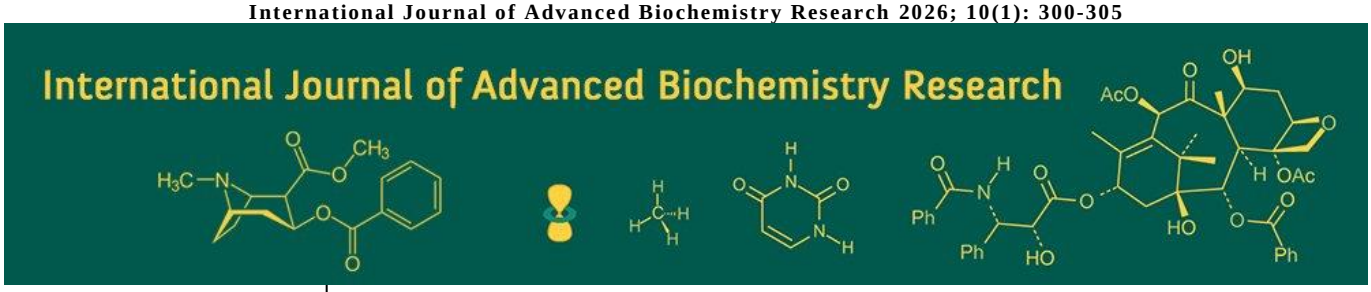


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# Bio-efficacy of promising medicinal and aromatic plants against diamondback moth, *Plutella xylostella* (L.) on cabbage under field conditions

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**Abstract**
A field experiment was conducted during the summer season of 2019 (April-June) at a farmer's field in Nellakunte, Doddaballapur taluk, Bengaluru Rural district to evaluate the bio-efficacy of selected medicinal and aromatic plant extracts against diamondback moth (*Plutella xylostella* L.) on cabbage. The experiment was laid out in a randomized block design with ten treatments and three replications. The results of the field trial clearly indicated the superior efficacy of 5 percent neem seed kernel extract (NSKE) against DBM on cabbage compared to the other plant extracts evaluated. The plant extracts such as pongamia, datura, bael, calotropis and hebbevu exhibited moderate effectiveness against DBM. Further, the plots treated with plant extracts recorded higher activity of natural enemies such as *Cotesia plutellae* and spiders compared to chemical insecticide treated plots, indicating the eco-friendly nature of botanical treatments. In addition, NSKE registered the highest cabbage yield and benefit-cost ratio (2.48), followed by datura (2.15), bael (2.05), tulasi (1.64), nagadali (1.41), hebbevu (1.35), pongamia (1.25) and calotropis (1.20). The study demonstrates that botanical extracts, especially NSKE, offer an effective and environmentally safe alternative for the management of diamondback moth in cabbage under field conditions.

**Keywords:** Diamondback moth, bio-efficacy, medicinal and aromatic plant extracts, cabbage

## Introduction
Cabbage is an important cruciferous vegetable crop; however, its productivity is severely constrained by the diamondback moth (*Plutella xylostella* L.), one of the most destructive pests of cruciferous vegetables worldwide. The pest is capable of causing up to 90 percent loss in marketable yield of cabbage (Gashawbeza, 2006) [4]. At the farmer level, management of this pest relies predominantly on chemical insecticides. Unfortunately, the effectiveness of these chemicals has declined drastically due to the pest's rapid development of resistance to almost all major groups of insecticides, including biopesticides such as *Bacillus thuringiensis* and spinosyns (Tabashnik *et al.*, 2003) [12]. As a result, satisfactory control has become increasingly difficult even with newer insecticide molecules.

The continuous and indiscriminate use of synthetic insecticides has also led to several serious problems such as insecticide resistance, pest resurgence, environmental contamination and health hazards to farmers and consumers. These challenges have created an urgent need for pest management strategies that are both environmentally safe and economically feasible.

