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EFFICACY OF DIFFERENT MANAGEMENT PRACTICES AGAINST TOMATO FRUIT BORER, *Helicoverpa armigera* Hubner

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Abstract

The study was conducted to evaluate the efficacy of different management practices to control tomato fruit borer (TFB) under field condition. The field experiment was carried out with eight treatments, namely Neem oil, Mahogany oil, Fish and Fermented *Gur* (brown sugar), Netting, Chlorpyriphos, Emamectin Benzoate and Cartap along with untreated control in Randomized Complete Block Design (RCBD) and each treatment was replicated thrice. The study was under taken during the period from 25 October, 2017 to 06 April 2018. Data were collected on number and weight of total fruits plot^{-1}, number and weight of total healthy fruits plot^{-1}, number and weight of total infested fruits plot^{-1}, fruits infestation (%) in number and weight, infestation reduction over control for number and weight, number of holes, and larvae plot^{-1}, total yield plot^{-1} and marketable yield plot^{-1}. Among the different management practices, netting provided the highest infestation reduction over control. The percent fruit infestation reduction over control (number basis) was the highest in Netting treated plot resulting 61.87%, 73.27%, 84.68% and 92.70% at four different harvests, respectively. The percent fruit infestation reduction over control (weight basis) was the highest with the same treatment resulting 61.38%, 74.26%, 88.41% and 91.71% at four different harvests, respectively. The number of holes plot^{-1} was also the lowest in Netting treated plot resulting 5.00, 8.00, 15.33 and 8.67 at four different harvests, respectively. The number of larvae plot^{-1} was the lowest with the same treatment resulting 2.00, 2.33, 3.67 and 3.00 at four different harvests, respectively. The maximum marketable yield (33.95 t ha^{-1}) was achieved in the Emamectin Benzoate treated plot with the highest (1.46) benefit cost ratio.

Keywords: Tomato fruit borer, Infestation reduction, Management practices, Effectiveness.

Introduction

In Bangladesh vegetables are cultivated about in 414980 ha of the total cultivable land and its production was 4.05 m metric tons during the crop year 2016-17 where ha^{-1} yield was 9754.03 t (BBS, 2017) due to favourable soil and climatic condition.

Among vegetables tomato is one of the most important crop after potato belongings to the family Solanaceae and genus *Solanum*. Itis native to Peruvian and Mexican region which is herbaceous in nature. A good commercial yield

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under irrigation is 45 to 65 $tha^{-1}$of fresh fruit (FAOSTAT, 2001). In Bangladesh, tomato is cultivated in about 27530 haof the total cultivable land of all vegetables and its yield was 0.37 m metric tons during the crop year of 2016-17 where ha^{-1} yield was 14044.42 t (BBS, 2017) which is very low to fulfill the demand of the country.

In terms of nutrition, tomato contains double amount of nutritive elements compared to apple. It is the cheapest source of vitamins (A, B and C), minerals like calcium and proteins which majority of people can buy easily (Bose and Som, 1990; Pedro and Ferreira, 2007). Lycopene in ripe tomato is a potential antioxidant which reduces the risk of prostate cancer of human (Hossain *et al.*, 2004). Regular consumption of tomatoes can prevent short sightedness, night blindness, and other eye diseases. It is also helpful in preventing joint pain problems and the respiratory disorder as well (Friedman, 2013).

Generally, *rabi* season is suitable for tomato cultivation in Bangladesh but it has also great potentiality to grow in summer because of its photo insensitiveness. There are several reasons behind low production of tomato like insect infestation anddiseases. Generally tomato plant is affected by various types of insects, among them; tomato fruit borer (*Helicoverpa armigera)*causes devastating loss to tomato. It is polyphagous insect and attacks tomato, eggplant, cotton, tobacco, maize, sorghum, various legumes, okra, pepper and other horticultural crops. It reduces the yield as well as quality drastically (Wagh *et al*., 2012).

Damage mainly caused by larvae from seedling to fruiting stage to tomato plant as they feed on the seeds and flesh, and moth damage the host plant foliage mainly by ovipositional activities. Larvae also make holes, when they emerge which can provide a pathway for disease-causing micro-organisms (Shah *et al*., 2013). Larval damage makes the fruits unmarketable and unfit for human consumption and also responsible for decreasing the seed viability compared to undamaged fruit (Karabhantanal and Awaknavar, 2013).

