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Evaluation of Combined Management Options for Managing Brinjal Shoot and Fruit Borer

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Abstract: The study on the evaluation of some options and their combinations for managing brinjal shoot and fruit borer *(Leucinodes orbonalis* Guenee) was carried-out at Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur, Bangladesh during 10 October, 2006 to 15 March, 2007. Among the treatments, any single option such as sole mechanical control, schedule spray of Marshal® at 7 days interval or sole sex pheromone trap placed at plant canopy and in the centre of the plot, was inferior to any of other combined options and the combinations of three options was better than that of any two options. Among the single options, routine spray of Marshal® at 7 days interval (T_7) was better than sole sex pheromone trap placed at plant canopy and in the centre of the plot (T_9), which, however, was better than sole mechanical control (T_2) in all considerations. But among all combined treatments, T_1 comprised spraying of Marshal® at 2 days interval, mechanical control and using pheromone trap placed at plant canopy and in the centre of the plot, performed the best in all respects ensuring the lowest shoot (6.27%) and fruit (3.19 % by number and 2.83% by weight) infestation, the highest reduction of shoot (79.65%) and fruit (89.03% by number and 90.72% by weight) infestation to compare with control. As a result, the maximum fruit yield (32.71 tons/ha) was produced in T_1, which contributed the highest yield of healthy fruits (30.42 tha^{-1}) as well as gave maximum BCR (2.05). The sex pheromone confused the male adult for mating and thus preventing fertilized egg production *vis-à-vis* reduces larval and adult population build–up. Marshal® was applied, when adult population reached at alarming phase indicated by monitoring results i.e., 10 to 15 adults caught per pheromone trap. Thus Marshal® killed the BSFB larvae as well as adults by its systemic and contact action. These treatments altogether significantly reduced the BSFB population and its infestation level, which ultimately increased the yield of brinjal.

Key words: Insect control · IPM · Sex pheromone · Marshal® · Mechanical control · *Leucinodes orbonalis*

INTRODUCTION

In the context of seriousness of the brinjal shoot and fruit borer (BSFB), *Leucinodes orbonalis* Guenée as a pest. Brinjal plants are very much susceptible to insect attack right from seedling to final harvesting stage. Brinjal is attacked by 53 species of insect pests [1] of which 8 are considered as major pests causing enormous damage to the crop in every season in every year and the remaining ones including one species of mites are considered as minor pests as they generally cause little damage [2]. Among the major insect pests, brinjal shoot and fruit borer (BSFB) is the most destructive pest of brinjal in Bangladesh [3-6] and India [7]. BSFB causes severe infestation by virtue of its reproductive potential, rapid turnover of generations and continuous perpetuation through intensively cultivated brinjal crop in both wet and dry seasons of the year. This pest is active throughout the year at places having moderate climate. They are very active in summer months especially in the rainy season. The damage is sometimes more than 90% [8]. The yield losses have been estimated up to 86% [9], 67% [10] and 95% [11] in Bangladesh. Despite the importance of brinjal and severity of BSFB problem, the management practices to combat BSFB are still limited to frequent sprays of toxic chemical pesticides [12, 13]. For vegetables in general, Sabur and Mollah [14] observed an increased use of pesticides by farmers, a wide range of organo-phosphorus, carbamate and synthetic pyrethroid insecticides with various spray formulations have been

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advocated from time to time against this pest [15-18]. The use of inappropriate pesticides, incorrect timing of application and improper doses have resulted in high pesticides costs with little or no appreciable reduction in target pest populations. Socio-economic studies of current BSFB control practices in Jessore District of Bangladesh indicated that 98% of farmers relied exclusively on the use of insecticides and more than 60% of farmers sprayed their crop 140 times or more in the 6-7 months cropping season [19]. Some farmers believed that excess use of insecticide could solve the insect pest's problem. They used insecticides frequently without considering the level of infestation. They usually sprayed insecticide in their field indiscriminately even without thinking the economic return of their investment. The abuse of pesticides, including the use of excessive rates and non-registered chemicals, as well as a disregard for re-entry and harvest-delay intervals, have resulted in both loss of pesticides' effectiveness as well as damage to the environment and human health [13]. Such indiscriminate use of insecticides are reported to cause insecticide resistance in insect pests, resurgence or increased infestation by some insect species due to the destruction of natural predators and parasitoids, changed pest status of mites and other minor insect pests, ecological imbalance and danger to health of the pesticide applicator and to consumers. At the advent of such increasing threat, integrated pest management (IPM) practices involving non-chemical alternatives, resistance management etc., have been undertaken in several countries including USA, Canada and Australia [20]. In Bangladesh, efforts are underway to popularize among the farmers the IPM practices involving pheromone traps, mechanical control, cleanliness, resistant varieties etc. in managing BSFB on brinjal.