Extensive literature indicates that many medicinal and aromatic plants possess a rich array of insecticidal active ingredients and bioactive chemical compounds. These plants offer several advantages for pest management, including easy availability, long-standing medicinal use and low or negligible toxicity to humans. Moreover, they exhibit a wide range of biological properties such as insecticidal, repellent, anti-feedant, growth inhibitory, oviposition-deterrent, ovicidal and growth-disrupting effects against various insect pests due to the presence of diverse insecticidal principles (Liu *et al.*, 2007) [8]. Unlike synthetic insecticides, botanical products are biodegradable, environmentally safe and generally harmless to non-target organisms and natural enemies.

Although many medicinal and aromatic plants have been reported to possess insecticidal properties, their field performance against diamondback moth on cabbage has not been

adequately evaluated. Therefore, the present investigation was undertaken to assess the bio-efficacy of selected promising medicinal and aromatic plant extracts against diamondback moth on cabbage under field conditions**,** with the aim of identifying effective and eco-friendly alternatives for sustainable pest management.

## Materials and Methods

**Preparation of plant extracts:** The plant extracts such as neem, pongamia, nagadali, tulasi, hebbevu, bael, datura and calatropis were selected for field evaluation against DBM on cabbage.

**Preparation of Neem seed kernel extract (NSKE) and Pongamia seed extracts:** The kernels were separated from freshly collected neem seeds by pounding and in the case of pongamia, the seeds were separated. Neem seed kernels and pongamia seeds were ground in to a fine powder using electrical grinder. 250 g of the fine powder was then mixed in a 750 ml of water. After mixing, the solution was stirred carefully until all the powder was mixed completely with the water. This solution was left overnight. Then the suspension was filtered through a muslin cloth and volume was made up to five litres by adding water. The concentration of the extract so prepared was five percent (Begna, 2017) [2].

**Preparation of leaf extracts of Nagadali, Tulasi, Hebbevu, Bael, Datura and Calatropis:** Fresh leaves of these plants were collected a day before spraying. The extracts of these six plants were prepared by weighing 500 g of each plants separately and crushed in to small pieces using knife, then the chopped leaf was ground using electrical grinder with little amount of water to make paste. The paste was soaked in 1000 ml of water and left for overnight. The next day morning the solution was filtered through muslin cloth. At the time of application, the aqueous extract was diluted in 4 litres of water and used for field spray. The concentration of the extract so prepared was ten percent. Whereas in the case of Daura and Caltropis, the concentration maintained was at five percent by adopting similar procedure (Oke *et al*., 2010) [9].

### Experimental details

The field experiment was carried out during summer season of 2019 (April-June) at farmer's field, Nellakunte, Doddaballapur taluk, Bengaluru Rural district. The experiment was laid out in a randomized block design with ten treatments and three replications. The treatment plot size was 2 m × 4 m. The cabbage crop (Unnathi) was raised as per the recommended package of practices of the University of Horticultural Sciences, Bagalkot.

The botanical extracts and insecticides were applied by using high volume Knapsack's sprayer at the rate of 400 to 500 liters of spray solution per ha depending on the stage of the crop. Soap solution was added to the spray solution as a sticker and spreader. Totally, three sprays were given to the crop at an interval of seven days depending on the level of DBM infestation. First spray was given when the population crossed ETL.

### Treatment details of promising medicinal and aromatic plants evaluated against *Plutella xylostella* on cabbage under field condition

The experiment consisted of ten treatments, which included eight promising different medicinal and aromatic plant extracts along with a standard insecticidal check and an untreated control. The treatments comprised neem seed kernel extract (5%; 50 g $l^{-1}$), pongamia seed extract (5%; 50 g $l^{-1}$), nagadali leaf extract (10%; 100 g $l^{-1}$), tulasi leaf extract (10%; 100 g $l^{-1}$), hebbevu leaf extract (10%; 100 g $l^{-1}$), bael leaf extract (10%; 100 g $l^{-1}$), datura leaf extract (5%; 50 g $l^{-1}$) and calotropis leaf extract (5%; 50 g $l^{-1}$). Spinosad at 0.3 ml $l^{-1}$ was included as the standard chemical check, while an untreated control was maintained for comparison.

### Observations

Observations were made on the number of DBM larvae per plant on ten randomly selected plants in each plot by adopting visual counting method. The pretreatment count was made a day before treatment imposition and post treatment counts were made at third and seventh days after each spray. Observation recorded on seventh day after each spray served as a pretreatment count for the next spray.

