Efficacy of Chemical and Organic Insecticides Against Diamondback Moth, *Plutella xylostella* (L.), (Lepidoptera: Plutellidae) on Cabbage

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Abstract

A survey carried out in Pindaya, Nyaung Shwe and Pin Laung Townships, Southern Shan State revealed that Cypermethrin was the most commonly used insecticide in survey areas and the highest spraying frequency was observed in Pindaya Township. Based on the survey results, Pindaya was selected as experimental area and the Cypermethrin was used as one of the treatments for field experiment. To determine the efficacy of chemical and organic insecticides for the control of diamondback moth (DBM) and their impact on natural enemies, experiments were conducted at Pindaya Township in winter and summer seasons during the period of September 2015 to June 2016. Field trial was arranged in Randomized Complete Block Design (RCB) with four replications. The treatments were (T1) Control (water only); (T2) White Gold (Cypermethrin 10% EC); (T3) Lightning (*Bacillus thuringiensis* var .*kurstaki*); (T4) Neem Seed Kernel Extract; (T5) Neem Oil; and (T6) Ywat Sein (Pyrethrin 2%+ Azadirachtin 0.5%). The result showed that higher population numbers of pest as well as natural enemy were recorded in summer season than those of winter season. The lowest population number of DBM was recorded in the plot treated with *Btk*. Furthermore, both of the natural enemy and parasitism rate were higher in *Btk* treated plot. In contrast, natural enemy populations as well as parasitism rate were lowest in Cypermethrin treated plot. Cypermethrin was not effective to control DBM in both seasons.

Key words: chemical insecticide, organic insecticides, diamondback moth, natural enemy

Introduction

Cabbage (*Brassica oleracea* var *capitata*) belonging to the family Cruciferae is one of the popular vegetables in Myanmar. The cabbage growing areas in Myanmar slightly increased from 31,095 ha in 2012-2013 to 31,471 ha in 2014-2015 (MOAI 2015). There are many insects which attack and feed upon cabbage due to its nutritional value and succulent nature. The insect pests complex associated with cabbage include such as aphids, *Aphis brassicae,* diamondback moth (DBM), *Plutella xylostella,* the cabbage webworm, *Hellula undalis* and the cabbage looper, *Trichoplusia ni* (Mochiahet al.2011). Among them, *P. xylostella* is one of the most destructive insect pests of cabbage and has a great economic importance worldwide which occurs wherever brassica crops are cultivated (Furlong et al. 2013). The outbreak of *P. xylostella* has been reported to cause more than 90% crop losses in Southeast Asia (Verkerk and Wright 1996). It was estimated that the worldwide annual DBM management costs US$ 5 billion (Zalucki et al. 2012) and $16 million annually in India (Mohan and Gujar 2003).

DBM has been routinely controlled by using chemical insecticides. However, the excessive use of these chemicals has caused several concerns related to the development of pest resistant (Sayyed et al. 2004), the accumulation of harmful pesticide residues in the environment and food (Tabashnik et al. 1990) and the impact of pesticide applications on the population of non-target organisms (Biondi et al. 2012). One of the efforts to solve these problems is the use of organic insecticides that are environmentally safer and friendlier than chemical insecticides. Microorganism, *Bacillus thuringiensis* is a promising biopesticide in the control of lepidopteran pests (Huang et al. 2010). Furthermore, plant-derived pesticides such as Neem are also considered in Integrated Pest management (IPM) programs for the control of cabbage pests (Charleston et al. 2006).The current study was therefore conducted to determine the efficacy of chemical and organic insecticides for the control of diamondback moth and their impact on natural enemy (NE).

Materials and Methods

Before conducting the field experiments, a survey (interview to the farmers) was carried out in Pindaya (Sat Kyar Gone Village), Nyaung Shwe (Kan Village) and Pin Laung Townships (Meedauk Village), Southern Shan State to get some idea about the most commonly used insecticides as well as the spray frequency. In total, 37 cabbage growers were interviewed: 18 in Pindaya, 11 in Nyaung Shwe and 8 in Pin Laung Townships.

The field experiments were conducted at Tha Byay Gone Village, Pindaya Township, Southern Shan State from September 2015 to June 2016 (winter and summer).The experiment was comprised of six treatments and four replications and laid out with Randomized Complete Block Design (RCB). Each plot was 6 x 3.6 m in size and the whole experimental area was 46.5 x 21.9 m^2. Two adjacent plots were interspaced with 1.5 m path. Treatments were: (T1) Control (water only); (T2) White Gold (Cypermethrin 10% EC); (T3) Lightning (*Bacillus thuringiensis* var. *kurstaki*); (T4) Neem Seed Kernel Extract; (T5) Neem Oil; and (T6) YwatSein (Pyrethrin 2% + Azadirachtin 0.5%).The application of insecticides for the control of DBM was done according to Economic Threshold Level (ETL) (>37 larvae/10 plants) developed in Malaysia by Jusoh *et al*.(1982). Agricultural practices such as weeding, fertilizer application and irrigation were conducted similar to those commonly adopted by local farmers.