Many prohibitive measures have been introduced to control the tomato fruit borer across the world. The research work of non-chemical control is not abundant. Generally the farmer of globe use chemical insecticides to control this pest and Bangladesh is not exception due to their easy availability and applicability. Though the rapid action of chemical insecticides, but they have extreme adverse effects on environment and consumers. Moreover, indiscriminate use of chemical insecticides for controlling insect pest of crop plant resulted hazardous effects causing serious problems including pest resistance, pest outbreak, pest resurgence and environmental pollution (Geiger *et al*., 2010).

Entomologistsare giving great emphasis on IPM practices. Now-a-days different eco-friendly control approaches like botanicals, netting, pheromone etc. are widely used to avoid the hazardous effect on environment. But the researches on the effectiveness of different management practices against TFB for sustainable

vegetable production in Bangladesh are not adequate as expected. In these circumstances, the present research was undertaken to evaluate the effectiveness of some management practices against TFB and to select the cost effective management practices.

Materials and methods

Experimental site and climatic condition

The experiment was conducted at the Field Laboratory of Agrotechnology Discipline, Khulna University, Khulna (22°47′57.84″N 89°31′53.48″E), Bangladeshbelonging to the Agro-ecological Zone "AEZ-13" (Ganges Tidal Floodplain) during 25 October, 2017 to 06 April 2018. The site was characterized by moderately high temperature and heavy rainfall during *kharif* season (April-October) and scantly rainfall with moderately low temperature during *rabi* season (November-March).

Raising of seedlings, setting experiment and transplanting

The seed of BARI Tomato 14 was collected from Bangladesh Agricultural Research Institute (BARI), Gazipur and seedling was raised in germplasm centre of Khulna University. Tomato seedling was raised in seedbed of 3m×1m size. Weeding, mulching and irrigation were done when required. The experiment was laid out in the Randomized Complete Block Design (RCBD) with three replications. The entire experimental plot was divided into 3 blocks each containing 8 units plots. In total there were 24 unit plots. The treatments were randomly assigned to each unit plot so as to allot one treatment once in each block. The unit plots were 2.5m×2m with 50 cm distance between the blocks and 40 cm between the unit plots. Each plot had 15 plants. Organic amendments and Chemical fertilizers were applied in the field as recommended by Bangladesh Agricultural Research Council (Anonymous, 2005). Healthy seedlings were uprooted from the seedbed and were transplanted in the experimental plots. Immediately after planting, the seedlings were watered. Seedlings were also planted around the experimental field for gap filling.

Preparation of fish and *gur* fermentation

For preparing fish and fermented *gur*(brown sugar), 500 g *gur* and 1 kg small fish mixed properly in a plastic container. Then, the mixed substances kept for 30 days in air tight container for fermentation.

Netting

For this study the plots of the blocks were covered with net houses measuring 2.50 m length, 2.0 m width and 1.50 m height.

Treatment application

The treatments, namely control (only water), Neem oil @ 4ml $l^{-1}$of water at 7 days interval, Mahogany oil @ 4ml $l^{-1}$of water at 7 days interval, Gur fermentation @ 10 ml $l^{-1}$of water at 7 days interval, Netting, Chlorpyriphos @ 2 ml $l^{-1}$of water at 7 days interval, Emamectin Benzoate @ 1g l^{-1} of water at 7 days interval and Cartap @ 2 g l^{-1} of water at 7 days interval were applied as foliar sprays starting from 35 days after transplanting. Care was taken to avoid drifting of treatment to neighboring plots.No pest control technique was applied in untreated control plots except an equal volume of water, which was used for other plots, was sprayed at 7 days interval.After transplanting of seedlings, weeding, irrigation were accomplished for better growth and development of the plants. After 15 days of transplanting a single healthy seedling per pit was allowed to grow. To support the individual seedling propping was done with bamboo stick and tied them with jute rope.