Observations on the occurrence of natural enemies *viz*., *Cotesia plutella* and spiders were also made from ten randomly selected plants in each treatment at one day before and third and seventh day after each spray. Further, yield was recorded in each treatment plots and then converted in to tones per hectare basis.

### Benefit cost ratio (BCR)

The yield of cabbage from each plot was recorded and converted to tonnes per hectare. The price of inputs that prevailing at the time their use was considered for working out the cost of cultivation. Benefit-cost analysis was expressed in terms of cost-benefit ratio by using the following formula:

$$\text{Cost-benefit ratio} = \frac{\text{Net return (Rs./ha)}}{\text{Cost of treatment (Rs./ha)}}$$

**Statistical analysis:** Data on the DBM population on the cabbage plant and percent population reduction over control were subjected to square root before analyzing the data with one-way ANOVA. The treatment means were separated by using DMRT (Duncan's Multiple Range Test).

## Results

The field experiment was carried out during summer season of 2019 at farmer's field, Nellakunte, Doddaballapur taluk, Bengaluru rural district to assess the efficacy of aqueous extracts of promising medicinal and aromatic plants against diamondback moth on cabbage with fairly good level of infestation. During the study period, the DBM larvae per plant in the untreated control ranged from 1.17 to 2.03. The crop received three sprays at an interval of seven days. Pre-treatment count on number of larvae per plant in all the plots ranged from 1.13 to 1.90 per plant, indicating uniform distribution of pest population throughout the experimental field and there was no significant difference between the treatments. Then onwards, the tested plant extracts were found statistically significant in reducing the DBM population compared to control and results obtained are mentioned in the (Table 1).

The percent reduction of DBM larval population over control worked out after three rounds of spray revealed that, the NSKE at 5 percent registered superior efficacy against

DBM on cabbage as that of other plant extracts evaluated by recording 0.43 larvae per plant and 74.04 percent reduction in the larval population over control. The mean number of larvae per plant and percent reduction over control recorded in other plant extracts ranged from 0.49 to 0.70 and 59.06 to 70.28, respectively (Table 1).

While, the lowest mean of 0.14 larvae per plant and maximum percent reduction of larval population on cabbage plant was registered with the plots treated with spinosad @ 0.3 ml/l. The mean larva population prevailed in the untreated plots during the experimental period was 1.70 per plant.

**Activity of natural enemies prevailing in cabbage ecosystem after application of different plant extracts**

The activity of *Cotesia plutella* a promising parasitoid on *Plutella xylostella* and spiders was recorded in the plots where different medicinal and aromatic plant extracts were treated during the experimental period. The results obtained are mentioned in Table 2. A day before spray, distribution of *Cotesia plutella* and spiders was uniform throughout the experimental field and it was ranged from 0.03 to 0.17 per plant. However, the significant difference among the treatments was observed at subsequent sprays made on the crop.

On the whole, it is evident from the data recorded on both *C. plutellae* and spider after three rounds sprays of plant extracts that, the maximum activity of both the natural enemies was observed in the plots treated with leaf extract of datura and NSKE both at 5 percent with 0.47. population per plant, followed by nagadali leaf extract at 10 percent, pongamia seed extract at 5 percent and tulasi leaf extract at 10 percent recorded with 0.41, 0.40 and 0.36 per plant, respectively and found on for with each other. Whereas, chemical treated plots registered comparatively lowest population of 0.17 per plant.

**Yield and cost economics**

Yield and cost economics of different plant extracts evaluated against *Plutella xylostella* on cabbage are presented in Table 3. Significant differences were observed in respect of the yield recorded from plots treated with different plant extracts. The highest yield 35.94 t/ha was recorded from the NSKE at 5 percent treated plots with a net return of Rs. 3,84,062.00 per ha. It was followed by leaf extract of datura at 5 percent by recording 32.38 t/ha with a net return of Rs. 3,31,687.50 per ha. Moderate level of yield was recorded in the plots treated with bael leaf extract at 10 percent, tulasi leaf extract at 10 percent, nagadali leaf extract at 10 percent, hebbevu seed extract at 5 percent, and pongamia leaf extract at 10 percent by recording 31.33, 27.10, 24.78, 24.00 and 23.19. While, the untreated control plots recorded the lowest yield of 21.58 t/ha with a net return of Rs. 1,71,750.00 per ha.