Data Collection

The data collection was started at two week after transplanting (WAT) and it was continued until harvest (16 WAT) at six days interval. The number of DBM larvae and pupae as well as the number of natural enemies was recorded from the 10 randomly selected plants per plot.

To evaluate the impact of insecticides on parasitization, 10 larvae and pupae of DBM were collected for each plot from 4 WAT to16 WAT. Collected DBM larvae and pupae were placed individually in a separate plastic cup covered with muslin cloth and reared at room temperature. Larvae were fed with fresh cabbage leaves until they pupate. The emergence of parasitoids was also recorded and the parasitization rate was calculated as followed by the formula proposed by McCutcheon (1987).

$$\% \text{ parasitism} = \frac{\text{No. of larvae from which a parasitoid emerged}}{\text{Total no. of larvae collected - (Diseased larvae + Larvae that died of undermined cause)}} \text{ X } 100$$

Rainfall data was obtained from Department of Agriculture (DOA), Pindaya Township. Maximum and minimum temperature was recorded by using Hygrothermometer in the field.

Statistical Analysis

Data analysis was carried out by using Statistix (Version 8.0) stat software and mean separation was done by using Tukey' HSD test at 5% level.

Results and Discussion

Use of insecticides to control DBM in Southern Shan State

In all interviewed areas, cabbage growers mainly relied on the use of chemical insecticides to control insect pests of cabbage. Six insecticides were widely used by the farmers. Among them, Cypermethrin (40%) was observed as the most commonly used insecticides followed by Acephate (21%), Chlorpyrifos + Cypermethrin (12%), Imidacloprid (9%), Abamectin (9%) and Emamectin benzoate + λ-cyhalothrin (9%) were recorded respectively (Figure 1). Therefore, Cypermethrin was chosen as one treatment for field experiments.

Most of the growers from survey areas sprayed the insecticides at 3 days, 5 days,7 days, 10 days and 14 days intervals and the frequency of spraying in these townships ranged from 6 to 30 times. The highest mean frequency (15.50) was observed in Pindaya followed by (13.64) in Nyaung Shwe and the lowest (10.50) in Pin Laung Township respectively (Figure 2).

Population changes of DBM larvae and natural enemy in winter season

In winter season, the earliest population of DBM larvae was observed at 3 WAT and the natural enemy at 4 WAT in all treatments (Figure 3).In general, the level of DBM larvae infestation from 3 WAT to 9 WAT was very low, that is <5 larvae/10 plants. After that, pest population increased gradually until final sampling date (16 WAT) (Figure 3). The highest mean population number of DBM larvae (22.00 larvae/ 10 plants) was observed at 14 WAT in the *Btk* treated plots but at 16 WAT (33.25 larvae/ 10 plants) in control plot, (26.25 larvae/ 10 plants) in Cypermethrin (Cyper), (29.75 larvae/ 10 plants) in Neem Seed Kernel Extract (NSE), (26.00 larvae/ 10 plants) in Neem Oil (NO), and (38.25 larvae/ 10 plants) in the plot treated with Ywat Sein (YS) respectively (Figure3).

Even though mean number of DBM larvae per 10 plants was not exceeded the ETL (>37 larvae/ 10 plants) at 13 WAT (Figure 3), the number of DBM population in some sub-plots exceed the ETL. Therefore, insecticide application was conducted only one time for the whole season in all treatments at 13 WAT except NO treated plot (Figure 3). After that, the number of larvae in these treatments was decreased below ETL at 14 WAT and 15 WAT. Then, the mean number of larvae increased above ETL in control, NSE and YS plots at 16 WAT (Figure 3).Almost all treatments, the population of NE was lower than that of pest population. The highest mean number of natural enemy (8.25 NE/10 plants) was observed at 7 WAT in the plot treated with YS, but at 13 WAT (10.25 NE/10 plants) in the control plot, (9.50 NE/10 plants) in Cyper, (12.00 NE/ 10 plants) in *Btk*, (11.25 NE/10 plants) in NO and at 15 WAT (8.00 NE/ 10 plants) in the NSE treated plots (Figure 3).

Mean number of larvae in all treatments was maintained below ETL from 3 WAT to 12 WAT. According to this result, insecticides application was not needed within 72 days after transplanting for winter cabbage (3 WAT to 12 WAT) (Figure 4).It might be due to the rainfall. During this period, the rainfall (14.73 mm) at 3 WAT, (2.29 mm) at 6 WAT and (3.81 mm) at 9 WAT were recorded respectively. Talekar and Shelton (1993) reported that the rainfall can dislodge DBM larvae from the plants and can draw the larvae in the water in the soil.

