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Comparative Efficacy of Botanical and Chemical Insecticides against Major Lepidopteran Pest of Cauliflower (*Brassica oleracea var. botrytis* L.) under Field Conditions

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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

Cauliflower (*Brassica oleracea var. botrytis* L.) is an economically important vegetable crop widely cultivated for its nutritional and commercial value. However, severe infestations of insect pests, particularly diamondback moth (*Plutella xylostella* L.) and tobacco caterpillar (*Spodoptera litura* Fabricius), significantly reduce yield and market quality. Excessive dependence on synthetic pesticides has resulted in environmental pollution, pesticide resistance, and health-related concerns, creating the need for sustainable pest management alternatives. The present study evaluated the efficacy of selected botanical extracts against major insect pests of cauliflower under field conditions and compared their effectiveness with a conventional chemical

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pesticides. The experiment was conducted using a randomized complete block design (RCBD) with multiple treatments including tobacco leaf extract, papaya leaf extract, dhatura extract, chlorpyrifos and an untreated control. Data on pest infestation, plant growth, and yield attributes were collected and analyzed using analysis of variance (ANOVA). All botanical treatments significantly reduced pest infestation compared with the untreated control ($p < 0.05$). Among the botanical treatments, tobacco leaf extract showed the highest efficacy against *P. xylostella and S. litura*, resulting in lower leaf damage (63.46% over control) and improved curd yield (84.63% over control). Chlorpyrifos demonstrated the maximum suppression (81.79% reduction over control) of pest infestation and produced the highest marketable yield (113.58% over control); however, botanical treatments showed promising eco-friendly potential for sustainable pest management.

Keywords: Botanical extracts; cauliflower; lepidopteran pests; eco-friendly pest management.

1. Introduction

Cauliflower (*Brassica oleracea var. botrytis* L.) is one of the most important cruciferous vegetable crops cultivated worldwide because of its high nutritional, medicinal, and economic value. It is rich in vitamins, minerals, antioxidants, dietary fiber, and bioactive phytochemicals that contribute significantly to human health and nutrition. Cruciferous vegetables contain glucosinolates and antioxidant compounds associated with reduced risks of cardiovascular diseases and several forms of cancer (Higdon *et al*., 2007; Cartea & Velasco, 2008). In addition, cauliflower is recognized as a valuable source of vitamin C, calcium, phosphorus, potassium, and antioxidant compounds essential for balanced diets and nutritional security (Ahmed & Ali, 2013; Wang *et al*., 2022).

Global cauliflower production has expanded considerably over recent decades because of increasing consumer demand and expanding vegetable markets. Asian countries dominate cauliflower production, with Bangladesh emerging as one of the major producers due to favorable climatic conditions, fertile soils, and extensive vegetable cultivation practices (Food and Agriculture Organization of the United Nations, 2023). Despite its economic importance, sustainable cauliflower production is severely constrained by insect pest infestations that reduce yield and deteriorate market quality.

Among the insect pests affecting cruciferous vegetables, the diamondback moth (*Plutella xylostella* L.) is regarded as the most destructive pest worldwide (Talekar & Shelton, 1993). Larval feeding damages leaf tissues and reduces photosynthetic activity, ultimately decreasing crop productivity. Under severe infestation, complete crop failure may occur, resulting in substantial economic losses (Furlong *et al*., 2013). The annual global economic cost associated with diamondback moth management and crop loss has been estimated at billions of dollars (Zalucki *et al*., 2012).

The tobacco caterpillar (*Spodoptera litura* Fabricius) is another highly destructive polyphagous pest responsible for severe defoliation and yield reduction in cauliflower and other economically important crops. The pest has become increasingly difficult to manage because of widespread insecticide resistance and high reproductive potential (Ahmad *et al*., 2013).

Farmers primarily depend on synthetic chemical pesticides for insect pest management in cauliflower cultivation. Although chemical insecticides provide rapid pest suppression, excessive and indiscriminate application has caused serious environmental and public health concerns, including pesticide residues, ecological imbalance, destruction of beneficial organisms, pest resurgence, and insecticide resistance (Pimentel & Burgess, 2014). In particular, *P. xylostella* has developed resistance to several classes of insecticides globally, creating major challenges for sustainable pest management (Furlong *et al*., 2013; Jamtsho *et al*., 2021).

Increasing environmental awareness and consumer demand for residue-free vegetables have intensified interest in eco-friendly pest management approaches. Botanical pesticides are considered environmentally safer alternatives because they are biodegradable, less persistent in the environment, and comparatively safer to non-target organisms (Isman, 2020; Pavela, 2016). Plant-derived insecticides possess insecticidal, repellent, antifeedant, and growth-regulating activities against numerous agricultural pests (Lengai *et al*., 2020).

