

Soil arthropods and natural enemies' abundances in broccoli crops treated with insecticides

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Abstract. Heviyanti M, Dadang, Sartiami D, Kusumah RYM, Purwantiningsih. 2025. Soil arthropods and natural enemies' abundances in broccoli crops treated with insecticides. *Biodiversitas* 26: 1698-1705. Indonesia is known as one of the countries with the highest biodiversity in the world, consisting of a rich variety of flora and fauna across terrestrial and marine ecosystems. However, the excessive and inappropriate use of synthetic insecticides has led to a significant decline in biodiversity, including the death of natural enemies and the disruption of soil microorganisms. An environmentally sustainable alternative for pest control is the application of botanical insecticides. Therefore, this research aimed to assess the effect of the application of 50EC botanical insecticide, a mixture of spike pepper (*Piper aduncum*) and Chinese perfume (*Aglaia odorata*) (2:1 w/w) extracts on *Plutella xylostella* population and the abundance of soil arthropods and natural enemies in broccoli (*Brassica oleracea* var. *italica*) crops. Observations of the *P. xylostella* population were carried out by direct observation on sample plants from the second to the ninth Week After Planting (WAP). The diversity and abundance of soil arthropods and natural enemies were assessed using pitfall traps. The results showed that the 50EC botanical insecticide demonstrated a level of effectiveness comparable to that of synthetic insecticides containing the active ingredient emamectin benzoate and microbial insecticide with an active ingredient of *Bacillus thuringiensis* in controlling *P. xylostella*. The number of arthropod individuals obtained was 6,441, belonging to 3 classes, 12 orders, 32 families, and 62 morphospecies. The order Entomobryomorpha was the most abundant, accounting for 37.96% of the total arthropod population. In terms of species richness, the order Hymenoptera was predominant, contributing 25.00% and being largely represented by the Formicidae family. The highest number of arthropod individuals (1748) was recorded in the treatment involving the 50EC botanical insecticide. These findings support the use of botanical insecticides as an eco-friendly pest control solution that can reduce pesticide residues and promote sustainable farming practices.

Keywords: *Aglaia odorata*, biodiversity, botanical insecticides, morphospecies, pitfall trap, *Plutella xylostella*

INTRODUCTION

Broccoli (*Brassica oleracea* var. *italica*) is a high-value vegetable commodity in Indonesia, recognized for its nutritional and commercial significance. As a rich source of nutrients and antioxidants, broccoli plays a crucial role in promoting heart health, detoxifying the body, and addressing food security needs (Khrychov and Chernushenko 2023; Yan et al. 2023). Despite its potential, broccoli cultivation faces major challenges from pests and plant diseases. One of the primary pests affecting broccoli is diamondback moth (*Plutella xylostella*) which causes severe damage to the plant (Gu et al. 2022). In case of heavy attacks, yield losses can reach up to 100% if control is not carried out (Farias et al. 2021). To date, the control of *P. xylostella* has relied heavily on the application of synthetic insecticides. However, the unregulated and excessive use of these insecticides has resulted in various adverse consequences, including resistance, resurgence, and death of non-target insects (Dadang 2023). The death of non-target pests such as predatory insects, parasitoids,

and decomposers will decrease abundance and biodiversity (Paudel et al. 2022; Rinki et al. 2023).

The loss of biodiversity has wide-reaching effects that greatly impact food security, ecosystem health, and the sustainability of natural resources (Kumar et al. 2024). These impacts include the loss of crop varieties because of genetic erosion and dependence on a few varieties, soil quality degradation from intensive farming and improper pesticide use, and increased crop vulnerability to pests and diseases. These factors lead to unstable food production and a decline in ecosystem functions, causing imbalances (Kumar et al. 2024; Maurya et al. 2024). This imbalance can lead to pest population explosions and greater reliance on synthetic insecticides by farmers. However, misuse of these insecticides can harm biodiversity, kill natural predators, and damage soil microorganisms (Dadang 2023).

