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Research Article

Occurrence and diversity of insect species in a jujube orchard in Southern Oltenia, Romania

Ana-Maria STOENESCU[1,2]*, Cătălin STAN[3], Florin STĂNICĂ[4]*

[1]*University of Craiova, Faculty of Horticulture, Department of Horticulture and Food Science, Str. A.I. Cuza, 13, Craiova, 200585, Romania; anamaria.stoenescu@edu.ucv.ro (*corresponding author)*
[2]*Research and Development Station for Plant Culture on Sands, Str. Petre Baniță, 217, Călărași, 207220, Romania;*
[3]*University of Craiova, Faculty of Horticulture, Department of Biology and Environmental Engineering, Str. A.I. Cuza, Craiova, 200585, Romania; catalin.stan@edu.ucv.ro*
[4]*University of Agronomic Sciences and Veterinary Medicine of Bucharest, Faculty of Horticulture, Department of Bioengineering of Horti-Viticultural Systems, Blvd. Mărăști, 59, București, 011464, Romania; florin.stanica@usamv.ro (*corresponding author)*

Abstract

This study aimed to address the lack of comprehensive research on the occurrence and diversity of insect species in jujube orchards. The research focused on identifying key insect species and assessing their potential impacts on the orchard ecosystem. Insect species were sampled from 2022 to 2024 using field surveys with direct observation, and their diversity was analysed based on occurrence. 12 orders, 42 families, and 57 species were identified over the three-year study period. Primary pollinators were found to belong to the Hymenoptera, Coleoptera, and Diptera orders, while most identified pests were from the Hemiptera, Coleoptera, and Lepidoptera orders. Predators were part of Coleoptera and Araneae, while occasional visitors were part of Coleoptera, Diptera, and Odonata orders. The analysed diversity indices suggest high species diversity and evenness (Shannon-Weiner = 3.593; Simpson's = 0.461; and Pielou's Evenness Index = 0.889). The major jujube pests identified were *Phaneroptera nana*, *Halyomorpha halys*, *Nezara viridula*, and *Stictocephala bisonia*. The study emphasizes the significance of understanding insect biodiversity in agroecosystems, demonstrating that the Chinese jujube is highly attractive to entomofauna. These findings provide valuable insights for future pest management and sustainable farming practices in jujube orchards.

Keywords: Chinese date; fruit trees; pests; pollinators; *Ziziphus jujuba*

Introduction

Jujube (*Ziziphus jujuba* Mill., Rhamnaceae, Rosales, 2n=24), a species native to China, is highly valued for its nutritional, medicinal, therapeutic, and ecological benefits (Liu *et al*., 2020; Li *et al*., 2023). It plays an important role in environmental restoration, particularly in rehabilitating degraded lands, due to its ability to thrive in extreme climates and poor soils (Huiqin *et al*., 2021). However, despite its benefits, the expansion of jujube cultivation faces several challenges, primarily due to biotic and abiotic factors (Alle *et al*., 2024). *Z. jujuba*

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is a temperate deciduous fruit tree belonging to the "direct flowering" group, meaning flower bud differentiation, blooming, and fruit development occur after dormancy release during a single growing season (Meir *et al.*, 2016). The growth of jujube branchlets, flower initiation, blooming, fruit set, and fruitlet development unfold together (Yao *et al.*, 2015), with the flowering period extending over a prolonged duration, exhibiting flowers alongside all stages of fruit development. These particular characteristics attract a wide variety of arthropods. Currently, insect abundance and diversity are declining (Sisterson *et al.*, 2020), with pollinators suffering from anthropogenic pressures such as habitat fragmentation (Samih *et al.*, 2024), pollution, climate change, changes in land use, and agricultural intensification (Pardo and Borges, 2020; Hausmann *et al.*, 2022). Pest regulation and pollination are essential ecosystem services that contribute significantly to ensuring sustainable food production and economic stability (Porcel *et al.*, 2018). Insect pests also pose a significant threat to jujube production, reducing both quality and yield (Shi *et al.*, 1998). Taking these aspects into consideration, entomology is crucial for understanding the role that insects play in ecosystems, serving essential functions in crop pollination, stabilizing yields, preserving seed genetic diversity, and preventing inbreeding depression, which collectively enhance ecosystem and agricultural resilience (Singh and Adhikary, 2021). Insects constitute the most abundant group within the invertebrate kingdom, exhibiting significant ecological adaptability. They inhabit both natural ecosystems, such as meadows, forests, and grasslands, as well as artificial ecosystems, including agroecosystems. Throughout their developmental stages, insects are intricately associated with vegetation, which serves as a substrate for egg deposition, a nutritional resource for larvae and adults, and a refuge for pupae. Furthermore, insects serve as reliable bioindicators of environmental health, responding promptly to adverse anthropogenic influences (Șerban and Cristescu, 2013). In jujube orchards, insects contribute to pollination and pest control, with some cultivars exhibiting resistance to pests and others vulnerable to damage from Hemiptera, Lepidoptera larvae, mites, and fruit borers. Predatory insects, including bees, wasps, mites, and spiders, play a crucial role in regulating pest populations. Lamarre *et al.* (2018) emphasize the significance of insect predators in regulating herbivorous pests, which contributes to biodiversity and agricultural sustainability. Biological control methods, such as utilizing biocontrol organisms or bioinsecticides, can help maintain agroecosystem stability, although they may also pose unintended risks to beneficial arthropods, potentially destabilizing natural regulatory systems (Daniel *et al.*, 2018).

Environmental factors, including food availability, humidity, photoperiod, and temperature, have a significant influence on insect growth and development. Understanding these factors is essential for effective pest management (Kumar, 2018). Specific location characteristics, such as geographic coordinates, elevation, and proximity to natural and anthropogenic factors, are vital for understanding insect diversity, frequency, and distribution. Climatic, edaphic, and anthropogenic factors, including soil cultivation and crop management practices like phytosanitary treatments, may influence insect populations (Popov *et al.*, 2018) and, consequently, the species composition within the orchard. These factors can lead to the migration of insect species in response to environmental changes. Coteț *et al.* (2024) highlight that climatic changes in southern Oltenia, Romania, during the past decade, marked by increased air temperatures, prolonged droughts, and episodes of excessive precipitation, have contributed to significant alterations in both the frequency and intensity of harmful organism infestations across diverse plant species. Although conventional agriculture often relies on chemical inputs, there is growing interest in reducing pesticide use, promoting biodiversity within orchards, and creating habitats for beneficial organisms to sustain food webs in agroecosystems (Simon *et al.*, 2011). As highlighted by Popov *et al.* (2018), organic management practices, such as reduced pesticide use and crop diversification, may further enhance biodiversity, thereby supporting the development of ecologically balanced and productive agroecosystems.