Several studies have reported the effectiveness of botanical extracts against cruciferous insect pests. Shah *et al*. (2019) demonstrated that neem-derived insecticides significantly reduced cauliflower pest infestation under field conditions. Similarly, Sapkota *et al*. (2021) observed successful eco-friendly management of cauliflower insect pests using botanical approaches in Nepal. Botanical extracts such as tobacco, papaya, and dhatura contain biologically active compounds including alkaloids, terpenoids, flavonoids, and phenolics that interfere with insect feeding and development (Pavela, 2016).

The adoption of Integrated Pest Management (IPM) and sustainable agricultural systems has further accelerated the use of botanical pesticides because of their reduced environmental impact and compatibility with ecological farming systems (Pretty & Bharucha, 2015). Traditional botanical insecticides are also considered economically feasible alternatives for smallholder farmers in developing countries (Dougoud *et al*., 2019).

Despite increasing interest in botanical pest management, comparative information regarding the effectiveness of locally available plant extracts against major lepidopteran pests of cauliflower under Bangladeshi field conditions remains limited. Therefore, the present study was conducted to evaluate the efficacy of selected botanical extracts against major insect pests of cauliflower and compare their performance with a conventional chemical pesticide under field conditions.

The study was guided by the hypothesis that selected botanical extracts would significantly suppress lepidopteran pest infestation and improve cauliflower yield compared with untreated control conditions.

2. Materials and Methods

2.1 Experimental Site

The field experiment was conducted during the Rabi season at the experimental field of the Department of Crop Science and Technology, University of Rajshahi, Bangladesh. The experimental site is located at approximately 24.3745°N latitude and 88.6042°E longitude with an elevation of 18 m above sea level. The soil belongs to the High Ganges River Floodplain (AEZ-11) characterized by fertile alluvial soil.

2.2 Experimental Design and Treatments

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The total experimental area consisted of 18 plots, each measuring 2.5 m × 1.5 m.

Six treatments were included in the experiment:

- T0 = Untreated control
- T1 = Papaya leaf extract @ 3 mL per litre of water
- T2 = Chlorpyrifos @ 0.5–1.0 mL per litre of water
- T3 = Tobacco leaf extract @ 3 mL per litre of water
- T4 = Dhatura leaf extract @ 3 mL per litre of water
- T5 = Akk leaf extract @ 3 mL per litre of water

Spraying was initiated two weeks after transplanting and repeated at 3-day intervals.

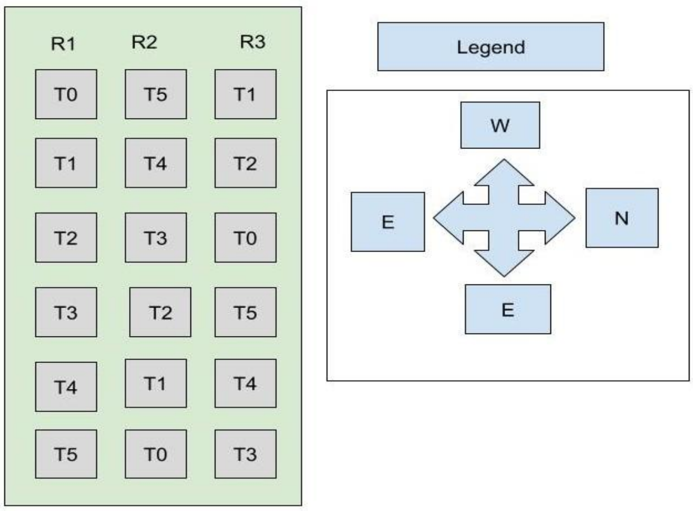

Fig. 1. Layout of the experimental plot

2.3 Crop Establishment and Management

Hybrid cauliflower seeds were collected from the local market and seedlings were raised in a prepared seedbed. Five-week-old seedlings were transplanted into the main field maintaining a spacing of 45 cm × 70 cm. Fertilizers and intercultural operations were applied following standard agronomic practices recommended by Bangladesh Agricultural Research Council (BARC).

2.4 Preparation of Botanical Extracts

Fresh leaves of papaya, tobacco, dhatura, and akk were collected and processed separately. Approximately 250g of plant material was crushed and mixed with water for extraction. The extracts were filtered through Whatman No. 1 filter paper and stored at 4°C prior to application.