Under the above context, the present experiment comprising different combinations of sex pheromone trap, cultural method, mechanical device and insecticides use based on some indicators has been undertaken with the following objectives to identify the most effective treatment combination(s) for managing BSFB and to recommend the best integrated practice for managing BSFB at farmer level.

MATERIALS AND METHODS

The experiment on the evaluation of some management options and their combinations for managing brinjal shoot and fruit borer (BSFB), *Leucinodes orbonalis* Guenee, was carried out at the experimental farm of Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur, Bangladesh during 10 October, 2006 to 15 March, 2007. In the study, cow dung and other chemical fertilizer were applied as recommended by Rashid [21] for brinjal cultivation @ 15 tons of cow dung and 115, 72 and 75 kg of N, P_2O_5 and K_2O, respectively per hectare. The half of cow dung and P_2O_5 were applied as basal dose during land preparation. The remaining cow dung, P_2O_5 and one-third of K_2O was applied in the pits at transplanting of brinjal seedlings. The entire dose of N and the rest of K_2O were applied as top dressing. The first top dressing of urea (one third) was made at 15 days after transplanting. One-third of N and one-third of K_2O were applied at the time of flower initiation and rest of urea and MP and MP at the time of fruit initiation were applied to keep the plants at normal growth, development and production. The whole field was divided into three blocks of equal size having 2 m space between the blocks and each block was again sub-divided into 10 plots (3 m × 3 m) with 2 m space between the plots. Fifteen pits were made in each plot at a distance of 100 cm between rows and 60 cm between pits on a row. Forty day old healthy seedlings (3/4 leaf stage) were transplanted in the experimental plots.

Design of Experiment: The experiment comprised 9 treatments including sex pheromone trapping, mechanical control, application of insecticide based on number of BSFB adults monitored using sex pheromone, routine spray of carbosulfan and a control, laid out in a Randomized Complete Block Design (RCBD) with 3 replications.

Details of the Treatments:

- T_1: Spraying of Marshal® 20 EC at 2 days interval + Mechanical control + Pheromone trap placed at plant canopy and in the centre of the plot,
- T_2: Mechanical control,
- T_3: Spraying of Marshal® 20 EC at 3 days interval + Mechanical control + Pheromone trap placed at plant canopy and in the centre of the plot,
- T_4: Spraying of Marshal® 20 EC at 10 adult catch in pheromone trap + Mechanical control,
- T_5: Spraying of Marshal® 20 EC at 12 adult catch in pheromone trap + Mechanical control,
- T_6: Spraying of Marshal® 20 EC at 15 adult catch in pheromone trap + Mechanical control,
- T_7: Spraying of Marshal® 20 EC at 7 days interval (Routine spray),

T_8: Spraying of Marshal® 20 EC at 7 days interval (Routine spray) + Mechanical control,

T_9: Pheromone trap placed at plant canopy and in the centre of the plot

T_{10}: Treatment having no pheromone trap and other options

The plots having pheromone traps (T_1 and T_3) in combinations with insecticides were set at the extreme end of the farm (half kilometer away) from the plots with treatments having no pheromone trap. The BSFB adults were monitored through 3 sex pheromone traps set in a plot half kilometer away from the experimental plots to keep the experimental plots out of pheromone influence zone.

Mechanical Control: Mechanical control comprised scouting the mechanical control labeled plots every alternate day to locate the infested shoot and/or twig if any, tearing-off them and destroying by hand any stage of the BSFB inside the infested shoot and/or twig, if any.
Insecticides application

Marshal® 20EC was collected from the local market of Gazipur District. Marshal® 20EC was applied by a Knapsack sprayer @ 1 ml per liter of water i.e., 0.1% (by mixing 6 ml of insecticide with 6 liter of water). The mixture in the spray machine was shaken well and sprayed covering the whole plants. Six liters spray material was required to spray three plots.

