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Effectiveness of Some Bio-pesticides in Managing Major Lepidopteran Insect Pests of Cabbage (*Brassica oleracea* var. *capitata* L.)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aims: The study aimed to evaluate the efficacy of some bio-pesticides applied against major insect pests of cabbage.
Study Design: With three replications, the experiment was set up in a Randomized Complete Block Design (RCBD).
Place and Duration of Study: The experiment took place in the Sher-e-Bangla Agricultural University's experimental field in Dhaka, Bangladesh, from October 2019 to January 2020.
Methodology: Seven treatments, viz. T_1 (Abamectin 1.2EC @ 1 ml/L of water); T_2 (Azadirachtin 1EC @ 1 ml/L of water); T_3 (Potassium salt of fatty acid @ 1 ml/L of water); T_4 (Spinosad 45SC @ 1 ml/L of water); T_5 (*Bacillus thuringiensis* @ 1 ml/L of water); T_6 (Abamectin + *Bacillus thuringiensis* @ 1 ml/L of water) and T_7 (untreated control) were used. All the treatments were applied at ten days interval.
Results: Among the management practices, the lowest mean leaf infestation by cabbage caterpillar (6.00 leaves/5 plants) and diamondback moth larvae (4.48 leaves/5 plants) was found in Spinosad treated plot that reduced the highest leaf infestation over control (62.02% and 49.85 % respectively); whereas the highest infestation by cabbage caterpillar (15.80 leaves/5 plants) and diamondback moth larvae (8.93 leaves/5 plants) was found in un-treated plot. The lowest cabbage head

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infestation (21.37%) was recorded in Spinosad treatment, that gave the highest yield of cabbage (36.40 t/ha) followed by Abamectin (34.07 t/ha).

Conclusion: From the above study it was found that, the treatment T_4 comprised of Spinosad 45SC @ 1 ml/L of water at 10 days interval produced the highest performance compared to all other treatments used under the present study.

Keywords: Biopesticides; Bacillus thuringiensis; azadirachtin; cabbage caterpillar; diamondback moth.

1. INTRODUCTION

“Vegetable production in Bangladesh is very low as compared to the actual requirements. In 2018-2019, total vegetable (summer and winter season) production area was 434 thousand ha with total production of 4.32 million tons” [1]. Cabbage (*Brassica oleracea var. capitata* L.) is one of the five leading vegetables in the country which belong to the Cruciferae family. In 2018-2019, 2320 thousand metric tons of cabbage was produced in 19008 ha of land, which ranked fifth among the vegetables produced in the country [1]. “In our country, the vegetable’s consumption rate is 33 kg/head/yr. but in developed countries it is 7-8 times higher” [2].

“There are various variables that limit cabbage output, and insect pests play an important role in reducing cabbage yield. The cabbage crop is harmed by a variety of insect pests. The most harmful insect pests of cabbage are Lepidopterous insects such as the cabbage semi-looper (*Trichoplusia ni* Hub.), diamondback moth (*Plutella xylostella* L.), and cabbage caterpillar/prodenia caterpillar (*Spodoptera litura* Fab)”. [3]. “Cabbage looper (*Trichoplusia ni* Hub.) is one of the most damaging pests, devouring cabbage leaves with its ferocious appetite. They lay their eggs at the leaf edge on the underside of leaves. Semi-looper caterpillars are ravenous eaters who wreak havoc on cabbage heads by making holes in them” [4].

The cabbage caterpillar (*Spodoptera litura* Fab.) is a polyphagous pest that wreaks havoc on plants [5]. It is one of the most important insect pests of crops in the Asian tropics, according to [6], and the pest has been detected in cabbage growing areas. In some cabbage genotypes, it can lower output by more than 50% [7]. According to [8], cabbage caterpillars in Bangladesh cause 3.99 percent to 13.44 percent damage to leaves and 23.33 percent to 58.33 percent damage to plants, depending on the types.

“The diamondback moth (*Plutella xylostella* L.) is a major pest of cabbage fields, causing significant losses due to larval feeding” [9]. “The adult moth's egg laying site is on the underside of the lower leaves, where they lay eggs singly or in clusters. Larvae eat all sections of the plant, but they prefer to eat around the bud of little transplants. Young larvae crawl between the bottom and upper leaf pieces, while older larvae construct irregular short tunnels while maintaining the upper surface” [3].