Cost-effectiveness of each treatments was worked out based on net returns and B:C ratio. Among the different treatments, highest cost benefit ratio was observed with NSKE at 5 percent with B:C ratio of 2.48. This was followed by leaf extract of datura at 5 percent with 2.15. The lowest B:C ratio was registered in untreated control plots with 1.13. While, Spinosad @ 0.3ml/l recorded maximum B:C ratio of 3.11.

**Table 1:** Bio-efficacy of promising medicinal and aromatic plants against *Plutella xylostella* on cabbage crop

| Treatments | Concentrations (%) | Number of larvae/plant on different days after spray | | | | | | | Pooled mean | Percent reduction over control |
|---|---|---|---|---|---|---|---|---|---|---|
| | | First spray | | | Second spray | | Third spray | | | |
| | | DBS | 3 DAS | 7 DAS | 3 DAS | 7 DAS | 3 DAS | 7 DAS | | |
| $T_1$-Neem seed kernel extract | 5 | 1.13 (1.28) | 0.73 (1.11)$^{bc}$ | 0.93 (1.2)$^{bc}$ | 0.57 (1.03)$^{b}$ | 0.40 (0.95)$^{bc}$ | 0.23 (0.86)$^{b}$ | 0.13 (0.80)$^{bc}$ | 0.43 (1.00)$^{b}$ | 74.04 |
| $T_2$-Pongamia seed extract | 5 | 1.80 (1.52) | 1.37 (1.37)$^{ab}$ | 0.83 (1.15)$^{b}$ | 0.70 (1.10)$^{b}$ | 0.60 (1.05)$^{b}$ | 0.40 (0.95)$^{b}$ | 0.30 (0.89)$^{bc}$ | 0.70 (1.12)$^{b}$ | 59.06 |
| $T_3$-Nagadali leaf extract | 10 | 1.60 (1.45) | 1.23 (1.32)$^{ab}$ | 0.90 (1.18)$^{b}$ | 0.50 (1.00)$^{bc}$ | 0.40 (0.95)$^{bc}$ | 0.27 (0.88)$^{b}$ | 0.20 (0.84)$^{bc}$ | 0.58 (1.07)$^{b}$ | 66.04 |
| $T_4$-Tulasi leaf extract | 10 | 1.53 (1.43) | 0.90 (1.18)$^{bc}$ | 0.80 (1.14)$^{b}$ | 0.67 (1.08)$^{b}$ | 0.60 (1.05)$^{b}$ | 0.30 (0.89)$^{b}$ | 0.23 (0.86)$^{bc}$ | 0.58 (1.07)$^{b}$ | 65.67 |
| $T_5$-Hebbevu leaf extract | 10 | 1.17 (1.29) | 0.80 (1.14)$^{bc}$ | 1.00 (1.22)$^{b}$ | 0.53 (1.02)$^{b}$ | 0.47 (0.98)$^{bc}$ | 0.30 (0.89)$^{b}$ | 0.30 (0.89)$^{bc}$ | 0.57 (1.06)$^{b}$ | 66.23 |
| $T_6$-Bael leaf extract | 10 | 1.07 (1.25) | 0.97 (1.21)$^{b}$ | 0.90 (1.18)$^{b}$ | 0.67 (1.08)$^{b}$ | 0.67 (1.08)$^{b}$ | 0.43 (0.97)$^{b}$ | 0.33 (0.91)$^{b}$ | 0.66 (1.11)$^{b}$ | 60.69 |
| $T_7$-Datura leaf extract | 5 | 1.53 (1.43) | 0.83 (1.15)$^{bc}$ | 0.53 (1.02)$^{bc}$ | 0.50 (1.00)$^{bc}$ | 0.50 (1.00)$^{b}$ | 0.33 (0.91)$^{b}$ | 0.23 (0.86)$^{bc}$ | 0.49 (1.02)$^{b}$ | 70.28 |
| $T_8$-Calotropis leaf extract | 5 | 1.53 (1.43) | 0.90 (1.18)$^{bc}$ | 0.70 (1.10)$^{bc}$ | 0.70 (1.10)$^{b}$ | 0.67 (1.08)$^{b}$ | 0.43 (0.97)$^{b}$ | 0.33 (0.91)$^{b}$ | 0.62 (1.09)$^{b}$ | 62.63 |
| $T_9$-Spinosad | 0.3ml/l | 1.23 (1.32) | 0.30 (0.89)$^{c}$ | 0.20 (0.84)$^{c}$ | 0.13 (0.80)$^{c}$ | 0.13 (1.80)$^{c}$ | 0.10 (0.77)$^{b}$ | 0.00 (0.71)$^{c}$ | 0.14 (0.84)$^{c}$ | 89.77 |
| $T_{10}$-Untreated control | - | 1.90 (1.55) | 2.00 (1.58)$^{a}$ | 1.70 (1.48)$^{a}$ | 1.090 (1.55)$^{a}$ | 2.03 (1.59)$^{a}$ | 1.40 (1.38)$^{a}$ | 1.17 (1.29)$^{a}$ | 1.70 (1.50)a | - |
| SEm ± | | - | 0.09 | 0.19 | 0.13 | 0.06 | 0.06 | 0.11 | 0.22 | |
| C.D. (0.05) | | NS | 0.27 | 0.56 | 0.39 | 0.17 | 0.19 | 0.34 | 0.07 | |

