Insect abundance and diversity associated with okra (*Abelmoschus esculentus* L.) agricultural ecosystem in Kunduz city

Abdul Baqi Rostaee[1], Ahmad Munir Amini[2], Mohammad Alim Behzad[3]
[1]Department of Plant Protection, Faculty of Agriculture, Kunduz University, Afghanistan
[2]Department of Agronomy, Faculty of Agriculture, Kunduz University, Afghanistan
[3]Department of Agronomy, Faculty of Agriculture, Kunduz University, Afghanistan
Corresponding author email: abrostaee@gmail.com

Abstract
Okra (*Abelmoschus esculentus* Linnaeus.) holds significance as a vital vegetable crop in Afghanistan but it is often infested by various species of pests, leading to significant crop damage. The research aimed to assess the abundance and diversity of insects in the agricultural ecosystem of okra. The experiment laid out at the experimental farm of Agriculture, Irrigation, and Livestock Directorate. Four sampling methods, including visual observation, pitfall traps, sweep nets, and yellow sticky traps, were employed. A total of 36 families belong to 9 orders were identified. There was considerable variation in insect abundance across different orders ($F = 501.81$, d.f = 7, 96; $P < 0.05$), with hemiptera being the most abundant order (2.94 ± 0.06). Differences in feeding habits were significant ($F = 597.05$, d.f = 6, 84; $P < 0.05$), with sap-feeders having the highest abundance (2.93 ± 0.06). The families cicadellidae among pests and hormicidae among natural enemies were recorded as the most abundant. Int terms of diversity, the analysis revealed a significant difference among feeding habits ($F = 52.41$, d.f = 6, 119; $P < 0.05$). Notably, predators exhibited the highest diversity (1.57 ± 0.08), Moreover, a notable disparity in diversity emerged between pests and natural enemies ($F = 212.66$, d.f = 1, 24; $P < 0.05$), with non-pests (natural enemies) showcasing the greatest abundance and variety (mean value of $H'=1.80 \pm 0.06$). The findings of this research contribute valuable knowledge for enhancing eco-friendly and sustainable practices in pest management, particularly through the promotion of biological control methods.
Keywords: Okra, *Abelmoschus esculentus*; feeding habits, abundance, diversity, correlation coefficient, week, kunduz

مطالعه فراوانی و تنوع حشرات در اکوسیستم زراعتی بامیه (*Abelmoschus esculentus* L.) در مرکز ولایت کندز

عبدالباقی روستایی[1،*] احمد منیر امینی[2] محمد عالم بهزاد[3]
[1]دیپارتمنت حفاظه نباتات، پوهنحی زراعت، پوهنتون کندز
[2،3]دیپارتمنت اگرانومی، پوهنحی زراعت، پوهنتون کندز
*. ایمیل آدرس: abrostaee@gmail.com

بامیه (*Abelmoschus esculentus* Linnaeus) یکی از سبزیجات کلیدی و مهم در افغانستان شناخته می‌شود. با این حال، این گیاه به طور معمول تحت تأثیر انواع مختلف آفات قرار می‌گیرد که موجب خسارات قابل توجهی به محصول می‌شود. این تحقیق با هدف ارزیابی فراوانی و تنوع حشرات در اکوسیستم زراعتی بامیه در فارم تحقیقاتی ریاست زراعت از ماه ثور تا جوزا سال ۱۴۰۲ انجام گردید. در این مطالعه، از چهار روش نمونه‌گیری حشرات شامل مشاهده بصری، تلک چاله ای، جال جمع‌آوری و تلک‌های چسبنده زرد استفاده شد. در مجموع، ۳۶ خانواده متعلق به ۹ ردیف دریافت گردید. نتایج نشان داد که تفاوت قابل ملاحظه در فراوانی حشرات بین ردیف‌های مختلف وجود دارد ($F = 501.81$, d.f = 7, 96; $P < 0.055$)، ردیف نیم سخت بالپوشان (hemiptera) با اوسط (2.94 ± 0.06) به عنوان فراوان‌ترین ردیف شناسایی شد. علاوتاً، تفاوت در عادات غذایی نیز قابل ملاحظه بود ($F = 597.05$, d.f = 6, 84; $P < 0.05$) و حشرات شیره خوار بالاترین فراوانی را (2.93 ± 0.06) به ثبت رساند. در بین خانواده های آفت cicadellidae و در میان خانواده دشمنان طبیعی formicidae بیشترین فراوانی را نشان دادند. به همین ترتیب، تحلیل تفاوت عادت غذایی نشان داد که حشرات شکارگر با اوسط (1.57 ± 0.08)، بیشترین تنوع را در مقایسه با سایر گروه‌ها به خود اختصاص داد. نهایتاً، تفاوت قابل ملاحظه در تنوع بین آفات و دشمنان طبیعی مشاهده شد ($F = 212.66$, d.f = 1, 24; $P < 0.05$)، به طوری که حشرات غیر آفت (دشمنان طبیعی) با اوسط ($H'=1.80 \pm 0.06$) بیشترین تنوع را به نمایش گذاشتند. شناسائی آفات این نبات می‌تواند به عنوان منبعی ارزشمند برای تقویت شیوه‌های سازگار با محیط زیست و پایدار در مدیریت آفات، به ویژه از طریق ترویج روش‌های کنترل بیولوژیکی مورد استفاده قرار گیرد.
واژه های کلیدی: آفت، بامیه، تنوع، عادات غذایی، فراوانی، هفته، هم بستگی