Biodiversity conservation and management necessitate a predictive understanding of the role of diversity in ecosystem structure and function, as well as how global changes, such as climate and land-use alterations, might affect these relationships (Chiarucci *et al.*, 2011). In this context, the occurrence of diverse and abundant insect communities is considered a key indicator of ecosystem sustainability across various habitats, underscoring the importance of maintaining biodiversity for the resilience of ecosystems (Ramzan *et al*., 2021). Due to the long history of jujube cultivation in China, people have extensive knowledge of the insects present in jujube orchards, including pollinators, pests, and predators (Feng and Song, 2010; Wang *et al*., 2011; Huo and Qiu, 2021; Ma, 2023). As jujube cultivation expands in Europe, it is imperative to understand the insect species present in European jujube orchards, including both beneficial and harmful organisms. Regarding Romania, detailed information on the insect species present in jujube orchards is limited (Mardare *et al*., 2016; Ciceoi *et al*., 2017; Stoli and Stănică, 2021). The alarm was raised by Chireceanu *et al*. (2013) after the discovery of the first attack of the Mediterranean fruit fly (*Ceratitis capitata* (Wied.) in a Bucharest jujube orchard. Only first-ripe fruits were attacked by *Ceratitis*. Since then, the population has been monitored with the help of Trephi Traps.

The present study aimed to fill the existing knowledge gap by exploring the occurrence and diversity of insect species in a jujube orchard located in the Southern Oltenia region of Romania, focusing on identifying key species and assessing their potential impacts on the orchard ecosystem.

Materials and Methods

Experimental site and habitat description

The study was conducted in a 4-year-old jujube orchard located in Bratovoești Commune, Dolj County, within the Oltenia region, southwest of Romania (44°07'12.9"N 23°54'24.4"E) at an elevation of 59 m above sea level. The orchard consists of various jujube individuals, including the Chinese cultivars 'Lizao', 'Xuancheng Jian', 'Lang', 'Fengmiguan', and 'Dabaizao', the Fellini selection (a local selection of an Italian fruit grower from Gambettola, Italy), the Jurilovca biotype (a wild type from the Dobrogea region, Romania), and the genotypes R5 (possibly of Chinese origin), S1, and K1.

The orchard is located approximately 60 m South of Bratovoești Forest, which is part of the Natura 2000 network (91F0 habitat - Riparian mixed forests of *Quercus robur*, *Ulmus laevis*, *Ulmus minor*, *Fraxinus excelsior*, and *Fraxinus angustifolia* along major rivers of *Ulmenion minoris*).

The region is delineated to the West by the Jiu River, approximately 2000 m away. A diverse array of aquatic ecosystems is present in the South West, including the Giorocel stream, marshlands, lacustrine environments, and pastures. Additionally, the orchard is influenced by the adjacent agricultural fields.

Climate characteristics

The experimental site experiences a continental climate with an average annual precipitation of 500 mm (with the majority in May and June and smaller amounts in August and September). Temperatures typically exceed 25 °C, with hot summer days often above 35 °C. According to Bogdan *et al*. (2011), in Dolj County, early springs are frequently followed by cold conditions in April and late spring frosts, which negatively impact the development of vegetation, particularly in vegetable crops, orchards, and vineyards. During the study period (2022–2024), minimum winter temperatures ranged from −3.8 °C to −14.2 °C.

Ziziphus jujuba is a temperate fruit tree whose buds typically burst in early May, a phenological trait that makes it less susceptible to late spring frost damage. According to Liu *et al*. (2020), optimal conditions for jujube cultivation in China include annual average temperatures between 5.5 and 22 °C, flowering season temperatures of ≥22-24 °C, minimum temperatures no lower than −38.2 °C, and annual precipitation between 20 and 2000 mm. Based on these climatic requirements, the conditions at the study site are suitable for the successful cultivation of jujube.

Agro-management practices

To enhance soil quality and promote biodiversity, the orchard maintains a uniform grass cover composed of species such as *Festuca pratensis*, *Phleum pratense*, *Festuca rubra*, *Dactylis glomerata*, *Agrostis gigantea*, *Festulolium*, *Bromus inermis*, *Lolium hybridum*, *Lolium multiflorum*, and *Lolium perenne*.

Mowing is performed infrequently, timed according to the growth stage of the grass, typically when plants reach seed maturity, to preserve species richness and help maintain soil moisture.

Irrigation is provided via a sprinkler system every three days or as needed based on weather conditions, with particular attention during flowering and young fruit development stages.

Importantly, no phytosanitary treatments or fertilizers were applied during the study period, allowing natural insect populations to develop without chemical interference.

Research methods

A descriptive research approach was used to monitor and identify beneficial and potentially harmful insect species in the orchard over the three growing seasons (2022-2024). Visual surveys were conducted at a 7-day interval (sometimes day and night, to observe general behaviour and food selection), seven times a day, for 30 min each session (8 am; 10 am; noon; 2 pm; 4 pm; 6 pm and 8 pm), regardless the weather conditions, beginning from the onset of flowering (BBCH 60, first flowers open) and continuing until fruit senescence (BBCH 89, fruits begin to soften and wrinkle). The surveys focused on identifying species that positively or negatively affected jujube trees, as well as those with no significant effect. Insects that did not contribute to the health or damage of trees were classified as occasional visitors. Insect observations were correlated with the phenological stages of jujube development following the BBCH scale outlined by Hernández *et al*. (2015). The primary phenological stages were used to assess the temporal patterns of insect activity and their potential impacts on the orchard. Insect identification was based on the photographic documentation of insect morphology, with specimens compared to a dichotomous key guide for insects. The images were cross-referenced with the available literature to confirm species identification. Essential taxonomic identification was performed to distinguish between species and track the diversity of the insect populations throughout the growing season.

Statistical analysis

XLSTAT (version 2016, Addinsoft©) was used to analyse and classify insects. To assess the biodiversity within the orchard, several key diversity indices (Table 1) were calculated (Chiarucci *et al*., 2011; Popov *et al*., 2018; Kasi *et al*., 2021; Stamin and Cosmulescu, 2025): Shannon-Weiner Diversity Index (H'), Simpson's Diversity (D) and Dominance Indices, Pielou's Evenness Index (J'), and Gleason, Menhinick, and Margalef's Richness Indices. The obtained results assessed the richness and evenness of the species' distribution within the orchard. Figures were generated using Python Programming Language, version 3.11, with the Pandas, Matplotlib, and Seaborn libraries.

Table 1. Calculated diversity indices

Diversity Index	Formula		
Shannon-Weiner Diversity Index (H') Variation limits: 0 ≥ 3.5 (Fernando, 1998)	$H' = -\sum_{i=1}^{s} \frac{ni}{N} \log \frac{ni}{N}$	s = total number of families ni = total number of species from family i N = total number of species	(1)
Simpson's Diversity Index (D) Variation limits: 0 - 1 (Peng *et al.*, 2018)	$D = \sum \frac{ni(ni-1)}{N(N-1)}$	N = total number of species ni = total number of species from family i	(2)
Simpson's Dominance Index Variation limits: 0 - 1 (Odum, 1971)	1 - D	D = Simpson's Diversity Index	(3)
Pielou's Evenness Index (J') Variation limits: 0 - 1 (Gumela *et al.*, 2023)	$J' = \frac{H'}{\ln(S)}$	H′ = Shannon-Weiner Diversity Index S = total number of species	(4)
Maximum Entropy (Hmax)	$H_{max} = \ln(S)$	S = total number of species	(5)
Gleason Richness Index Variation limits: 0 - 30 (Gleason, 1922)	$G = \frac{S}{\ln N}$	S = total number of families N = total number of species	(6)
Menhinick Index	$D_{Mn} = \frac{S}{\sqrt{N}}$		(7)
Margalef's Richness Index Variation limits: < 2.0: Low species richness; 2.0-3.0: Moderate species richness; > 3.0: High species richness; > 5.0: Exceptionally high species richness (Chugani, 2025)	$D_{Mg} = \frac{S-1}{\ln N}$		(8)