Harvesting and data collection

Harvesting of fruits was started from16th March and continued up to 6th April with an interval of 7 days. Harvesting was usually done manually. In order to observe the effects of the treatments on controlling TFB, data were collected on number and weight of total fruits plot^{-1}, number and weight of total healthy fruits plot^{-1}, number and weight of total infested fruits plot^{-1}, fruits infestation (%) in number and weight, infestation reduction over control in number and weight, no. of holes and larvae plot^{-1}, total yield plot^{-1} and marketable yield plot^{-1}, cost of production, gross return and benefit cost ratio (BCR). BCR was calculated by the ratio between gross return of a management practices and total cost of production of those management practices ha^{-1}.

Data analysis

The collected data were analyzed statistically for analysis of variance (ANOVA) with the help of Statistical Tool for Agricultural Research (STAR) 2.0.1 software where the means were separated by Duncan's Multiple Range Test (DMRT).

ResultsandDiscussion

Effect of management practices on yield by number and weight at first harvest

Total fruits plot^{-1}, healthy fruits plot^{-1}, infested fruits plot^{-1}and fruits infestation (%) by number and weight at first harvest (16 March, 2018) were statistically significant (Table 1). The maximum number of total fruits plot^{-1} (17.00) was harvested from T_8treated plot which was statistically similar to T_6 (16.33) and T_7 (16.00) treated ones. The same treatment produced the highest number (13.00) of healthy fruit plot^{-1} which was statistically similar to that of T_6 (12.67) treated

plot. Among the treatments, the highest number of infested fruits plot^{-1} was recorded in T_1 (5.00) whereas the lowest number of infested fruits plot^{-1} was recorded in T_5 (2.00). The fruit infestation was highest in untreated control T_1 (38.31%) plot and the minimum infestation in T_5 (14.76) treated plot. The percent fruit infestation reduction over control by Number was the highest in Netting treated plot resulting 61.87% reduction at first harvest. The maximum weight of total fruits plot^{-1} (1143.33 g) was obtained from T_8treated plot which was statistically similar to that of T_6 (1116.67 g) treated ones. The same treatment produced maximum weight of healthy fruit plot^{-1} (864.33 g) which was statistically similar to T_6 (857.67 g) treated ones. Among the treatments, the highest infested fruits plot^{-1} by weight was recorded in T_1 (327.00 g) whereas the lowest infested fruits plot^{-1} in weight basis was recorded in T_5 (139.33 g) treated plot. The fruit infestation was highest in untreated control T_1 (40.78%) plot and the minimum infestation was in T_5 (15.75%) plot. The percent fruit infestation reduction over control by weight was the highest in Netting treated plot resulting 61.38% reduction at first harvest.Similar result was observed by Dey *et al.* (2016) where they obtained the highest number of infested fruits plot^{-1} in untreated control and the lowest number of infested fruits plant^{-1} was recorded in netting treatment.

Effect of management practices on yield by number and weightbasis at second harvest

Total fruits plot^{-1}, healthy fruits plot^{-1}, infested fruits plot^{-1} and fruits infestation (%) by number and weight at second harvest (23 March, 2018) was statistically significant (Table 2). The highest number of total fruits plot^{-1} (56.00) was observed in T_6treated plot. The same treatment produced the highest number (43.00) of healthy fruit plot^{-1} which was statistically similar to that of T_7 (41.33) treated plot. Among the treatments, the highest number of infested fruits plot^{-1} was recorded in T_1 (17.00) treated plot whereas the lowest number of infested fruits plot^{-1} was obtained from T_5 (3.00) treated plot. The fruit infestation was the highest in untreated control T_1 (42.53%) plot and the minimum infestation was in T_5 (10.90%) treated plot. The percent fruit infestation reduction over control by number was the highest in Netting treated plot (T_5) resulting 73.27% reduction at second harvest. The maximum weight of total fruits plot^{-1} (3878.33 g) was recorded in T_6 treated plot. The same treatment produced maximum weight of healthy fruit plot^{-1} (2968.67 g) which was statistically similar to T_7 (2772.33 g) treated plot. Among the treatments, the highest infested fruits plot^{-1}by weight was recorded in T_1 (1049.67 g) treated plot whereas the lowest infested fruits plot^{-1}by weight was recorded in T_5 (199.00 g). The fruit infestation was the highest in untreated control T_1 (42.31%) plot and the minimum infestation was in T_5 (10.89%) treated plot. The percent fruit infestation reduction over control by weight was the highest in Netting treated plot resulting 74.26% reduction at second harvest. Prasannakumar *et al*. (2013) showed in a study where Neem,