Introduction

Okra (*Abelmoschus esculentus* L.) is a widely consumed vegetable that belongs to the Malvaceae family. It is known for its nutritional value and health benefits. The immature pods of okra are rich in essential minerals, vitamins, amino acids, and dietary fibers, making it a valuable addition to a balanced diet [24]. Okra has the potential to enhance livelihoods in both urban and rural areas [21]. It is considered a nutrient powerhouse, low in calories and fat-free [25]. Additionally, okra fruit is rich in antioxidants, particularly carotenoids, flavonoids, and vitamin C [11].

In Afghanistan, okra production lags significantly behind other nations despite its significance. Global okra production, as reported by the FAO, reached approximately 10.8 million metric tons. India emerged as the leading producer, contributing 6.47(MT), while Nigeria followed closely with 1.92 (MT). In Afghanistan, the production area for vegetables, including okra, is recorded at 170,250 hectares, with a total production of 1,303,978.8 (MT) in 2021 [10, 22].

Athar and Bokhari [4] found that insect pests are a key factor negatively impacting okra productivity. Insect and disease causes (35-40%) loses to okra yield [18]. Insect pests pose significant challenges to okra production, with the number of species varying across countries and regions. Several insect pests, such as Leaf hopper (*Amrasca biguttula biguttula*), Leaf beetle (Podagrica sp.), Blister beetle (*Mylabris pustulata* Olivier), Leaf folder (*Syllepte derogate* Fabricius), Aphid (*Aphis gossypii* Glover), White fly (*Bemisia tabaci* Gennadius), *Dysdercus cingulatus* (Fabricius), and *Earias vittella* (Fabricius), have been found to be more abundant in okra fields [19]. Different studies have documented a range of insect pest species attacking okra. Mallick et al. [17] identified 72 species, whereas Rachana et al. [23] reported 37 species. Apart from pests, honey bees, bumble bees, ants, butterflies, and other pollinators play vital roles in the okra agroecosystem, serving as decomposers, predators, parasitoids, and pollinators. The golden yellow flowers of okra, which contain nectar, attract these insects [5, 20]. In the okra agroecosystem of Northern Sudan, Abdalla et al. [1] documented nine insect species from four families and four orders serving as predators.

Despite existing research on insect abundance in okra, there remains a lack of comprehensive information about the entire insect community within the okra agroecosystem. This knowledge gap is particularly evident in Afghanistan, specifically in Kunduz province. The absence of such information hinders the development and implementation of effective strategies for insect control management. This study aimed to fill the knowledge gap by investigating the community structure of pests and beneficial insects in the okra agroecosystem. Its objective was to evaluate insect abundance and biodiversity in the okra ecosystem.

Materials and Methods

The study was conducted at the experimental research farm of Agriculture, Irrigation, and Livestock in Kunduz, Afghanistan, from May to June 2023. The geographical coordinates of the region are approximately 36°42'43.2" N and 68°51'20.8" E, with an elevation of 404 meters. The okra cultivar 'Mahali' seeds were sown in the plot, and DAP and Urea fertilizers were applied in two split doses to promote crop health. Manual hoeing was carried out for weed management. The field was divided into three equal-sized plots with a one-meter space between them, and each plot consisted of five rows measuring 10 meters in length. The distance between plants within a row was maintained at 30 cm. Each plot covered an area of 5 x 10 square meters, resulting in a total field size of 150 square meters.