“Diamondback moth infestations resulted in yield losses of 12.00 to 20.7-tons ha^{-1} in the first season, and 27.00- and 48.7-tons ha^{-1} in the second season” [7]. “In circumstances where pest infestation levels are high, a yield loss of up to 30% was regarded bearable as an alternative to severe insect damage. During the summer, these insect pests cause more substantial harm to cabbage” [10].

However, due to human and environmental risks, there are numerous obstacles in pest management from an economic and ecological standpoint, the majority of which are created by synthetic chemical pesticides [11]. “Chemical pesticides were used indiscriminately, resulting in issues such as pesticide resistance, secondary pest outbreaks, pest resurgence, bioaccumulation of chemicals in the food chain, pollution, human health risks, and destruction of non-target creatures. Safer chemicals, such as botanicals, are gaining popularity around the world as more environmentally friendly alternatives to very persistent synthetic pesticides. As a result, biorational approaches based on botanical preparations and natural products are gaining traction as potential alternatives for environmentally acceptable insect pest management” [11]. Therefore, the present experiment was carried to evaluate the effectiveness of some biopesticides in managing major lepidopteran insect pests of cabbage.

2. MATERIALS AND METHODS

The current experimental field was located in the Sher-e-Bangla Agricultural University's central farm in Sher-e-Bangla Nagar, Dhaka, Bangladesh and the experiment was conducted during October, 2019 to January, 2020. The experimental plot's soil was a shallow red-brown terrace soil that was slightly acidic (pH 5.8-6.5). In this experiment, the planting material was Magic-65. On 1^{st} October 2019, seeds were acquired from Lal Teer Seed Limited, Tejgaon, Dhaka and sowed on the seedbed. The seedbed was carefully prepared and made ideal for seedling formation before seed sowing. Healthy and uniform seedlings of 35 days old were transplanted in the experimental plots on 5^{th} November, 2019. Seven treatments, viz. T_1 (Abamectin 1.2EC @ 1 ml/L of water); T_2 (Azadirachtin 1EC @ 1 ml/L of water); T_3 (Potassium salt of fatty acid @ 1 ml/L of water); T_4 (Spinosad 45SC @ 1 ml/L of water); T_5 (*Bacillus thuringiensis* @ 1 ml/L of water); T_6 (Abamectin + *Bacillus thuringiensis* @ 1 ml/L of water) and T_7 (untreated control) were used. All the treatments were applied at ten days interval and there were a total 5 applications.

We used a Randomized Complete Block Design (RCBD) with three replications to set up the experiment. A single plot of the experiment was 6 m^2 (3 m × 2 m) in size. The land was thoroughly prepared before seedling transplantation, with deep plowing and laddering. On 5^{th} November, 2019, 35 days-old seedlings were transplanted in the main field at a rate of 21 seedlings $plot^{-1}$. Manures and fertilizers were applied according to the fertilizer doses recommended for cabbage production per hectare by [12].

All manures and fertilizers were applied at the time of final land preparation, with the exception of urea and MoP. Urea and MoP were applied in two equal installments using the ring technique at 15 and 35 days after transplanting (DAT) under moist soil conditions, and the fertilizers were fully mixed with the soil as soon as feasible for better use. Gap filling, weeding, earthing up, watering, and other intercultural operations were performed as needed to ensure and sustain normal crop development. Five plants were chosen at random from each unit plot to record the necessary data on various crop attributes. Data collection began at the vegetative stage and continued until the cabbage heads were harvested.

The number of infested leaves by cabbage caterpillar and diamondback moth larvae, the weight of each individual head, the height, and width of cabbage heads, and the yield (t ha^{-1}) were all recorded. At the time of harvesting, only the totally compact and marketable heads were harvested. Using the Statistix-10 computer package, the collected data was analyzed using ANOVA procedures. The Least Significant Difference (LSD) test was used to determine the mean separation.

3. RESULTS AND DISCUSSION

3.1 Leaf Infestation by Cabbage Caterpillar

In terms of leaf infestation owing to cabbage caterpillar attack at different days after transplanting (DAT), significant differences ($p>0.05$) were detected across different treatments employed for management techniques (Table 2). At 15 DAT, the un-treated control plot had the highest leaf infestation (14.33 leaves/5 plants), which was different from all other treatments, followed by T_3 (11.33 leaves/5 plants) and T_5 (10.33 leaves/5 plants), but they were statistically different. T_4 (6.33 leaves/5 plants) had the lowest leaf infestation, which was significantly different from all other treatments, followed by T_1 (7.67 leaves/5 plants), T_6 (8.33 leaves/5 plants), and T_2 (9.33 leaves/5 plants), all of which were statistically distinct. More or less similar results of leaf infestation by number were also recorded at 25 DAT, 35 DAT, 45 DAT, and 55 DAT (Table 1).