Population changes of DBM larvae and natural enemy in summer season

In summer season, the earliest population of both DBM larvae and natural enemy was recorded at the first sampling date of 2 WAT (Figure 5). The peak population of DBM (361.00 larvae/10 plants) was observed at 6 WAT in control plot, (333.50 larvae/10 plants) in NSE, (360.50 larvae/10 plants) in NO and (332.25 larvae/10 plants) in YS treated plots but at 7 WAT in the plots treated with Cyper (997 larvae/10 plants) and *Btk* (109.25 larvae/10 plants) (Figure 5).The number of DBM larvae was observed above ETL (> 37 larvae/ 10 plants) in all treatments since the initial sampling date (2 WAT) (Figure 5).So, insecticide application was conducted from 2 WAT to 8 WAT in all treatments. After that, the number of larvae decreased in all treatments and only some treatments needed to spray insecticide. Insecticide spraying frequency of different treatments were Cyper - 12 times (2-13 WAT), *Btk* - 8 times (2-8 and 12 WAT), NSE - 8 times (2-9 WAT), NO - 9 times (2-9 and 12 WAT) and YS - 9 times (2-8, 12 and 13 WAT) respectively (Figure 5).

As for natural enemy, the same trend was observed as in winter season. The highest mean population number of NE (22.50 NE/ 10 plants) was observed at 6 WAT in the plot treated with YS but at 7 WAT (32.00 NE/10 plants) in the control plot, (45.75 NE/ 10 plants) in *Btk*, (28.25 NE/ 10 plants) in NSE,(31.00 NE/ 10 plants) NO treated plots and at 12 WAT (8.75 NE/ 10 plants) in the plot treated with Cyper (Figure 5).

Unlike the winter season, mean number of DBM larval population in this season was high since initial sampling date (2 WAT) and apparently increased until 8 WAT (Figure 6). During this period, there was no rainfall. Minimum and maximum temperatures were (24.63°C) and (32.03 °C) respectively. This condition could favor the multiplication of DBM. This result was in agreement with the finding of Tufail and Ansari (2010) who reported that temperature ranged from 25.20 to 35 °C significantly increases DBM population. The larval population was drastically decreased from 9 WAT till the final sampling date 16 WAT (Figure 6). This may be due to unusually heavy rain, (39.12 mm) at 9 WAT, (12.70 mm) at 10 WAT, (59.18 mm) at 11 WAT, (15.24 mm) at 13 WAT, (66.55 mm) at 14 WAT and (65.02 mm) at 16 WAT were recorded respectively occurred in experimental area. Ayalew et al. (2006) reported that heavy rain significantly reduce DBM larval population. The number of DBM larvae in *Btk* plot was much lower than other treated plots throughout the growing season (Figure 6). Although insecticide application was done 12 times in Cyper treated plot, the numbers of DBM larvae were remained in higher level compared with the other treatments. This may be due to the development of resistance by DBM to this insecticide. This result was in line with the finding of Rowell et al. (2005) who reported that the higher DBM larval densities in the plot treated with Cyper was as a consequence of resistance to this commonly used insecticide and the probable destruction of non-resistant natural enemies.

Season-long mean number of DBM larvae in winter and summer seasons

In winter season, the season-long mean numbers of DBM larvae were not statistically differences among the treatments. The highest season-long mean number of DBM larvae (11.93 larvae/ 10 plants) was observed in the plot treated with YS followed by control plot, NSE, Cyper, NO and *Btk* treated plots (Table 1).

In summer season, season long mean number of DBM larvae was highly significant different among the treatments (Table 1). The highest number (203.07 larvae/ 10 plants) was observed in Cyper treated plot and the lowest in the plot treated with *Btk.* The result was similar to Sayyed et al. (2005) who reported that DBM has developed resistance to pyrethroids in Southeast Asia and elsewhere. Elzen and James (2002) have reported that *Btk* formulation was superior to other insecticides for the control of DBM. Season-long mean numbers of larvae in the plots treated with NSE, NO, YS and control plot were not significantly different from one another.

Occurrence of natural enemy in winter and summer seasons

Irrespective of treatments, the occurrence of natural enemy on all treatments was recorded. In winter season, a total of 1417 (individuals) natural enemy of 5 genera under 4 orders; parasitoid (Hymenoptera), ant (Hymenoptera), hoverfly (Diptera), spider (Araneae) and ladybird beetle (Coleoptera) were recorded (Table 2). The most dominant natural enemy in order Hymenoptera constituted 49.57 % of total natural enemy and the second highest in Diptera 30.84 % followed by Araneae 19.34 % and Coleoptera 0.28 % were recorded respectively (Table 2).

In summer season, a total of 3642 (individuals) natural enemy of 4 genera under 3 orders; parasitoid (Hymenoptera), ant (Hymenoptera), hoverfly (Diptera) and spider (Araneae) were recorded (Table 2). The most dominant natural enemy in order Hymenoptera constituted 76.00 % of total natural enemy followed by Araneae 14.83 % and Diptera 9.17 % were recorded respectively (Table 2).