To assess insect abundance in the okra agroecosystem, four sampling techniques, including pitfall trap, yellow sticky trap, visual observation and sweeping net were employed to gather data. The insect assessment commenced three weeks after transplanting and extended throughout the vegetative, flowering, and fruiting stages of the plants.

Sampling was conducted twice a week, with a three-day interval between each sampling event, except for the yellow sticky trap method, which was performed once a week. Various equipment, such as zipper plastic bags, sweep nets, hand lenses, small plastic containers, brushes, sieves, funnels, glass vials, yellow sticky traps, and ethanol, were employed for the sampling techniques.

Visual observation involved examining a random selection of 10 plants per plot for arthropods. From each plant, five leaves were chosen, and both sides of the leaves were meticulously inspected for insect presence. The collected insects were subsequently preserved in the laboratory for further analysis.

Sweep-net sampling was used to assess the abundance of flying and sessile insects on the okra plants. A single round of sweeping was performed in each row to obtain a composite sample. Sampling was carried out in both the morning and evening, and the collected specimens were preserved for subsequent analysis.

To capture insects dwelling on the soil surface, pitfall traps were utilized. Nine traps were placed in each plot, and the insects trapped within them were collected, preserved, and labeled for further processing. Yellow sticky traps were employed to collect flying and jumping insects. Three traps were placed in each plot, and the trapped insects were counted and identified in the laboratory.

After collection, all specimens were taken to the Laboratory of Entomology for further processing. They were appropriately labeled and preserved in the refrigerator. For identification purposes, the specimens were examined up to the family level using the identification key provided by Johnson [14] and Goulet and Huber [12], along with additional online resources.

Data Analysis

Abundance and Diversity

The data obtained on insect abundance were examined using Statistical Analysis Software (SAS) version 9.4, utilizing one-way and two-way analysis of variance (ANOVA) methods. The analysis involved comparing the abundance of insects across different weeks, considering their orders and feeding habits. If necessary, the data were transformed using Log10 (X+1), log and square root in order to meet the assumptions of statistical analysis. To determine significant differences between means, a least significant difference (LSD) test was carried out at a significance level of 0.05. The measurement of insect diversity employed the Shannon-Wiener formula: $H' = pi \ln (pi)$. The diversity index was computed utilizing the given equation.

$$H' = -\sum_{i=1}^{S} Pi \ln Pi$$

In the context of this study:
H' = represents the Shannon-Wiener diversity index.
Pi = denotes the proportion of the population attributed to species i.
S = represents the total number of species observed in the sample.

In order to assess insect diversity based on pests and natural enemies, feeding habits, and weeks, one-way and two-way analysis of variance (ANOVA) tests were conducted.

Results

Insect Order Composition and Abundance

During the conducted experiment, nine orders were collected, which included hemiptera, hymenoptera, diptera, coleoptera, araneae, neuroptera, orthoptera, and lepidoptera.

Table 1: Means comparison of insect's abundance according to orders

No	Orders	Mean ± SE	Total ind.	Percentage (%)
1	Hemiptera	2.94 ± 0.06 a	17858	83.18
2	Hymenoptera	2.02 ± 0.04 b	2024	9.43
3	Diptera	1.39 ± 0.10 c	634	2.95
4	Coleoptera	1.35 ± 0.09 c	598	2.79
5	Araneae	1.06 ± 0.08 d	270	1.26
7	Neuroptera	0.31 ± 0.09 e	47	0.22
8	Orthoptera	0.13 ± 0.06 f	26	0.12
9	Lepidoptera	0.06 ± 0.05 f	13	0.06

Means with the same letter are not significantly different at p=0.05 using LSD

The abundance of insects varied significantly among these orders (F = 501.81, d.f = 7, 96; P < 0.05). Hemiptera was recorded the most abundant (2.94 ± 0.06), followed by hymenoptera (2.02 ± 0.04), diptera (1.39 ± 0.10), coleoptera (1.35 ± 0.09), araneae (1.06 ± 0.08), neuroptera (0.31 ± 0.09), orthoptera (0.13 ± 0.06), and lepidoptera (0.06 ± 0.05) as the least abundant order. Among these orders, hemiptera was the most abundant with 83.18%, followed by hymenoptera (9.43%), diptera (2.95%), coleoptera (2.79%), araneae (1.26%), neuroptera (1.26%), orthoptera (0.12%), and lepidoptera with the lowest abundance of 0.06% (table 1).