Results and Discussions

Insect diversity and abundance

Table 2 summarizes the primary species observed during the three-year study period (2022–2024), categorized by their functional roles: pollinators, pests, occasional visitors, and predators. The study documented 12 insect orders, 42 families, and 57 species. Regarding family distribution, the Hymenoptera order was the most prevalent, comprising 21.43% of the identified families. This order encompasses important pollinators, including bees, wasps, and ants, which are crucial to plant reproduction and the stability of ecosystems. Coleoptera (beetles) followed, representing 16.67% of families, while Hemiptera (true bugs, including aphids, leafhoppers, and cicadas) accounted for 14.29%. The orders Diptera (flies) and Araneae (spiders) contributed 11.90% and 9.52%, respectively, while Lepidoptera (butterflies and moths) and Odonata (dragonflies and damselflies) each made up 7.14% of the family distribution. The remaining orders: Mecoptera (scorpionflies), Mantidae (mantises), Orthoptera (grasshoppers, crickets), Planipennia (alderflies), and Dermaptera (earwigs)- each represented 2.38% of the families. At the genus and species level, Coleoptera dominated, contributing 31.58% of the total species counts. This high proportion is consistent with the well-known diversity of beetles across various ecosystems, both herbivorous species and decomposers that play crucial roles in organic matter recycling. Hymenoptera contributed 19.30% of the species, reflecting their dual role as pollinators and natural pest controllers. In comparison, Hemiptera represented 12.28%, reflecting their widespread impact as agricultural pests and vectors of plant diseases. Diptera contributed 8.77%, with members of this order functioning as decomposers, pollinators, and occasional pests. Araneae and Lepidoptera each accounted for 7.02%, with spiders acting as predators in food webs and butterflies and moths serving important pollination functions. Odonata represented 5.26%, with individuals acting as occasional visitors. At the same time, the remaining orders, Mecoptera, Mantidae, Orthoptera, Planipennia, and Dermaptera, each contributed 1.75%, indicating their relatively minor role in species richness in the studied ecosystem. These findings are significant in the context of the broader ecological dynamics within the study area. The high diversity observed, particularly within Hymenoptera, Coleoptera, and Hemiptera, suggests a complex and multi-faceted insect community with varied ecological functions. Pollinators, such as those within Hymenoptera, are critical to the reproductive success of both wild and cultivated plants, thus directly influencing biodiversity and agricultural productivity. Conversely, pest species, particularly those within the Hemiptera order, can harm plant health and yield. Predators, particularly those from the Araneae and Diptera orders, play a crucial role in regulating pest populations, thereby contributing to ecological balance.

Table 2. Taxonomic classification, functional group, and feeding habit of insect species identified in the jujube orchard during 2022-2024

Order	Family	Species	English name	Functional group	Feeding habit
Coleoptera	Cerambycidae	*Chlorophorus varius* (Muller, 1766)	Grape wood borer/wasp beetle	Pest	Polyphagous
		Xylotrechus rusticus (Linnaeus, 1758)	Gray tiger longhorn beetle	Pest	Xylophagous
		Neoclytus acuminatus (Fabricius, 1775)	Red-headed ash borer	Pest	Xylophagous
		Cerambyx scopolii (Füssli, 1775)	Lesser capricorn beetle	Occasional	Xylophagous
		Aromia moschata (Linnaeus, 1758)	Musk beetle	Occasional	Xylophagous
		Leptura quadrifasciata (Linnaeus, 1758)	Four-banded longhorn beetle	Occasional	Phytophagous
	Coccinellidae	*Coccinella septempunctata* (Linnaeus, 1758)	Seven-spotted ladybird	Predator	Carnivorous
		Harmonia axyridis (Pallas, 1773)	Ladybird	Predator	Carnivorous
		Scymnus sp.	Ladybird	Predator	Carnivorous
	Chrysomelidae	*Clytra laeviuscula* (Ratzeburg, 1837)	Ant bag beetle	Occasional	Phytophagous
		Bruchus sp.	Leaf beetle	Occasional	Phytophagous
		Altica sp.	Flea beetle	Occasional	Phytophagous
	Dermestidae	*Anthrenus* sp.	Bird Nest Carpet Beetle	Occasional	Nectar/Pollen
	Cantharidae	*Rhagonycha fulva* (Scopoli, 1763)	Common red soldier beetle	Pollinator	Omnivorous
		Cantharis rustica (Fallén, 1807)	Rustic sailor beetle	Predator	Carnivorous
	Buprestidae	*Capnodis tenebrionis* (Linnaeus, 1761)	Flatheaded woodborer	Occasional	Phytophagous
		Dicerca alni (Fischer von Waldnheim, 1824)	-	Occasional	Xylophagous
	Cleridae	*Trichodes apiarius* (Linnaeus, 1758)	Checkered beetle	Pollinator	Polyphagous
Diptera	Sciaridae	-	Black fungus gnats	Occasional	Omnivorous
	Syrphidae	-	Hoverfly	Pollinator	Phytophagous
	Tipulidae	*Nephrotoma* sp.	Cranefly	Occasional	Phytophagous
	Stratiomyidae	*Chloromyia* sp.	Soldier fly	Occasional	Phytophagous
	Tephritidae	*Rhagoletis cerasi* (Linnaeus, 1758)	European cherry fruit fly	Pest	Phytophagous
Hemiptera	Cicadellidae	*Fieberiella* sp.	Leafhopper	Pest	Phytophagous
	Cicadidae	*Tibicina haematodes* (Scopoli, 1763)	Red cicada	Pest	Phytophagous
	Pentatomidae	*Halyomorpha halys* (Stål, 1855)	East Asian stink bug	Pest	Polyphagous
		Nezara viridula (Linnaeus, 1758)	Southern green stink bug	Pest	Polyphagous
	Membracidae	*Stictocephala bisonia* (Kopp and Yonke, 1977)	Buffalo treehopper	Pest	Phytophagous
	Miridae	*Deraeocoris ruber* (Linnaeus, 1758)	Red-spotted plant bug	Occasional	Carnivorous
	Psyllidae	*Psylla mali* (Schmidberger, 1836)	Apple leaf sucker	Occasional	Phytophagous
Hymenoptera	Apidae	*Apis mellifera* (Linnaeus, 1758)	European Honey bee	Pollinator	Nectar/Pollen
		Bombus sp.	Bumblebee	Pollinator	Nectar/Pollen
	Sphecidae	*Chalybion femoratum* (Fabricius, 1781)	Mud-dauber wasp	Pollinator	Nectar
		Sceliphron caementarium (Drury, 1773)	Yellow-legged mud dauber wasp	Pollinator	Nectar
	Argidae	*Arge ochropus* (Gmelin, 1790)	Rose sawfly	Occasional	Nectar
	Chrysididae	*Chrysis* sp.	Cuckoo wasp	Pollinator	Parasitoid/Nectar
	Ichneumonidae	*Ichneumon* sp.	Ichneumon wasp	Pollinator	Parasitoid/Nectar
	Colletidae	*Hylaeus* sp.	Masked bee	Pollinator	Nectar/Pollen
	Braconidae	*Apanteles* sp.	Parasitoid wasp	Pollinator	Parasitoid/Nectar
	Eurytomidae	*Eurytoma schreineri* (Schreiner, 1908)	Plum seed wasp	Occasional	Phytophagous
	Vespidae	*Vespula germanica* (Fabricius, 1793)	European wasp	Pollinator	Omnivorous
Lepidoptera	Scythrididae	*Scythris sinensis* (Felder and Rogenhofer, 1875)	Moth	Occasional	Phytophagous
	Gelechiidae	*Tuta absoluta* (Meyrick, 1917)	Tomato borer	Pest	Phytophagous
	Noctuidae	*Helicoverpa armigera* (Hübner, 1808)	Cotton bollworm	Pest	Polyphagous
		Emmelia trabealis (Scopoli, 1763)	Spotted Sulphur	Occasional	Phytophagous

