BIODIVERSITAS
Volume 24, Number 10, October 2023
Pages: 5368-5375

ISSN: 1412-033X
E-ISSN: 2085-4722
DOI: 10.13057/biodiv/d241019

Spatial, seasonal variation and impacts of anthropogenic factors on insect assemblages (Arthropoda: Insecta) in Northwest Morocco

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Manuscript received: 29 August 2023. Revision accepted: 17 October 2023.

Abstract., *El Harche H, El Hassouni S, Fadli M, Dahmani J 2023. Spatial, seasonal variation and impacts of anthropogenic factors on insect assemblages* (*Arthropoda: Insecta*) *in Northwest Morocco. Biodiversitas 24: 5368-5375.* Agriculture has been identified as one of the main causes of biodiversity loss due to the vast area dedicated to this activity. In Morocco, agroecosystems are becoming increasingly developed, which makes it necessary to study their impact on the local entomofauna. We studied the influence of seasonality and anthropogenic activities, including habitat type, on insect diversity in northwestern Morocco. The insects were collected between March 2019 and February 2020, covering all seasons, using three sampling techniques (sweep nets, pitfall traps, and sight hunting). Our study revealed the presence of 83 species, which were classified into 7 orders belonging to 32 families. Our findings demonstrate that insects diversity changes with the seasons, being higher in spring and summer than in autumn and winter. In addition, insect richness varies according to habitat type, with heterogeneous fields showing greater diversity than homogeneous ones. Research also indicates that anthropogenic pressures have had a detrimental impact on insect diversity, particularly in agricultural activities such as grazing, tillage, and the widespread use of pesticides. The results of this study are essential for the effective conservation and management of insect species worldwide. Accordingly, we make several recommendations to help preserve insect diversity and improve their survival, including reducing the massive use of pesticides and contributing to the global effort to reduce the impacts of climate change, which will not be possible without the cooperation of landowners, farmers, managers, and researchers. Therefore, we can enhance effective conservation and ensure insect species' long-term survival by fostering collaboration and knowledge-sharing among these groups.

Keywords: Anthropogenic pressures, habitat type, insects, Morocco, seasonality

INTRODUCTION

The intensity of agricultural land management has increased significantly in recent decades, leading to a simplification of agricultural landscapes due to the growing need of the human population for agricultural products (Dong et al. 2020). The trend towards increased production and expanded agricultural harvested areas can be attributed to growing inputs like fertilizers and pesticides (Sattler et al. 2018). Since many farmers have increased their use of pesticides because they believe it is the only method to suppress pest insects, the importance of pesticides has significantly increased in recent decades (Flor et al. 2018). Besides their usefulness in defense against pests, pesticides have numerous negative effects. They harm beneficial insects and pose risks to the environment and human health alongside the pests they are intended to target (Sattler et al. 2020). The intensification of agriculture has dire consequences, as it leads to the wanton destruction of habitats and exerts a profoundly negative impact on biodiversity. To illustrate, pollinators, crucial for plant reproduction, immensely suffer as they lose their vital food sources, potentially resulting in significant crop losses. Moreover, the obliteration or fragmentation of natural habitats leaves numerous species with no alternative refuge. Consequently, biodiversity is grievously affected, with countless species vanishing globally. This alarming loss of species diversity not only diminishes our planet's innate beauty and awe-inspiring nature but also disrupts the fundamental functions of ecosystems and the delicate ecological balance these habitats meticulously uphold. (Franin et al. 2016).

Agricultural practices like grazing, tillage, crop rotation, drainage, and extensive use of fertilizers and pesticides majorly impact the soil fauna (Ghosh et al. 2020). Many publications have reported that the following cultivation practices negatively impact arthropod populations in an agroecosystem: grazing management systems on coleopteran dung beetles (Magdoff and van Es 2021), mulches and pest management on arboreal arthropods in chili pepper (Herlinda et al. 2021), weed management on arthropod communities (Bryant et al. 2013), insecticide on not-targeted arthropods (Prabawati et al. 2019). These intense cultivation systems tend to lose their biodiversity and become destabilized. Management practices can decrease the diversity and abundance of beneficial arthropods caused by human activity (Jaworski et al. 2023). Therefore, these agricultural practices seriously threaten biodiversity and related ecosystem services.

