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# ECO-FRIENDLY MANAGEMENT APPROACHES OF MAJOR INSECT PESTS IN CAULIFLOWER

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## ABSTRACT

In Bangladesh, the cultivation of cauliflower (*Brassica oleracea* L. *var. botrytis*) faces critical challenges from insect pest infestations, which lead to substantial reductions in both marketable yield and curd quality. This study aimed to evaluate the efficacy of five eco-friendly management approaches against major cauliflower pests and their impact on natural enemies and economic returns. The field experiment was conducted at Gazipur Agricultural University during the *Rabi season* (November 2023 to January 2024) using a Randomized Complete Block Design (RCBD) with three replications. Treatments included Vermitec 1.8 EC (Abamectin) @ 1.2 mL $L^{-1}$ of water, Tracer 45 SC (Spinosad) @ 0.4 ml $L^{-1}$ of water, Bio-Action 1.5 SL (Matrine) @ 1.5 mL $L^{-1}$ of water, Phytoclean (Potassium salt of fatty acid 40%) @1.5 mL $L^{-1}$ of water, Proclaim 5 SG (Emamectin Benzoate) @ 1 mL $L^{-1}$ of water as an untreated control. Among the treatments, Tracer 45 SC (Spinosad) @ 0.4 ml $L^{-1}$ was the most effective, resulting in the lowest number of diamondback moth ($1.7 \pm 0.0$/head) and prodania caterpillar ($1.5 \pm 0.0$ head$^{-1}$), lowest head infestation rates (3.9% by number and 3.5% by weight), highest yield ($29.9 \pm 0.4$ t ha$^{-1}$), and maximum MBCR (8.3). Three applications of Tracer 45 SC (Spinosad) @ 0.4 ml $L^{-1}$ was found as an effective, economically viable, and environmentally sustainable strategy for managing major cauliflower pests in Bangladesh, ensuring high productivity and conserving beneficial arthropods.

***Keywords:*** Biopesticides, Diamondback moth, Prodania caterpillar, Eco-friendly management, Spinosad, BARI Fulkopi-1

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## INTRODUCTION

Cauliflower (*Brassica oleracea* L. *var. botrytis*) is a globally significant cruciferous vegetable, prized for its high nutrient density, including dietary fiber, folate, and essential vitamins (A, C, and K). In Bangladesh, it is a cornerstone of winter vegetable production, ranking ninth globally and contributing significantly to the rural economy (FAOSTAT 2021, BBS 2023). Beyond its nutritional value, cauliflower contains bioactive compounds like Indole-3-carbinol, which offer protective benefits against chronic diseases and certain cancers (Fageria *et al*. 2010).

Despite its economic and nutritional importance, cauliflower yields in Bangladesh remain below potential. The primary constraint is a complex of approximately 24 insect pest species that can cause marketable yield losses ranging from 50% to 80% (Shankar *et al*. 2016). Among these, the tobacco caterpillar (*Spodoptera litura* Fab.) and the diamondback moth (DBM) (*Plutella xylostella* L.) are the most devastating. *S. litura* is a highly polyphagous pest capable of complete defoliation, resulting in yield losses of up to 100% under severe outbreaks (Tuan *et al*. 2014). Similarly, *P. xylostella* larvae cause characteristic "windowing" damage, which can compromise up to 90% of global brassica production (Verkerk and Wright 1996). Additionally, sap-sucking pests like aphids act as vectors for viral diseases, further reducing crop vigor and quality.

Historically, farmers have relied almost exclusively on synthetic chemical insecticides to manage these pests. However, indiscriminate application has led to the development of insecticide resistance, environmental degradation, and significant health risks due to chemical residues (Abbas *et al*. 2014). The disruption of natural enemy populations and pollinators further highlights the unsustainability of current chemical-intensive practices.

Consequently, there is an urgent need for bio-rational or eco-friendly management strategies that prioritize environmental safety and consumer health without sacrificing efficacy. Integrated management packages using bio-control agents and bio-pesticides offer a sustainable alternative. The present study was therefore conducted to evaluate the effectiveness of selected bio-rational approaches against major cauliflower pests and to determine their economic viability through benefit-cost ratio analysis.