Mecoptera	Panorpidae	*Panorpa communis* (Linnaeus, 1758)	Common scorpionfly	Occasional	Carnivorous/ Scavenger
Mantodea	Mantidae	*Hierodula tenuidentata* (Saussure, 1869)	Giant Asian Mantis	Occasional	Carnivorous
Orthoptera	Tettigoniidae	*Phaneroptera nana* (Fieber, 1853)	Southern sickle bush-cricket / Mediterranean katydid	Pest	Phytophagous
Odonata	Libellulidae	*Orthetrum* sp.	Dragonfly	Occasional	Carnivorous
	Platycnemididae	*Platycnemis pennipes* (Pallas, 1771)	White-legged Damselfly	Occasional	Carnivorous
	Calopterygidae	*Calopteryx splendens* (Harris, 1782)	Banded demoiselle	Occasional	Carnivorous
Dermaptera	Forficulidae	*Forficula auricularia* (Linnaeus, 1758)	Common earwig	Occasional	Omnivorous
Planipennia	Chrysopidae	*Chrysopa carnea* (Stephens, 1836)	Common lacewing	Occasional	Carnivorous
Araneae	Araneidae	*Argiope bruennichi* (Scopoli, 1772)	Wasp spider	Predator	Carnivorous
	Thomisidae	*Thomisus onutus* (Walckenaer, 1806)	Crab spider	Predator	Carnivorous
	Salticidae	*Heliophanus* sp.	Jumping spider	Predator	Carnivorous
	Tetragnathidae	*Tetragnatha* sp.	The long-jawed orb-weaving spider	Predator	Carnivorous

*sp. – species identified only at the genus level; Pollinator: Contributes to the pollination of plants; Pest: Feeds on plant parts and may cause damage to crops; Predator: Preys on other insects, which is often beneficial for pest control; Occasional: Infrequently observed or with unclear role; includes accidental visitors or species not directly impacting the jujube orchard

Diversity indices, often referred to as ecological or species diversity indices, are widely utilized in scientific studies to characterize changes in biodiversity and to represent data on species abundance within communities (Bandeira *et al*., 2013). These indices, particularly those measuring diversity and richness, are frequently employed to elucidate patterns of insect species across various ecosystems (Shi *et al*., 2005; Wang *et al*., 2009; Chima *et al*., 2013; Mokam *et al*., 2014; Morris *et al*., 2014; Goswami *et al*., 2023). This approach is particularly relevant given the significant role of insect species in regulating and maintaining ecosystem services (Noriega *et al*., 2018). In the present study, the biodiversity within the jujube orchard was evaluated using multiple diversity indices, as detailed in Table 3.

Table 3. Analysed diversity indices to assess insect species richness and evenness in the jujube orchard

Diversity Index	Value
Species Richness	57
Family Richness	42
Shannon-Weiner Diversity Index (H')	3.593
H max	4.043
Pielou's Evenness Index (J')	0.889
Simpson's Diversity Index (D)	0.461
Simpson's Dominance Index (1-D)	0.539
Gleason Richness Index	10.388
Menhinick Index	5.563
Margalef's Richness Index	10.141

*Diversity indices calculated according to the formulas mentioned in Table 1

These indices provide insights into species richness and the evenness of distribution across families. The biodiversity indices indicate that the orchard supports a diverse and well-balanced ecosystem. The Shannon-Weiner Diversity Index (H') was calculated at 3.593, suggesting a relatively high species diversity level in the orchard. Peng *et al*. (2018) mention that the higher value of H means higher species richness and signifies that different species in the quadrat or a community are nearly equally abundant. In combination with the Shannon index, Pielou's Evenness Index (J') of 0.889 further supports the idea of a balanced insect community. This high evenness value suggests that the distribution of individuals among species is relatively uniform, implying that no single species significantly outweighs the others in terms of abundance. Simpson's Diversity Index (D), which measures the probability that two randomly selected individuals will belong to the same species, was found to be 0.461. This moderate value indicates that the insect community is somewhat diverse, with a fair likelihood that individuals chosen randomly will be from different species. However, some species may still be more common. In contrast, Simpson's Dominance Index (1-D) was calculated at 0.539, suggesting moderate dominance by a few species within the orchard. While there are some more abundant species, the dominance is not overwhelming, and the insect community remains fairly balanced overall.

The Gleason Richness Index, which integrates both species richness and abundance distribution, was found to be 10.388. This value supports the findings of moderate species richness and highlights the presence of a relatively diverse insect community, both in terms of species count and the distribution of individuals. Similarly, the Menhinick Index (5.563), which adjusts for sample size, indicates that the species richness is relatively high, suggesting a well-diversified insect population relative to its overall abundance. Lastly, Margalef's Richness Index (10.141), which also accounts for species richness, further substantiates the assertion that the orchard supports a high level of biodiversity relative to the total insect population. According to Chugani's (2025) classification, a value exceeding 5.0 indicates exceptionally high species richness. Sina and Zulkarnaen (2019) mention that abundance increases proportionally with the value of the Margalef index. This measure provides additional evidence of the orchard's ecological complexity, underscoring the importance of maintaining a variety of species within the ecosystem. Kunak *et al.* (2023) mention the Shannon-Wiener index as important in the assessment of community heterogeneity, the Simpson index as an indicator of community evenness, and the Margalef and Menhinick indices as being used for the assessment of species richness. Overall, the obtained results indicate a healthy and resilient orchard ecosystem with a balanced species mix and even distribution, thereby enhancing the ecological stability of the jujube orchard.

Reif *et al.* (2021) suggested that promoting the use of spontaneous vegetation cover through agri-environmental schemes could help increase species richness. For example, Wang *et al.* (2009) analysed the communities and diversity of beneficial insects on jujube trees in Taigu, Shanxi Province, across two sites: one intercropped with pasture and the other without. Their results indicated a higher species richness in the intercropped site, with a total of 64 species recorded over the three-year study period. The findings from this study suggest that the insect community in the jujube orchard is diverse, with a balanced distribution of species and relatively high species richness. In conclusion, the jujube orchard supports a relatively diverse and balanced insect community, consistent with findings from similar studies on insect communities in jujube orchards (Shi *et al.*, 2005; Wang *et al.*, 2009). This diversity is essential for maintaining the ecological health of the agroecosystem. According to Kunak *et al.* (2023), biodiversity indices exhibit varying degrees of sensitivity to the distribution of species quantity and abundance. In contrast, species richness indices demonstrate formal insensitivity to the distribution of species abundance, and evenness indices display formal insensitivity to species quantity.

