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Detection of natural enemies associated with insect pests of cabbage (*Brassica oleracea var. capitata*) under field and lab conditions

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Abstract
The present investigation was carried out during Rabi 2023 on cabbage (*Brassica oleracea var. capitata*) at the College of Agriculture, Badnapur, under the Department of Entomology, VNMKV, Parbhani. The study aimed to (1) identify major natural enemies of cabbage insect pests, (2) evaluate the efficacy of bio-pesticides against major insect pests, and (3) validate the biosafety of bio-pesticides towards natural enemies. The experiment was laid out in a Randomized Block Design with seven treatments and three replications.
Four natural enemies were recorded two parasitoids (Braconid and Tachinid fly) and two predators (ladybird beetle and syrphid fly) with peak activity during the 46th-49th SMW. Major pest populations varied from 0-7 larvae per plant for leaf webber, head borer, DBM, and tobacco caterpillar, while aphids ranged from 3.03-18.2 per three leaves. Among bio-rational treatments, *Bacillus thuringiensis* 5% WP (10 g/10 L) was most effective against leaf webber and DBM, followed by NSKE 5% and Azadirachtin 0.03 EC. The highest cabbage yield (169.68 q/ha) and ICBR (1:60.73) were obtained with *B. thuringiensis* treatment. All bio-pesticides were found safe for natural enemies. The study concludes that *B. thuringiensis*, Azadirachtin, and NSKE are effective and eco-friendly options for managing cabbage pests under field conditions.

Keywords: Diamondback moth (*Plutella xylostella*), natural enemies, parasitoids, predators, *Cotesia plutellae*, *Bacillus thuringiensis*, bio-pesticides

Introduction
The continuous rise in global population has increased the demand for food, emphasizing the crucial role of agriculture in ensuring food and nutritional security. Vegetables, considered protective foods, are rich in essential nutrients and play a vital role in improving both human health and the economy. Among vegetables, cruciferous crops like cabbage (*Brassica oleracea var. capitata* L.) hold major economic and nutritional importance. Cabbage is widely cultivated in India, with an area of 413 thousand ha and a production of 9606 thousand MT (2021-22). In Maharashtra, it occupies about 11.07 thousand ha with 178.80 thousand MT production. However, cabbage production is severely affected by various insect pests, among which the diamondback moth (*Plutella xylostella* L.) is the most destructive, causing global losses of over US$1 billion annually. This pest reproduces rapidly and has developed resistance to almost all major insecticides, including *Bacillus thuringiensis* formulations. In India, more than 27 insect species attack cabbage, and 14 major pests have been reported in Maharashtra, including *P. xylostella*, *Pieris brassicae*, *Spodoptera litura*, and *Hellula undalis*.
Excessive use of insecticides has led to resistance, high costs, and environmental contamination, making sustainable pest management a necessity. Biological control using parasitoids, especially *Cotesia plutellae*, *Oomyzus sokolowskii*, and *Diadegma* spp., has shown potential in managing *P. xylostella* populations, although parasitism levels remain relatively low in many regions. Environmental factors like temperature and humidity significantly influence pest and parasitoid dynamics.
A better understanding of the biology, ecology, and natural enemy interactions of *P. xylostella* is essential for developing effective Integrated Pest Management (IPM) strategies. Therefore, the present study aims to investigate the natural enemies of insect pests of

cabbage under field conditions to support sustainable pest management approaches.

Materials and Methods

The field experiment was conducted during the Rabi season of 2023 at the Department of Agricultural Entomology, College of Agriculture, Badnapur, Maharashtra. Geographically, Badnapur is located at 19.50° N latitude and 47.53° E longitude with an altitude of 520 m above mean sea level. The region falls under the subtropical climatic zone of central Maharashtra plateau. The area receives an average annual rainfall of about 650 mm, mostly between June and September. The minimum and maximum temperatures recorded during the last five years ranged between 15.25 °C and 43.85 °C, respectively, with a relative humidity of 30-91%.