2.5 Data Collection

Five plants from each plot were randomly selected and tagged for data collection. Observations were recorded weekly beginning two weeks after transplanting.

The following parameters were recorded:

- Number of diamondback moth larvae
- Number of tobacco caterpillar larvae
- Number of infested leaves
- Percentage of curd infestation
- Yield per plot and yield per hectare

The infestation levels of leaves and plants per plant and plot were then determined using the following formula:

$$\%\text{ leaf or plant infestation} = \frac{\text{No.of infested leaves or plants}}{\text{Total no.of leaves or plants}} \times 100$$

Insect infestation (%) on curds was calculated at vegetative and harvesting stages using the following formulae:

a. By Number

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

b. By Weight

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

Yield plot-1 was recorded from the field and then it was converted to total yield (t ha^{-1}). Percent increase or decrease of yield over control was calcu- lated by using the following formula:

$$\%\text{ Increase in yield over control} = \frac{\text{Yield of treated plots} - \text{Yield of control plots}}{\text{Yield of control plots}} \times 100$$

$$\%\text{ Decrease in yield} = \frac{\text{Yield of control plots} - \text{Yield of treated plots}}{\text{Yield of control plots}} \times 100$$

2.6 Statistical Analysis

The collected data were analyzed using analysis of variance (ANOVA) with using Statistix 10 software. Treatment means were separated using Duncan's Multiple Range Test (DMRT) and Least Significant Difference (LSD) test at a 5% level of significance.

3. Results

3.1 Incidence of Major Insect Pests in Cauliflower Field

During the experimental period, the cauliflower field was heavily infested by several insect pests, among which diamondback moth (*Plutella xylostella* L.) and tobacco caterpillar (*Spodoptera litura* Fabricius) were the most dominant and destructive species. The infestation intensity varied among treatments throughout the cropping season. Significant variations in pest incidence were observed following the application of botanical extracts and chemical pesticide.

3.2 Effect of Treatments on Leaf Infestation

The application of botanical extracts and chemical pesticide significantly influenced leaf infestation caused by major insect pests of cauliflower. The untreated control plots consistently recorded the highest level of leaf damage throughout the study period, whereas treated plots showed comparatively lower infestation.

Among all treatments, chlorpyrifos demonstrated the highest efficacy in reducing leaf infestation, resulting in an 80.88% reduction over control. Tobacco leaf extract was the most effective botanical treatment, reducing leaf infestation by 63.46%, followed by akk leaf extract (59.21%), dhatura leaf extract (57.76%), and papaya leaf extract (38.17%). Statistical analysis indicated significant differences among treatments at the 5% level of probability. The reduced infestation observed in botanical-treated plots indicated the insecticidal and repellent effects of plant-derived bioactive compounds. Tobacco extract showed comparatively superior performance among botanicals throughout the experimental.

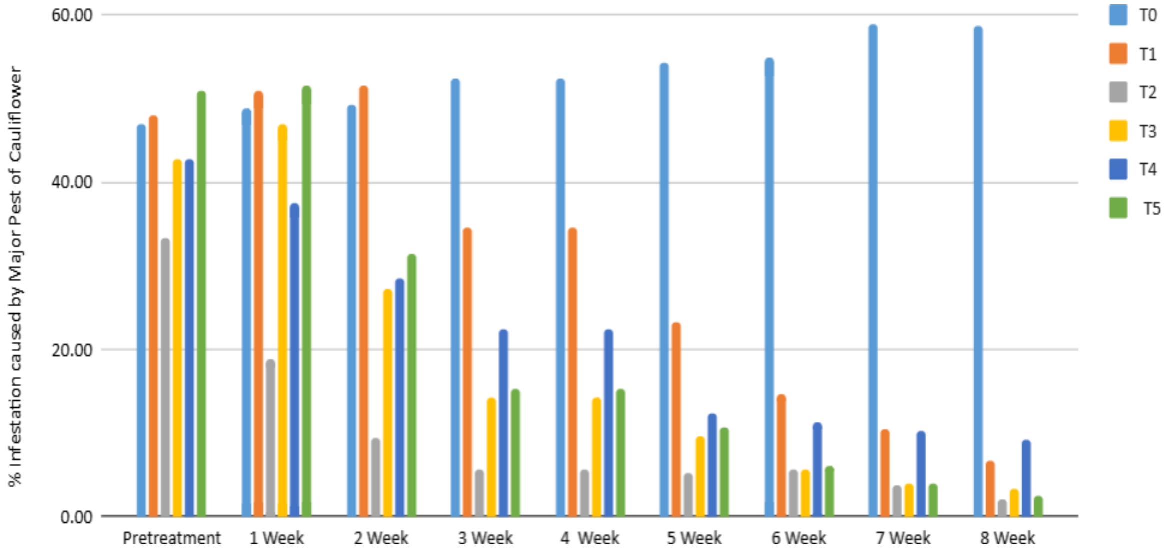

Fig. 2. Infestation of Cauliflower leaf caused by major insect-pests at different weeks after transplanting