In this study, parasitoid was the most dominant species among the natural enemy in both winter and summer seasons. It was also observed that the population of natural enemy in summer season was higher than that of winter season. This may be due to the high density of prey in summer season. Ali et al. (2013) observed that the abundance of natural enemy was depending on prey density.

Season-long mean number of natural enemy in winter and summer seasons

In winter season, although the season-long mean numbers of natural enemy were not statistically different among the treatments, the highest mean number (5.54 NE/ 10 plants) was observed in the plot treated with *Btk* and the lowest (3.71 NE/ 10 plants) in the Cyper treated plot (Table 3).

In summer season, the highest season-long mean number of NE (15.55 NE/ 10 plants) was observed in the *Btk* treated plot and the lowest (4.32 NE/ 10 plants) in Cyper plot. This may be due to the absence of negative effects of *Btk* on NE. Roh et al. (2007) documented that the application of *Btk* has been regarded to reduce populations of DBM without affecting the survival of beneficial insects as compared to chemical pesticides. The second largest mean number (12.13 NE/ 10 plants) was observed in the control plot, followed by NO and NSE treated plots which in turn were not significantly different from YS (Table 3).

Parasitism rate of DBM parasitoids in winter and summer seasons

In winter season, the highest mean parasitism rate (12.31 %) was recorded in the *Btk* treated plot, followed by control plot (9.62 %) which in turn was not significantly different from Cyper, NSE, NO, and YS treated plots (Figure 7).

In summer season, the highest parasitism rate (33.69 %) was recorded in the control plot and it was not significantly different with the plot treated with *Btk* (22.12 %) but significantly higher than the other treated plots whereas YS (15.55 %) followed by NO (15.22 %), NSE (13.32 %) and the lowest parasitism rate (7.36 %) was recorded in Cyper treated plot. During the study period, parasitism rate in summer season was higher than that of winter season (Figure 7).

Conclusion

The experiments revealed that *Btk* significantly reduced the DBM population on cabbage as compared to other treatments. YS, NO and NSE were moderately effective in managing DBM in the field and Cyper was the least effective. According to the results, organic insecticides used in these experiments have no negative impact on natural enemy as well as parasitism rate. Therefore, *Btk*, YS, NO and NSE should be incorporated to the integrated management of DBM as an alternative to synthetic insecticides because they have valuable advantages in that they are not only environmentally friendly but also reduce the chance of insecticide resistance development as well as residue levels on cabbage.

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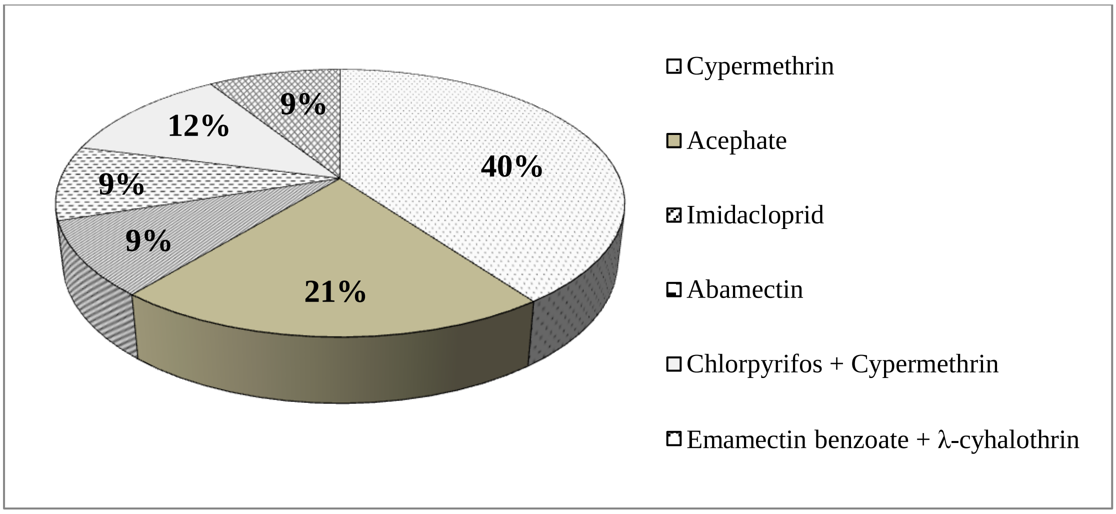

Figure 1. Insecticides used in Pindaya, Nyaung Shwe and Pin Laung Townships, Southern Shan State