Insects' Abundance According to Weeks

Table 2 visually demonstrates a notable distinction in the total weekly insect abundance (F = 35.03, d.f = 5, 12; P < 0.05). Third week exhibited the highest mean abundance (3.25 ± 0.05), followed by week four (3.14 ± 0.03), week two (3.12 ± 0.02), week five (3.05 ± 0.01), week six (2.94 ± 0.01), and week one displayed the lowest mean abundance (2.82 ± 0.02).

Table 2: Overall insect's abundance according to weeks

No. of weeks	Means ± std error
Week 1	2.82 ± 0.02 e
Week 2	3.12 ± 0.02 bc
Week 3	3.25 ± 0.05 a
Week 4	3.14 ± 0.03 b
Week 5	3.05 ± 0.01 c
Wek 6	2.94 ± 0.01 d

Means with the same letter are not significantly different at p=0.05 using LSD

Insect Abundance According to Feeding Habits

Table 3 displays the abundance of different feeding habits. The analysis revealed a significant difference among feeding habits (F = 597.05, d.f = 6, 84; P < 0.05). Notably, sap-feeders exhibited the highest abundance (2.93 ± 0.06), followed by omnivorous (2.12 ± 0.04), predators (1.81 ± 0.05), leaf-feeders (0.72 ± 0.05), parasitoid (0.47 ± 0.06), pollinator (0.43 ± 0.07) and the lowest abundance were recorded in fruits borer (0.22 ± 0.07).

Table 3: Abundance based on insect feeding habit

Feeding habits	Mean ± SE	Percentage (%)
Sap-feeders	2.93 ± 0.06 a	81.10
Omnivorous	2.12 ± 0.04 b	11.84
Predator	1.81 ± 0.05 c	6.14
Leaf-feeders	0.72 ± 0.05 d	0.41
Parasitoid	0.47 ± 0.06 e	0.21
Pollinator	0.43 ± 0.07 e	0.20
Fruit borer	0.22 ± 0.07 f	0.10

Means with the same letter are not significantly different at p = 0.05 using LSD

Insect abundance according to pest families

According to Table 4, totally 12 families collected, the identified families included six that are classified as sap-feeder, five as leaf-feeder, one family as fruit borer were observed within the okra agricultural ecosystem. The abundance of insects varied significantly among these families (F = 225.38, d.f = 11, 204; P < 0.05). cicadellidae was recorded the most abundant (2.93 ± 0.06), followed by chrysomelidae (0.49 ± 0.07), miridae (0.30 ± 0.06), drosophilidae (0.22 ± 0.07), aphididae (0.22 ± 0.07), Acrididae (0.20 ± 0.06), Elateridae (0.18 ± 0.07), cixiidae (0.08 ± 0.04), issidae (0.07 ± 0.03), pyrgomorphidae (0.05 ± 0.03), and both membracidae (0.02 ± 0.02) and cixiidae with (0.02 ± 0.02), were recorded the least abundant families (table 4).

Table 4: Pest abundance in okra agricultural ecosystem

Order	Family	Mean ± SE	Status
Coleoptera	Cicadellidae	2.93 ± 0.06 a	Sap-feeder
Coleoptera	Chrysomelidae	0.49 ± 0.07 b	Leaf-feeder
Hemiptera	Miridae	0.30 ± 0.06 c	Sap-feeder
Diptera	Drosophilidae	0.22 ± 0.07 cd	Fruit borer
Hemiptera	Aphididae	0.22 ± 0.07 cd	Sap-feeder
Orthoptera	Acrididae	0.20 ± 0.06 cde	Leaf-feeder
Coleoptera	Elateridae	0.18 ± 0.07 cdef	Leaf-feeder
Hemiptera	Cixiidae	0.08 ± 0.04 cdef	Sap-feeder
Hemiptera	Issidae	0.07 ± 0.03 efg	Sap-feeder
Orthoptera	Pyrgomorphidae	0.05 ± 0.03 fg	Leaf-feeder
Hemiptera	Membracidae	0.02 ± 0.02 g	Sap-feeder
Lepidoptera	Pieridae	0.02 ± 0.02 g	Leaf-feeder