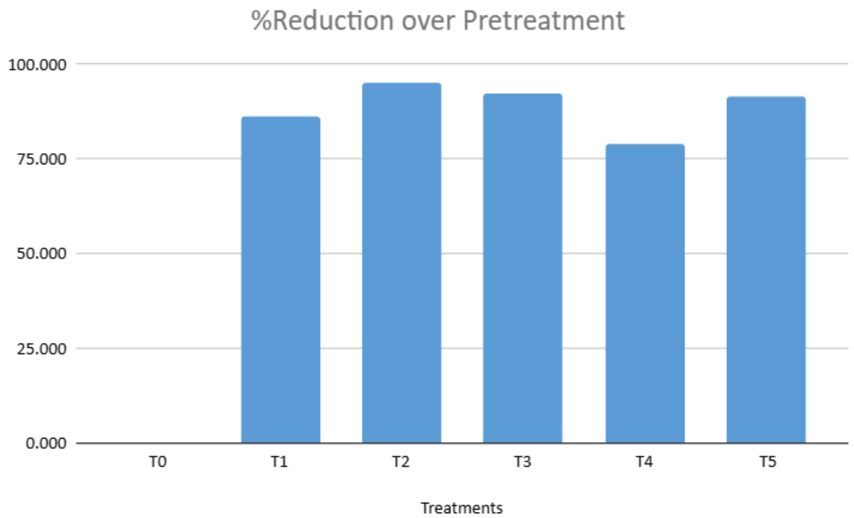

Fig. 3. Percentage (%) Reduction in leaf infestation over Pretreatment levels

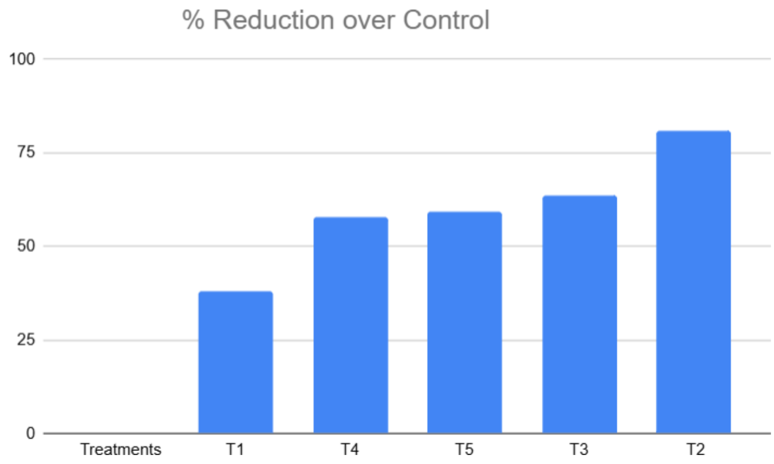

Fig. 4. Percentage (%) Reduction in leaf infestation over Control

3.3 Effect of Treatments on Diamondback Moth Population

The treatments exerted significant effects on the population density of diamondback moth larvae in cauliflower plants. The highest larval population was observed in untreated control plots, while all treated plots exhibited lower infestation levels. Chlorpyrifos treatment produced the greatest suppression of diamondback moth population with an 82.57% reduction over control. Among the botanical treatments, tobacco leaf extract achieved 60.72% reduction, followed by dhatura leaf extract (49.44%), akk leaf extract (48.29%), and papaya leaf extract (27.87%). The larval population gradually declined after repeated application of treatments, indicating the effectiveness of both synthetic and botanical pesticides in suppressing pest infestation.