Table 1. Effect of treatments on the tomato fruit borer infestation expressed in number of total, healthy and infested fruits, infestation percent and infestation reduction over control at first harvest (16.03.2018)

Treatment	Total Fruits plot^{-1}		Total healthy fruits plot^{-1}		Total infested fruits plot^{-1}		Infestation (%)		Infestation reduction over control (%)	
	Number	Weight (g)	Number	Weight (g)	Number	Weight (g)	Number	Weight (g)	Number	Weight (g)
T_1	13.00ab	799.67bc	8.00c	472.67c	5.00a	327.00a	38.31a	40.78a	-	-
T_2	13.33ab	875.00abc	9.67abc	629.67abc	3.67abc	245.33abc	27.69b	28.15b	28.47	30.97
T_3	11.00b	721.33c	8.67bc	563.67bc	2.33bc	157.67bc	21.06bc	21.74bc	45.60	46.69
T_4	15.33ab	1006.00ab	11.67abc	796.67ab	3.67abc	213.00abc	23.99bc	21.74bc	38.03	46.69
T_5	13.67ab	887.33abc	11.67abc	748.00ab	2.00c	139.33c	14.76c	15.75c	61.87	61.38
T_6	16.33a	1116.67a	12.67a	857.67a	3.67abc	259.00abc	22.39bc	23.17bc	42.16	43.18
T_7	16.00a	1080.67ab	12.00ab	822.00ab	4.00ab	258.67abc	25.07bc	23.92bc	35.24	41.34
T_8	17.00a	1143.33a	13.00a	864.33a	4.00ab	282.33ab	23.47bc	24.63bc	39.37	39.60
LS	**	**	**	**	**	**	**	**	-	-
CV (%)	10.87	10.34	12.24	13.03	18.61	19.62	14.95	16.26	-	-

LS= Level of Significance

CV= Coefficient of variation

**= Significant at 1% level

Means followed by common letter(s) in a column do not differ significantly by DMRT

[where, T_1= Untreated control (only water), T_2= Neem oil @ 4ml l^{-1} of water at 7 days interval, T_3= Mahogany oil @ 4ml l^{-1} of water at 7 days interval, T_4= Fish+Fermented *Gur* @ 10 ml l^{-1} of water at 7 days interval, T_5= Netting, T_6= Chlorpyriphos @ 2ml l^{-1} of water at 7 days interval, T_7= Emamectin Benzoate @ 1g l^{-1} of water at 7 days interval and T_8= Cartap @ 2 g l^{-1} of water at 7 days interval].

Table 2. Effect of t treatments on the tomato fruit borer infestation expressed in number of total, healthy and infested fruits, infestation percentage and infestation reduction over control at second harvest (23.03.18)

Treatment	Total Fruits plot^{-1}		Total healthy fruits plot^{-1}		Total infested fruits plot^{-1}		Infestation (%)		Infestation reduction over control (%)	
	Number	Weight (g)	Number	Weight (g)	Number	Weight (g)	Number	Weight (g)	Number	Weight (g)
T_1	40.00cd	2477.67 cd	23.00b	1428.00b	17.00a	1049.67a	42.53a	42.31a	-	-
T_2	42.00bc	2777.00bc	29.00b	1916.33 b	13.00ab	860.67ab	31.05ab	31.08ab	26.99	26.54
T_3	38.00cd	2495.67 cd	27.00b	1798.33 b	11.00 abc	697.33abc	28.87b	27.80b	28.87	34.30
T_4	32.67cd	2108.00 cd	26.00b	1688.67 b	6.67bc	419.33bc	20.35bc	19.75bc	50.10	53.32
T_5	28.00d	1887.67d	25.00b	1688.67b	3.00c	199.00c	10.90c	10.89c	73.27	74.26
T_6	56.00a	3878.33a	43.00a	2968.67a	13.00ab	909.67ab	22.64bc	22.92bc	44.48	45.83
T_7	52.33ab	3490.00ab	41.33a	2772.33a	11.00abc	717.67abc	21.05bc	20.62bc	48.38	51.26
T_8	33.67cd	2155.00cd	25.33b	1678.33 b	8.33bc	476.67bc	25.00b	22.11bc	38.70	47.74
LS	**	**	**	**	**	**	**	**	-	-
CV(%)	10.57	10.55	12.45	13.39	26.97	27.76	17.34	18.50	-	-

