canopy are subject to physical barrier due to

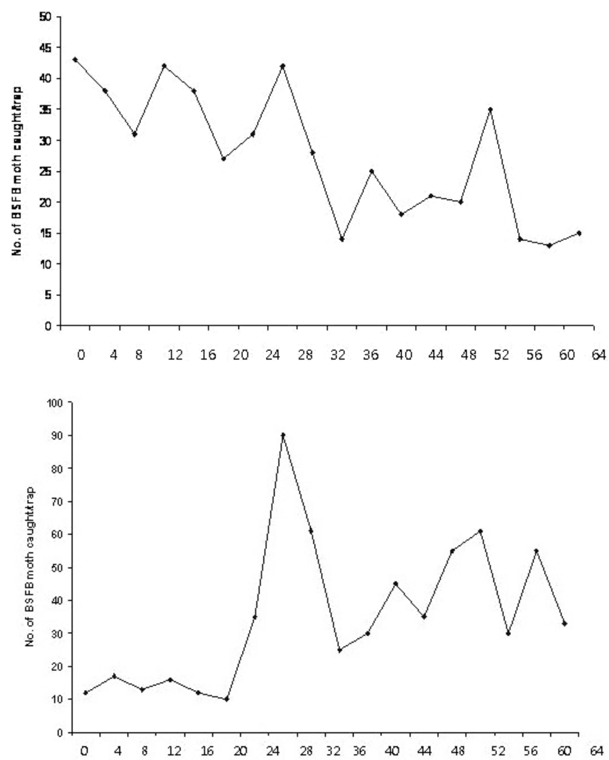

Fig. 2. Abundance of BSFB adult moth caught per trap during shooting stages (above) and fruiting stages (lower) at 4 days interval.

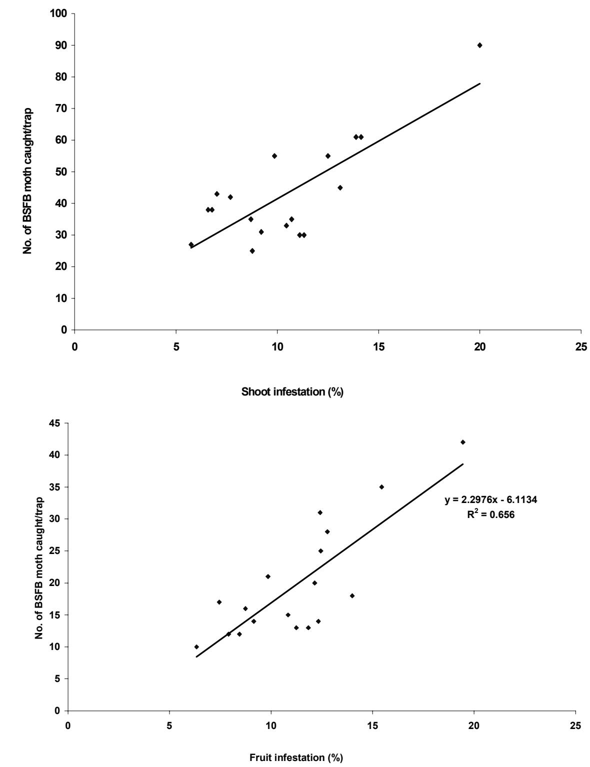

Fig. 3. Relationship between shoot infestation level (above) and fruit infestation level (lower) weekly observed adult BSFB month in the Brinjal field by sex pheromone trap

crop canopy. Moreover, the placement of the traps in the center of the field provided a uniform distribution of the traps throughout the crop field, which facilitate uniform and more attraction of the BSFB moths to the trap. Such findings have resemblance with the findings of many other researchers. The highest catch of adult BSFB was observed at plant canopy resulting in minimum shoot infestation (Alam *et al*., 2003). Brinjal has a relatively open canopy that might allow sustained flight of the pest adults inside and outside the crop (Mason *et al*., 1997). IPM is compatible and potential to be adopted on a broad scale and to provide a low cost management strategy (Gahukar, 2000; Hillocks, 1995)).

Correlation between number of BSFB adults trapped and infestation

The numbers of the BSFB adults trapped in the most appropriate trap setting position comprising trap set at plant canopy and in the center of the plot throughout the crop season observed in two occasions is shown in Fig. 2. The minimum number of adult caught was 12 on 18th observations, while the maximum number was 90 on 8th observation, which demonstrated that the number of BSFB adult caught was higher in the mid stage than late stage of the crop. The relationship between the adult catch and the shoot and fruit infestation presented in Fig. 3, and found positive linear correlation both shoot infestation (r = 0.781) and fruit infestation (r = 0.810). The infestation was higher at higher catch of the BSFB adults, but increase of the number of trapped adults, the rate of increase in infestation differed, which was greater in case of shoot than fruit. However, at the minimum 25 adults trapped, the infestation in shoot was 8.77% whereas it was 6% in fruit, and at the maximum 90 adults trapped, the infestation in shoot was 20% while it was 19.45% in fruit. Finally, we can conclude that the minimum number of 32.17 adults caught by T_1, which was the best pheromone trap settings, placed at plant canopy and in the centre of the plot with 10.02% shoot infestation and 20.95% fruit infestation.

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