The expansion of agricultural areas and intensification of management measures are significant factors contributing to the loss of terrestrial biodiversity at local and global scales (Tscharntke et al. 2012). This is primarily due to habitat loss and fragmentation, decreasing species diversity. As habitats vanish or fragmented, numerous species struggle to survive or reproduce in the altered environment (Rybicki et al. 2020). This loss of genetic diversity can have long-lasting implications for the adaptability and resilience of ecosystems. Additionally, reduced available habitat often leads to dwindling population sizes for many species (Rybicki et al. 2020). Smaller populations are more susceptible to disease, predation, and environmental changes, making them highly vulnerable to extinction. Furthermore, the conversion of terrestrial habitats further exacerbates the problem by causing the loss of countless species, including those that may be unique and irreplaceable; as their habitats disappear, these species face an imminent risk of extinction. Moreover, habitat destruction disrupts the interconnectedness of ecosystems, thereby reducing the resilience and functionality of the entire landscapes. This conversion also disturbs the intricate functioning of ecosystems, as the removal or alteration of key species can have cascading effects on vital ecological processes such as nutrient cycling, predation, and pollination. Consequently, this disturbance leads to imbalances and reduced ecosystem productivity, affecting humans and wildlife (Batáry et al. 2020). Intensive agriculture endangers biodiversity and the environmental services that farmers depend on (Knapp et al. 2022). Arthropods offer a wide range of ecosystem services for agricultural landscapes, including pollination, decomposition of organic matter (Culliney 2013), and biological control (Hasibuan et al. 2022). They are also crucial in food chains (Knapp et al. 2022) and contribute to weed suppression via herbivory and seed predation. Biological control of weeds using insects has frequently been successful for invasive weeds in natural settings (Myers and Sarfraz 2017). Due to their physiology, short generation time, and abundance, arthropods are excellent indicators of environmental changes (Chowdhury et al. 2023). Understanding the possible effects of anthropogenic pressure on arthropods is crucial, given their fundamental importance in many ecosystems.

The abundance and diversity of arthropods are not solely affected by human disturbance but are also influenced by a range of factors that vary from year to year. These fluctuations in factors can exert a significant impact on arthropod populations, ultimately altering their overall diversity. One crucial factor that can disrupt the delicate balance of ecosystems is the rise in temperatures, which can have profound effects on the timing of key events such as flowering or hatching. This mismatch between the life cycles of species and their required resources can result in reduced food availability or heightened predation pressure. Moreover, climate change can also facilitate the proliferation of invasive species. As temperatures continue to warm, previously unsuitable habitats become favorable for the establishment of non-native species. In a professional tone, it is important to convey the information clearly and concisely while maintaining a sense of authority and expertise (Matheson and McGaughran 2023). The diversity within a specific taxonomic group can exhibit substantial variations from one season to another, reaching its peak when the environmental conditions are most conducive for their growth and proliferation (Chatelain et al. 2018). Seasonal fluctuations, a common occurrence in nature, can impose stress on organisms and impede population growth, particularly among insect groups such as Coleoptera, Hymenoptera, Lepidoptera, Diptera, and Hemiptera (Tougeron et al. 2020). These insects, belonging to diverse orders, are especially vulnerable to the challenges posed by seasonal shifts. Physiological constraints can be imposed due to temperature and water availability fluctuations (Tougeron et al. 2020), as well as changes in the availability of nutrients required for individual development and reproduction (Kang et al. 2022). However, ecologically and taxonomically, different groups cannot be expected to respond similarly to climate variables and changes in agricultural practices (Cameron et al. 2019; Le Provost et al. 2021).

The objective of this study was to evaluate the effect of season, habitat type (cultivated and non-cultivated land), and some anthropogenic pressures like pesticide application, tillage, and harvesting periods on insect diversity in northwestern Morocco. Here, we tested two possible hypotheses: (1) the diversity of insects is different in each of the stations tested in the study area; (2) anthropogenic activities like deep tillage and exhaustive use of fertilizers and pesticides impact insect abundance and diversity structure. The present article contributes to understanding the effect of different agricultural practices on insect abundance and diversity and evaluating the seasonality and distribution of insects in northwestern Morocco.

MATERIALS AND METHODS

Study area

The study was conducted in 3 stations in the region of Sidi Kacem (34°13′00″N, 5°42′00″W) located in northwestern Morocco (Figure 1). The climate of the region is classified as semi-arid; the temperature in autumn goes down to 6°C, while in summer, it can exceed 40°C, with a probability of daily precipitation above 13%.

Station 1: 34°12'35"N-5°42'31"W. It is a field of *Vicia faba* L. beans (Fabaceae). Station 2: 34°14'41"N-5°42'14"W. This is a field of cereal crops: soft wheat: *Triticum aestivum* L. (Poaceae). Station 3: 34°13'50"N-5°42'14"W. This is an undisturbed field. The plant species that dominate the area are *Nicotiana glauca* (Solanaceae), *Ferula communis* (Apiaceae), *Cynara humilis* L. (Asteraceae), and *Ammi visnaga* (Apiaceae).