Table 1. Infestation of Cauliflower leaf caused by diamondback moth at different weeks after transplanting

Treatments	Number of Infested Leaves per Five Plants									MEAN	% Reduction over control	% Reduction over Pretreatment
	Pretreatment	1Week	2Week	3Week	4Week	5Week	6Week	7Week	8Week			
T0	29.256 ab	34.248 ab	31.19 ab	31.702 a	31.702 a	31.864 a	31.064 a	29.869 a	30.350 a	31.22 a		
T1	29.114 ab	35.516 ab	34.979 a	25.928 b	25.928 b	17.754 b	11.266 b	7.221 b	4.130 c	22.52 b	27.8700	85.828
T2	17.048 c	10.131 d	5.279 e	3.336 e	3.336 e	3.015 e	3.045 d	2.091 c	1.240 d	5.44 d	82.5700	95.146
T3	28.511 b	29.371 bc	18.154 d	8.909 d	8.909 d	6.435 d	4.273 d	2.655 c	2.080 d	12.26 c	60.7200	91.235
T4	21.362 c	24.951 c	21.399 cd	17.225 c	17.225 c	9.216 c	8.439 c	7.682 b	6.810 b	15.79 c	49.4400	68.121
T5	35.678 a	38.529 a		11.741 d	11.741 d	7.443 cd	4.709 d	3.094 c	2.480 cd	16.15 c	48.2900	90.254
LSD (0.05)	7.0588	8.0893	6.2348	3.3096	3.3096	2.0928	1.8410	1.5228	1.7685	5.1283		
CV	14.4600	15.4400	15.1100	11.0400	11.0400	9.1100	9.6700	9.5500	12.3900	55.3600		
S.E. (±)	3.1680	3.6305	2.7982	1.4853	1.4853	0.9392	0.8262	0.6834	0.7937	2.5960		

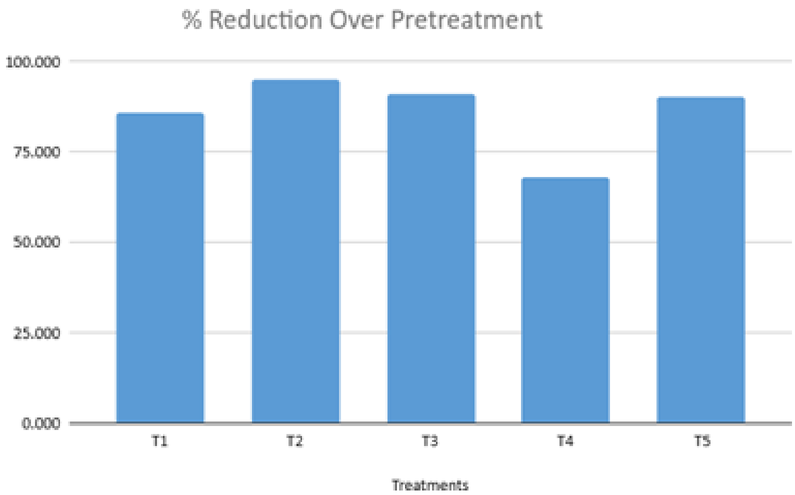

Fig. 5. Percentage (%) Reduction in the population density of diamondback moth larvae over Pretreatment

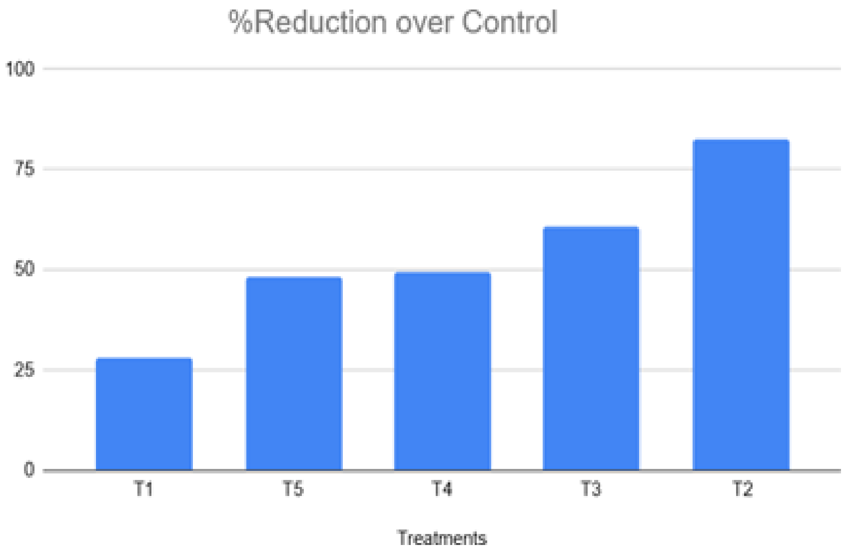

Fig. 6. Percentage (%) Reduction in the population density of diamondback moth larvae over Control

3.4 Effect of Treatments on Tobacco Caterpillar Population

Significant differences among treatments were also observed in controlling tobacco caterpillar infestation. The untreated control plots maintained the highest larval population during the study period. Chlorpyrifos treatment resulted in the maximum suppression of tobacco caterpillar infestation with an 81.79% reduction over control. Among the botanical treatments, tobacco leaf extract again demonstrated the highest efficacy with a 62.86% reduction in larval population, whereas papaya leaf extract showed comparatively lower effectiveness. Dhatura and akk extracts provided moderate suppression of the pest population. The results indicated that botanical extracts possess substantial potential to reduce tobacco caterpillar infestation under field conditions.