DBS: Day before spray, DAS-Days after spray NS-Non Significant

Figures in parenthesis are square root ($\sqrt{x+0.5}$) transformed value,

Figures in each column followed by same alphabet (s) are not significantly different (P = 0.05)

**Table 2:** Activity of natural enemies in the cabbage ecosystem where medicinal and aromatic plants evaluated for their efficacy against *Plutella xylostella.*

| Treatments | Concentration (%) | Before spray | Natural enemies population (*Cotesia plutella*& Spiders)/plant | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | 1st spray | | 2st spray | | 3rd spray | | Mean |
| | | | 3DAS | 7DAS | 3DAS | 7DAS | 3DAS | 7DAS | |
| $T_1$-Neem seed kernel extract | 5 | 0.03 | 0.10 (0.80)$^{cd}$ | 0.13 (0.84)$^{c}$ | 0.23 (0.86)$^{bc}$ | 0.77 (0.93)$^{a}$ | 0.77 (1.08)$^{a}$ | 0.80 (1.14)$^{a}$ | 0.47 (0.98)$^{b}$ |
| $T_2$-Pongamia seed extract | 5 | 0.07 | 0.13 (0.91)$^{bcd}$ | 0.20 (1.03)$^{bc}$ | 0.20 (0.84)$^{bc}$ | 0.37 (0.91)$^{c}$ | 0.67 (0.93)$^{ab}$ | 0.80 (1.14)$^{a}$ | 0.40 (0.95)$^{ab}$ |
| $T_3$-Nagadali leaf extract | 10 | 0.17 | 0.33 (0.77)$^{a}$ | 0.57 (0.84)$^{a}$ | 0.33 (0.91)$^{ab}$ | 0.33 (1.00)$^{c}$ | 0.37 (0.95)$^{cd}$ | 0.50 (1.00)$^{b}$ | 0.41 (0.95)$^{ab}$ |
| $T_4$-Tulasi leaf extract | 10 | 0.07 | 0.10 (0.75)$^{cd}$ | 0.20 (0.80)$^{bc}$ | 0.27 (0.88)$^{bc}$ | 0.50 (0.89)$^{bc}$ | 0.40 (1.00)$^{bcd}$ | 0.67 (1.08)$^{ab}$ | 0.36 (0.93)$^{ab}$ |
| $T_5$-Hebbevu leaf extract | 10 | 0.03 | 0.07 (0.80)$^{d}$ | 0.13 (0.80)$^{c}$ | 0.17 (0.82)$^{c}$ | 0.30 (0.95)$^{c}$ | 0.50 (1.00)$^{abc}$ | 0.50 (1.00)$^{b}$ | 0.28 (0.88)$^{bc}$ |
| $T_6$-Bael leaf extract | 10 | 0.1 | 0.13 (0.88)$^{bcd}$ | 0.13 (0.91)$^{c}$ | 0.20 (0.84)$^{bc}$ | 0.40 (1.11)$^{bc}$ | 0.50 (1.08)$^{abc}$ | 0.67 (1.08)$^{ab}$ | 0.34 (0.92)$^{b}$ |
| $T_7$-Datura leaf extract | 5 | 0.17 | 0.27 (0.86)$^{ab}$ | 0.33 (0.88)$^{b}$ | 0.47 (0.98)$^{a}$ | 0.73 (0.91)$^{ab}$ | 0.67 (0.91)$^{ab}$ | 0.73 (1.11)$^{ab}$ | 0.53 (1.02)$^{a}$ |
| $T_8$-Calotropis leaf extract | 5 | 0.1 | 0.23 (0.77)$^{abc}$ | 0.27 (0.84)$^{bc}$ | 0.27 (0.88)$^{bc}$ | 0.33 (0.86)$^{c}$ | 0.33 (0.86)$^{cd}$ | 0.53 (1.02)$^{b}$ | 0.33 (0.91)$^{b}$ |