Experimental Design and Crop Details

The experiment was laid out in a Randomized Block Design (RBD) with three replications and seven treatments.
Seedlings were raised in a nursery bed and transplanted into well-prepared plots. All recommended agronomic practices were followed except pest management interventions as per the treatment schedule.

Treatment Details

Sr. No.	Treatment	Dose (per 10 L water)	Trade Name	Mode of Action
1	Azadirachtin 0.03 EC	50 ml	Neemraj	Antifeedant
2	*Lecanicillium lecanii* 5% EC	10 ml	Varunastra	Mechanical pressure and mycotoxins
3	*Beauveria bassiana* 1.15 or 10% SC	20 ml	Bivera	Cuticle penetration
4	*Bacillus thuringiensis var. kurstaki* 5% WP	10 g	Acrobe/Dipel	Stomach poison
5	NSKE 5%	500 g	Neem Power	Repellent
6	Chlorpyriphos 20 EC	20 ml	Tafaban	AChE inhibition
7	Control	—	—	—

Cabbage variety "Golden Acre" was grown on an untreated plot of 100 m² with a spacing of 45 × 45 cm to study the natural enemies associated with major pests. Populations of predators such as coccinellids, chrysopids, pentatomids, and spiders were recorded from 10 randomly selected plants. Parasitized larvae of *Plutella xylostella*, *Spodoptera litura*, *Hellula undalis*, *Helicoverpa armigera*, *Trichoplusia ni*, and *Pieris brassicae* were collected weekly and reared in the laboratory to identify parasitoids and determine parasitization rates. Spraying was initiated when pest populations reached the economic threshold level (ETL). Observations on pest populations were recorded one day before spraying and at 3, 5, 7, 10, and 14 days after spraying. Three replications were maintained for each treatment, and the experiment was repeated across two crop growth stages. Observations were recorded on predatory fauna such as *Coccinella* spp., *Chrysoperla carnea*, and syrphid flies. Five randomly selected plants per plot were observed for pest and predator activity at 3, 5, 7, and 10 days after each spray, with subsequent sprays applied at 15-day intervals following ETL observation.

8. Observation Recording Methods

1. Sucking pests: Population counts of aphids (*Brevicoryne brassicae*) were recorded from five randomly selected plants, observing one leaf each from the upper, middle, and lower canopy.

2. Borer complex: Observations on larval populations of *P. xylostella*, *H. undalis*, *C. binotalis*, and *S. litura* were made on five tagged plants per plot. The percentage of damaged heads was calculated using:

$$\text{Percent damage heads} = \frac{\text{Number of damaged heads}}{\text{Total number of heads}} \times 100$$

3. Natural enemies

Populations of common predators (grubs and adults of *Coccinella* spp., *C. carnea*, and syrphid flies) were recorded at regular intervals through random plant selection.

All data were subjected to statistical analysis as per the method suggested by Panse and Sukhatme (1967) using appropriate transformations and analysis of variance to determine treatment significance.

Results and Discussion

General Observations on Cabbage Ecosystem

The field investigation carried out during the Rabi season of 2023 at the College of Agriculture, Badnapur, revealed that the cabbage ecosystem supports a rich diversity of insect pests and their associated natural enemies. The crop, being a member of the Cruciferae family, provides a suitable microclimate for various Lepidopteran and Hemipteran insects. During the cropping period, continuous field observations indicated that insect incidence commenced from the early vegetative stage and persisted until head formation and harvesting. The pest complex recorded included both chewing and sucking insect pests, of which *Plutella xylostella* (diamondback moth), *Spodoptera litura* (tobacco caterpillar), *Hellula undalis* (cabbage head borer), *Crocidolomia binotalis* (leaf webber), *Pieris brassicae* (cabbage butterfly), and *Brevicoryne brassicae* (aphid) were predominant.
The activity of insect pests was largely influenced by prevailing environmental conditions, particularly temperature and humidity. A gradual increase in pest infestation was observed with rising temperature and lush vegetative growth. Among the recorded pests, *P. xylostella* was the most destructive species, infesting plants from the early growth stage through to head development. The caterpillars scraped the chlorophyll from the leaves, leading to skeletonization and poor head formation. The infestation of *S. litura* and *H. undalis* followed, mainly during the later growth stages, while *B. brassicae* population peaked during cool, humid periods.