## MATERIALS AND METHODS

**Experimental design and cultivation of crop:** The study was set in the field under the Department of Entomology, Gazipur Agricultural University (GAU), Gazipur during the month of November 2023 to January 2024. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications of equal size. The Seed of BARI Fulkopi-1(Rupa) was collected from Bangladesh Agricultural Research Institute (BARI), Gazipur for this experiment. Seeds were sown in the seed bed measuring 3m x1m was at the nursery bed. Around thirty to forty days old seedlings were transplanted. The unit plot size was 3m×2m and plant to plant distance was 60 cm and row to row distance was 45 cm.

**Treatments and methods of application:** Five treatments viz., Vermitec 1.8 EC (Abamectin) @ 1.2 mL $L^{-1}$ of water, Tracer 45 SC (Spinosad) @ 0.4 ml $L^{-1}$ of water, Bio-Action 1.5 SL (Matrine) @ 1.5 mL $L^{-1}$ of water, Phytoclean (Potassium salt of fatty acid 40%) @1.5 ml $L^{-1}$ of water, Proclaim 5 SG (Emamectin Benzoate) @ 1 mL $L^{-1}$ of water was an untreated control (application of tap water only) were evaluated on the basis of pest infestation and reduction of cauliflower production.

All the insecticides were collected from local market of Gazipur district. The insecticide mixture in the spray machine was shaken well and covered spray by a knapsack sprayer. Before spraying, the spray machine was calibrated to find out the required quantity of spray material for 3 plots. During the entire cropping season, a total of 3 sprays of insecticides was done, among them 2 were applied at vegetative stages and another 1 was applied after head formation. The spraying was done early in afternoon to avoid bright sunlight and drift caused by strong wind and adverse effect on pollinating bees.

**Data collection and analysis:** Data were collected some pre-selected parameters, such as insect pests and natural enemies with seasonal fluctuation, rate of leaf infestation by insect pests, number of infested, healthy and total heads, Yield (t $ha^{-1}$) and marginal benefit cost ratio analysis for different treatments. The observations on the incidence of insect pests and their natural enemies were counted visually with the help of magnifying lens at 10 days interval recorded from their appearance on plants till harvest. Sample was taken from 5 plants randomly and then converted to 18 plants (3×2 $m^2$) for expressing rate of plant infestation and number of arthropods pests per plot. For obtaining head yield (t $ha^{-1}$), the weights of healthy, infested, and total curd of all harvests were taken plot-wise. The yield of healthy, infested, and total curds obtained were transformed into curds yield in ton per hectare. The weight of infested pods was recorded from the total weight of the harvested curd for each plot and the percent yield loss was calculated.

The economic analysis or Marginal Benefit Cost Ratio (MBCR) was calculated on the basis of total expenditure of the respective treatment along with the total return from that particular treatment (Ali *et al*. 1996). Data were analyzed by using SPSS software for analysis of variance. ANOVA was done by F variance test (Gomez and Gomez 1984) and the mean comparisons were performed by Tukey HSD posthoc statistics.

## RESULTS AND DISCUSSION

**The infestation rates of sucking pests as affected by eco-friendly management approach:** From Table 1, the highest rate of leaf infestation by jassid was recorded in the untreated control plot (71.7±3.4%) at both 3 and 7 days after treatment (DAT), indicating a severe infestation in the absence of any pest control. Among the treated plots, Bio-Action 1.5 SL showed a comparatively high jassid infestation (38.7±0.3%) and was significantly lower than the untreated control. In contrast, the lowest and statistically similar jassid infestations were recorded in Phytoclean (9.6±0.1%), Vermitec 1.8 EC (9.7±0.1%), Tracer 45 SC (11.3±0.1%), and Proclaim 5 SG (17.0±0.2%) at treated plot both 3 and 7 DAT and all showing effective suppression of jassid infestation. In case of aphid infestation, the untreated control again exhibited the highest rate of plant infestation, with 26.6±1.2% at 3 DAT and 29.2±1.2% at 7 DAT. The lowest and statistically similar infestations were observed in Phytoclean (1.0±0.0% at 3 DAT and 0.7±0.0% at 7 DAT), Bio-Action 1.5 SL (4.3±0.1% at 3 DAT and 3.0±0.1% at 7 DAT), Tracer 45 SC (5.3±0.1% at 3 DAT and 4.0±0.1% at 7 DAT), and Proclaim 5 SG (7.0±0.1% at 3 DAT and 5.6±0.1% at 7 DAT) treated plots. Vermitec 1.8 EC showed moderate control of aphids, with 11.3±0.2% and 9.9±0.2% infestation at 3 and 7 DAT, respectively, which was significantly lower than the untreated control.