LS= Level of Significance

CV= Coefficient of variation

**= Significant at 1% level

Means followed by common letter(s) in a column do not differ significantly by DMRT

[where, T_1= Untreated control (only water), T_2= Neem oil @ 4ml l^{-1} of water at 7 days interval, T_3= Mahogany oil @ 4ml l^{-1} of water at 7 days interval, T_4= Fish+Fermented *Gur* @ 10 ml l^{-1} of water at 7 days interval, T_5= Netting, T_6= Chlorpyriphos @ 2ml l^{-1} of water at 7 days interval, T_7= Emamectin Benzoate @ 1g l^{-1} of water at 7 days interval and T_8= Cartap @ 2 g l^{-1} of water at 7 days interval].

Mahogany and pheromone were found effective in controlling tomato fruit borer but netting treatment was superior. In early fruiting stage, Neem and Mahogany oil were statistically similar in their effectivenessand in mid and late fruiting stage Mahogany oil did not show any significant difference from pheromone whereas netting was significantly different from all others. Present study also showed Mahogany is moderately effective in controlling tomato fruit borer. Majumdar and Powell (2011) also observed that Netting offered 90% reduction of tomato fruit infestation in the field condition which was almost similar to the present study.

Effect of management practices on yield by number and weight at third harvest

Total fruits plot^{-1}, healthy fruits plot^{-1}, infested fruits plot^{-1} and fruits infestation (%) by number and weight at third harvest (30 March, 2018) was statistically significant (Table 3). The highest number of total fruits plot^{-1} (134.33) was recorded in T_1treated plot which was statistically identical to that T_7 treated plot. Thehighest number (110.00) of healthy fruit plot^{-1} was harvested from T_7 treated plot. Among the treatments, the highest number of infested fruits plot^{-1}(59.33) was recorded in untreated control plot (T_1) whereas the lowest number of infested fruits plot^{-1} was obtained from T_5 (5.67) treated plot. The fruit infestation was the highest in control T_1 (44.05%) plot and the minimum infestation was in T_5 (6.35%) treated plot. The percent fruit infestation reduction over control by number was the highest in Netting treated plot resulting 84.68% reduction at third harvest. The maximum weight (g) of total fruits plot^{-1} (8823.33) was harvested from T_7 treated plot. The same treatment produced maximum weight (7202.67) of healthy fruit plot^{-1}. Among the treatments, the highest infested fruits plot^{-1}by weight was recorded in T_1 (3997.67) untreated plot whereas the lowest infested fruits plot^{-1}by weight was recorded in T_5 (338.33) treated plot. The fruit infestation was the highest in untreated control (T_1)(46.69%) and the minimum infestation was in in T_5 (5.41) treatment. The percent fruit infestation reduction over control by weight was the highest in Netting treated plot (T_5) resulting 88.41% reduction at third harvest. Majumdar *et al.* (2015) showed that the armyworm and tomato fruit worm caterpillar numbers reduced 98-100% under net house which was more or less similar to the present findings.

Effect of management practices on yield by number and weight at fourth harvest

Total fruits plot^{-1}, healthy fruits plot^{-1}, infested fruits plot^{-1} and fruits infestation (%) by number and weight at fourth harvest (06 April, 2018) was statistically significant except total fruits plot^{-1} (Table 4). The highest number of total fruits plot^{-1} (114.33) was observed in untreated control plot (T_1) and lowest in T_5 treated plot. The highest number (96.33) of healthy fruit plot^{-1} was recorded in T_6treated plot which was similar to that of T_7, T_5, T_4 and T_3treated plot. Among