| $T_9$-Spinosad | 0.3ml/l | 0.07 | 0.10 (0.77)$^{cd}$ | 0.20 (0.80)$^{c}$ | 0.23 (0.86)$^{bc}$ | 0.23 (0.95)$^{c}$ | 0.23 (1.08)$^{d}$ | 0.00 (0.71)$^{c}$ | 0.17 (0.82)$^{c}$ |
| $T_{10}$-Untreated control | - | 0.1 | 0.10 (1.44)$^{cd}$ | 0.13 (1.67)$^{bc}$ | 0.13 (0.80)$^{c}$ | 0.40 (2.21)$^{c}$ | 0.67 (2.37)$^{ab}$ | 0.67 (1.08)$^{ab}$ | 0.35 (0.92)$^{b}$ |
| SEm ± | | - | 0.05 | 0.05 | 0.05 | 0.11 | 0.09 | 0.08 | |
| C.D. (0.05) | | NS | 0.15 | 0.16 | 0.15 | 0.33 | 0.27 | 0.24 | |

DAS-Days after spray NS-Non Significant

Figures in parenthesis are square root ($\sqrt{x+0.5}$)transformed value

Figures in each column followed by same alphabet (s) are not significantly different (P = 0.05) by DMRT

**Table 3:** Cost economics of management of *Plutella xylostella* on cabbage through different plants extracts.

| Treatments | Yield (t/ha) | Cost of cultivation (Rs./ha) | Cost of plant protection (Rs./ha) | Total cost of cultivation (Rs./ha) | Grass return (Rs./ha) | Net returns (Rs./ha) | B:C ratio |
|---|---|---|---|---|---|---|---|
| $T_1$-Neem seed kernel extract | 35.94$^{ab}$ | 150000 | 5000 | 155000 | 539062.50 | 3,84,062.50 | 2.48 |
| $T_2$-Pongamia seed extract | 23.19$^{cde}$ | 150000 | 4800 | 154800 | 347812.50 | 1,93,012.50 | 1.25 |
| $T_3$-Nagadali leaf extract | 24.78$^{cde}$ | 150000 | 4000 | 154000 | 371625.00 | 2,17,625.00 | 1.41 |
| $T_4$-Tulasi leaf extract | 27.10$^{bcde}$ | 150000 | 4000 | 154000 | 406500.00 | 2,52,500.00 | 1.64 |
| $T_5$-Hebbevu leaf extract | 24.00$^{cde}$ | 150000 | 3500 | 153500 | 360000.00 | 2,06,500.00 | 1.35 |
| $T_6$-Bael leaf extract | 31.33$^{bcd}$ | 150000 | 4000 | 154000 | 469937.50 | 3,15,937.50 | 2.05 |
| $T_7$-Datura leaf extract | 32.38$^{abc}$ | 150000 | 4000 | 154000 | 485687.50 | 3,31,687.50 | 2.15 |
| $T_8$-Calotropis leaf extract | 22.43$^{dc}$ | 150000 | 3000 | 153000 | 336375.00 | 1,83,375.00 | 1.20 |
| $T_9$-Spinosad | 43.06$^{a}$ | 150000 | 7000 | 157000 | 645937.50 | 4,88,937.50 | 3.11 |
| $T_{10}$-Untreated control | 21.58$^{e}$ | 150000 | 2000 | 152000 | 323750.00 | 1,71,750.00 | 1.13 |
| SEm ± | 0.99 | - | - | - | - | - | - |
| C.D. (0.05) | 2.95 | - | - | - | - | - | - |