In terms of overall effectiveness against both jassid and aphid infestations, Phytoclean and Tracer 45 SC demonstrated consistently superior performance across both observation periods. Partially similar findings were reported by Ghosh & Chakraborty (2015), who found that Spinosad 45 SC achieved 79.77% suppression of jassid, with efficacy comparable to Imidacloprid. Likewise, Ghosh *et al*. (2009) observed 71.76% suppression of aphid on lady's finger by Spinosad 45 SC at 1.0 ml per 3 L, followed by Polygonum extract (7.0%) with 59.00% suppression.

**Table 1.** Effect of different eco-friendly management approaches against aphid and jassid of cauliflower grown during *Rabi season* 2023-24

| Treatment | Rate of leaf infestation (%) by jassid | | Rate of plant infestation (%) by aphid | |
|---|---|---|---|---|
| | 3 DAT | 7 DAT | 3 DAT | 7 DAT |
| Vermitec 1.8 EC | 9.7±0.1c | 9.7±0.1c | 11.3±0.2b | 9.9±0.2b |
| Tracer 45 SC | 11.3±0.1c | 11.3±0.1c | 5.3±0.1c | 4.0±0.1c |
| Bio-Action 1.5 SL | 38.7±0.3b | 38.7±0.3b | 4.3±0.1c | 3.0±0.1c |
| Phytoclean | 9.6±0.1c | 9.6±0.1c | 1.0±0.0c | 0.7±0.0c |
| Proclaim 5 SG | 17.0±0.2c | 17.0±0.2c | 7.0±0.1c | 5.6±0.1c |
| Untreated control | 71.7±3.4a | 71.7±3.4a | 26.6±1.2a | 29.2±1.2a |

Means within a column followed by same letter(s) are not significantly different (P=0.05) according to Tukey HSD posthoc statistic at < 0.05.

**The infestation rates of chewing pests as affected by eco-friendly management approach:** Table 2 showed the highest number of DBM (5.8±0.0 larvae head$^{-1}$) and was recorded in untreated control plot, followed by Vermitec 1.8 EC (4.0±0.0 larvae head$^{-1}$), Bio-Action 1.5 SL (3.9±0.0 larvae head$^{-1}$) and Phytoclean (3.5±0.0 larvae head$^{-1}$) treated plots. Proclaim 5 SG and Tracer 45 SC treated plots showed the lowest and statistically similar larval abundance per head of cauliflower (1.5±0.0 and 1.7±0.0 larva head$^{-1}$, respectively). The highest number of *Spodoptera litura* (Prodania caterpillar) larvae (3.6±0.0 head$^{-1}$) was also recorded in the untreated control plot. In contrast, the lowest and statistically similar numbers of caterpillars were observed in Tracer 45 SC (1.5±0.0) and Proclaim 5 SG (1.8±0.0) treated plots. The plots treated with Vermitec 1.8 EC (2.7±0.0), Phytoclean (2.5±0.0), and Bio-Action 1.5 SL (2.4±0.0) showed statistically similar but significantly lower caterpillar abundance compared to the untreated control (Table 2).

The highest rate of head infestation (33.3±0.4%) was recorded in the untreated control plot, while the lowest infestation rate was observed in the Tracer 45 SC treated plot (6.1±0.0%). The treatments with Bio-Action 1.5 SL (23.7±0.2%), Phytoclean (21.2±0.2%), and Vermitec 1.8 EC (19.4±0.2%) resulted in statistically similar head infestation rates, which were significantly higher than that of Proclaim 5 SG (16.3±0.2%) but considerably lower than the untreated control.

The present findings are supported by Hasan *et al.* (2023), who also obtained that the treatment using Tracer 45 SC (Spinosad) @ 0.4 g $L^{-1}$ of water showed the best results, resulting in the lowest number of diamondback moths (0.4 per head) and tobacco caterpillars (0.2 $head^{-1}$) as well as the lowest rate of head infestation in cabbage.