Before spraying, the spray machine was calibrated to find out the required quantity of spray materials for three plots. The spraying was done in the afternoon to avoid bright sunlight and drift caused by strong wind and adverse effect on pollinating bees.

Data Collection: The comparative effectiveness of the treatments in reducing shoot and fruit borer infestation was evaluated on the basis of some pre-selected parameters. The total number of shoots and the number shoots infested by the BSFB was recorded at weekly intervals from 5 plants of each plots.. In case of mechanical control, the infested shoots were clipped, removed and destroyed after counting.

$$\text{Shoot infestation} = \frac{\text{Number of infested shoots}}{\text{Total number of shoots}} \times 100$$

The marketable fruits were harvested at 7 days interval at early, mid and late fruiting stages and counted.Number of the healthy fruits (HF) and infested fruits (IF) harvested at early, mid and late fruiting stages of the plant. There was 4, 4 and 3 harvest at early, mid and late fruiting stage, respectively. In total, eleven harvests were done throughout the fruiting period. Infestation rate (by number and weight) of brinjal fruits caused by BSFB at early, mid and late fruiting stage in different treatments and its reduction over control were calculated. The weight of healthy and infested fruits at early, mid and late fruiting stage of eggplants was taken separately per plot for each treatment.

The overall percent fruit infestations and those at 3 different fruiting stages were calculated using the following formulae.

$$\%\ \text{Fruit infestation by number} = \frac{\text{Number of infested fruits}}{\text{Total number of fruits}} \times 100$$

$$\%\ \text{Fruit infestation by weight} = \frac{\text{Weight of infested fruits}}{\text{Total weight of fruits}} \times 100$$

$$\%\ \text{Reduction in infestation} = \frac{\%\ \text{infestation of untreated control} - \%\ \text{infestation of treatment}}{\%\ \text{infestation of untreated control}} \times 100$$

The stage-wise percent fruit infestation was calculated on the basis of the infestation occurred at each fruiting stage of the crop. The overall or accumulated infestation rate (both by number and weight) was derived from early, mid and late fruiting stages for different treatments and its reduction over control were also calculated.

The healthy and total yield of brinjal per hectare for each treatment was calculated in tha^{-1} from the cumulative fruit production in a plot. Effect of different treatments on the increase and decrease of brinjal yield over control was also calculated.

The data were analyzed statistically for important parameters like percent shoot and fruit infestation, healthy and infested yield, extent of damage, fruit bearing capabilities, intensity of attack, etc. The analysis of variance (ANOVA) of different parameters was performed and the range test of the means was done by using Duncan's Multiple Range Test (DMRT). Before statistical analysis, the data transformation was done where appropriate using square root and arcsine transformation procedures for the accuracy of results.For benefit cost analysis record of costs incurred in each treatment and that of control were maintained. Similarly, the price of the harvested fruits of each treatment and that of control were calculated at market rate. Benefit-Cost analysis was expressed in terms of Benefit Cost ratio (BCR).

RESULTS AND DISCUSSION

The comparative effectiveness of ten treatment combinations of various control options in managing the brinjal shoot and fruit borer (BSFB) in terms of shoot and fruit infestation, infested and healthy fruit yield, total yield and BCR, was assessed. The findings are presented under the following headings. The comparative effectiveness of various control options along with schedule spray on percent shoot infestation by the BSFB has been presented in Table 1. The results revealed that all treatments ensured significantly less infestation in shoot to compare with control (T_{10}), which had the highest shoot infestation (30.83%). Among the treatments, the lowest shoot infestation (6.27%) was recorded from T_1 (spraying of Marshal® 20 EC at 2 days interval + Mechanical control + Pheromone trap placed at plant canopy and in the centre of the plot you have notice the methods that are used in T_1 before, so it is not necessary to repeat again), followed by T_3 (spraying of Marshal® 20 EC at 3 days interval + Mechanical control) (9.67%),followed by T_8 (spraying of Marshal® at 7 days interval + mechanical control) (11.12%), T_7 (schedule spray of Marshal® at 7 days interval) and T_4 (spraying of Marshal® at 10 adult catch in pheromone trap + mechanical control). Accordingly, the shoot infestation reduction over control was the highest (79.65%) in T_1, followed by T_3 (68.64%). The shoot infestation reduction over control was the lowest (22.24%) in T_2 (sole mechanical control), which differed significantly from all other treatments. Similar trend has been reported for shoot infestation, all tested treatments showed significant effects on fruit infestation as compared to the control, which had the highest rate of fruit infestation (29.14% by number and 30.48% by weight) as shown in Table 2. As was in case of shoot, the lowest fruit infestation (3.19% by number and 2.83% by weight) was recorded in T_1, followed by T_3 (4.94% by number and 6.36% by weight), T_8, T_4 (9.36% by number and 13.26% by weight).