Gross return = Yield x Market price of onion (Rs. 15/kg), Net Returns = Gross Returns-Total Cost

Figures in each column followed by same alphabet (s) are not significantly different (P = 0.05) by DMRT

## Discussion

The present investigation clearly demonstrated that among the different medicinal and aromatic plant extracts evaluated, the NSKE at 5 percent was found superior in reducing population of DBM on cabbage as it was evident from the data on pooled mean (0.43/plant) and percent reduction (74.04 %) over control after three rounds of spraying. The reduction of the insect population recorded in neem could be due to their pungent and repellent mode of action against the pest (Figure 1).

Results of the present investigation are in close agreement with findings of Iqbal *et al.* (2015) [5] who reported superior efficacy of neem against diamond back moth on cabbage varieties such as Green Charm, Alphet and Prize by recorded 82.19, 84.19 and 84.65 percent reduction in larval population, respectively after seven days of first spray. Present findings are also in confirmation with the findings of Jitendra *et al.* (2017) [6] who reported that, spinosad was showed 57.41 percent larval reduction in field trail against DBM and found best treatment after the chloropyriphos (61.78%). Similarly, Begna (2017) [2] reported that neem significantly reduced the DBM larval and pupal population (2.25 and 0.50 per plant) after sixth week compared to other tested botanicals. Akbar *et al.* (2014) [1] also reported the superior efficacy of neem against *Plutella xylostella* on cabbage (6.0 larvae/plant).

The activities of natural enemies were also observed and recorded from the plots sprayed with plant extracts which were evaluated against DBM on cabbage. Similar kind of natural enemies activities were also observed in the cabbage ecosystem by Klemm and Schmutterer (1993) [7] who reported that spraying of NSKE against DBM did not affect the parasitization of DBM eggs by the trichogrammatid parasitoids. Sahana and Tayde (2017) [10] also observed higher activities of spiders and coccinellids in brinjol ecosystem sprayed with spinosad 0.1 ml/l, neem oil 3

percent, pongemia oil at 3 percent, NSKE at 5 percent and neem leaf extract 50 ml/lit. Thus, these plant products proved their safety to spiders and coccinellids by recording 0.46 to 0.63 per plant, and they were on par with untreated check.

The present findings are also close agreement with that of Jitendra *et al.* (2017) [6] who reported that the plot treated with spinosad showed yield of 275.15 q/ha, followed by NSKE at 2 percent (138.15 q/ha), neem leaf extract at 10 percent (130.15 q/ha) and untreated control (70.32 q/ha).

The present findings in respect of cost-benefit ratio are in close agreement with Devi and Tayde, (2017) [3], who reported that, the highest cost benefit ratio was obtained with NSKE (1:6.9) followed by Neem oil (1:6.8) and varied from 1:3.1 to 1:6.9 in different insecticidal treatments against *Plutella xylostella* on cabbage. The present findings on yield and benefit cost ratio obtained with spinosad are in line with Suresh Singh and Tayde (2017) [11], who also obtained highest yield and benefit cost ratio in spinosad 45 SC (195.22 q/ha and 1:7.06, respectively).