Synthetic insecticides, commonly used to control pests, are often non-selective, damaging not just pests but also beneficial insects such as bees and predators of pests. Research by Buchori et al. (2020) showed the presence of neonicotinoid residues in bees and honey, albeit in small

amounts. Additionally, synthetic insecticides disrupt the ecosystem balance, leading to an increase in pest populations as they develop resistance to these chemicals (Ara and Haque 2021). The adverse effects of synthetic insecticides extend to human health, as pesticide residues in the food chain have been linked to chronic conditions such as cancer and hormonal disorders (Vishaka et al. 2023; Ahmad et al. 2024). Then, to address this issue, organic farming has become a more environmentally friendly alternative. In organic agriculture, synthetic pesticides are avoided and replaced with plant-based insecticides derived from secondary metabolites (Priyanka et al. 2024; Tahir et al. 2024). These metabolites, such as alkaloids and terpenoids, are the plant's natural defense against pests. Organic farming also encourages crop rotation and the use of natural fertilizers and helps maintain soil ecosystem balance, thereby enhancing the sustainability of food production and supporting biodiversity conservation (Rengasamy et al. 2022).

Plant-based insecticides play an essential role in Integrated Pest Management (IPM) systems, which combine various pest control methods comprehensively and sustainably. Unlike conventional methods that rely heavily on chemical insecticides, IPM incorporates various strategies such as crop rotation, natural enemy management, and habitat management to suppress pest development without damaging the ecosystem (Silva et al. 2022). This approach has proven effective in reducing the negative impacts of synthetic insecticide use on the environment and human health. Various types of plants have the potential to produce active compounds that can function as botanical insecticides. Among the plants that show this potential, *Piper aduncum* and *Agliaia odorata* have attracted attention as sources of plant-based insecticides (Ngo et al. 2021). *Piper aduncum* contains alkaloids, flavonoids, and terpenoids that are toxic and repellent to several pest species. Meanwhile, *A. odorata*

also contains active compounds such as alkaloids and essential oils that have the potential to repel or kill the pest insects (Mahfud 2016; Lina et al. 2017). These plants have long been used in traditional medicine and as insect deterrents. The fruit of *P. aduncum* hexane extract and twigs of *A. odorata* methanol extract, both singly and in the mixture (2:1 w/w), are known to have good insecticidal activity against *P. xylostella* larvae, as well as the emulsifiable concentrate (50EC) formulation (unpublished data). Therefore, this research aimed to assess the effect of applying 50EC, a mixture of *P. aduncum* and *A. odorata* (2:1 w/w), on the *P. xylostella* population and abundance of soil arthropods and natural enemies in broccoli crops.

MATERIALS AND METHODS

Study area

This research was conducted in Buniaga Hamlet, Ciherang Village, Pacet Sub-district, Cianjur District, West Java, Indonesia (6°45'26.6"S 107°02'59.0" E) (Figure 1). The identification of soil arthropods and calculation of the abundance of soil arthropods and natural enemies were conducted at the Insect Physiology and Toxicology Laboratory, Department of Plant Protection, Faculty of Agriculture, Institut Pertanian Bogor, Bogor, West Java.

Procedures

Land preparation and insecticide application

Before planting, the soil was loosened by digging to a depth of 30 cm. The planting plots measured 4×5.5 m, each containing 24 plots with 4 beds measuring 1×3 m, and the total plants per plot are 64 plants Three-week-old Bejo variety broccoli seedlings with four leaves were transplanted at a spacing of 70×50 cm, and each planting hole was given a basal fertilizer of approximately 500 g of manure.