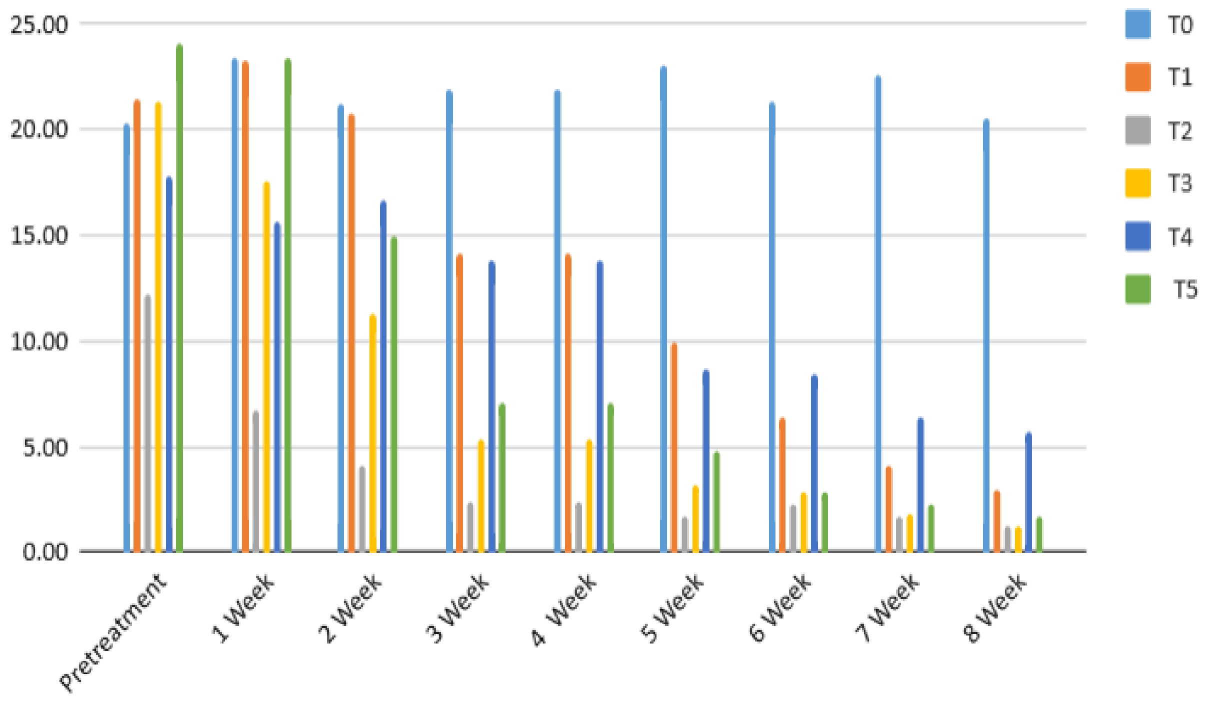

Fig. 7. Infestation of Cauliflower leaf caused by tobacco caterpillar at different weeks after transplanting

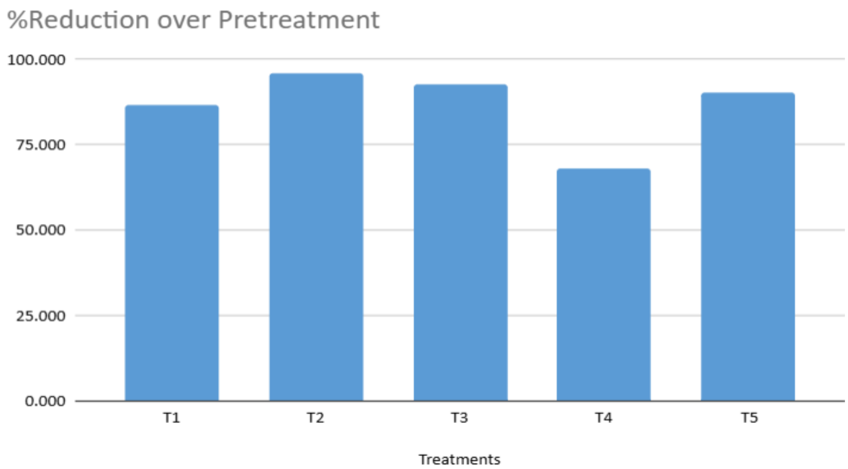

Fig. 8. Percentage (%) Reduction in tobacco caterpillar population over Pretreatment