In terms of mean infestation, the control plot (T_7) had the largest number of leaf infestation (15.80 leaves/5 plants), which was substantially different from all other treatments, followed by T_3 (10.33 leaves/5 plants) and T_5 (10.20 leaves/5 plants), which were statistically identical. T_4 (6.00 leaves/5 plants) had the lowest infestation, which was significantly different from all other treatments, and was followed by T_1 (7.07 leaves/5 plants), T_6 (8.07 leaves/5 plants), and T_2 (9.07 leaves/5 plants), all of which were statistically not similar (Table 1).
T_4 had the highest percent reduction of leaf infestation over control (62.02%), followed by T_1 (55.27%), T6 (48.94%), and T_2 (42.61%). T_3 (30.99%) had the smallest reduction in leaf infestation compared to control, which was quite close to T_5 (35.44%). (Table 1).

More or less similar result was found by [13] by using Spinosad, mycojaal (*Beauveria bassiana*), malathion, lipel (*Bacillus thuringiensis var. kurstaki*), and Azadirachtin. Spinosad was found most effective to control tobacco caterpillar registering lower extent of mean leaf damage by 24.30 percent.

Table 1. Effect of biopesticides on leaf Infestation of cabbage caused by cabbage caterpillar at different days after transplanting (DAT)

Treatments	Number of infested leaves per five plants					Mean	% reduction over control
	15 DAT	25 DAT	35 DAT	45 DAT	55 DAT		
T_1	7.67 f	7.67 e	7.33 de	6.67 ef	6.33 ef	7.07 e	55.27
T_2	9.33 d	9.67 c	9.33 bc	8.67 cd	8.33 cd	9.07 c	42.61
T_3	11.33 b	11.00 b	10.33 b	9.67 bc	9.33 bc	10.33 b	34.60
T_4	6.33 g	6.33 f	6.33 e	5.67 f	5.33 f	6.00 f	62.02
T_5	10.33 c	10.67 b	10.33 b	10.00 b	9.67 b	10.20 b	35.44
T_6	8.33 e	8.67 d	8.33 cd	7.67 de	7.33 de	8.07 d	48.94
T_7	14.33 a	15.67 a	16.00 a	16.33 a	16.67 a	15.80 a	
LSD (0.05)	0.67	0.90	1.16	1.25	1.00	0.62	
CV%	3.93	5.06	6.74	7.59	6.26	3.64	

[In a column, the numeric value reflects the mean of three replications; each replication is generated from five plants per treatment; in a column, means with similar letter(s) are statistically identical at the 0.05 level of probability, T_1: Abamectin 1.2 EC; T_2: Azadirachtin 1 EC; T_3: Potassium salt of fatty acid; T_4: Spinosad 45 SC; T_5: Bacillus thuringiensis; T_6: Abamectin 1.2 EC + Bacillus thuringiensis; T_7: Untreated control]

Table 2. Effect of biopesticides on leaf Infestation caused by diamondback moth larvae at different days after transplanting (DAT) of cabbage

Treatments	Number of infested leaves per five plants					Mean	% reduction over control
	15 DAT	25 DAT	35 DAT	45 DAT	55 DAT		
T_1	5.00 de	5.00 f	4.90 f	4.83 d	4.73 de	4.89 e	45.23
T_2	5.60 cd	5.73 d	5.63 d	5.53 c	5.43 c	5.59 c	37.46
T_3	6.33 b	6.63 b	6.53 b	6.43 b	6.67 b	6.52 b	27.01
T_4	4.60 e	4.70 g	4.60 g	4.37 e	4.13 e	4.48 f	49.85
T_5	5.90 bc	6.03 c	5.93 c	5.63 c	4.13 e	5.81 c	35.01
T_6	5.90 bc	5.43 e	5.33 e	5.30 c	5.13 cd	5.31 d	40.52
T_7	8.33 a	8.67 a	8.67 a	9.33 a	9.67 a	8.93 a	
LSD (0.05)	0.67	0.23	0.23	0.38	0.66	0.23	
CV%	6.41	2.14	2.17	3.64	6.34	2.19	