the treatments, the highest number of infested fruits plot^{-1} was recorded from untreated control plot (T_1) (52.33) whereas the lowest number of infested fruits plot^{-1} was recorded in T_5 (3.00) treated plot. The fruit infestation was highest in untreated control (T_1)(46.13%) plot and the minimum infestation was in T5 (3.27%) treated plot. The percent fruit infestation reduction over control by number was the highest in Netting treated plot (T_5) resulting 92.70% reduction at fourth harvest. The maximum weight (g) of total fruits plot^{-1} (7531.33) was obtained in T_4 treated plot followed by T_3 and T_7 treatment. The maximum weight (6607.67) of healthy fruit plot^{-1} was recorded from T_6. Among the treatments, the highest infested fruits plot^{-1} by weight was recorded in T_1 (3125.33) treated plot whereas the lowest infested fruits plot^{-1} by weight was recorded in T_5 (210.33) treatment. The fruit infestation was highest in untreated control T_1 (45.85%) plot and the minimum infestation was in T_5 (3.80%) treated plot. The percent fruit infestation reduction over control by weight basis was the highest in Netting treated plot resulting 91.71% reduction at fourth harvest. Shah *et al.* (2013) observed that the effect of different botanicals extracts i.e., Neem seed extract (2.5%), Turmeric extract (5%), Henge extract (1.25%), Garlic extract (5%) and insecticide, emamectin benzoate (0.07%) were very effective in controlling *Helicoverpa armigera* infestation in tomato where maximum yield (7540 kg ha^{-1}) was recorded in Neem seed extract (2.5%) and percent infestation of larvae of tomato fruit worm was minimum (0.40) in emamectin benzoate treated plot whereas maximum was in untreated control plot.So in terms of environment healthiness point of viewthe neem seed extract was the most promising insecticide for the effective management of tomato fruit worm larvae which was more or less similar to the present findings.

Number of larvae and holesplot^{-1} at different harvest

The lowest number of larvae plot^{-1} was recorded in netting (2.00, 2.33, 3.67 and 3.00) at four different harvests, respectively and the highest number of larvae was recorded from untreated control plot resulting 5.67, 17.33, 56.33 and 48.33 at four harvests, respectively (Table 5). The highest number of fruit holes plot^{-1} was recorded in control plots at all four harvests (17.33, 55.67, 181.00 and 153.00 at 1st, 2nd, 3rd, and 4th harvest, respectively) and the lowest number of holes was in netting plot at all four harvest (5.00, 8.00, 15.33 and 8.67 at 1st, 2nd, 3rd, and 4th harvest, respectively) (Table 5). Martin *et al.* (2013) found that the net with finest pore diameter made a strong physical barrier to insect pests that literally disrupted their feeding on tomato fruits resulting in no hole on tomato which was almost similar to present finding. Dutta *et al. (*2011) found that the botanicals efficiently protected the larval infestation in fruit at different fruiting stages and which was similar to the present findings when botanicals were used as treatment.

Table 3. Effect of treatments on the tomato fruit borer infestation expressed in number of total, healthy and infested fruits, infestation percentage and infestation reduction over control at third harvest (30.03.18)

Treatment	Total Fruits plot^{-1}		Total healthy fruits plot^{-1}		Total infested fruits plot^{-1}		Infestation (%)		Infestation reduction over control (%)	
	Number	Weight (g)	Number	Weight (g)	Number	Weight (g)	Number	Weight (g)	Number	Weight (g)
T_1	134.33a	8569.67ab	75.00bc	4572.00c	59.33a	3997.67a	44.05a	46.69a	-	-
T_2	108.00ab	7239.00ab	69.33c	4652.33c	38.67b	2586.67b	35.74a	35.58b	18.86	23.80
T_3	106.00ab	7456.33ab	68.33c	4906.67bc	37.67b	2549.67b	36.13a	34.27b	17.98	26.60
T_4	122.67ab	7975.33ab	105.67ab	6847.00ab	17.00cd	1128.33cd	13.83bc	14.13d	68.60	69.74
T_5	90.00b	6255.00b	84.33abc	5916.67abc	5.67d	338.33d	6.35c	5.41e	84.68	88.41
T_6	109.00ab	7183.00ab	90.33abc	5974.33abc	18.67c	1208.67c	17.21b	16.94cd	60.93	63.72
T_7	133.67a	8823.33a	110.00a	7202.67a	23.67c	1620.67c	17.60b	17.97cd	60.05	61.51
T_8	101.33ab	6612.00ab	78.67abc	4994.00bc	22.67c	1618.00c	22.33b	24.36c	49.31	47.83
LS	*	*	**	**	**	**	**	**	-	-
CV(%)	12.09	11.62	13.76	12.55	15.25	15.62	12.97	11.27	-	-

LS= Level of Significance

CV= Coefficient of variation

*= Significant at 5% level

**= Significant at 1% level

Means followed by common letter(s) in a column do not differ significantly by DMRT

[where, T_1= Untreated control (only water), T_2= Neem oil @ 4ml l^{-1} of water at 7 days interval, T_3= Mahogany oil @ 4ml l^{-1} of water at 7 days interval, T_4= Fish+Fermented *Gur* @ 10 ml l^{-1} of water at 7 days interval, T_5= Netting, T_6= Chlorpyriphos @ 2ml l^{-1} of water at 7 days interval, T_7= Emamectin Benzoate @ 1g l^{-1} of water at 7 days interval and T_8= Cartap @ 2 g l^{-1} of water at 7 days interval].