Means with the same letter are not significantly different at p = 0.05 using LSD

Beneficial insect abundance

During the study, a total of 8 taxonomic orders and 24 families of beneficial insects were collected. The abundance of insects exhibited significant variation among these families ($F = 53.22$, d.f. = 19, 340; $P < 0.05$). Notably, the family formicidae was the most abundant, with a mean abundance of 2.00 ± 0.04, followed by muscidae (1.31 ± 0.11), anthocoridae (1.21 ± 0.11), and theridiidae (0.99 ± 0.11). Other families recorded include coccinellidae (0.87 ± 0.07), carabidae (0.80 ± 0.15), chrysopidae (0.40 ± 0.09), vespidae (0.34 ± 0.09), Braconidae (0.32 ± 0.06), and Staphylinidae (0.27 ± 0.08). The least abundant families were sarcophagidae (0.24 ± 0.06), apidae (0.19 ± 0.05), araneidae (0.15 ± 0.07), scarabaeidae (0.14 ± 0.04), erebidae (0.14 ± 0.06), tachinidae (0.13 ± 0.05), gryllidae (0.13 ± 0.05), antipidae (0.12 ± 0.06), ichneumonidae (0.10 ± 0.04), calliphoridae (0.06 ± 0.03), piophilidae (0.03 ± 0.02), pipunculidae (0.02 ± 0.02), halictidae (0.02 ± 0.02), and chalcididae (0.02 ± 0.02). According to Table 5, the identified families included six that are classified as omnivores, five as parasitoids, nine families as predators, and four as pollinators, all of which were observed within the okra agricultural ecosystem.

Table 5: Beneficial insects' abundance in okra agricultural ecosystem

Order	Family	Mean ± SE	Status
Hymenoptera	Formicidae	2.00 ± 0.04 a	Omnivores
Diptera	Muscidae	1.31 ± 0.11 b	Omnivores
Hemiptera	Anthocoridae	1.21 ± 0.11 b	Predator
Araneae	Theridiidae	0.99 ± 0.11 c	Predator
Coleoptera	Coccinellidae	0.87 ± 0.07 c	Predator
Coleoptera	Carabidae	0.80 ± 0.15 c	Predator
Neuroptera	Chrysopidae	0.40 ± 0.09 d	Predator
Hymenoptera	Vespidae	0.34 ± 0.09 de	Predator
Hymenoptera	Braconidae	0.32 ± 0.06 def	Parasitoid
Coleoptera	Staphilinidae	0.27 ± 0.08 defg	Predator
Diptera	Sarcophagidae	0.24 ± 0.06 defgh	Omnivores
Hymenoptera	Apidae	0.19 ± 0.05 efghi	Pollinator
Araneae	Araneidae	0.15 ± 0.07 efghi	Predator
Coleoptera	Scarabaeidae	0.14 ± 0.04 efghi	Pollinator
Lepidoptera	Erebidae	0.14 ± 0.06 fghi	Pollinator
Diptera	Tachinidae	0.13 ± 0.05 fghi	Parasitoid
Orthoptera	Gryllidae	0.13 ± 0.05 fghi	Omnivores
Araneae	Antipidae	0.12 ± 0.06 ghi	Predator
Hymenoptera	Ichneumonidae	0.10 ± 0.04 ghi	Parasitoid
Diptera	Calliphoridae	0.06 ± 0.03 hi	Omnivores
Diptera	Piophilidae	0.03 ± 0.02 i	Omnivores
Diptera	Pipunculidae	0.02 ± 0.02 i	Parasitoid
Hymenoptera	Halictidae	0.02 ± 0.02 i	Pollinator
Hymenoptera	Chalcididae	0.02 ± 0.02 i	Parasitoid

Means with the same letter are not significantly different at p = 0.05 using LSD

Insect Abundance in Accordance with Pest and Natural Enemy

The analysis of the categories "pest" and "natural enemies" revealed a significant difference ($F = 1063.07$, $d.f = 1, 24$; $P < 0.05$). In terms of abundance, there was a notable contrast between pest insects, with a calculated mean of (2.93 ± 0.06), and non-pest arthropods, which exhibited a mean of (2.32 ± 0.03). Pest arthropods exhibited a higher population compared to non-pest arthropods table 6.

Table 6: Insect Abundance According to Pest and Natural Enemies

Category	Mean ± SE
Natural enemy	2.32 ± 0.03 a
Pest	2.93 ± 0.06 b

Means with the same letter are not significantly different at p = 0.05 using LSD

Correlation Coefficient Amongst Pest and Natural Enemies

The Pearson's correlation coefficient was utilized to calculate the correlation value (r) between beneficial insects and insect pests on okra. The findings indicated a positive and significant correlation (r = 0.81) between the populations of beneficial insects and insect pests ($P < 0.05$), as demonstrated in Table 7.