[In a column, the numeric value reflects the mean of three replications; each replication is generated from five plants per treatment; in a column, means with similar letter(s) are statistically identical at the 0.05 level of probability, T_1: Abamectin 1.2 EC; T_2: Azadirachtin 1 EC; T_3: Potassium salt of fatty acid; T_4: Spinosad 45 SC; T_5: Bacillus thuringiensis; T_6: Abamectin 1.2 EC + Bacillus thuringiensis; T_7: Untreated control]

3.2 Leaf Infestation by Diamondback Moth Larvae

In terms of leaf infestation by Diamondback moth larvae at different days after transplanting, significant differences ($p>0.05$) were identified among different treatments (Table 2) for different management approaches (DAT). At 15 days after transplantation, the control plot (T_7) had the highest leaf infestation (8.33 leaves/5 plants), which was substantially different from all other treatments, followed by T_3 (6.33 leaves/5 plants) and T_6 (5.90 leaves/5 plants). T_4 (4.60 leaves/5 plants) had the lowest leaf infestation, which was significantly different from all other treatments, followed by T_1 (5.00 leaves/5 plants) and T_2 (5.60 leaves/5 plants), all of which were statistically distinct (Table 2).

In terms of mean infestation, T_7 (8.93 leaves/5 plants) had the highest number of leaves, which was statistically substantially different from all other treatments, followed by T_3 (6.52 leaves/5 plants), T_2 (5.59 leaves/5 plants), and T_5 (5.8 leaves/plants). T_2 and T_5 are statistically similar in this case. T_4 (4.48 leaves/5 plants) had the lowest infestation, followed by T_1 (4.89 leaves/5 plants) and T_6 (5.31 leaves/5 plants), which were statistically unrelated.

Considering the percent decrease of leaf invasion over control, the most noteworthy decrease over control was accomplished in T_4 (49.85%) trailed by T_1 (45.23%) and T6 (40.52%). Then again, the base decrease of leaf pervasion over control was found in T_3 (27.01%) trailed by T_2 (37.46%) and T_5 (35.01%) (Table 2) [13]. Discovered a similar outcome using Spinosad, mycojaal (*Beauveria bassiana*), malathion, lipel (*Bacillus thuringiensis* var. *kurstaki*), and Azadirachtin. Spinosad was shown to be the most effective at controlling diamondback moth larvae, with a 14.22 percent reduction in mean leaf damage [14]. Discovered similar results in his study. Spinosad was found to be the most effective at reducing diamondback moth population by up to 94.33 percent, followed by indoxacarb (91.00 %) and Flubendiamide (78.66 %).

3.3 Effect of Biopesticides on Yield and Yield Contributing Characteristics of Cabbage

In case of diameter of cabbage head, T_4 had the largest head diameter (23.50 cm), which was statistically different from all other treatments, followed by T_1 (22.17 cm) and T6 (22.17 cm) (21.43cm). T_7, on the other hand, had the smallest head diameter (14.83), which was substantially different from all other treatments. T_2 (20.47 cm) and T_5 (20.87 cm) were statistically identical. In terms of percent increase in diameter above control, T_4 treatment resulted in the largest increase (58.43%), while T_3 treatment resulted in the smallest increase (22.24%) (Fig. 1).

In terms of cabbage height, T_4 had the highest head height (10.70 cm), which was statistically equivalent to T_1 (10.34 cm). T_7, on the other hand, had the shortest head height (7.33 cm), which was significantly lower than all other treatments (Fig. 1). However, among the treated plots, T_3 had the lowest head height (8.93cm), which was statistically equivalent to T_2 (9.33), followed by T_5 (9.97cm), and T_6 (9.97cm) (10.10 cm). T_4 (45.91%) had the highest percent increase over control on head height, followed by T_1 (40.91%), and T_3 (21.8%) had the lowest percent increase over control on head height, which was close to T_2 (27.27%).

3.4 Single head Weight (kg) and Total Yield (t ha^{-1}) during Harvesting

In case of single head weight (kg) of cabbage, T_4 had the highest single head weight (1.50kg), which was substantially higher than all other treatments, followed by T_1 (1.39kg) and T_6 (1.34kg). T_7, on the other hand, had the smallest single head weight (0.92 kg), which was much lower than the other treatments. However, in the treated plots, T_3 had the smallest single head weight (1.12 kg), which was statistically equivalent to T_2 (1.17 kg) and T_5 (1.23 kg) (Fig. 2).