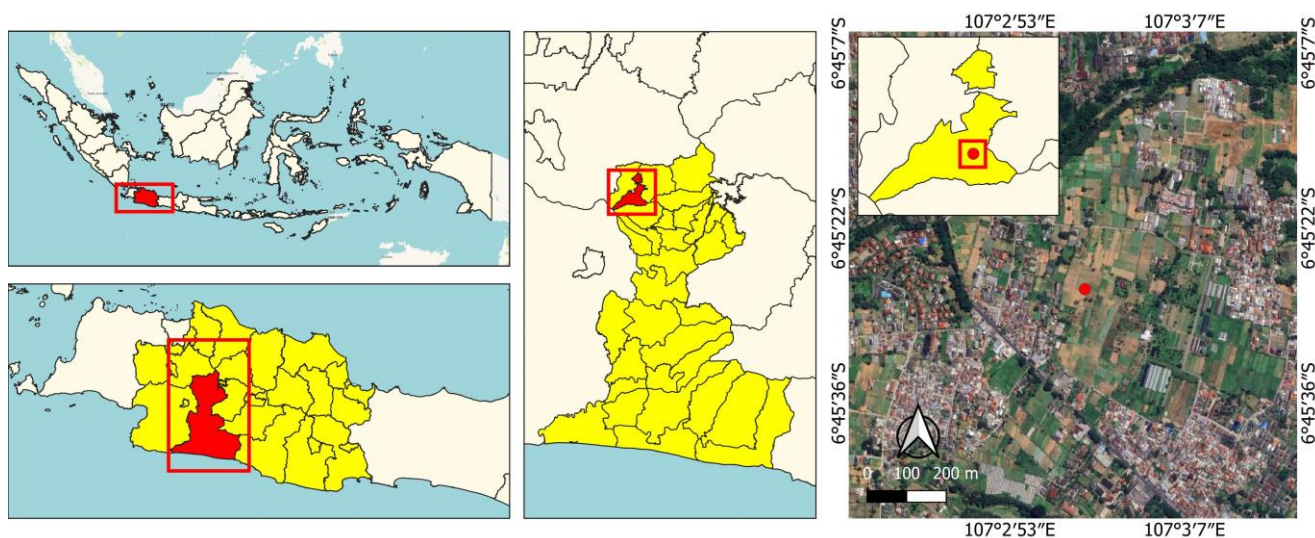


Figure 1. The location of the broccoli plantation in Buniaga Hamlet, Ciherang Village, Pacet Sub-district, Cianjur District, West Java, Indonesia

Watering was done daily until the broccoli plants established (lilir) and then adjusted as needed. Replanting (resowing) was carried out if any plants died and was stopped after the plants reached 10-15 days after transplanting. Weeding and soil loosening (earthing-up) were done alongside the first and second fertilization, which took place when the plants were 1, 3, and 5 weeks after planting. The treatment processes consisted of botanical insecticide (50EC formulation of *P. aduncum* and *A. odorata* mixture), microbial insecticide (Agrisal WP; *Bacillus thuringiensis* as an active ingredient), synthetic insecticides (Emacel 30 EC; emamectin benzoate as an active ingredient), and control.

The concentration of the tested plant-based insecticide formulations was determined based on the results of toxicity tests in the laboratory (equivalent to $2 \times LC_{95}$). Meanwhile, the comparison insecticides were applied at the recommended concentrations, namely the bioinsecticide *B. thuringiensis* at 2 g/L and the synthetic insecticide emamectin benzoate at 1.5 mL/L. Initial spraying was carried out when at least one of the *P. xylostella* larvae/ten plants were found in the cabbage plants. Subsequent insecticide spraying was carried out weekly using a knapsack sprayer.

Observation of *Plutella xylostella* population

Observation of the *P. xylostella* pest population involves monitoring the total population. Observations were conducted directly on sample plants from the second to the ninth Week After Planting (WAP). The population of *P. xylostella* was counted based on the number of larvae and pupae found on sample plants in each treatment. Six sample plants were selected for each treatment plot (Figure 2).

Evaluation of soil arthropod population and natural enemies' abundances

Monitoring soil arthropod abundance was conducted using pitfall traps (3 traps per treatment plot) (Figure 3). The traps were constructed using plastic cups measuring 50 mm in diameter and 100 mm in height. Each cup was filled to one-third of its capacity with a soap solution and then placed into pre-dug holes, ensuring the rim of the cup was flush with the soil surface. A cover was placed over the cup to prevent the trap from being exposed to rainwater. Traps were set on both ends on the first, second, and fourth beds, and trap installation was carried out 4 times, specifically at 2, 4, 6, and 8 WAP for 24 hours. Trapped arthropods were placed into plastic bottles containing 96% alcohol, then identified in the laboratory, counted, and recorded.

Data analysis

The mean population of *P. xylostella* larvae was analyzed using variance analysis in Minitab version 18, followed by Tukey's test at a 5% confidence level to determine the differences in mean values between treatments. The arthropods collected were identified to the morphospecies level using identification books by Zborowski and Storey (1995), Borror et al. (1996), and the website www.bugguide.net, managed by Iowa State University Entomology. The identification was performed using an Olympus SZ51 light microscope, and the

identified arthropods were tabulated into a database as a pivot table. Arthropod specimens were categorized based on their ecological roles, which include phytophagous, parasitoids, predators, pollinators, and detritivores using multiple identification resources. Scientific literature and research papers were consulted to determine the functional roles of identified species. Additionally, online databases and identification tools, such as iNaturalist, were used to cross-check species identification and ecological functions.