Table 7: Pearson Correlation Coefficients between pest and natural enemies

Category	Pest	Natural enemies
Pest	1	-0.029
Natural enemies	-0.029	1

*Correlation is significant at the 0.05 level

Insect Diversity

Table 8 shows the diversity of different feeding habits. The analysis revealed a significant difference among feeding habits (F = 52.41, d.f = 6, 119; $P < 0.05$). Notably, predators exhibited the highest diversity (1.57 ± 0.08), followed by omnivorous (0.88 ± 0.09), leaf-feeders (0.58 ± 0.09), pollinators (0.45 ± 0.13), sap-feeders (0.07 ± 0.04), and the lowest diversity were recorded with parasitoid (0.07 ± 0.04).

Table 8: Diversity index based on insect feeding habit

Feeding habits	**Mean ± SE**
Predator	1.57 ± 0.08 a
Omnivorous	0.88 ± 0.09 b
Leaf-feeders	0.58 ± 0.09 c
Pollinator	0.45 ± 0.13 c
Sap-feeders	0.07 ± 0.04 d
Parasitoid	0.07 ± 0.04 d

Means with the same letter are not significantly different at p = 0.05 using LSD

Examining Insect Diversity Based on Pests and Natural Enemies

The analysis of the pest and natural enemies categories yielded a significant distinction (F = 212.66, d.f = 1, 24; $P < 0.05$). Regarding the diversity index, a notable difference was observed between pest insects and beneficial insects. Additionally, the findings indicated that the highest diversity was observed among non-pest insects (natural enemies), with a mean value of 1.80 ± 0.06 (Table 9).

Table. 9: Diversity Index According to Pest and Natural Enemies

Category	Mean ± SE
Natural enemy	1.80 ± 0.06 a
Pest	0.22 ± 0.08 b

Means with the same letter are not significantly different at p = 0.05 using LSD

Examining Insect Diversity Across Various Weeks

Table 10 presents a summary of the diversity index based on different insects, where an increase in the index value indicates higher diversity. Overall, there were significant variations observed between weeks ($F = 22.74$, d.f = 5, 12; $P < 0.05$). Among the various weeks, the highest diversity was recorded in week one with a value of 1.78 ± 0.06, followed by week two with 0.78 ± 0.02, week three with 0.65 ± 0.18, week four with 0.75 ± 0.08, week five with 0.93 ± 0.07, and the least diverse was week six with 0.88 ± 0.01.

Table. 10: The Mean Comparison of Diversity Index According to Weeks

No. weeks	Mean ± SE
Week 1	1.78 ± 0.06 a
Week 2	0.78 ± 0.02 bc
Week 3	0.65 ± 0.18 c
Week 4	0.75 ± 0.08 bc
Week 5	0.93 ± 0.07 b
Week 6	0.88 ± 0.01 bc

Means with the same letter are not significantly different at $p = 0.05$ using LSD

Discussion

The study recorded a total 36 families under 9 orders, in the okra agroecosystem. Hemiptera was the most abundant group, reflecting its ecological compatibility with okra, where many species thrive as sap-sucking pests. There is consistent increase in the population of Hemiptera throughout the six-week sampling period. Statistical analysis indicated a highly significant interaction amidst taxonomic orders and numerous weeks of data collection sampling. Specifically, the population of Hemiptera increased from the first week to weeks three and four, with week three being the peak. This suggests a direct relationship between plant growth and the rise in hemiptera population, indicating that the robust growth of okra crops may contribute to increased insect populations. However, a decline in the Hemipteran population was observed during weeks five and six. The results align with earlier studies conducted by Bhatt et al. [6] and Nair et al. [19], which similarly found that Hemiptera is the most prevalent order in okra agroecosystems. Conversely, Amin et al. [2] observed 24 families across 10 orders in the okra fauna, which contrasts with the findings of the present study.

The abundance of insects varied significantly across the weeks of sampling with week three exhibiting the highest abundance due to the presence of maximum branches and leaves on the plants. Conversely, week one showed the lowest abundance as it corresponded to the initial stage of the plants with minimal foliage and branches.

Understanding the feeding habits of insects is crucial for comprehending terrestrial ecosystems. In this study, each species was categorized based on its known food habits or, if unidentified, based on the food habits of its family. The specimens that were gathered were categorized into seven groups based on their feeding habits: leaf feeder, fruit borer, sap-feeders, omnivorous, parasitoids, predators, and pollinators. According to El-Shafie's [9] findings, sap-feeders were the most prevalent group in okra.