**Table 2.** Effect of different eco-friendly management approaches on percent head infestation and number of diamondback moth (DBM) and Prodania caterpillar on cauliflower grown during *Rabi season* 2023-24

| Treatment | No. of DBM larvae/head | No. of Prodania caterpillar $head^{-1}$ or $plant^{-1}$ | Rate (%) of head infestation (n/n) |
|---|---|---|---|
| Vermitec 1.8 EC | 4.0±0.0b | 2.7±0.0b | 19.4±0.2b |
| Tracer 45 SC | 1.7±0.0c | 1.5±0.0c | 6.1±0.0d |
| Bio-Action 1.5 SL | 3.9±0.0b | 2.4±0.0b | 23.7±0.2b |
| Phytoclean | 3.5±0.0b | 2.5±0.0b | 21.2±0.2b |
| Proclaim 5 SG | 1.5±0.0c | 1.8±0.0c | 16.3±0.2c |
| Untreated control | 5.8±0.0a | 3.6±0.0a | 33.3±0.4a |

Means within a column followed by same letter(s) are not significantly different (P=0.05) according to Tukey HSD posthoc statistic at < 0.05.

**Effect of eco-friendly management approach on natural enemies:** The highest and statistically similar abundance of lady bird beetle was recorded in the untreated control plot (33.8±1.4), followed by Vermitec 1.8 EC (32.7±1.3), Proclaim 5 SG (31.2±1.1) and Tracer 45 SC (25.0±1.4%) treated plots (Table 3). The lowest and statistically similar numbers were observed in Bio-Action 1.5 SL (22.9±0.9) and Phytoclean (20.6±0.9) treated plots.

In case of syrphid fly, there was no significant variation among the treatments, including the untreated control. The abundance ranged from 1.7±0.0 to 3.0±0.0 per plot, indicating a uniform distribution across all plots. The highest and statistically similar abundance of black ant was found in the untreated control (107.9±5.6), Vermitec 1.8 EC (101.7±4.2), and were statistically similar to Tracer 45 SC (96.7±3.4) and Proclaim 5 SG (96.2±3.7) treated plots. The lowest abundance was recorded in Bio-Action 1.5 SL (88.6±3.1) and Phytoclean (87.4±2.9) treated plots, which were statistically similar and significantly lower than the untreated control. For spiders, no significant variation was observed among the treatments, with population ranging from 5.3±0.0 to 8.6±0.0 per plot across all treated and untreated plots. In the case of mirid bug, although the highest abundance was found in Proclaim 5 SG and the untreated control (both 2.3±0.0) and all treatments showed statistically similar populations, ranging from 1.0±0.0 to 2.3±0.0 per plot. These results suggest that eco-friendly treatments, especially Vermitec 1.8 EC, proclaim 5 SG, and Tracer 45 SC, were able to suppress pests while conserving beneficial arthropod populations like lady bird beetles, black ants, and mirid bugs during the *Rabi season*.

The present findings were in agreement with Efad *et al*. (2021) who found that Azadirachtin, Spinosad and Abamectin were bio-rational with the beneficial arthropods like lady bird beetle, syrphid fly, black ant and spider's presence on field during entire season in brinjal. In their study, the abundance of lady bird beetles and black ants showed no significant statistical difference between Spinosad- and Abamectin-treated plots and the untreated control, while no statistical variation was found in syrphid fly and spider populations across all treatments.

**Table 3.** Effect of different eco-friendly management approaches on abundance of beneficial arthropods per plot ($3 \times 2m^2$) during entire cropping season (Mean of 12 observations)

| Treatments | No. of lady bird beetle $plot^{-1}$ | No. of syrphid fly $plot^{-1}$ | No. of black ant $plot^{-1}$ | No. of spider's $plot^{-1}$ | No. of mirid bug $plot^{-1}$ |
|---|---|---|---|---|---|
| Vermitec 1.8 EC | 32.7±1.3a | 2.3±0.0a | 101.7±4.2a | 8.6±0.0a | 1.7±0.0a |
| Tracer 45 SC | 25.0±1.4a | 2.3±0.0a | 96.7±3.4ab | 7.6±0.0a | 1.7±0.0a |
| Bio-Action 1.5 SL | 22.9±0.9b | 1.7±0.0a | 88.6±3.1b | 6.0±0.0a | 1.0±0.0a |
| Phytoclean | 20.6±0.9b | 1.7±0.0a | 87.4±2.9b | 5.3±0.0a | 1.0±0.0a |
| Proclaim 5 SG | 31.2±1.1a | 3.0±0.0a | 96.2±3.7ab | 6.6±0.0a | 2.3±0.0a |
| Untreated control | 33.8±1.4a | 2.3±0.0a | 107.9±5.6a | 8.0±0.0a | 2.3±0.0a |