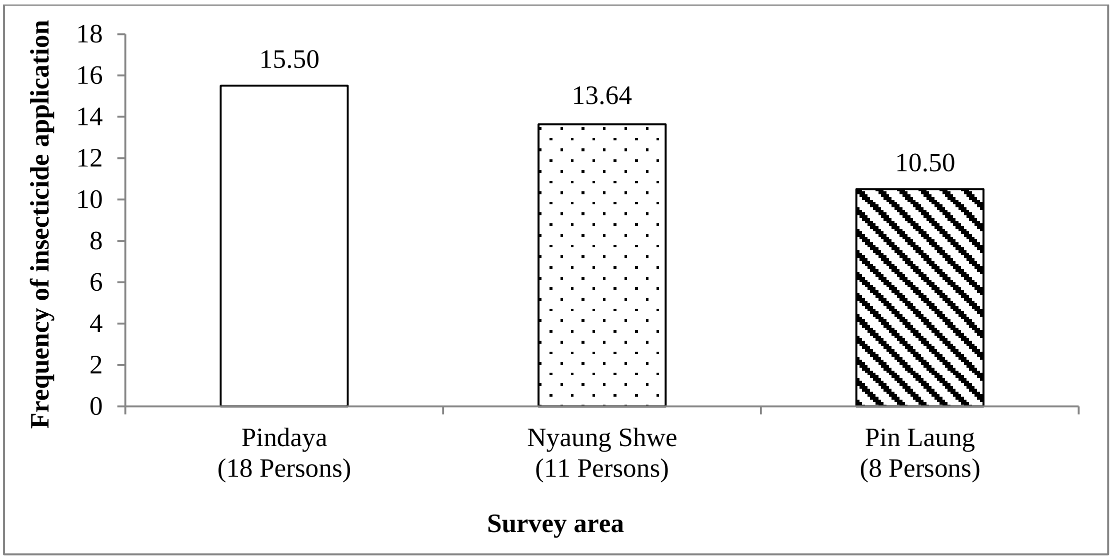

Figure 2. Mean frequency of insecticide spraying in survey areas

Table 1.Season-long mean number of DBM larvae per 10 plants in winter and summer seasons

Treatment	Winter Season (Mean ± SE)	Summer Season (Mean ± SE)
Control	11.54 ± 0.06a	114.80 ± 0.80 b
Cypermethrin	11.05 ± 0.01a	203.07 ± 13.54 a
Bacillus thuringiensis var. *kurstaki*	10.18 ± 0.13 a	34.40 ± 10.81 c
Neem Seed Kernel Extract	11.38 ± 0.04 a	104.57 ± 0.68 b
Neem Oil	10.52 ± 0.08 a	103.40 ± 0.85 b
Ywat Sein	11.93 ± 0.12 a	95.38 ± 2.00 b

Pr>F	0.8802	0.0000
CV%	20.18	20.42

Table 2. Occurrence of natural enemy recorded in winter and summer seasons

Order	Common name	Winter season		Summer season	
		Individuals	**(%)**	**Individuals**	**(%)**
1. Hymenoptera	1. Parasitoid	471	33.24	2201	60.43
	2. Ant	231	16.30	567	15.57
		(702)	(49.57)	(2768)	(76.00)
2. Diptera	3. Hoverfly	437	30.84	334	9.17
3. Araneae	4. Spider	274	19.34	540	14.83
4. Coleoptera	5. Ladybird beetle	4	0.28	0	0.00
Total		**1417**		**3642**	