Expert consultation with entomologists and taxonomists further verified the classification. The pest-natural enemy ratio was calculated from the total pest-to-natural enemy ratio found, followed by analysis using the Shannon-Wiener Diversity Index (H') and species Evenness Index (E'). The following formula is used to estimate it: $(H') = H' = \sum_{i=1}^n Pi \ln(Pi)$; $(Pi=ni/N)$; ni : number of individuals per species; N : number of individuals of all species. Where $H' < 1.5$: low diversity, $1.5 < H' < 3.5$: moderate diversity, $H' > 3.5$: high diversity (Magurran 1988). Equitability (E) which is the ratio between the maximum diversity (H' max) is represented as follows: $E = H'/H' \text{ max}$ (E : Equitability Index; H' : Shannon-Weaver Diversity Index; $H' \text{ max}$: Maximum diversity obtained by the following formula $H' \text{ max} = \log_2(S)$ (S : The number of species forming the stand) (Frahtia et al. 2022).

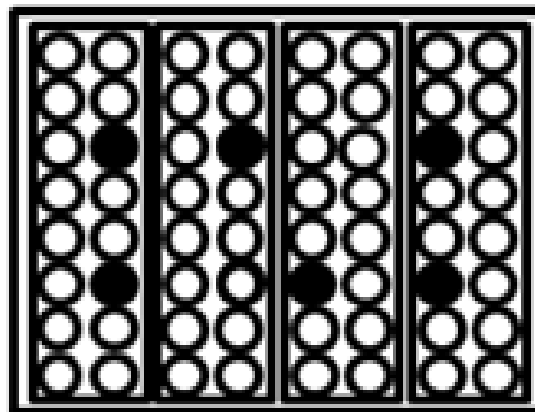


Figure 2. Determination of sample plants in each treatment plot
Note: ● : Broccoli sample; ○ : Broccoli non-sample

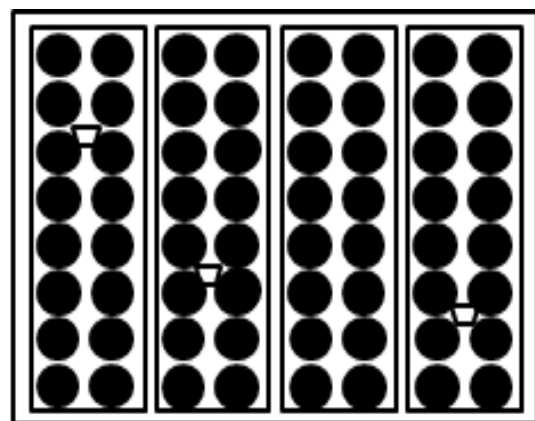


Figure 3. Pitfall trap placed in experimental plots. Note: ● : Broccoli plants; ◻ : Pitfall traps

RESULTS AND DISCUSSION

Population development of *Plutella xylostella*

Observations on the effect of different insecticide applications on *P. xylostella* populations in the field showed variations in the effectiveness of pest control (Figure 4). It was noted that *P. xylostella* larvae started to appear approximately 2 weeks after planting in both the treatment and control groups. The population of *P. xylostella* in the field increased along with the increase in plant age until the formation of flowers and before harvest. Five weeks after planting, the population of *P. xylostella* in the control group decreased from 0.42 to 0.11 larvae per plant. Meanwhile, the population in the botanical insecticide treatment remained low (0.17 larvae per plant), whereas the microbial and synthetic insecticides showed an increase to 0.31 and 0.53 larvae per plant, respectively. Subsequently, in the control, which received no insecticide treatment, the *P. xylostella* population increased significantly after 5 weeks of planting, peaking at around 2.5 larvae per plant at 7 weeks. In general, the population of the larvae in the control group was higher than in the treatment group. This may indicate that insecticide effectiveness can fluctuate depending on environmental conditions and pest development in the field.

Insect population fluctuations are influenced by complex interactions among environmental conditions such as climate, microclimate, natural enemies, biological interactions such as population density and tropic interactions, and human activities such as pesticide use, habitat destruction, and climate change (Solbreck et al. 2022). The high rainfall observed at 3-4 WAP caused a significant decrease in *P. xylostella* population. However, the population increased again at 6-7 WAP and then decreased when entering harvest time. The increase in *P. xylostella* population in the field was due to low rainfall and punctuated by frequent heat at 6-9 WAP until harvest.