Means within a column followed by same letter(s) are not significantly different (P=0.05) according to Tukey HSD posthoc statistic at < 0.05

**Effect of eco-friendly management approach on cauliflower head quality:** The lowest number of healthy heads per plot (12.0±0.2) was recorded from the untreated control plot. On the other hand, the highest number of healthy heads per plot (17.3±0.3) was obtained from the Tracer 45 SC treated plot. The plots treated with Proclaim 5 SG (15.7±0.3), Vermitec 1.8 EC (15.0±0.3), Phytoclean (14.7±0.3), and Bio-Action 1.5 SL (14.3±0.3) showed statistically similar results and had a higher number of healthy heads per plot than the untreated control (Table 4). In terms of the number of infested heads per plot, the highest number (6.0±0.0) was found in the untreated control plot, whereas the lowest (0.7±0.0) was observed in the Tracer 45 SC treated plot. The plots treated with Proclaim 5 SG (2.3±0.0), Vermitec 1.8 EC (3.0±0.0), Phytoclean (3.3±0.0), and Bio-Action 1.5 SL (3.7±0.0) showed statistically similar results and were significantly lower than the untreated control.

The lowest weight of healthy heads per plot (18.5±0.3 kg) was recorded in the untreated control plot, while the highest weight (29.9±0.4 kg) was obtained from the Tracer 45 SC treated plot. This was followed by Proclaim 5 SG (26.1±0.4 kg), Vermitec 1.8 EC (23.8±0.3 kg), Phytoclean (23.2±0.4 kg), and Bio-Action 1.5 SL (22.4±0.4 kg) and all were statistically similar but significantly the higher weights of healthy heads compared to the untreated control plot.

For the weight of infested heads per plot, the lowest (1.1±0.0 kg) was recorded in the Tracer 45 SC treated plot. The treatments Proclaim 5 SG (3.9±0.1 kg), Vermitec 1.8 EC (4.7±0.1 kg), Phytoclean (5.2±0.1 kg), and Bio-Action 1.5 SL (5.7±0.1 kg) resulted in statistically similar weights of infested heads, all of which were lower than the untreated control plot. The highest weight of infested heads (9.2±0.3 kg) was observed in the untreated control (Table 4).

**Effect of eco-friendly management approach on yield and yield contributing traits:** The effect of different eco-friendly management approaches on yield and yield contributing characters of cauliflower was presented in Table 5. The highest yield (29.9±0.4 t $ha^{-1}$) was recorded from the Tracer 45 SC treated plot, followed by Proclaim 5 SG (26.1±0.4 t $ha^{-1}$) and Vermitec 1.8 EC (23.8±0.3 t $ha^{-1}$) treated plots. The lowest yield (18.5±0.5 t $ha^{-1}$) was observed in the untreated control plot.

**Table 4.** Effect of different eco-friendly management approaches on number and weight of cauliflower head per plot ($3 \times 2\ m^2$) grown during *Rabi season* 2023-24

| Treatment | Number of healthy head plot$^{-1}$ | Number of infested head plot$^{-1}$ | Weight of healthy head plot$^{-1}$ (kg) | Weight of infested head plot$^{-1}$ (kg) |
|---|---|---|---|---|
| Vermitec 1.8 EC | 15.0±0.3ab | 3.0±0.0b | 23.8±0.3b | 4.7±0.1b |
| Tracer 45 SC | 17.3±0.3a | 0.7±0.0c | 29.9±0.4a | 1.1±0.0c |
| Bio-Action 1.5 SL | 14.3±0.3ab | 3.7±0.0b | 22.4±0.4b | 5.7±0.1b |
| Phytoclean | 14.7±0.3ab | 3.3±0.0b | 23.2±0.4b | 5.2±0.1b |
| Proclaim 5 SG | 15.7±0.3ab | 2.3±0.0b | 26.1±0.4b | 3.9±0.1b |
| Untreated control | 12.0±0.2b | 6.0±0.0a | 18.5±0.3c | 9.2±0.3a |