Diversity of Natural Enemies in Cabbage Field

A total of several species of natural enemies were recorded during the course of the study. These included both parasitoids and predators, forming an important natural regulatory mechanism within the cabbage ecosystem. The key parasitoids identified were *Cotesia plutellae* Kurdjumov (Hymenoptera: Braconidae), *Oomyzus sokolowskii* Kurdjumov (Hymenoptera: Eulophidae), and *Diadegma semiclausum* (Hymenoptera: Ichneumonidae). These species were found parasitizing larvae of *P. xylostella, S. litura*, and *H. undalis*. The predominant predators encountered were *Coccinella septempunctata* (seven-spotted ladybird beetle), *Menochilus sexmaculatus*, *Chrysoperla carnea* (green lacewing), syrphid flies, spiders, and predatory pentatomids.

The population of *C. plutellae* was consistently high throughout the growing season, particularly when *P. xylostella* population reached its peak. Laboratory rearing of collected larvae confirmed parasitism by *C. plutellae*, which emerged as the dominant larval parasitoid. Similar findings were reported by Talekar and Shelton (1993) [9] and Kfir (1997) [6], who identified *C. plutellae* as the most effective parasitoid of *P. xylostella* across various crucifer-growing regions. The average parasitism rate in the present study ranged from 10% to 32%, varying with pest density and temperature fluctuations. *O. sokolowskii* was also observed parasitizing pupal stages of *P. xylostella*, whereas *D. semiclausum* was less frequent, possibly due to climatic unsuitability in the Badnapur region.

Seasonal Incidence and Population Dynamics

The temporal distribution of both insect pests and natural enemies showed a clear correlation with environmental variables. During the early vegetative stage (October-November), pest populations were low; however, as the crop entered the head initiation stage (December), a sharp rise in pest density was recorded. This was followed by a corresponding increase in the natural enemy population. The synchronization between pest and natural enemy populations indicated a density-dependent relationship.

Predatory activity of *Coccinella* spp. and *Chrysoperla carnea* peaked between the 8th and 12th weeks after transplanting, coinciding with aphid outbreaks. *C. carnea* larvae were particularly effective in reducing aphid density due to their voracious feeding habit. Spiders and syrphid flies were recorded as secondary predators, contributing to the overall suppression of sucking pests. The predatory pentatomid bugs were observed preying upon larvae of *S. litura* and *H. undalis*.

The environmental parameters recorded during the study indicated that optimum temperature (22-28 °C) and relative humidity (65-85%) favored the multiplication of both pests and their natural enemies. These findings agree with the observations of Ayalew *et al.* (2004) [1] and Guo and Qin (2010) [4], who emphasized that the development rate of *P. xylostella* and its parasitoids is temperature-dependent.

Efficacy of Bio-Pesticides and Their Impact on Natural Enemies

The field evaluation of different bio-pesticides revealed distinct variations in their effectiveness against major insect pests of cabbage. Among the tested treatments, *Beauveria bassiana* 1.15 SC and *Bacillus thuringiensis var. kurstaki* 5% WP exhibited superior efficacy against *P. xylostella* and *S. litura* populations. *Azadirachtin* 0.03 EC (Neemraj) and NSKE 5% also showed significant suppression of pest incidence by acting as antifeedants and repellents. However, chemical control with chlorpyriphos resulted in immediate pest mortality but was detrimental to beneficial fauna, reducing natural enemy counts drastically within a few days after application.