In terms of total yield (t ha^{-1}), T_4 produced the highest yield (36.40 t ha^{-1}), which was significantly higher than all other treatments. T_1 (34.07 t ha^{-1}) and T_6 (32.37 t ha^{-1}) followed. T_7 had the lowest yield (22.97 t ha^{-1}), which was significantly lower than the other treatments. However, in the treated plots, T_3 had the lowest yield (26.63 t ha^{-1}), followed by T_2 (29.57 t ha^{-1}), and T_5 (30.37 t ha^{-1}) (Fig. 2).

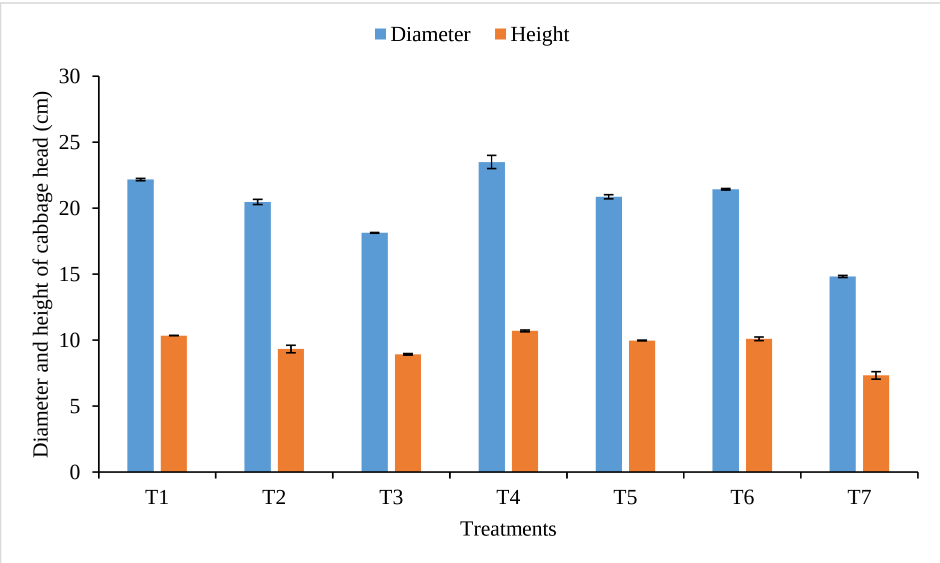

Fig. 1. Effect of different treatments on diameter and height of cabbage head
[Means ±SD are calculated from three replications where each replication is derived from 5 plants per treatment; T_1: Abamectin 1.2 EC; T_2: Azadirachtin 1 EC; T_3: Potassium salt of fatty acid; T_4: Spinosad 45 SC; T_5: Bacillus thuringiensis; T_6: Abamectin 1.2 EC + Bacillus thuringiensis; T_7: Untreated control]

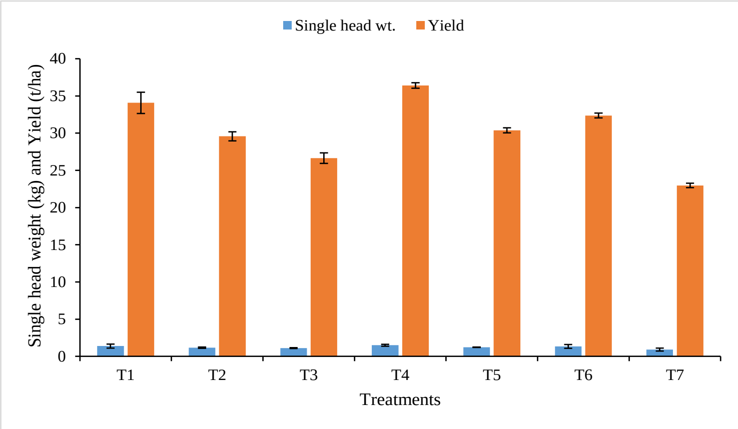

Fig. 2. Individual head weight (kg) and total yield (t ha^{-1}) of cabbage in different treatments during harvesting

[Means ±SD are calculated from three replications where each replication is derived from 5 plants per treatment; T_1: Abamectin 1.2 EC; T_2: Azadirachtin 1 EC; T_3: Potassium salt of fatty acid; T_4: Spinosad 45 SC; T_5: Bacillus thuringiensis; T_6: Abamectin 1.2 EC + Bacillus thuringiensis; T_7: Untreated control]