Means within a column followed by same letter(s) are not significantly different (P=0.05) according to Tukey HSD posthoc statistic at < 0.05

The weight of single head was not statistically different in the plots treated with different insecticides including untreated control plot which ranged from 1.5±0.0 kg to 1.7±0.0 kg (Table 5). Regarding head diameter, the lowest diameter of cabbage head was recorded in untreated control plot (15.1±0.0cm) which was not statistically different from the diameter of cauliflower head obtained from plots treated with Tracer 45 SC (19.9±0.0cm), Proclaim 5 SG (18.8±0.0cm), Phytoclean (17.0±0.0cm) and Bio-Action 1.5 SL (18.6±0.0cm).

A similar finding was reported by Shapla (2021) and found that the statistically significant highest yield of cauliflower (51.48 t ha$^{-1}$) was recorded from Spinosad 45SC treatment followed by Abamectin 1.8EC (47.26 t ha$^{-1}$), Cypermethrin 10EC (43.58 t ha$^{-1}$) and Sevin 85SP (41.41 t ha$^{-1}$) respectively and the lowest yield of cauliflower was obtained from untreated control plot (38.5 t ha$^{-1}$). The yield of cauliflower per hectare reported by Shapla (2021) was comparably higher than in this present study which could be attributed to differences in environmental conditions, variety, or agronomic practices.

The higher yields in case of Spinosad have also been showed by Gautam (2022). Similarly, Sapkota *et al*. (2020) reported that Spinosad @ 0.5 mL/L resulted in the largest curd diameter (16.10 cm) and the highest yield (22.02 t ha$^{-1}$) among all treatments. This was followed by Emamectin benzoate @ 0.6 g/L, which recorded a curd diameter of 14.77 cm and a yield of 19.29 t $ha^{-1}$. Treatments with BEFCU @ 1:5 and Neemix @ 3 mL/L produced moderate curd sizes of approximately 14.49 cm and 14.17 cm, with corresponding yields of 16.04 t $ha^{-1}$ and 16.19 t $ha^{-1}$, respectively. The control treatment had the smallest curd diameter (13.37 cm) and the lowest yield (13.76 t $ha^{-1}$). These findings further reinforce the efficacy of Spinosad in improving both curd quality and yield of cauliflower.

**Table 5.** Effect of different eco-friendly management approaches on yield and yield contributing character of cauliflower grown during *Rabi season* 2023-24

| Treatments | Single head weight (kg) | Diameter of head (cm) | Yield (t $ha^{-1}$) |
|---|---|---|---|
| Vermitec 1.8 EC | 1.6±0.0a | 18.4±0.0a | 23.8±0.3bc |
| Tracer 45 SC | 1.7±0.0a | 19.9±0.0a | 29.9±0.4a |
| Bio-Action 1.5 SL | 1.5±0.0a | 18.6±0.0a | 22.4±0.3c |
| Phytoclean | 1.6±0.0a | 17.0±0.0a | 23.2±0.3c |
| Proclaim 5 SG | 1.7±0.0a | 18.8±0.0a | 26.1±0.4b |
| Untreated control | 1.5±0.0a | 15.1±0.0a | 18.5±0.5d |

Means within a column followed by same letter(s) are not significantly different (P=0.05) according to Tukey HSD posthoc statistic at < 0.05

The percent increase in cauliflower yield over the untreated control under different eco-friendly management approaches were presented in Fig. 1. Among the treatments, the highest yield increase (61.6%) was observed in plots treated with Tracer 45 SC, followed by Proclaim 5 SG (41.1%) and Vermitec 1.8 EC (28.6%). Phytoclean and Bio-Action 1.5 SL also showed positive effects with 25.4% and 21.1% yield increases, respectively. The untreated control had no increase in yield (0.0%). These results indicate that all eco-friendly treatments improved yield over the untreated control, with Tracer 45 SC showing the most effective performance.