The treatment of botanical insecticide showed good effectiveness in suppressing pest populations of about 5 WAP, with populations remaining consistently low, below 0.5 larvae per plant. Despite an increase after 5 WAP, this treatment was still able to keep the population below 1.0 larvae per plant until the end of the observation, indicating that this plant-based insecticide is quite effective in controlling *P. xylostella*. Meanwhile, the microbial insecticide containing *B. thuringiensis* also showed good results in suppressing the pest population at the beginning of the observation. However, its effectiveness declined after 6 WAP, with the larval population reaching approximately 1.0 larvae per plant by 8 WAP. Despite this decline, the microbial insecticide treatment remained more effective than the control, demonstrating that microbial insecticides provide reasonably good pest control. However, their efficacy is not as strong as that of plant-based or synthetic insecticides. Treatment with synthetic insecticide (emamectin benzoate) also provided effective control throughout the observation. The population of *P. xylostella* remained low until 6-9 WAP, and even after a slight increase at 7-8 WAP, the pest population could still be maintained below 1.0 larvae per plant until 9 WAP.

Statistical analysis showed no significant differences among botanical insecticide and synthetic insecticide (F: 5.62; P: 0.006), but demonstrated significant differences compared to the control (Table 1). Post hoc Tukey's test indicated that the control was significantly different from the treatments (P<0.05), while there were no significant differences among the botanical insecticide and synthetic insecticide treatments (P>0.05). The average larval population of *P. xylostella* on broccoli plants indicated that insecticide treatments significantly reduced the larval population compared to the control. The larval population in the control group had the highest average compared to other treatments. This indicates that treating botanical insecticide formulations containing *P. aduncum*: *A. odorata* (2:1 w/w) extracts are as effective as synthetic and microbial insecticides. The treatment of botanical insecticide showed the highest efficacy, reaching 87.50% at 3 WAP and consistently remained above 60% up to 9 WAP. The microbial insecticide reached its peak efficacy of 82.78% at 7 WAP, while the synthetic insecticide (emamectin benzoate) achieved a maximum efficacy of only 57.24% at 9 WAP. These findings suggest that the effectiveness of synthetic insecticides against *P. xylostella* is relatively low.

Abundance and diversity of arthropods

Based on different insecticide treatments applied to broccoli crops, 6,441 arthropod individuals belonging to 3 classes, 12 orders, 32 families, and 62 morphospecies were collected. The most dominant class of arthropods was insects, with 9 orders, and other arthropod classes found were Arachnids and Entognaths. Hymenoptera was the order with the highest species richness. There were 15 morphospecies in the Hymenoptera order, making up 25.00% of the total morphospecies found. Approximately 32.96% of the species richness in the Hymenoptera order was identified as belonging to the Formicidae family.

The subsequent highest species richness was reported in the Coleoptera order (21.67%), followed by Araneae (11.67%), Hemiptera (10.00%), Acarine (8.33%), Dermaptera (5.00%), Orthoptera (5.00%), Entomobryomorpha (5.00%), and Blattodeae (3.63%). The order Entomobryomorpha was found to have the highest abundance of individuals at 37.96%. The subsequent highest abundance of individuals was arthropods of the order Hymenoptera (33.97%), followed by Acarine (7.92%), Araneae (5.54%), Coleoptera (4.27%), and Dermaptera (4.55%) (Table 2).

The total of arthropods found in each insecticide treatment includes botanical insecticide (4.2 mL/L) with 1748 individuals, microbial insecticide (2 g/L) with 1,615 individuals, synthetic insecticide (1.5 mL/L) with 1,405 individuals, and the control with 1,673 individuals (Table 3). Treatments with plant-based pesticides, a promising alternative, showed a dominance of arthropods functioning as decomposers and phytophagous, indicating that plant-based pesticides tend to be more selective and have a lower impact on decomposers and other non-target arthropods. Microbial insecticides reduced the number of phytophagous arthropods while still allowing decomposers and predators to persist. In contrast, synthetic insecticides

reduced arthropod populations across almost all categories, including predators and parasitoids (Figure 5). This indicates the less selective nature of synthetic pesticides and their potential to disrupt ecosystem balance. These numbers reflect the effect of various pesticides on the arthropod population in broccoli cultivation.