T_1: Spraying of Marshal® at 2 days interval + Mechanical control + Pheromone trap placed at plant canopy at the centre of the plot; T_2: Mechanical control; T_3: Spraying of Marshal® at 3 days interval + Mechanical control + Pheromone trap placed at plant canopy at the centre of the plot; T_4: Spraying of Marshal® at 10 adult catch in Pheromone trap + Mechanical control; T_5: Spraying of Marshal® at 12 adult catch in Pheromone trap + Mechanical control; T_6: Spraying of Marshal® at 15 adult catch in Pheromone trap + Mechanical control; T_7: Spraying of Marshal® at 7 (Routine spray) days interval; T_8: Spraying of Marshal® at 7 (Routine spray) days interval + Mechanical control; T_9: Pheromone trap placed at plant canopy and in the centre of the plot; T_{10}: Untreated control.

Accordingly, T_1 rendered the highest fruit infestation reduction (89.03% by number and 90.72% by weight) over control which was followed by T_3 (83.03% by number and 79.13% by weight), T_8 (78.52% by number and 77.19% by weight), T_7 and T_4, while it was the lowest in T_2 (41.51% by number and 39.01% by weight) and T_9 (50%). Interestingly, the reduction in fruit infestation in all treatments was higher than those in case of shoot infestation and only T_1 and T_3 could reduce fruit infestation over 80% while none could reduce shoot infestation even at the level of 80%. Consistent with the effectiveness in reducing the infestation both in shoot and fruits, T_1 was resulted in the highest healthy fruit yield (30.42 t ha^{-1}), which was followed by T_3 (25.68 t ha^{-1}) and T_8 (24.34 t ha^{-1}) (Table 3). The lowest healthy fruit yield (13.92 t/ha) was recorded from untreated control.

T_1: Spraying of Marshal® at 2 days interval + Mechanical control + Pheromone trap placed at plant canopy at the centre of the plot; T_2: Mechanical control; T_3: Spraying of Marshal® at 3 days interval + Mechanical control + Pheromone trap placed at plant canopy at the centre of the plot; T_4: Spraying of Marshal® at 10 adult catch in Pheromone trap + Mechanical control; T_5: Spraying of Marshal® at 12 adult catch in Pheromone trap + Mechanical control; T_6: Spraying of Marshal® at 15 adult catch in Pheromone trap + Mechanical control; T_7: Spraying of Marshal® at 7 (Routine spray) days interval; T_8: Spraying of Marshal® at 7 (Routine spray) days interval + Mechanical control; T_9: Pheromone trap placed at plant canopy and in the centre of the plot; T_{10}: Untreated control.

Conversely, the lowest infested fruit yield (2.29 t ha^{-1}) was harvested from T_1, which was followed by T_3 (4.43 t/ha) and T_8 (4.63 t ha^{-1}) and T_7 (5.70 t ha^{-1}). The highest infested fruit yield (9.27 t ha^{-1}) was recorded in untreated control. Accordingly was the trend of total yield in different treatments, the highest being 32.71 t ha^{-1}in T_1 and the lowest being 26.76 tons/ha in T_9 among the treatments and being only 23.19 t ha^{-1} in control.