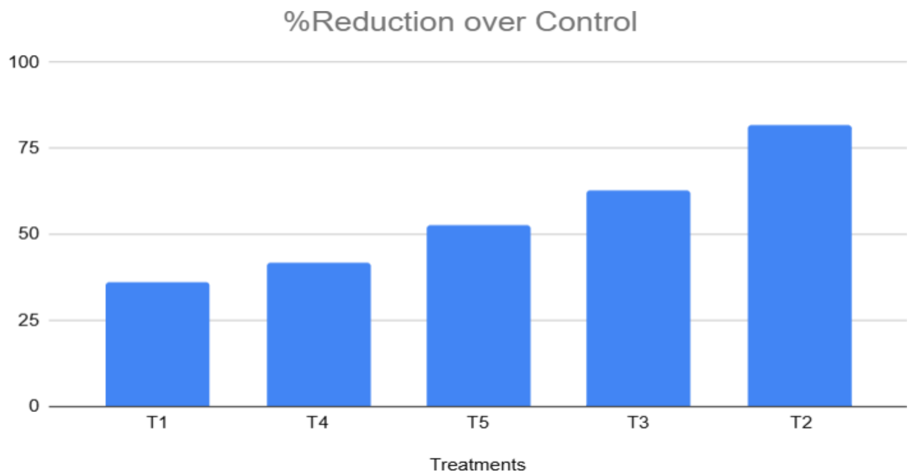

Fig. 9. Percentage (%) Reduction in tobacco caterpillar population over Control

3.5 Effect of Treatments on Curd Infestation

The treatments significantly affected curd infestation percentage in cauliflower. The highest curd infestation was recorded in untreated control plots, whereas treated plots showed comparatively lower infestation levels. Chlorpyrifos-treated plots exhibited the minimum curd infestation, followed by tobacco leaf extract treatment. The reduction in curd infestation in botanical-treated plots demonstrated the protective effect of plant extracts against lepidopteron pests.

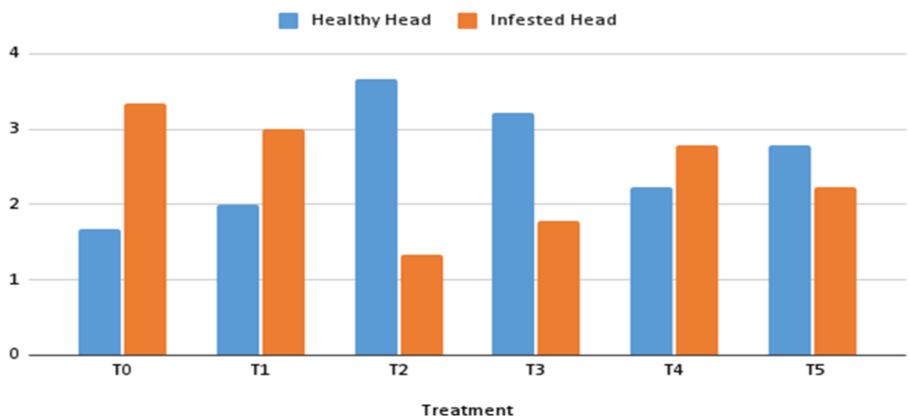

Fig. 10. Effect of management practices on cauliflower curd infestation

3.6 Effect of Treatments on Yield of Cauliflower

Significant variation in yield performance was observed among the treatments. The highest marketable yield was recorded from chlorpyrifos-treated plots due to effective suppression of insect pests and reduced crop damage. Among the botanical treatments, tobacco leaf extract produced the highest yield, followed by akk and dhatura extracts. The untreated control plots produced the lowest yield because of severe pest infestation and higher curd damage. The increase in yield in treated plots indicated that effective pest management contributed directly to improved crop health, curd development, and marketable yield.