The Shannon-Wiener Diversity Index (H') was used to assess species variation within the arthropod community, with all treatments showing uniform values ranging from 3.00 to 3.03. This indicates that arthropod species diversity is relatively stable and not significantly affected by the use of insecticide. The Evenness Index (E) showed that the synthetic insecticide treatment has the highest evenness (0.44), followed by the control (0.42), microbial insecticide (0.41), and botanical insecticide (0.38). A higher evenness value in the synthetic insecticide treatment suggests that arthropod individuals were more evenly distributed among species compared to other treatments. Conversely, the lower evenness observed in botanical insecticide treatment shows that in areas sprayed with this insecticide, some species may be more dominant than others. This suggests that botanical insecticide might substantially affect specific species, allowing others to dominate the community.

Species diversity within a community is often influenced by the ability of species to withstand external pressures, such as insecticide application (Bhattacharyya et al. 2023). Selective insecticides, as observed in botanical insecticides, may only affect certain species, while more resistant species dominate the community, thereby reducing overall diversity. However, statistically, the Shannon-Wiener diversity index and Evenness values for all insecticide treatments did not show significant differences based on Tukey's test at the 5% level; they exhibited moderate criteria (>3.00) (Table 4). The uneven distribution in botanical insecticide suggests selective pressure that causes certain species to reproduce more quickly while others decline. This could be due to the specific tolerance of some arthropod species to the active ingredients in botanical insecticide, allowing these species to dominate (Lina et al. 2017). In contrast, the more balanced distribution observed with synthetic insecticides indicates that, while these treatments reduce the total number of individuals, they achieve this proportionally across species, preventing any single species from dominating.

Discussion

This research indicates that the 50EC botanical insecticide formulation, a mixture of *P. aduncum* and *A. odorata* extracts, offers an effective and sustainable alternative to synthetic and microbial insecticides for controlling *P. xylostella*. The botanical insecticide reached an impressive peak effectiveness level of 87.50% in the 3 WAP and maintained effectiveness above 60% until the 9 WAP. This performance was comparable to synthetic insecticides, such as emamectin benzoate, and microbial insecticides, such as *B. thuringiensis*. However, the botanical insecticides showed a clear advantage in maintaining soil arthropod populations, which were significantly higher (1748 individuals) than the use of

synthetic insecticide treatment (1405 individuals). This suggests that botanical insecticide applications exert less selection pressure on non-target organisms, reducing risks such as resistance and resurgence associated with synthetic formulations (Sonhafouo-Chiana et al. 2022).

Table 1. Mean population of *Plutella xylostella* larvae on broccoli plants

| Treatments | Average larval population per plant ($\bar{x} \pm SD$) ^a |
|-----------------------|---|
| Control | 2.05±0.66 ^a |
| Botanical insecticide | 0.76±0.38 ^b |
| Microbial insecticide | 1.24±0.79 ^{ab} |
| Synthetic insecticide | 0.88±0.55 ^b |

Notes: Numbers in the same column followed by the same letter indicate not significantly different based on Tukey's test at the α : 5% level

Table 2. Species richness and individual abundance of arthropods in broccoli crops

| Order | Species richness | (%) | Individual abundance | (%) |
|-------------------|------------------|-------|----------------------|-------|
| Arachnids | | | | |
| Acarine | 5 | 8.06 | 510 | 7.92 |
| Araneae | 7 | 11.29 | 357 | 5.54 |
| Insects | | | | |
| Blattodea | 2 | 3.23 | 18 | 0.28 |
| Coleoptera | 13 | 20.97 | 275 | 4.27 |
| Dermoptera | 1 | 1.61 | 293 | 4.55 |
| Diptera | 6 | 9.68 | 153 | 2.38 |
| Hemiptera | 6 | 9.68 | 54 | 0.84 |
| Hymenoptera | 15 | 24.19 | 2188 | 33.97 |
| Lepidoptera | 1 | 1.61 | 3 | 0.05 |
| Orthoptera | 2 | 3.23 | 73 | 1.13 |
| Thysanoptera | 1 | 1.61 | 72 | 1.12 |
| Entognaths | | | | |
| Entomobryomorpha | 3 | 4.84 | 2445 | 37.96 |
| | 62 | 100 | 6441 | 100 |

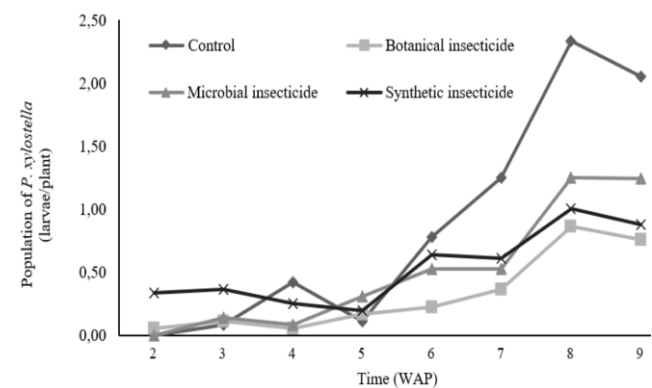


Figure 4. Total population of *Plutella xylostella* in different insecticide applications