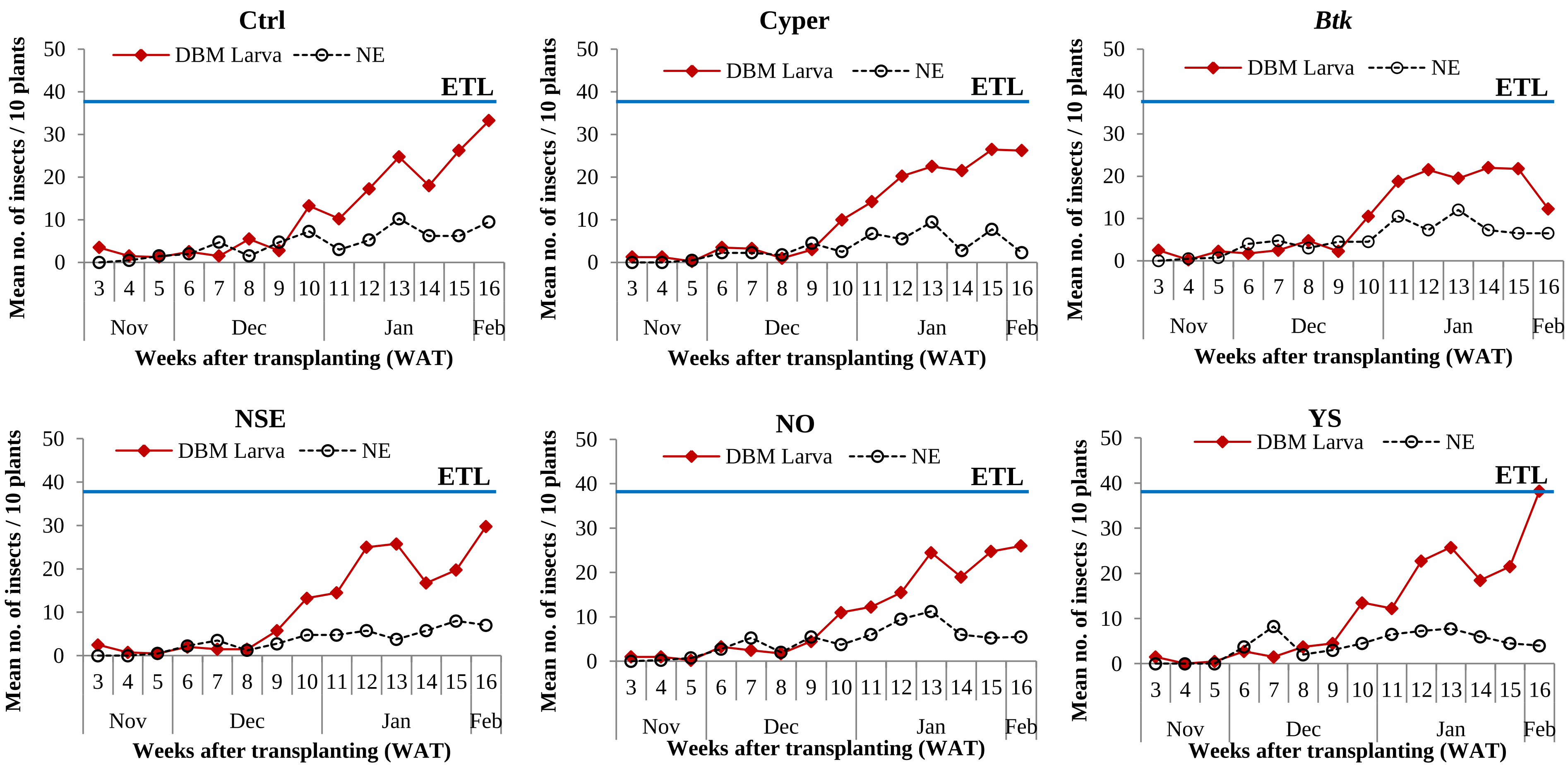

Figure 3.Population changes of DBM larvae and natural enemy per 10 plants in winter season

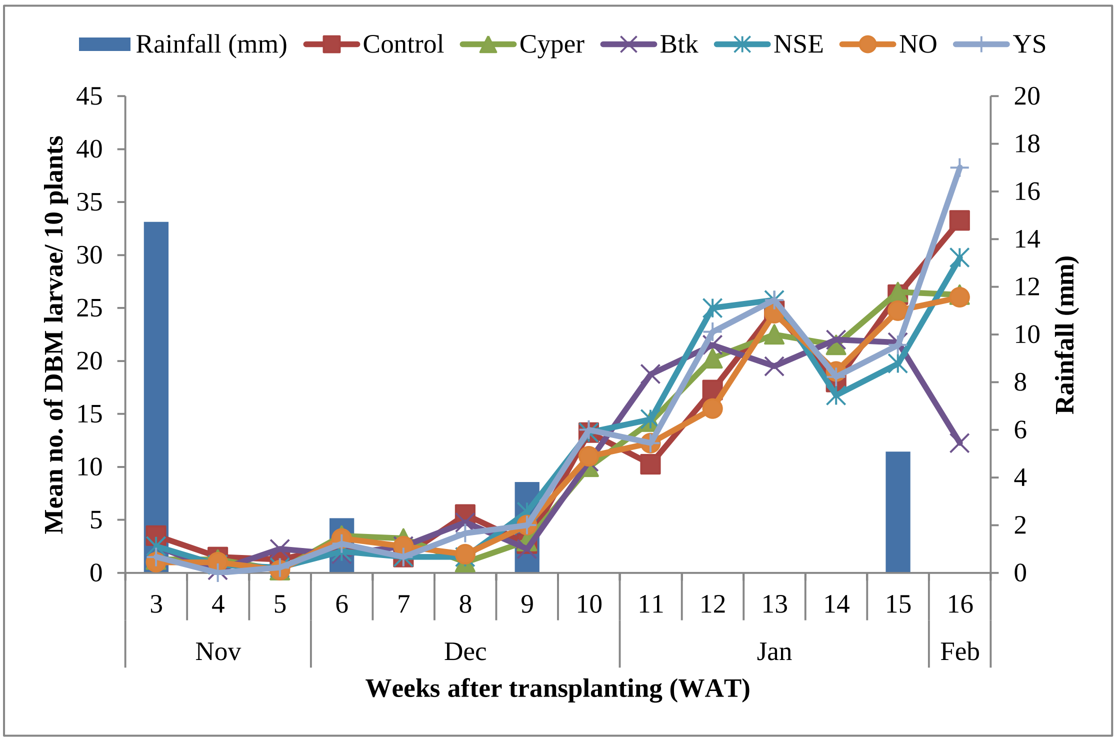

Figure 4. Population changes of DBMlarvae per 10 plants in winter season

Table 3.Season-long mean number of natural enemy per 10 plants in winter and summer seasons