Besides the most common pollinators (bees, wasps), the checkered beetle (*Trichodes apiarius*), a polyphagous coleopteran, was omnipresent during May and June, ensuring efficient pollination. This species is also a predator of small insects, making its role in the orchard highly beneficial. According to the obtained data (Figure 1), the predominant insect orders categorized into their functional group were as follows: pollinators of Hymenoptera (75%); pests of Hemiptera (41.67%); predators of Coleoptera (50%) and Araneae (50%); and occasional visitors of Coleoptera (36%).

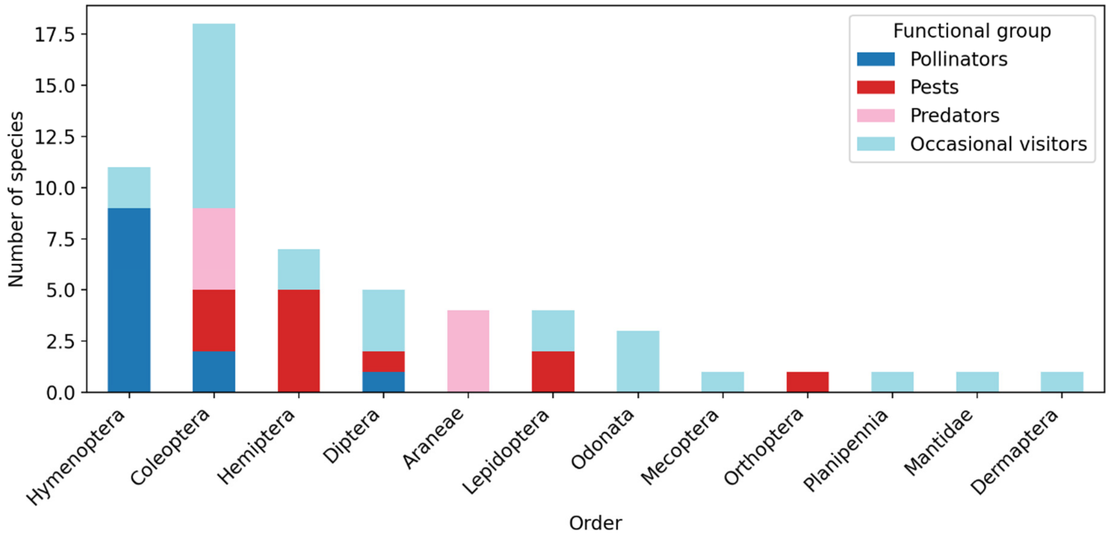

Figure 1. Representation of the identified insect species (order level) based on the functional group and total number of species

Descriptive summary of species richness across arthropod orders and functional groups. Bar height represents total species recorded per order, while coloured segments show the proportion of pollinators, pests, predators, and occasional visitors within each order

In a 'Huping' cv. jujube orchard in Shanxi Province, China, Cheng *et al.* (2021) identified flower-visiting insects from eight orders, 57 families, and 90 species. These included Hymenoptera (33.33% families and 18.71% individuals), Diptera (19.30% families and 36.47% individuals), Coleoptera (14.04% families), Lepidoptera, Thysanoptera (24.72% individuals), Hemiptera (15.79% families), Neuroptera, and Psocoptera. Shi *et al.* (2005) detected eight orders, 25 families, and 58 species at an integrated pest management (IPM) jujube site, compared to eight orders, 18 families, and 27 species at a conventional pest management site in Taigu, Shanxi Province. The study highlighted several dominant species, including *Inocclia* sp., *Coccinella septempunctata*, *Chrysopa shansiensis*, *Chelonos chinensis,* and *Anysis saissetiae*. In the same region Wang *et al.* (2009) identified eight orders, 25 families and 64 species in an intercropped jujube orchard. Ma (2023) highlights the dual role of jujube species in Gansu Province, China, as they attract harmful and beneficial arthropods. Specifically, his study identifies 16 orders, 38 families, 57 genera, and 60 species of insect pests, alongside 14 orders, 22 families, and 31 genera of beneficial insects, underscoring the complex ecological interactions associated with jujube cultivation. The results obtained in this study are consistent with those reported by the above-mentioned authors. However, the higher number and diversity of identified species can likely be attributed to differences in the size of the study area, location, and local climatic conditions. Additionally, variations in management practices and soil types may contribute to the observed diversity in insect populations. Also, Pardo and Borges (2020) found that the majority of apple pollinators studied belonged to the order Hymenoptera, as theoretically expected. However, there were also considerable numbers of pollinator species from the order Diptera (Syrphidae) and minor frequencies of Lepidoptera, Hemiptera, and Coleoptera. These results are consistent with our findings. Shi *et al.* (2005) note that the composition, structure, function, and succession of beneficial insect communities in jujube orchards are heavily influenced by artificial disturbances, such as pesticide use and other agricultural practices, as well as environmental complexities.

Temporal dynamics of insect activity

Phenology represents the temporal occurrence and duration of biological events influenced by climate factors. It is optimally exemplified through the specific growth stages, or BBCH scale, applied to monocotyledonous and dicotyledonous plant species (Stoenescu *et al.*, 2024). Each stage denotes a distinct growth and developmental change in plants over one annual vegetation cycle. This information is valuable for comprehending plant developmental requirements and, consequently, its impact on insect activity. Ramzan *et al*. (2021) highlight that temperature and humidity have a significant influence on insect diversity. The authors note that during the summer months, elevated temperatures have been observed to negatively impact the diversity and abundance of fauna. In contrast, moderate to average temperatures during other seasons favoured higher insect richness, promoting greater diversity and abundance within the ecosystem. In terms of temporal variation in insect activity, there were notable variations in the phenological stages of jujube trees. As expected, pollinators (starting the first year of planting), particularly honeybees, wasps, and hoverflies, peaked during the flowering phase (BBCH 60) up until the end of flowering (BBCH 69). In contrast, pest species such as *Nezara viridula* and *Stictocephala bisonia* became more prevalent during the fruit ripening stages (BBCH 80-89) (Figure 2). The nymphs of *Phaneroptera nana* began feeding on young leaves in June, whereas the adults started producing damage on fruits from BBCH 72 (fruit formation) up to BBCH 89 (fruits begin to wrinkle).