During this research, a total of 6,441 arthropods, representing 62 morphospecies, were identified. Among these, Hymenoptera showed the highest species richness (25%), with approximately 32.96% belonging to the Formicidae family. They also made significant contributions to ecosystem services such as pest control. The Formicidae family is one of the most diverse insect

groups and plays an important role in ecosystems (Schultheiss et al. 2022). With their complex social structure and high adaptability, ants contribute to pest control, seed dispersal, and soil improvement. The interaction of ants with their environment underlines their importance as an integral part of ecological balance both in the wild and on farms (Chamoli et al. 2023).

Table 3. The abundance of soil arthropods under different insecticide treatments in broccoli fields

| Taxa | Treatments | | | | Grand total |
|-------------------------|-----------------------|-----------------------|-----------------------|-------------|-------------|
| | Botanical insecticide | Microbial insecticide | Synthetic insecticide | Control | |
| Class Arachnids | | | | | |
| Acarine | 100 | 150 | 135 | 125 | 510 |
| Acarine | 100 | 150 | 135 | 125 | 510 |
| Araneae | 90 | 91 | 79 | 97 | 357 |
| Araneae | 90 | 91 | 79 | 97 | 357 |
| Class Insects | | | | | |
| Blattodea | 3 | 1 | 2 | 12 | 18 |
| Blattidae | | | 2 | | 2 |
| Termitidae | 3 | 1 | | 12 | 16 |
| Coleoptera | 60 | 67 | 63 | 85 | 275 |
| Carabidae | 20 | 10 | 17 | 33 | 80 |
| Chrysomelidae | 11 | 12 | 2 | 3 | 28 |
| Curculionidae | 1 | 8 | | 3 | 12 |
| Ptilidae | 1 | 5 | 11 | | 17 |
| Scarabaeidae | 5 | 3 | 4 | 2 | 14 |
| Staphylinidae | 22 | 29 | 29 | 44 | 124 |
| Dermaptera | 85 | 85 | 58 | 65 | 293 |
| Sphongiphoridae | | 5 | 9 | | 14 |
| Spongiphoridae | 85 | 80 | 49 | 65 | 279 |
| Diptera | 38 | 38 | 23 | 54 | 153 |
| Cecidomyiidae | 26 | 13 | 13 | 4 | 56 |
| Chironomidae | 7 | 6 | 6 | 19 | 38 |
| Drosophilidae | | 3 | 2 | 3 | 8 |
| Muscidae | 3 | | | 7 | 10 |
| Phoridae | 2 | 16 | 2 | 4 | 24 |
| Chironomidae | | | | 17 | 17 |
| Hemiptera | 24 | 8 | 9 | 13 | 54 |
| Aphididae | 7 | | 2 | | 9 |
| Cicadellidae | 14 | 6 | 4 | 13 | 37 |
| Cydidae | 1 | | 1 | | 2 |
| Delphacidae | | 2 | 2 | | 4 |
| Reduviidae | 2 | | | | 2 |
| Hymenoptera | 536 | 557 | 515 | 580 | 2188 |
| Apidae | | 1 | | 1 | 2 |
| Diapriidae | 4 | 1 | 3 | 3 | 11 |
| Formicidae | 510 | 549 | 503 | 561 | 2123 |
| Pteromalidae | 16 | | | 2 | 18 |
| Scelionidae | 6 | 6 | 9 | 13 | 34 |
| Lepidoptera | 1 | | 1 | 1 | 3 |
| Noctuidae | 1 | | 1 | 1 | 3 |
| Orthoptera | 7 | 20 | 14 | 32 | 73 |
| Gryllidae | 7 | 19 | 13 | 32 | 71 |
| Gryllotalpidae | | 1 | 1 | | 2 |
| Thysanoptera | 17 | 35 | 6 | 14 | 72 |
| Thripidae | 17 | 35 | 6 | 14 | 72 |
| Class Entognaths | | | | | |
| Entomobryomorpha | 787 | 563 | 500 | 595 | 2445 |
| Total | 1748 | 1615 | 1405 | 1673 | 6441 |