The benefit cost ratio (BCR) calculated from the cost incurred in different treatments and the return from the fruit harvest showed significant variations among the treatments, all of which differed significantly from the control (Table 4). Consistent with the higher healthy fruit

Table 1: Effect of different management options on shoot infestation in brinjal

Treatments	Brinjal shoot in number	
	% infestation	Decrease over control
T_1	6.27 h	79.65
T_2	23.97 b	22.24
T_3	9.67 g	68.64
T_4	13.87 e	55.01
T_5	16.90 d	45.18
T_6	17.76 cd	42.40
T_7	12.69 ef	58.83
T_8	11.12 fg	63.91
T_9	19.22 c	37.66
T_{10}	30.83 a	--

In a column, numeric data represent the mean value of three replications; each replication is derived from 10 plants per treatment in 3 harvests
In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

Table 2: Effect of different management options on fruit infestation in brinjal

Treatment	Brinjal fruit in number		Brinjal fruit in weight (g)	
	% infestation	Decrease over control	% infestation	Decrease over control
T_1	3.19 g	89.03	2.83 f	90.72
T_2	17.04b	41.51	18.59 b	39.01
T_3	4.94 f	83.03	6.36 e	79.13
T_4	9.36 e	67.86	13.26 c	56.50
T_5	11.80 d	59.49	12.52 cd	58.93
T_6	12.47 d	57.21	13.72 c	54.97
T_7	9.89 e	66.06	10.14 d	66.71
T_8	6.26 f	78.52	6.95 e	77.19
T_9	14.54 c	50.10	15.05 c	50.62
T_{10}	29.14 a	--	30.48 a	--

In a column, numeric data represent the mean value of 3 replications; each replication is derived from 10 plants per treatment in 3 harvests
In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

Table 3: Effect of different management options on total, healthy and infested fruit yields of brinjal

Treatment	Healthy fruit yield (t/ha)	Infested fruit yield (t/ha)	Increase/ decrease over control
T_1	30.42 a	2.29 e	32.71
T_2	19.84 d	7.35 b	27.19
T_3	25.68 b	4.43 d	30.11
T_4	21.67 cd	6.91 b	28.58
T_5	22.17 cd	7.31 b	29.84
T_6	21.86 cd	7.21 b	29.07
T_7	21.63 cd	5.70 c	27.33
T_8	24.34 bc	4.63 d	28.97
T_9	20.55 d	6.21 c	26.76
T_{10}	13.92 e	9.27 a	23.19

In a column, numeric data represent the mean value of 3 replications; each replication is derived from 10 plants per treatment in 3 harvests
In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

Table 4: Cost and benefit analysis for management options for managing BSFB in brinjal

Treatments	Number of spray	Cost of pest Management (Tk.)	Yield (t ha^{-1})		Gross return (Tk.)	Net Return (Tk.)	Adjusted net return (Tk.)	Benefit: costratio
			Healthy	Infested				
T_1	33	85400	30.42	2.29	631300	545900	174800	2.05
T_2	-	38500	19.84	7.35	470300	431800	60700	1.58
T_3	23	65600	25.68	4.43	557900	492300	121200	1.85
T_4	11	55600	21.67	6.91	502500	446900	75800	1.36
T_5	10	55000	22.17	7.31	516500	461500	90400	1.64
T_6	9	54000	21.86	7.21	509300	455300	84200	1.56
T_7	11	44500	21.63	5.70	473100	428600	57500	1.29
T_8	11	52800	24.34	4.63	489600	436800	65700	1.24
T_9	-	66400	20.55	6.21	533100	466700	95600	1.44
T_{10}	-	--	13.92	9.27	371100	371100	--	--

Healthy fruits TK. 20/- per kg. and infested fruits TK. 10/- per kg yield in different treatments, the gross return was in descending order as $T_1 > T_3 > T_8 > T_5 > T_6 > T_4 > T_7 > T_9$, the highest being Tk 6,31,300.00 in T_1 and the lowest being Tk. 5,33,100.00 in T_9 among the treatments. But due to variations in costs of treatments, the order of net return in some cases changed and thus the order of BCR also changed in some cases. Among the treatments, T_1 provided the highest BCR (2.05), T_3 (1.85), while it was the lowest (1.29) in T_9. Although the BCR in T_3 was close to T_1, the healthy fruit yield in T_3 (25.68 t ha^{-1}) was much less than T_1 (30.42 t ha^{-1}). Similarly, the healthy fruit yield in T_7 (21.63 t ha^{-1}a) which was also much less than T_8 (24.34 t ha^{-1}) although its BCR was higher (1.66) than T_8. Consistent with its effect on all other yield contributing parameters, the BCR of T_9 was very low (1.29).