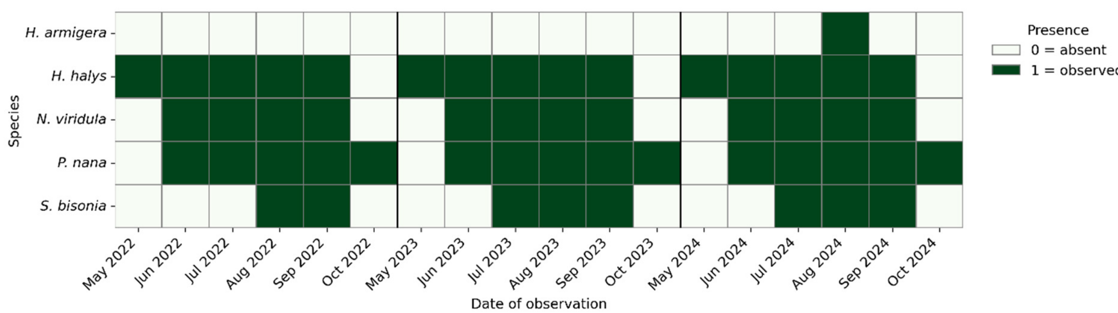

Figure 2. Seasonal presence–absence matrix of the five identified pest species in the jujube orchard (May-October, 2022-2024)

Halyomorpha halys, nymph, and adult began their activity with jujube fruit formation (BBCH 72), feeding on fruits up until the end of September. Fruits that were fed upon ceased development and eventually dropped prematurely, leading to a measurable reduction in yield. Pest species were first detected in 2022, yet visible damage did not appear until 2023. This lag likely reflects the increasing susceptibility of older trees, consistent with Zhu *et al*. (2024), who documented a rise in jujube pest and disease incidence as stand age advances. These observations highlight the intricate relationship between insect activity and the phenological stages of jujube trees. The timing of insect appearances and their feeding behaviours are closely synchronized with specific growth stages of the host plant. Kőrösi *et al*. (2018) analysed how the phenological shift of apple trees affected the abundance and diversity of pollinators, herbivores, and predatory arthropods. Their results suggested that spatiotemporal variation in environmental conditions plays a crucial, taxon-specific role in responses to climate-induced phenological asynchrony. The authors also provide evidence that phenological mismatches between orchard crops and various arthropod groups can have diverse effects on the abundance, diversity, and species composition of these arthropods.

Understanding temporal patterns is important for developing effective pest management strategies and optimizing pollination services in jujube orchards.

Identified jujube pests and their impact

The major pests identified in this study included *Phaneroptera nana*, *Nezara viridula*, *Halyomorpha halys*, and *Stictocephala bisonia* (Figure 3). According to Simon *et al*. (2011), grass covers and tree assemblages are designed to promote and attract a complex of specific species, including both beneficial organisms and pests. Targeted plant species serve as sources of nutrition, favourable reproductive environments, oviposition sites, or a combination of these factors. Adults and nymphs of *Halyomorpha halys* (Figure 3C) are significant pests of jujube trees (Feng and Song, 2010). This invasive species targets various parts of the jujube, including leaves, young shoots, and fruits. As they pierce the plant tissue to extract sap, they leave behind black spots on the affected area and weaken the plant's growth (Stan and Țucă, 2023). This major pest has been previously mentioned (Macavei *et al*., 2015; Ciceoi *et al*., 2017; Rechițean *et al*., 2021), affecting many crops, including jujube. Stan and Țucă (2023) additionally identified the brown marmorated stink bug in Dolj County as a significant pest affecting peaches, grapevines, peppers, and tomatoes (both nymphs and adults).

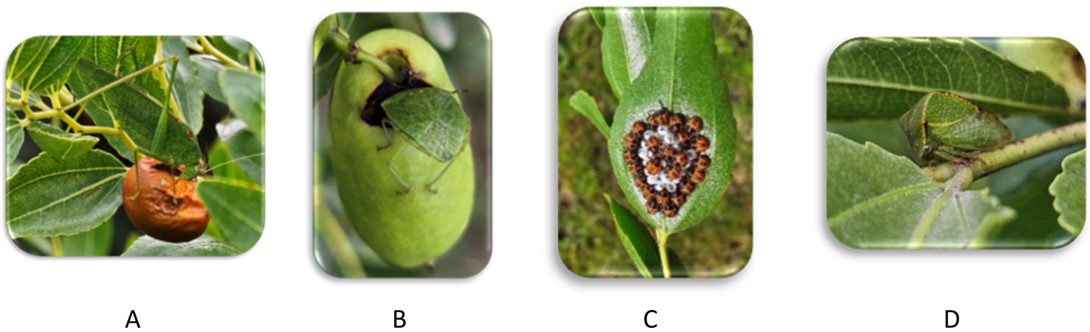

Figure 3. *Phaneroptera nana* (A), *Nezara viridula* (B), *Halyomorpha halys* (C), and *Stictocephala bisonia* (D) pests identified in the jujube orchard

Phaneroptera nana, the Mediterranean katydid, is considered to be responsible for feeding damage on pear fruits in California (Varela *et al*., 2011). This species was identified in all three years of the study, causing damage to jujube fruits (Figure 3A). Varela *et al*. (2011) mention that the species overwinters as eggs on vines, and the nymphs migrate to the edge of the orchard as the fruit ripens. These observations are consistent with those from this study: nymphs feed on young jujube leaves, while adults feed on jujube fruits at all ripening stages (fruit formation to maturity of harvest). Based on the observations, both nymphs and adults seem to feed mainly during the night, which is consistent with the observation of Gangwere (1973), where the damage is visible during the day. Although Reif *et al*. (2021) mentioned *P. nana* as a potential natural predator of *Lobesia botrana* pupae, its omnivorous diet can also damage various plant parts. The biological control method suggested by Massa *et al*. (2004) involves the use of the blue tit (*Cyanistes caeruleus*), which feeds on nymphs, among other things. Other bird species, such as *Parus major* and *Passer domesticus*, may also be beneficial. Currently, there are no findings in the literature regarding *Phaneroptera nana* as a pest of jujube. However, this information could be useful for future studies on pest management in jujube orchards.

Stictocephala bisonia (Figure 3D) appears to be a potential pest for agricultural and forest ecosystems (Świerczewski and Stroiński, 2011), causing damage to plant stems during oviposition. The species deposits over 100 eggs, which are inserted into the bark of young branches using a robust ovipositor. This process results in wounds measuring 2 mm in depth and 3-4 mm in length, affecting the phloem layer of the branch and extending to the cambium tissue. The annual recurrence of this behavior may progressively lead to the deterioration of the plant (Świerczewski and Stroiński, 2011). The buffalo treehopper was identified only in the adult stage in the jujube orchard. Another potential jujube pest is *Helicoverpa armigera*, a polyphagous pest first identified in August 2024. According to Li *et al*. (2024), the species began causing damage to walnuts produced in Xinjiang, China, a region renowned for its cultivation of jujube, apple, grape, pear, apricot, and walnut. The same authors mentioned in their findings the preference of the larvae for the kernel, which is consistent with the observations made in this study: *H. armigera* larvae consumed the jujube kernel (in the green fruit stage).

Another important pest is *Nezara viridula* (Figure 3B). These cosmopolitan and polyphagous species have been previously documented by Grozea *et al*. (2012, 2016) as a pest affecting tomato crops in western Romania, despite their broad dietary range encompassing more than 30 plant families. Both *N. viridula* and *H. halys* (nymphs and adults) have been reported by Grozea *et al*. (2022) as causing adverse effects on various agroecosystems in Romania, and it has been observed that both species coexist (Stan and Țucă, 2023).