Table 4. Total arthropod and arthropod diversity index (H') and species evenness (E') in 4 insecticide treatments

| Treatments | Order | Family | Genus | Morphospecies | Total individual | H' | E' |
|-----------------------|-------|--------|-------|---------------|------------------|-------|-------|
| Botanical insecticide | 12 | 26 | 27 | 47 | 1748 | 2.84a | 0.38a |
| Microbial insecticide | 11 | 25 | 26 | 51 | 1615 | 3.00a | 0.41a |
| Synthetic insecticide | 12 | 26 | 26 | 48 | 1405 | 3.03a | 0.44a |
| Control | 12 | 25 | 24 | 47 | 1673 | 2.98a | 0.42a |

Notes: H': Shannon-Wiener Diversity Index; E': Evenness Index

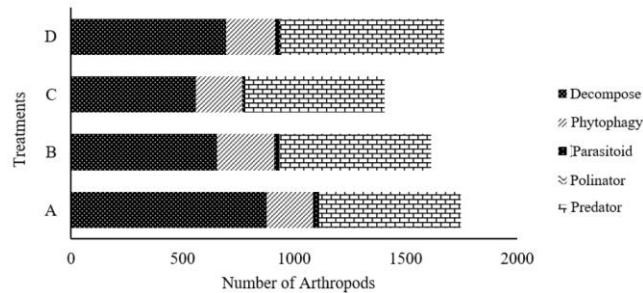


Figure 5. Abundance of individual arthropods based on their role in broccoli crops. A. Botanical insecticide; B. Microbial insecticide; C. Synthetic insecticide; D. Control

Entomobryomorpha, which has the most considerable abundance (37.96%), plays an important role in decomposition and nutrient cycling. In agricultural fields, entomobryomorpha act as decomposers, feeding on decaying organic matter such as plant debris, leaf litter, and dead roots. Their activity accelerates the breakdown of organic matter into smaller particles, further broken down by soil microorganisms into essential nutrients that plants can absorb. This process contributes significantly to maintaining soil fertility, improving soil structure, and sustaining balanced agricultural ecosystems. Consequently, their presence in sufficient numbers is often regarded as an indicator of healthy soil.

Fields treated with synthetic insecticides show lower species richness and reduced abundance of predatory arthropods compared to untreated fields (Kamlesh et al. 2024). The decline in predatory arthropods can lead to increased pest populations due to the reduction of natural enemies, thereby creating a cycle of dependence on chemical control (Macfadyen et al. 2015). This indicates that plant-based insecticides do not significantly reduce arthropod numbers compared to synthetic insecticides, which appear to reduce populations faster. The reduction in the number of individuals using synthetic insecticide treatments could be attributed to the direct effects of synthetic insecticides, which are more aggressive toward arthropod populations. In contrast, plant-based insecticides, such as botanical insecticides, tend to be more environmentally friendly and do not significantly reduce arthropod populations.

These empirical observations underscore the ecological advantages of botanical insecticides, which have minimal impact on biodiversity while effectively maintaining

essential ecosystem functions. In contrast, synthetic insecticides are often associated with reduced biodiversity, the emergence of pest resistance, and disruptions within food chains (Bhattacharyya et al. 2023). Synthetic insecticides also pose significant risks to non-target organisms and the broader environment (Ali et al. 2021). While botanical insecticides demonstrate marginally lower uniformity values (E': 0.38), which may inadvertently favor specific species, they exhibit enhanced ecological compatibility by sustaining a greater abundance and diversity of arthropods. This observation is in line with the foundational principles of Integrated Pest Management (IPM), which aims to harmonize effective pest control measures with preserving ecological integrity. By reducing the dependence on synthetic chemicals, botanical insecticides effectively address critical challenges in contemporary agricultural practices, including maintaining soil health, preserving water quality, and safeguarding non-target organisms. Future research initiatives should focus on the refinement of botanical formulations to alleviate potential ecological disruption and assess their economic feasibility and scalability to promote broader adoption.

In conclusion, 50EC botanical insecticide presented a sustainable alternative for managing *P. xylostella* while concurrently preserving biodiversity and ecosystem functions. Its incorporation into IPM frameworks can significantly contribute to resilient agricultural practices, bolstering productivity while ensuring environmental protection. These findings underscore the significant role of plant-derived insecticides in fostering sustainable agricultural practices and biodiversity conservation.

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