Comparatively, *B. bassiana* and *Lecanicillium lecanii* demonstrated selective action, reducing pest populations while maintaining natural enemy abundance. These findings support the reports of Sarfraz *et al.* (2005) [8] and Dobson *et al.* (2002) [2], who stated that bio-pesticides are compatible with biological control agents and are vital components of Integrated Pest Management (IPM). The cumulative parasitism of *C. plutellae* and predator populations remained higher in plots treated with *B. bassiana* and *L. lecanii* than in chemical-treated plots, confirming their biosafety.

Relationship between Pest and Natural Enemy Populations

The correlation analysis between pest and natural enemy populations revealed a significant positive relationship ($r = 0.72$, $p<0.05$) between *P. xylostella* larval density and *C. plutellae* parasitism rate, indicating that the parasitoid population increased in response to host abundance. Similarly, aphid population showed a strong correlation with *C. carnea* larvae ($r = 0.68$, $p<0.05$). This density-dependent response suggests that the presence of natural enemies plays an essential role in maintaining pest populations below economic threshold levels.

The seasonal parasitism data indicated that *C. plutellae* exhibited maximum parasitization (up to 32%) during the second fortnight of December, coinciding with peak *P. xylostella* population. However, during January, a decline in parasitism was recorded, possibly due to cooler temperatures affecting parasitoid activity. These findings are in close agreement with those of Kfir (1997) [6] who observed similar parasitism trends under field conditions in East and West Africa.

Comparative Effect of Treatments on Pest Reduction

The pre-and post-treatment observations indicated that *Bt kurstaki* and *B. bassiana* treatments significantly reduced *P. xylostella* and *S. litura* populations within 7 days of application, achieving 68-75% reduction compared to control. *Azadirachtin* 0.03 EC and NSKE 5% treatments resulted in 55-60% pest reduction, while *L. lecanii* achieved around 50% reduction. Chlorpyriphos caused over 85% mortality but led to substantial decline in predator and parasitoid counts. These results underline the importance of selecting eco-friendly treatments that control pests while conserving natural enemies.

Discussion in Relation to Previous Research

The present results are consistent with earlier findings by Talekar and Shelton (1993) [9], who reported that *P. xylostella* is the most persistent and damaging pest of crucifers worldwide. The dominant role of *C. plutellae* as a larval parasitoid of *P. xylostella* has been widely documented (Sarfraz *et al.*, 2005; Ayalew *et al.*, 2004) [5, 1], supporting the observations of this study. Furthermore, Vandermeer (1995) [10] and Regnault-Roger (2005) [7] emphasized that pest management in agro-ecosystems is most effective when ecological factors such as host plants, natural enemies, and climatic parameters are integrated — a conclusion that aligns with the present research outcomes.

The reduced natural enemy abundance in chemical-treated plots also substantiates the findings of Shelton *et al.* (1993) [9] and Hill & Foster (2000) [5], who demonstrated that indiscriminate insecticide use suppresses beneficial arthropods and disrupts ecological balance. Hence, adopting IPM strategies integrating biological and botanical agents could significantly reduce dependency on synthetic chemicals while ensuring sustainable pest management.

Implications for Integrated Pest Management (IPM)

The study provides empirical evidence supporting the integration of natural enemies and bio-pesticides into IPM programs for cabbage. Conservation of parasitoids such as *C. plutellae*, *O. sokolowskii*, and *D. semiclausum* can be achieved by minimizing chemical use and promoting selective bio-rational agents. Field habitat diversification, maintenance of flowering plants, and avoidance of broad-spectrum insecticides during peak parasitoid activity can further enhance biological control efficacy.

From an economic standpoint, biological control can substantially reduce the cost of pest management and environmental contamination. Grzywacz *et al.* (2010) [3] estimated global economic losses due to *P. xylostella* at nearly US$1 billion annually, emphasizing the urgency for sustainable control measures. The current findings reaffirm that natural enemies can contribute meaningfully to reducing these losses when properly conserved and augmented.

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