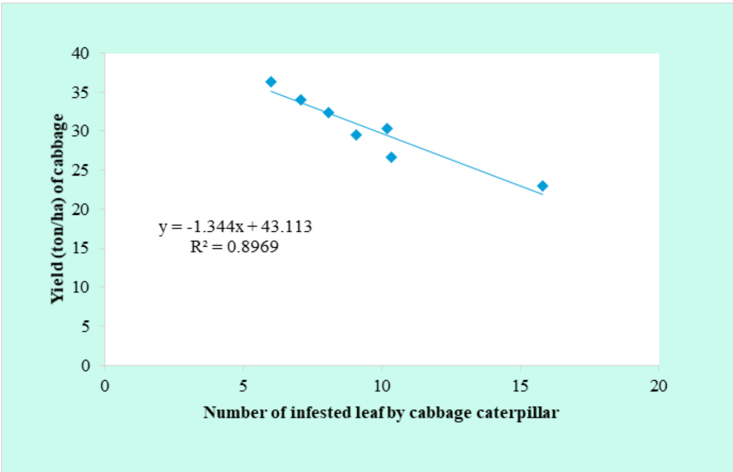

Fig. 3. Relationship between leaf infestation by cabbage caterpillar and yield of cabbage

3.5 Relationship between leaf Infestation by Cabbage Caterpillar and Yield of Cabbage

When a connection was fitted between these two parameters, a significant link between caterpillar leaf infestation and cabbage yield was discovered (Fig. 3). There was a substantial (R^2=0.896) and negative (slope =-1.344) association between caterpillar leaf infestation and cabbage production, indicating that cabbage yield declined as caterpillar leaf infestation increased. Infestation of cabbage caterpillars on leaves hampered plants' ability to produce and supply nutrients and water. With a lower output, the plant's growth and development were inhibited.

3.6 Relationship between leaf Infestation by Diamondback moth Larvae and Yield of Cabbage

When the production of cabbage was compared to the leaf infestation by diamondback moth larvae, a significant association was noticed. These two factors had a highly significant (p0.05), very strong (R^2=0.8945), and negative (slope =-2.907) association (Fig. 4), indicating that cabbage output declined as leaf infestation by diamondback moth larvae increased. According to the findings of this study, diamondback moth larvae infested leaves hindered plants from producing and supplying nutrients and water. With a lower output, the plant's growth and development were inhibited.

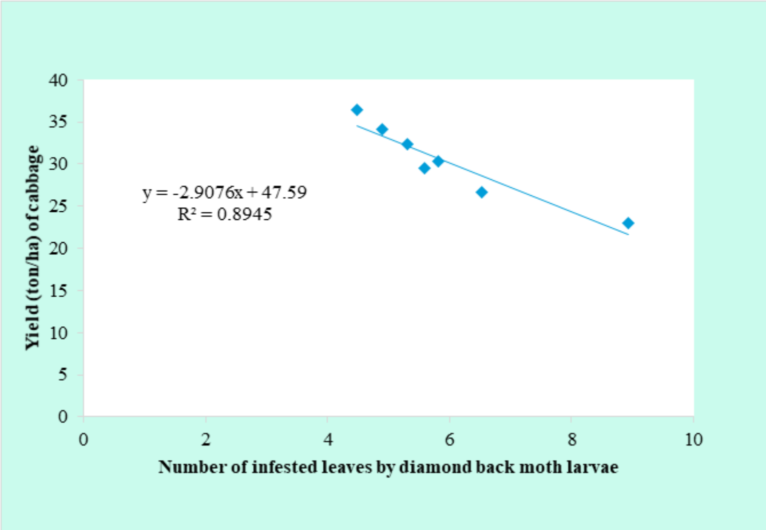

Fig. 4. Relationship between leaf infestation by diamondback moth larvae and yield of cabbage

4. CONCLUSION

From the above discussion, it may be concluded that, the treatment Spinosad 45SC @ 1 ml/L of water at 10 days interval gave the highest performance such as the lowest mean infestation of cabbage leaf by cabbage caterpillar (6.00 leaves/5 plants) and diamondback moth larvae (4.48 leaves/5 plants), the lowest cabbage head infestation (21.37%) and the highest yield of cabbage (36.40 t/ha) compared to all other treatments used under the present study where the lowest performance was achieved Potassium salt of fatty acid @ 1 ml/L of water at 10 days interval.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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