Table 4. Effect of treatments on the tomato fruit borer infestation expressed in number of total, healthy and infested fruits, infestation percentage and infestation reduction over control at fourth harvest (06.04.18)

Treatment	Total Fruits plot^{-1}		Total healthy fruits plot^{-1}		Total infested fruits plot^{-1}		Infestation (%)		Infestation reduction over control (%)	
	Number	Weight (g)	Number	Weight (g)	Number	Weight (g)	Number	Weight (g)	Number	Weight (g)
T_1	114.33	6866.00	62.00b	3740.67c	52.33a	3125.33a	46.13a	45.85a	-	-
T_2	112.00	7176.00	74.67ab	4798.67bc	37.33b	2377.33b	33.33b	33.18b	27.75	27.63
T_3	111.00	7308.67	88.00a	5844.00ab	23.00c	1464.67c	20.74c	20.05c	55.04	56.27
T_4	111.00	7531.33	89.00a	6152.00ab	22.00c	1379.33cd	19.55c	17.74cd	57.62	61.31
T_5	90.33	5598.33	87.33a	5388.00abc	3.00e	210.33e	3.37e	3.80e	92.70	91.71
T_6	106.00	7278.00	96.33a	6607.67a	9.67de	670.33de	9.13de	9.22de	80.20	79.89
T_7	108.67	7300.00	91.33a	6118.33ab	17.33cd	1181.67cd	15.95cd	16.20cd	65.42	64.67
T_8	102.00	6944.67	81.33ab	5504.67ab	20.67c	1181.67c	20.52c	21.01c	55.52	54.18
LS	NS	NS	**	**	**	**	**	**	-	-
CV(%)	9.69	10.05	10.48	10.70	13.06	17.46	12.59	15.97	-	-

LS= Level of Significance

CV= Coefficient of variation

**= Significant at 1% level

NS= Non-significant

Means followed by common letter(s) in a column do not differ significantly by DMRT,

[where, T_1= Untreated control (only water), T_2= Neem oil @ 4ml l^{-1} of water at 7 days interval, T_3= Mahogany oil @ 4ml l^{-1} of water at 7 days interval, T_4= Fish+Fermented *Gur* @ 10 ml l^{-1} of water at 7 days interval, T_5= Netting, T_6= Chlorpyriphos @ 2ml l^{-1} of water at 7 days interval, T_7= Emamectin Benzoate @ 1g l^{-1} of water at 7 days interval and T_8= Cartap @ 2 g l^{-1} of water at 7 days interval].

Table 5. Effect of treatments on number of larvae and number of fruit holes plot^{-1}at different harvest

Treatment	1st harvest		2nd harvest		3rd harvest		4th harvest	
	Larvae plot^{-1}	Holes plot^{-1}	Larvae plot^{-1}	Holes plot^{-1}	Larvae plot^{-1}	Holes plot^{-1}	Larvae plot^{-1}	Holes plot^{-1}
T_1	5.67a	17.33a	17.33a	55.67a	56.33a	181.00a	48.33a	153.00a
T_2	3.67b	12.00b	13.33ab	42.67ab	38.67ab	123.33b	35.67b	116.00b
T_3	2.67bc	7.67bc	11.00bc	35.33bcd	36.67bc	118.67b	22.00c	72.00c
T_4	3.00bc	10.00b	5.33de	19.00de	21.67bcd	46.00cd	18.00cd	59.67c
T_5	2.00c	5.00c	2.33e	8.00e	3.67d	15.33d	3.00e	8.67e
T_6	3.67b	11.67b	11.00bc	37.33bc	17.00d	56.00c	8.67de	29.00de
T_7	4.00b	12.00b	9.67bcd	32.00bcd	21.00bcd	68.67c	15.33cd	50.00cd
T_8	4.00b	12.00b	7.67cde	24.67cd	19.67cd	63.33c	18.00cd	57.67c
LS	**	**	**	**	**	**	**	**
CV (%)	15.97	14.92	19.25	17.97	23.70	13.27	16.48	12.04