T_1: Spraying of Marshal® at 2 days interval + Mechanical control + Pheromone trap placed at plant canopy at the centre of the plot; T_2: Mechanical control; T_3: Spraying of Marshal® at 3 days interval + Mechanical control + Pheromone trap placed at plant canopy at the centre of the plot; T_4: Spraying of Marshal® at 10 adult catch in Pheromone trap + Mechanical control; T_5: Spraying of Marshal® at 12 adult catch in Pheromone trap + Mechanical control; T_6: Spraying of Marshal® at 15 adult catch in Pheromone trap + Mechanical control; T_7: Spraying of Marshal® at 7 (Routine spray) days interval;

T_8: Spraying of Marshal® at 7 (Routine spray) days interval + Mechanical control; T_9: Pheromone trap placed at plant canopy and in the centre of the plot; T_{10}: Untreated control.

T_1: Spraying of Marshal® at 2 days interval + Mechanical control + Pheromone trap placed at plant canopy at the centre of the plot; T_2: Mechanical control; T_3: Spraying of Marshal® at 3 days interval + Mechanical control + Pheromone trap placed at plant canopy at the centre of the plot; T_4: Spraying of Marshal® at 10 adult catch in Pheromone trap + Mechanical control; T_5: Spraying of Marshal® at 12 adult catch in Pheromone trap + Mechanical control; T_6: Spraying of Marshal® at 15 adult catch in Pheromone trap + Mechanical control; T_7: Spraying of Marshal® at 7 (Routine spray) days interval; T_8: Spraying of Marshal® at 7 (Routine spray) days interval + Mechanical control; T_9: Pheromone trap placed at plant canopy and in the centre of the plot; T_{10}: Untreated control.

The findings presented under different parameters (e.g., shoot and fruit infestation, healthy and infested fruit yield, total fruit yield and BCR) indicate that any single option such as sole mechanical control, schedule spray of Marshal® at 7 days interval or sole sex pheromone trap placed at plant canopy and in the centre of the plot was inferior to any of the combined options and that the combinations of three options was better than that of two options. Among the single options, schedule spray of Marshal® at 7 days interval (T_7) was better than sole sex pheromone trap placed at plant canopy and in the centre of the plot (T_9), which, however, was better than sole mechanical control (T_2) in all considerations. The most fascinating finding is that the treatment T_1 attained superiority to T_3 in all aspects such as reduction in shoot and fruit infestation and infested fruit yield, increase of healthy fruit and total fruit yield and increase of BCR, just due to one day less interval of spraying Marshal® (the former having Marshal® spraying at 2 days interval and the later having the spraying at 3 days interval) although both had in common the mechanical control and the pheromone trap placed at plant canopy and in the centre of the plot. The above findings have resemblance with the findings of other researchers. It was reported that sanitation, sex pheromone and biological control put together in an integrated package of practices would help combat ESFB on a sustainable basis when in many instances the insecticides did not provide satisfactory control of the target pest timely. Duara *et al*. [22] reported that IPM gave effective control of shoot and fruit borers, as well as the highest BCR. Maleque *et al*. [23] observed that combination of mechanical and chemical gave the highest benefit cost ratio than untreated control and sole one. Amin [24] reported that spraying of Marshal® 20 EC at 1 ml L^{-1} of water + mechanical control produced the highest yield (39.69 t ha^{-1}), which was followed by use of sex pheromone (35.04 t ha^{-1}) with mechanical control. Thus either T_1 to harvest the highest healthy fruit yield and total fruit yield (30.42 tons and 32.71 t ha^{-1} respectively) would be the best choice from economics point of view, or for consumers' safety either T_8, T_5 or T_9 (only pheromone requiring no spray) at the sacrifice of 6 tons, 8 tons or 10 tons potential healthy yield per ha respectively, may be an alternative choice.

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