A similar trend was reported by Sapkota *et al*. (2020), who observed that Spinosad @ 0.5 mL/L resulted in the highest 60.03% increase over the untreated control, followed by Emamectin benzoate @ 0.6 g/L with a 40.19% increase over control. Moderate yield increases were recorded from Neemix @ 3 mL $L^{-1}$ (17.66% over the untreated control) and BEFCU @ 1:5 (16.57% increase over the untreated control). which is consistent with the findings of the present study. This agreement strengthens the reliability of the present results and highlights the efficacy of eco-friendly insecticides, particularly Spinosad (Tracer 45 SC), in enhancing cauliflower yield. Similarly, Hasan *et al.* (2023), in a study on cabbage, reported that Tracer 45 SC resulted in the highest yield increase over untreated control (61.3%), followed by Proclaim 5 SG, Abom 1.8 EC, Fytomax PM, and NSKE which further supporting the efficacy of Spinosad-based treatments across cruciferous crops.

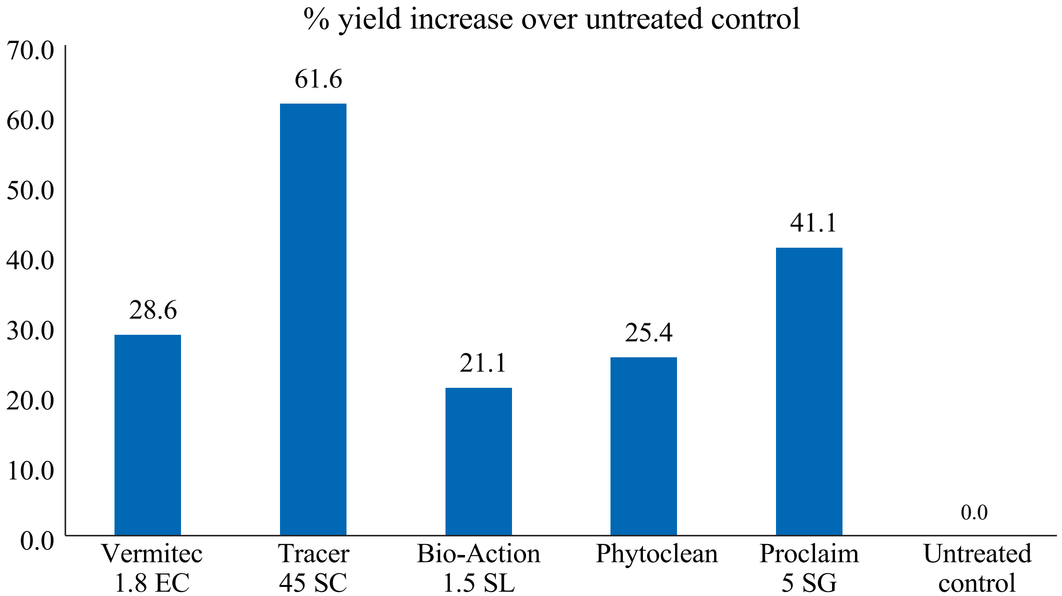


**Fig. 1.** Effect of different eco-friendly management approaches on % yield increase over untreated control of cauliflower grown during *Rabi season* 2023-24.

**Economic analysis of different environment friendly approaches against insect pests in cauliflower:** The details of the cost of pest management (Tk. $ha^{-1}$) under different eco-friendly approaches against arthropod pests in cauliflower grown during *Rabi season* 2023–24 is presented in Table 6. Management cost was the highest (Tk. 24,480.0) in Tracer 45 SC, followed by Bio-Action 1.5 SL with Tk. 19,080.0, and Vermitec 1.8 EC with Tk. 18,480.0. The lowest management cost (Tk. 17,880.0) was recorded in both Phytoclean and Proclaim 5 SG sprayed ones. As expected in Untreated control having no expenditure on pest management inputs or operations. The highest gross return was obtained from the treatment with Tracer 45 SC (Tk.