Chlorophorus varius is a polyphagous insect in deciduous trees (similar to *Neoclytus acuminatus*), active from May to September, and a serious pest of fruit trees, such as peaches (Holwah and Tadros, 2000). Olenici *et al*. (2022) identified *N. acuminatus* in the western and southern regions of Romania at low elevations on species such as *Quercus* sp. and *Fraxinus excelsior*, which aligns with the findings of this study, given the proximity of the forest containing the aforementioned tree species. Niculescu and Mitrea (2019) reported the occurrence of *Xylotrechus rusticus* in the southern, central, and northern parts of Romania, where deciduous forests are found. It is a stem-boring pest that can inhibit nutrient transportation in the stems and affect tree growth. Liu and Zhao (2009) report the presence of approximately 86 pests affecting jujube, with the peach fruit moth being the most common and damaging. In contrast, Ahmad *et al*. (2023) emphasize that fruit fly infestation in jujube fruit is a significant concern in Pakistan, India, and Middle Eastern countries. Huiqin *et al*. (2021), in a study conducted in Shanxi, mention the main pests of jujube as *Chihuo zao*, *Scythropus yasumatsui*, *Contarinia datifolia*, *Apolygus lucorum*, *Ancylis sativa,* and *Ceroplastes japonicus*. The species *Apolygus lucorum* was also mentioned by Li *et al*. (2023) as a significant pest in jujube culture. Other harmful species *include Carposina niponensis*, *Poryphyinia parva*, *Helicoverpa armigera*, and *Erthesina fullo*. Ciceoi *et al*. (2017) identified in the experimental field of USAMV Bucharest *Ceratitis capitata*, *Halyomorpha halys*, *Metcalfa pruinosa*, and *Nezara viridula* in the jujube orchard. Green stink bugs and brown marmorated stink bugs were also identified in the current study. Bunescu *et al*. (2010) identified in apple, plum, and cherry orchards from Cluj-Napoca, Romania, among others, species like *Psylla mali*, *Cantharis rustica*, *Forficula auricularia*, and *Eurytoma schreineri*, which have also been identified in this study. Alle *et al*. (2024) identified, in their study in Ethiopia, *Carpomya incompleta* (with the highest occurrence), *Drosophila hydei*, *Drosophila simulans*, *Zaprionus indianus*, and *Psyttalia concolor* as major jujube pests, with incidence and infestation levels being higher in fruits than in leaves. *Adoxophyes orana*, the summer fruit tortrix moth, was mentioned as a jujube leaf pest in regions of Northern Shaanxi by Li *et al*. (2019).

Plants serve as oviposition sites for most herbivorous insects, which deposit their eggs on almost all parts of the plants (Hilker and Meiners, 2011). Several jujube leaves were found to carry primarily lepidopteran and hemipteran eggs (*Halyomorpha halys*, *Nezara viridula*) on both the abaxial and adaxial surfaces of the leaves (Figure 3C). The results are consistent with the findings of Feng and Song (2010), who reported that stink bug eggs are predominantly located on the abaxial surface of jujube leaves, with a typical density of 20-30 eggs per leaf. Fernández *et al*. (2019) suggest contact cues from the leaf surface could influence host acceptance, and structural properties or chemical composition of the surface layer may determine an insect's acceptance of the plant as a host, providing a preference cue for specific positioning. Overall, jujube pests exhibit a higher incidence during the flowering and fruit production phenophase (Wang *et al*., 2009) which is consistent with the current study.

Predator species and their role in biological control

While pests pose a significant threat to jujube orchards, predator species, such as ladybugs and spiders, play a vital role in controlling their populations. Predator species such as bees, wasps, arachnids, *Ichneumon* sp., and *Chrysis* sp. can be utilized for biological pest control (Table 2). According to Vacante and Bonsignore (2018), the most important natural pest enemies belong to various insect orders, including Hemiptera (Anthocoridae, Miridae), Neuroptera (Chrysopidae, Coniopterygidae), Diptera (Cecidomyiidae, Muscidae, Syrphidae), Coleoptera (Alleculidae, Anthribidae, Cantharidae, Coccinellidae, Cybocephalidae, Endomychidae, Nitidulidae, Staphylinidae, and Tenebrionidae), and Hymenoptera (Braconidae, Platygastridae, Pteromalidae, Encyrtidae, Eulophidae, Aphelinidae). Earwigs (*Forficula auricularia*) are known to help combat lepidopteran pest eggs, larvae, and pupae (Reif *et al*., 2021). However, their presence is only occasionally observed in jujube trees. Coccinellid predation on aphids is well-documented (Obrycki *et al*., 2009), and it was observed in the jujube orchard with both larvae and adults present. Ladybugs seem to prefer jujube flowers, feeding on pollen and nectar. Species such as *Harmonia axyridis* (Chimișliu, 2016), *Coccinella septempunctata*, and *Propylea japonica* are seen as a measure of biological control (Li *et al*., 2021). Several of the species identified in this study are also reported by Bîrzanu and Mitrea (2022) in the Bratovoesti area, including *Apis mellifera*, *Vespula germanica*, *C. septempunctata*, and *F. auricularia*. Ladybugs, lacewings, parasitic wasps, predatory mites, parasitic flies, and spiders were identified by Feng and Song (2010) as effective agents for pest biocontrol, in addition to insectivorous birds such as the great tit, cuckoo, woodpeckers, magpies, hoopoe, swallow, robin, and leaf warblers, which were noted to be beneficial in controlling fruit tree pests including aphids, beetles, butterflies and moth larvae, sawflies, and leafhoppers. Stoenescu *et al*. (2024) highlight the importance of insects as a food source for insectivorous birds in the study area, which could help in controlling the pest population within the jujube orchard. Implementing ground covers in orchards is considered a crucial component of ecological orchard management in China, contributing to an increase in the population of natural enemies that can enhance the biological control of pests. Moreover, interplanted crops and grasses provide food, habitat, and breeding sites for predators in early spring (Zhou *et al*., 2014). However, in certain instances, elevated humidity levels caused by grass coverage may be conducive to weed proliferation and pest development; therefore, particular attention and caution must be exercised to prevent undesirable outcomes (Zhou *et al*., 2014).

Ecological context and implications for orchard management

An ecosystem is a dynamic community composed of living (biotic) and non-living (abiotic) components that interact within a specific environment. Biodiversity encompasses the variety of natural elements within an ecosystem, including wild and cultivated plants, animals, and microorganisms, contributing to ecological balance and resilience (Ramzan *et al*., 2021). While insect diversity is a key factor in orchard health, it is equally important to understand different species' roles, including their interactions as pollinators, pests, and predators. Pollinators such as bees, hoverflies, and butterflies are essential for orchard productivity; pests (aphids, fruit flies, and leafhoppers) cause damage to jujube trees either by feeding on leaves, stems, roots, and fruits or can be vectors of possible diseases; occasional visitors (flies, ants, dragonflies) are insects that are not frequent enough to be considered regular pollinators or pests; and predators (ladybugs, spiders, wasps, predatory beetles) are beneficial insects that can help control pest populations by feeding or parasitizing harmful insects, which makes them important key factors for integrated pest management (IPM). Noriega *et al*. (2018) report that pollinators, predators, parasitoids, herbivores, and decomposers constitute the most frequently investigated groups, while Hymenoptera, Coleoptera, and Diptera represent the most extensively studied taxa. The authors assert that insects contribute to ecosystem services through their diverse roles in provisioning, regulating, supporting, and cultural functions, highlighting their critical importance in maintaining ecological balance and supporting ecosystem functionality. Although many species were classified as occasional visitors, some may exhibit a dual role within the orchard, functioning both as pollinators and pests, or may be transient. For instance, the Cerambycidae family includes five identified pest species (Table 2), three frequent and two occasional visitors. During their adult stage, their feeding behavior involves consuming nectar, which may contribute to pollen dispersal. However, during the larval stage, these species harm various plant parts (Haak, 2017).