Treatment	Winter Season (Mean ± SE)	Summer Season (Mean ± SE)
Control	4.83 ± 0.04 a	12.13± 0.29 b
Cypermethrin	3.71 ± 0.12 a	4.32± 0.84 d
Bacillus thuringiensis var. *kurstaki*	5.54 ± 0.14 a	15.55± 0.78 a
Neem Seed Kernel Extract	3.85 ± 0.10 a	9.50± 0.09 bc
Neem Oil	4.90 ± 0.05 a	10.32± 0.03 bc
YwatSein	4.42 ± 0.02 a	8.88± 0.18 c
Pr>F	0.0784	0.0000
CV%	19.30	13.19

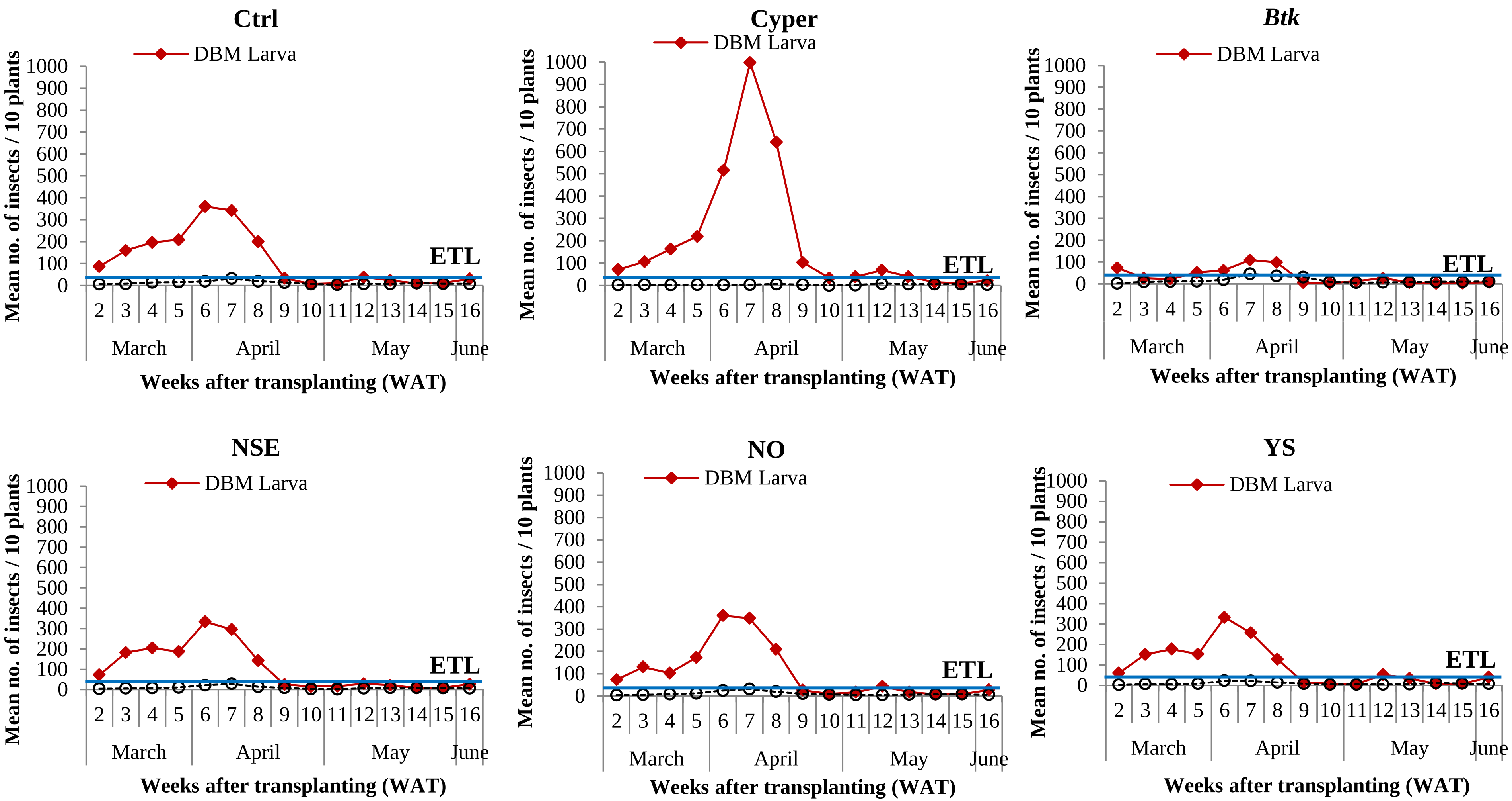

Figure 5.Population changes of DBM larvae and natural enemy per 10 plants in summer season