598,000.0 $ha^{-1}$), followed by Proclaim 5 SG (Tk. 522,000.0 $ha^{-1}$). In contrast, the lowest gross return was recorded in the untreated control (Tk. 370,000.0 $ha^{-1}$). Among the other treatments, Bio-Action 1.5 SL, Phytoclean, and Vermitec 1.8 EC yielded gross returns of Tk. 448,000.0 $ha^{-1}$, Tk. 464,000.0 $ha^{-1}$, and Tk. 476,000.0 $ha^{-1}$, respectively (Table 6). The highest net return (Tk. 573520.0 $ha^{-1}$) was recorded in Tracer 45 SC, followed by Tk. (504120.0 $ha^{-1}$) in Proclaim 5 SG and the lowest (Tk. 370000.0 $ha^{-1}$) in Untreated control, followed by Tk. 428920.0 $ha^{-1}$ in Bio-Action 1.5 SL, Tk. 446120.0 $ha^{-1}$ in Phytoclean and Tk. 457520.0 $ha^{-1}$ in Vermitec 1.8 EC treatments (Table 6). The highest adjusted net return (Tk. 203520.0 $ha^{-1}$) was recorded in Tracer 45 SC followed by Tk. 134120.0 $ha^{-1}$ in Proclaim 5 SG and the lowest (Tk. 58920.0 $ha^{-1}$) in Bio-Action 1.5 SL followed by Tk. 76120.0 $ha^{-1}$ in Phytoclean and Tk. 87520.0 $ha^{-1}$ in Vermitec 1.8 EC (Table 6).

The highest MBCR of 8.3 was obtained from the plots treated with Tracer 45 SC and the second highest benefit cost ratio (7.5) was recorded from the plot treated with Proclaim 5 SG, followed by Vermitec 1.8 EC sprayed plot (4.7) and Phytoclean sprayed plot (4.3). The lowest benefit cost ratio (3.1) was found with the Bio-Action 1.5 SL treated plot (Table 6).

**Table 6.** Marginal benefit cost ratio (MBCR) analysis of selected eco-friendly management approaches against arthropod pests in cauliflower grown during *Rabi season* 2023-24

| Treatments | Management cost (Tk) | Gross return (Tk) | Net return (Tk) | Adjusted net return (Tk) | MBCR |
|---|---|---|---|---|---|
| Vermitec 1.8 EC | 18480.0 | 476000.0 | 457520.0 | 87520.0 | 4.7 |
| Tracer 45 SC | 24480.0 | 598000.0 | 573520.0 | 203520.0 | 8.3 |
| Bio-Action 1.5 SL | 19080.0 | 448000.0 | 428920.0 | 58920.0 | 3.1 |
| Phytoclean | 17880.0 | 464000.0 | 446120.0 | 76120.0 | 4.3 |
| Proclaim 5 SG | 17880.0 | 522000.0 | 504120.0 | 134120.0 | 7.5 |
| Untreated control | 0.0 | 370000.0 | 370000.0 | 0.0 | - |

Market value of Cauliflower= Tk. 20.0 $Kg^{-1}$; cost of Vermitec 1.8 EC per spray= 5000.0 Tk $ha^{-1}$, Tracer 45 SC per spray = 7000.0 Tk $ha^{-1}$, Bio-Action 1.5 SL per spray = 5200.0 Tk $ha^{-1}$, Phytoclean per spray = 4800.0 Tk $ha^{-1}$, Proclaim 5 SG per spray = 4800.0 Tk $ha^{-1}$, Labor cost= 550.0 Tk $day^{-1}$, No. of spray=3, sprayer rent= 30.0 Tk $day^{-1}$.

## CONCLUSION

The comparative evaluation of five eco-friendly management approaches demonstrated that the lowest number of diamondback moth (1.7 ± 0.0 per head), tobacco caterpillar (1.5 ± 0.0 per head); and the lowest rate of head infestation by tobacco/prodania caterpillar and/or diamondback moth (3.9% by number and 3.5% by weight); as well as the highest yield (29.9±0.4 t $ha^{-1}$) and Marginal benefit cost ratio (MBCR) (8.3) was recorded with the eco-friendly management approach comprising 3 spays of Tracer 45 SC (Spinosad) @ 0.4 g $L^{-1}$ of water. Therefore, management approach comprising 3 spays of Tracer 45 SC (Spinosad) @ 0.4 g $L^{-1}$ of water can be considered an effective, economically viable, and eco-friendly tool for suppressing diamondback moth, tobacco caterpillar as well as other cauliflower pests such as flea beetle, aphid, and jassid and also ensuring reduced head infestation and higher profitability.

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