LS= Level of Significance

CV= Coefficient of variation

**= Significant at 1% level

Means followed by common letter(s) in a column do not differ significantly by DMRT,

[where, T_1= Untreated control (only water), T_2= Neem oil @ 4ml l^{-1} of water at 7 days interval, T_3= Mahogany oil @ 4ml l^{-1} of water at 7 days interval, T_4= Fish+Fermented *Gur* @ 10 ml l^{-1} of water at 7 days interval, T_5= Netting, T_6= Chlorpyriphos @ 2ml l^{-1} of water at 7 days interval, T_7= Emamectin Benzoate @ 1g l^{-1} of water at 7 days interval and T_8= Cartap @ 2 g l^{-1} of water at 7 days interval].

Table 6.Effect of treatments on total yield, marketable yield and yield increased over control at all harvest

Treatment	Total yield (t ha^{-1})	Marketable yield (t ha^{-1})	Yield increased over control (%)	Gross return (Tk. ha^{-1})	Cost of Production (Tk. ha^{-1})	BCR
T_1	37.42 ab	20.42d	-	245400d	244266	1.00d
T_2	36.13ab	23.99cd	17.48	287880cd	277799	1.04cd
T_3	35.96ab	26.22bc	28.40	314640bc	278064	1.13c
T_4	37.24ab	30.97ab	51.67	371640ab	277749	1.34b
T_5	29.25c	27.48bc	34.57	329760bc	304259	1.08cd
T_6	38.81ab	32.81a	60.67	393720a	278629	1.41ab
T_7	41.39a	33.95a	66.26	407400a	278839	1.46a
T_8	33.71bc	26.08bc	27.72	312960bc	278279	1.12c
LS	**	**	-	**	NS	**
CV(%)	6.19	6.38	-	6.38	6.82	3.42

LS= Level of Significance

CV= Coefficient of variation

**= Significant at 1% level

Means followed by common letter(s) in a column do not differ significantly by DMRT,

[where, T_1= Untreated control (only water), T_2= Neem oil @ 4ml l^{-1} of water at 7 days interval, T_3= Mahogany oil @ 4ml $l^{-1}$of water at 7 days interval, T_4= Fish+Fermented *Gur* @ 10 ml $l^{-1}$of water at 7 days interval, T_5= Netting, T_6= Chlorpyriphos @ 2ml $l^{-1}$of water at 7 days interval, T_7= Emamectin Benzoate @ 1g l^{-1} of water at 7 days interval and T_8= Cartap @ 2 g l^{-1} of water at 7 days interval].

Yield and Benefit Cost Ratio of tomato cultivation

The yield plot^{-1} showed significant variation among the treatments (Table 6). The highest yield was (33.95 t ha^{-1}) found in T_7treated plot which was statistically identical to that of T_6 (32.81 t ha^{-1}) treated plot.Increased yield over control was highest in T_7 (66.26 %) treatment and the lowest was in T_2treated plot (17.48%). Material, non-material and overhead cost were recorded for all treatments on unit plot basis and calculated per hectare. The total cost of production ranged between Tk. 244266 and Tk. 304259 ha^{-1}. The highest cost of production was found in netting (Tk. 304259 ha^{-1}) treated plot and the lowest was found in the untreated control (Tk. 244266ha^{-1}). The range between the gross return was Tk. 245400 ha^{-1} to Tk. 407400 ha^{-1}. The maximum benefit cost ratio was found (1.46) in $T_7$and the minimum was in untreated control (1.00) plot.

Conclusion

The findings of the present study revealed that all the management practices namely Neem oil, Mahogany oil, Fish + Fermented *Gur*, Netting, Chlorpyriphos, Emamectin Benzoate and Cartap had considerable action against the tomato fruit borer, of which Netting showed the highest performance in reducing infestation over control compared to other management practices. Emamectin Benzoatewas found highly effective against tomato fruit borer and provided higher economic yield.

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