An analysis revealed a highly significant interaction between feeding habits and weeks of sampling. The population of sap-feeders experienced a rise, which can be attributed to the expansion of the okra crop. The third and fourth weeks exhibited the highest count of individuals, as the surge in plant-feeding insects coincided with the peak abundance of branches and leaves on the plants, as noted in the study conducted by Lara et al. [16]. Interestingly, the population of sap-feeders showed a direct correlation with the increase in omnivorous insects.

The results indicate a significant variation in insect abundance among the examined families, with a notable dominance of cicadellidae. The recorded abundance of cicadellidae suggests its ecological success in the studied environment, potentially due to favorable habitat conditions or resource availability. In contrast, families such as chrysomelidae and miridae showed much lower abundances. The dominance of the formicidae family, with a high mean abundance, underscores the ecological importance of ants in agroecosystems. This finding aligns with previous studies highlighting the relation of ants with hemipteran species. Honeydew that produced by hemipteran species, contains essential substances such as sugars, amino acids, amides, proteins, and vitamins, has fostered the evolution of various ant-hemipteran relationships. Ants gain a reliable and concentrated food source, while hemiptera receive protection from predators and benefit from the removal of honeydew, which mitigates the risk of suffocation and mold growth on their eggs and nymphs. This mutualism enhances food intake and promotes larger hemipteran populations [27, 26].

Insects, which are the most abundant and diverse creatures on our planet, showcase a vast array of physical attributes and inhabit a multitude of ecological roles [8, 13]. Biodiversity refers to the number and diversity of species within an ecosystem. In this study, diversity was assessed based on the presence of pests and beneficial insects. A noteworthy disparity in the diversity index was observed between pests and beneficial insects indicating a substantial difference in the levels of diversity between the two groups. The highest diversity was observed among natural enemies, consistent with Kuar et al. [15] who reported a Shannon diversity index of 1.84 for predators. This suggests that an increase in beneficial insect populations was associated with a decrease in pest populations. On the other hand, Anbalagan [3] reported a diversity index of 2.934 for hymenopteran insects in vegetable fields, which stands in contrast to our finding. However, our results partially align with Chakraborty [7], who discovered that predators exhibited the highest diversity with 38 species compared to other feeding habits.

There was also a significant difference in diversity index across the six weeks of sampling. Week one had the highest diversity, followed by week five, while week three had the lowest diversity index. The findings presented here offer valuable insights that can inform the development of efficient pest management strategies in the cultivation of okra.

Conclusion

In conclusion pests accounting for 81.61% and beneficial arthropods for 18.39% of the overall population. Hemiptera was identified as the most abundant order among the eight taxonomic groups analyzed. Among the various feeding habits, sap-feeders represented the largest group. Additionally, arthropods classified as natural enemies demonstrated the highest diversity, as indicated by the Shannon-Wiener diversity index. A strong positive correlation was found between pest arthropods and their natural enemies. These findings provide critical insights that can inform the development of environmentally sustainable pest management strategies, which are vital for promoting sustainable agriculture and achieving self-sufficiency in Afghanistan. Furthermore, they underscore the necessity for continued research into insect abundance and diversity within this agricultural context.

Acknowledgments

The authors gratefully acknowledge Mr. Abdul Matin and his personnel from the Department of Researches, Agriculture, Irrigation, and Livestock directorate for their invaluable assistance during the field works. They would also like to extend special thanks to the students of the horticulture and agronomy department, Faculty of Agriculture, for their dedicated support in field preparation and data collection. Their contributions significantly enhanced the quality and reliability of this study. In conclusion, the authors sincerely thank all those who have played a part in making this research possible. Their assistance and support have been instrumental in shaping the outcomes of this study, and their contributions will always be remembered with utmost gratitude.