Table 2. Individual head weight and total yield (ton/ha) of cauliflower in different treatments during harvesting

Treatment	Single curd wt (g)	% increase over control	Total yield (kg)/plot	% increase over control (yield)	Total yield (ton/ha)	% increase over control (yield)
T0	380.33 c		1.435 b		7.972 b	
T1	431.67 b	13.4988	2.282 b	37.1166	12.678 b	37.0698
T2	811.67 a	113.4120	4.870 a	113.4093	27.056 a	113.5775
T3	701.67 a	84.4898	4.210 a	84.4873	23.389 a	84.63306
T4	611.67 ab	60.8261	3.670 a	60.8238	20.389 a	60.9488
T5	655.00 a	72.2189	3.930 a	72.2174	21.833 a	72.3476
LSD (0.05)	209.1800		1.3018		7.2321	
CV	19.2100		21.0500		21.0500	
S.E. (±)	93.8820		0.5842		3.2458	

4. Discussion

The present study demonstrated that both botanical extracts and chemical pesticide significantly reduced infestations of major insect pests in cauliflower compared with the untreated control. Among the botanical treatments, tobacco leaf extract exhibited superior efficacy against *Plutella xylostella* and *Spodoptera litura*. The higher effectiveness of tobacco extract may be attributed to the presence of nicotine and other alkaloid compounds possessing strong insecticidal, antifeedant, and repellent activities against lepidopteran pests (Isman, 2020).

Similar findings were reported by Shah *et al.* (2019), who observed significant suppression of cauliflower pests using neem-derived insecticides under field conditions. Likewise, *Sapkota et al.* (2021) reported successful eco-friendly management of cauliflower insect pests using botanical approaches. The effectiveness of botanical pesticides may be associated with bioactive compounds such as alkaloids, flavonoids, terpenoids, and phenolics that interfere with insect feeding, growth, and reproduction (Lengai *et al*., 2020).

Chlorpyrifos provided the highest overall reduction in pest infestation and produced the maximum marketable yield among all treatments. This result agrees with earlier reports indicating that synthetic insecticides remain highly effective for rapid suppression of cruciferous insect pests (Talekar & Shelton, 1993). However, excessive reliance on chemical pesticides has created serious ecological and resistance-related problems worldwide. Diamondback moth has developed resistance to several classes of insecticides, making long-term management increasingly difficult (Ahmad *et al*., 2013; Furlong *et al*., 2013).

The moderate effectiveness observed in papaya and dhatura extracts may be related to variations in phytochemical composition and persistence of active compounds under field conditions. Similar observations were reported by Pavela (2016), who emphasized that the efficacy of botanical insecticides depends largely on the concentration and stability of biologically active compounds.

The reduction in pest infestation directly contributed to improved curd development and increased marketable yield in treated plots. Reduced feeding damage likely enhanced photosynthetic activity and nutrient accumulation, resulting in improved plant growth and productivity. Comparable findings were reported by Parajuli and Paudel (2019), who observed increased productivity in cruciferous vegetables following botanical pest management practices.

Botanical pesticides are increasingly recognized as environmentally sustainable alternatives because they degrade rapidly and pose comparatively lower risks to beneficial insects and non-target organisms than conventional insecticides (Isman, 2020). Furthermore, botanical pest management strategies are compatible with integrated pest management programs and sustainable agricultural systems aimed at reducing pesticide residues and environmental contamination (Pretty & Bharucha, 2015).

The growing demand for safe and residue-free vegetables has accelerated research interest in eco-friendly pest management approaches. Botanical insecticides may therefore reduce dependence on synthetic chemicals while minimizing environmental and health-related risks. Sustainable biological approaches are increasingly considered essential for environmentally sound cruciferous crop production systems (Mayanglambam *et al*., 2021).

Although chlorpyrifos remained the most effective treatment in the present study, tobacco leaf extract demonstrated promising efficacy among the botanical treatments. Further studies involving economic analysis, residue assessment, and multi-location trials are recommended to validate the long-term effectiveness of botanical pesticides under diverse agro ecological conditions.

Therefore, botanical formulations may serve as environmentally friendly alternatives or complementary components within integrated pest management strategies for cauliflower cultivation under Bangladeshi agroecological conditions.

5. Conclusion

The study demonstrated that botanical extracts significantly reduced infestations of major insect pests in cauliflower compared with untreated control conditions. Among the tested botanicals, tobacco leaf extract showed the highest efficacy against diamondback moth and tobacco caterpillar and produced comparatively higher marketable yield. Although chlorpyrifos provided the maximum pest suppression and yield performance, botanical treatments offered environmentally safer and sustainable alternatives for pest management. The findings suggest that tobacco-based botanical formulations may serve as environmentally friendly alternatives or complementary components within integrated pest management strategies for cauliflower cultivation under Bangladeshi agroecological conditions.

Disclaimer (Artificial Intelligence)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during writing or editing of this manuscript.

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Competing Interests

Authors have declared that no competing interests exist.

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