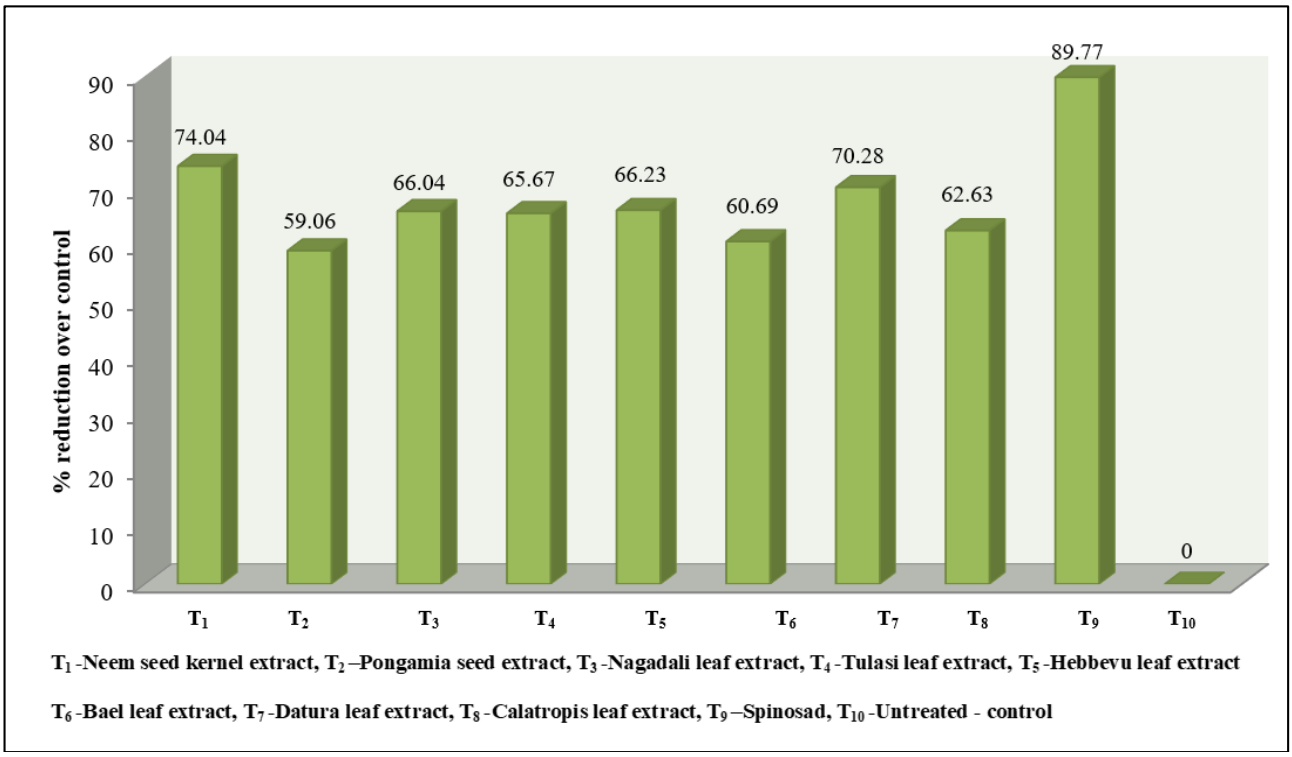


**Fig 1:** Field efficacy of promising medicinal and aromatic plants against *Plutella xylostella* on cabbage crop.

## Conclusion

Results of the field trail clearly concluded the superior efficacy of 5 percent NSKE against DBM on cabbage as that of other plant extracts evaluated. However, the other plants extract such as pongamia, datura, bael, calatropis and hebbevu exhibited moderate effectiveness against DBM. Further, the plots treated with the plants extract had maximum activity of natural enemies such as *Cotesia plutellae* and spiders as compared to chemical insecticide sprayed plots. The NSKE, besides exhibiting its superior efficacy against DBM, it also registered highest cabbage yield and B:C ratio of 2.48, followed by leaf extract of datura (2.15), bael (2.05), tulasi (1.64), nagadali (1.41), hebbevu (1.35), pongamia (1.25), and calotropis (1.20).

On the whole, it is evident from field studies that the NSKE, leaf extract of datura, bael, tulasi, nagadali, hebbevu and calotropis, and seed extracts of pongamia were found promising medicinal and aromatic plants by exhibiting their superior insecticidal activity against Diamondback moth and can be effectively utilized in sustainable cabbage pest management practices.

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