Hierodula tenuidentata is recognized as an invasive species exhibiting rapid expansion across Europe (László *et al.*, 2023), with reports of its presence in various European countries, including Romania. The species is progressively colonizing regions in Southern and Central Europe (László *et al.*, 2023; Pintilioaie *et al.*, 2023). It was initially recorded in the jujube orchard in 2023, where it appeared as an occasional visitor. During the winter months, oothecae were observed on the branches of jujube trees. According to Pintilioaie *et al.* (2021), oothecae were observed on multiple species, including *Platanus* sp., *Ulmus* sp., and *Aesculus* sp., within the Timișoara region. Future research is necessary to determine whether *H. tenuidentata* functions as a natural predator of harmful pests or if it may exert adverse effects on beneficial species within the jujube orchard ecosystem. Demestihas *et al.* (2017) note that the occurrence and abundance of pests and diseases are influenced by biotic interactions, including predation, species' ecological niches, habitat availability, and dispersal patterns. For example, Stan and Țucă (2023) observed increased activity of stink bugs on horticultural plants, which can be attributed to elevated winter temperatures and the absence of frost, resulting in a higher biological reserve.

The jujube orchard's location amidst diverse ecosystems, particularly the expansive 1300-hectare forest, creates a rich and complex environment for insect populations. Forests and meadows are important resource areas for pollinators in temperate fruit production landscapes, providing essential services such as nesting sites, alternative food resources, and habitat support (Watson *et al.*, 2011; Martins *et al.*, 2015). The proximity to diverse habitats enables a wide range of insect species to thrive, each adapted to distinct ecological niches. The forest, with its multi-layered vegetation structure and diverse plant species, serves as a reservoir for numerous insect populations that may interact with or migrate into the jujube orchard. Pardo and Borges (2020) suggest that the surrounding landscape composition and configuration should be a key component of sustainable land management strategies in agroecosystems. According to Zhou *et al.* (2015), the primary determinants of diversity are climatic conditions and environmental factors. The interplay between different insect populations contributes to the overall ecological balance within the orchard system, potentially impacting fruit production and orchard management practices. The high insect diversity recorded in the jujube orchard reflects the complex habitat structure created by management practices such as maintaining a grassy floor and abstaining from insecticide applications. This diverse community comprises several beneficial taxa that provide essential ecosystem services, particularly natural pest control. Predatory insects, such as the lacewings, spiders, giant Asian mantis, and various species of lady beetles (*C. septempunctata*, *H. axyridis*), are well-documented aphid predators that contribute to regulating pest populations. Additionally, parasitoid wasps (e.g., *Ichneumon* sp.) likely play a role in controlling lepidopteran and other herbivorous insect populations, although their specific impact within this orchard requires further study.

Among the identified phytophagous species, some pose potential threats to jujube cultivation. For instance, *H. armigera* is a well-known pest that causes significant damage to fruit crops, including jujube, by feeding on flowers and young fruits. It remains to be seen whether the species will cause damage in the years to come. Similarly, *Tuta absoluta*, although primarily a tomato pest, has been reported to attack other *Solanaceae* and could pose a risk if host plants are nearby. The stink bug *H. halys* is an invasive species increasingly recognized for its broad host range and potential to cause damage in fruit orchards through feeding and oviposition. Notably, *P. nana*, the most abundant phytophagous species observed, causes considerable damage in both nymph and adult stages based on visual assessments, and *N. viridula* could pose significant threats in the jujube orchard. Encouraging avian predators can provide an effective, low-input form of biological control by enhancing habitat features that attract insectivorous birds (e.g., installing perches, nest boxes, or maintaining nearby hedgerows). This approach enables orchards to establish a resident predator guild that naturally suppresses pest populations.

The absence of chemical control, combined with the presence of a diverse beneficial insect community, suggests that this orchard could support natural pest regulation, thereby reducing the need for insecticides. However, the coexistence of several phytophagous species underlines the importance of integrated pest management (IPM) strategies tailored to local pest dynamics. Future monitoring should focus on quantifying pest damage levels and predator-prey interactions to better understand the biological control potential within this system. Overall, the functional balance observed in this orchard highlights the benefits of sustainable management practices that foster biodiversity. Maintaining a grassy ground cover and avoiding insecticides not only promotes beneficial insects but may also enhance orchard resilience against pest outbreaks, contributing to sustainable jujube production.

Future research should investigate how variations in insect diversity impact orchard productivity and how various management practices influence insect populations and their ecological functions. Sustainable agricultural approaches that promote beneficial insects, support natural predators, and enhance soil biodiversity - both plant and animal - are vital for developing resilient agroecosystems capable of withstanding climate variability. Such practices not only contribute to food security but also foster environmentally responsible management strategies.

A thorough understanding of the life cycles and developmental stages of pest species is essential for effective pest management. This knowledge enables timely interventions that minimize environmental impacts while optimizing crop protection, thereby enhancing the sustainability of jujube cultivation. Insights gained can be applied to similar agroecosystems, aiding in enhanced pest control and the development of more resilient, biodiverse agricultural landscapes.

The findings of this study have broader implications for ecosystem health amid global concerns over insect declines caused by habitat loss, pesticide use, and climate change. Documenting insect diversity at this site provides a valuable baseline for future monitoring efforts, which are crucial for devising effective conservation strategies and promoting sustainable agriculture reliant on insect-mediated ecosystem services.

Conclusions

The findings of this research indicate that *Ziziphus jujuba* attracts a diverse array of insects. While they primarily serve as pollinators, there are occasional pest species that can negatively impact crop productivity and quality. This study may be the first to report *Phaneroptera nana* as a potential pest of jujube. The diversity and evenness of the insect community in the jujube orchard highlight the importance of maintaining a healthy, balanced ecosystem. These findings suggest that preserving insect biodiversity can play a key role in enhancing ecosystem services, such as pollination and pest control, ultimately contributing to the sustainability and productivity of the orchard. Future research will focus on expanding the taxonomic coverage of insect species in jujube orchards and investigating the long-term effects of integrated pest management (IPM) strategies on pest populations.

Authors' Contributions

Conceptualization, SAM; Investigation, SAM and SC; Methodology, SAM, SC, and SF; Software, SAM; Validation, SC and SF; Visualization, SAM; Writing - original draft, SAM; Writing - review and editing, SAM, SC, and SF.

All authors read and approved the final manuscript.

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Conflict of Interests

The authors declare that there are no conflicts of interest related to this article.

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