References

1. Abdalla A, Satti N, Bilal AA. The major predators and their seasonal abundance in okra fields at Elgorair Scheme, Northern Sudan. The Experiment. 2012;4(4):271-6.
2. Amin MR, Tripura K, Miah MRU, Kayesh E, Khan MAR. Diversity of insects in okra agro-ecosystem at Gazipur in Bangladesh. Indian J Ecol. 2019;46(1):214-6.
3. Anbalagan V, Paulraj MG, Ignacimuthu S. Diversity and abundance of Hymenoptera families in vegetable crops in north-eastern District of Tamil Nadu, India. Int J Fauna Biol Stud. 2015;2(3):100-4.
4. Athar M, Bokhari TZ. Ethnobotany and production constraints of traditional and commonly used vegetables of Pakistan. J Veg Sci. 2006;12(2):27-38.
5. Bajiya MR, Abrol DP. Flower-visiting insect pollinators of mustard (Brassica napus) in Jammu Region. J Pharmacogn Phytochem. 2017;6(5):2380-6.
6. Bhatt B, Joshi S, Karnatak AK. Biodiversity of insect pests and their predators on okra agroecosystem. J Pharmacogn Phytochem. 2018;7(4):84-6.
7. Chakraborty A, Kumar K, Rajadurai G. Biodiversity of insect fauna in Okra (Abelmoschus esculentus (L.) Moench) Ecosystem. Trends Biosci. 2014;7(16):2206-11.
8. Condamine FL, Clapham ME, Kergoat GJ. Global patterns of insect diversification: towards a reconciliation of fossil and molecular evidence. Sci Rep. 2016;6(1):19208.
9. El-Shafie. The use of neem products for sustainable management of homopterous key pests on potato and eggplant in the Sudan. PhD Thesis, Institute of Phytopathology and Applied Zoology, Justus Liebig University, Giessen, Germany; 2001. Available from: http://www.depositd-nb.de/cgi-bin/dokserv,idn.
10. FAO. FAOSTAT Rederived on 2 May 2023. Available from: https://www.fao.org/faostat/en/#data/QCL
11. Gemede HF, Ratta N, Haki GD, Woldegiorgis AZ, Beyene F. Nutritional quality and health benefits of okra (Abelmoschus esculentus): A review. J Food Process Technol. 2015;6(458):2.
12. Goulet H, Huber JT. Hymenoptera of the world: an identification guide to families.

13. Grimaldi D, Engel MS. Evolution of the Insects. Cambridge University Press; 2005.
14. Johnson NF, CA T. Borror and DeLong's Introduction to the Study of Insects. Thompson Brooks/Cole, Belmont, CA; 2005.
15. Kaur R, Singh R, Aulakh RK. Diversity of arthropods in relation to insecticide and biopesticide treatments in okra. Indian J Entomol. 2023;85(3):594-8.
16. Lara DP, Oliveira LA, Azevedo IF, Xavier MF, Silveira FA, Carneiro MAA, Fernandes GW. Relationships between host plant architecture and gall abundance and survival. Rev Bras Entomol. 2008; 52:78-81.
17. Mallick S, Chand P, Mandal SK. Tolfenpyrad 15% EC, a new pyrazole insecticide, against sucking pests of okra and its impact on natural enemies. Indian J Entomol. 2016;78(1):51-5.
18. Mohankumar SG, Durairaj C, Ramakrishnan S, Preetha B, Sambathkumar S. Integrated pest management of okra in India. In: Integrated Pest Management of Tropical Vegetable Crops. 2016;167-77.
19. Nair N, Giri U, Bhattacharjee T, Thangjam B, Paul N, Debnath MR. Biodiversity of insect pest complex infesting okra (Abelmoschus esculentus) in Tripura, NE India. J Entomol Zool Stud. 2017;5(5):1968-72.
20. Nandhini E, Padmini K, Venugopalan R, Anjanappa M, Lingaiah HB. Flower-visiting insect pollinators of okra (Abelmoschus esculentus (L.) Moench) in Bengaluru region. J Pharmacogn Phytochem. 2018;7(2):1406-8.
21. National Research Council. Lost crops of Africa: volume II: vegetables. National Academies Press; 2006.
22. NSIA. Statistical Yearbook. Available from: http://nsia.gov.af:8080/wp-content/uploads/2022/05/Afghanistan-Statistical-Yearbook.pdf
23. Rachana RR, Manjunatha M, Devi SG, Naik MI. Seasonal incidence of red spider mite Tetranychus neocaledonicus Andre and its natural enemies. Karnataka J Agric Sci. 2009;22(1):213-4.
24. Romdhane MH, Chahdoura H, Barros L, Dias MI, Corrêa RCG, Morales P, et al. Chemical composition, nutritional value, and biological evaluation of Tunisian okra pods (Abelmoschus esculentus L. Moench). Molecules. 2020;25(20):4739.
25. Sharma RK, Prasad K. Classification of promising okra (Abelmoschus esculentus) genotypes based on principal component analysis. J Trop Agric Food Sci. 2010;38(2):161-9.
26. Stadler B, Fiedler K, Kawecki TJ, Weisser WW. Costs and benefits for phytophagous myrmecophiles: when ants are not always available. Oikos. 2001;92(3):467–78.
27. Way MJ. Mutualism between ants and honeydew-producing Homoptera. Annu Rev Entomol. 1963;8(1):307–44.