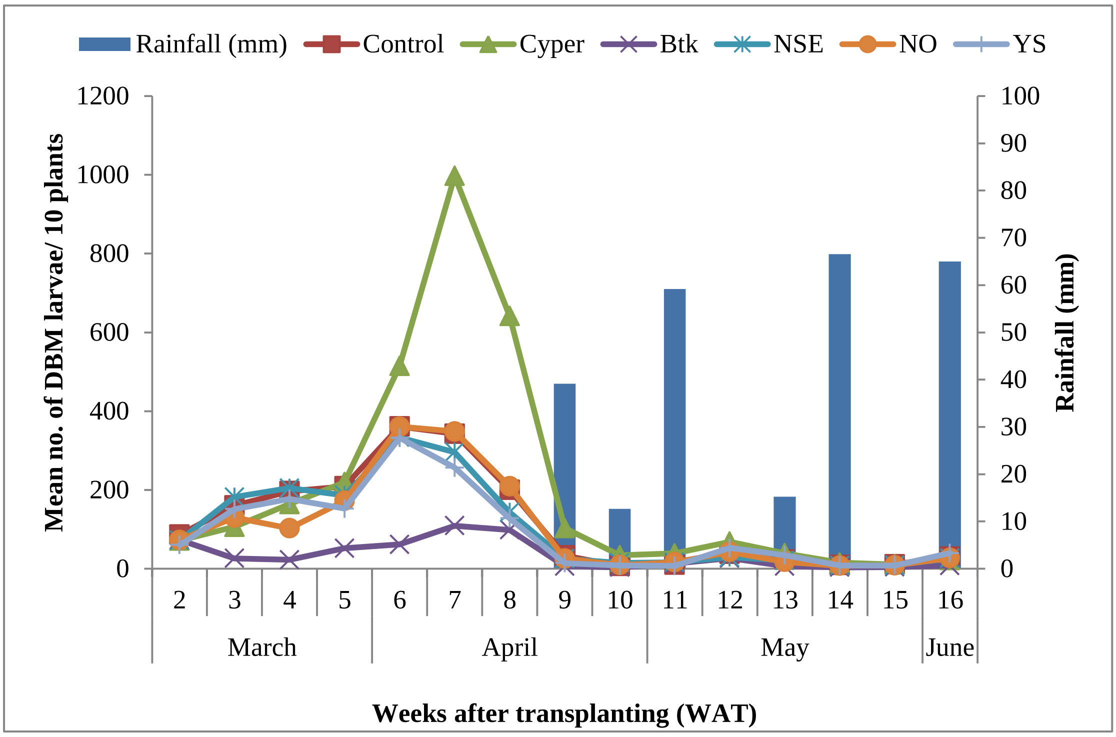

Figure 6. Population changes of DBM larvae per 10 plants in summer season

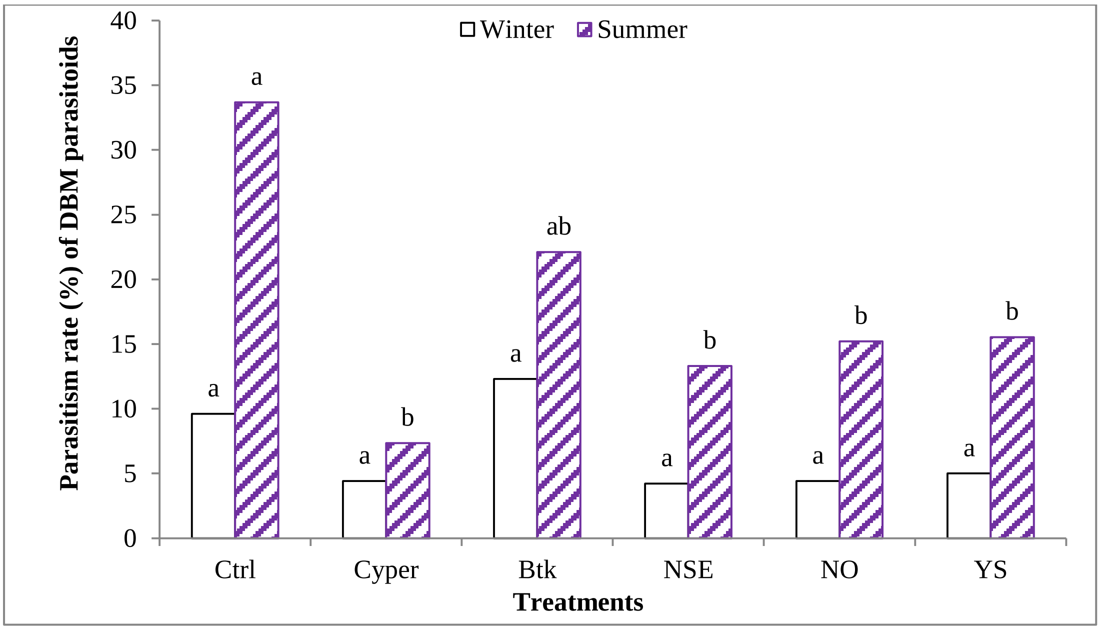

Figure 7. Parasitism rate of DBM parasitoids in winter and summer seasons

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