Insect sampling

We conducted this study in two habitat types (2 cultivated and undisturbed fields as the control.) from March 2019 to February 2020. Therefore, to study the influence of anthropogenic factors on insect abundance and richness, arthropods were collected during periods of absence of anthropogenic activities, pesticide application, high floristic diversity, weed cover, tillage, and harvesting periods.

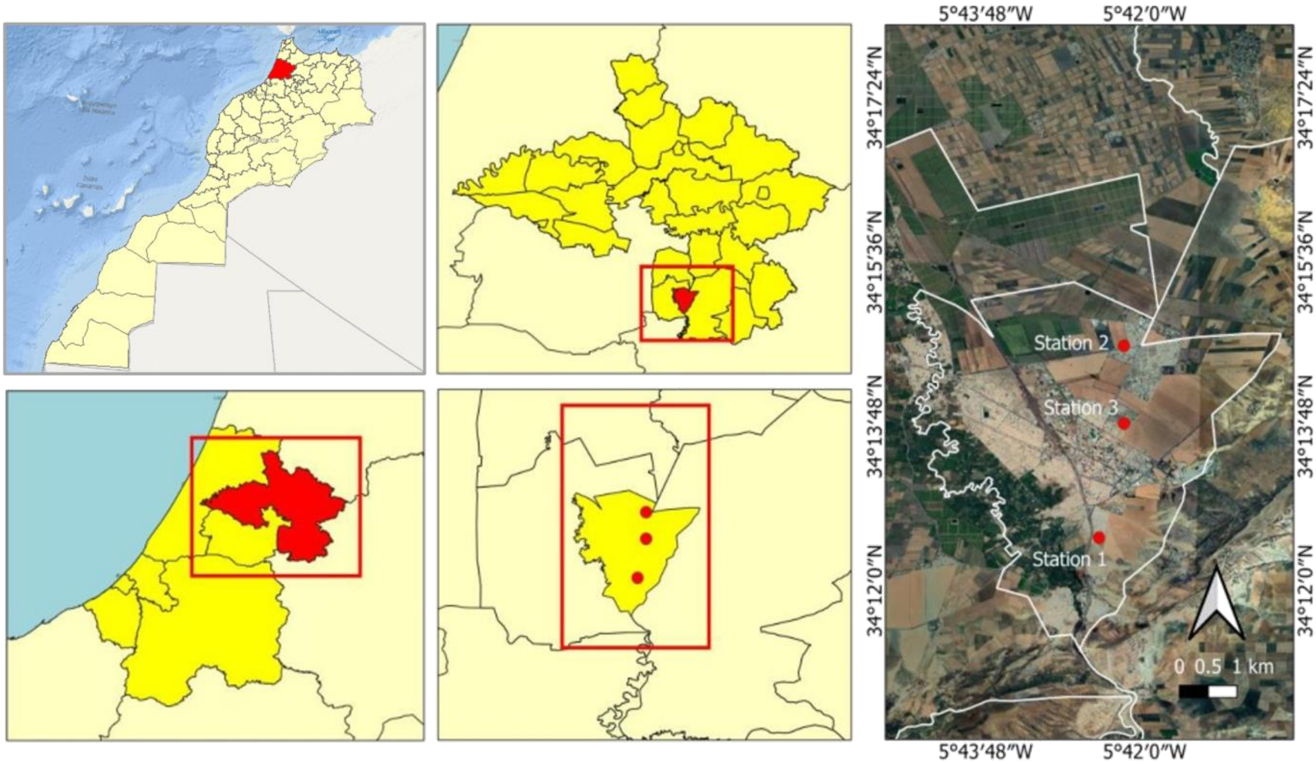

Figure 1. Geographic and sampling location of the study area in Sidi Kacem,northwestern Morocco

We sampled the insect community with three sampling techniques. Pitfall traps were utilized in this study, consisting of pots with a diameter of 10 cm and a height of 17 cm. In Stations, 10 pots were buried vertically, ensuring the opening aligned with the ground level. The soil was carefully packed around the opening to prevent hindering small arthropod species. To comprehensively survey the fauna, sight hunting was conducted during daylight hours for 2 hours. This involved observing the ground, leaf litter, grasses, logs, tree barks, and other substrates for visible fauna. Additionally, sweeping nets were employed to capture small species of geophilic insects and flying arthropods that inhabit grasses and shrubs. The sampling process was conducted for two hours, commencing at 9:00 am and concluding at 11:00 pm every two weeks. This allowed for consistent data collection and analysis. By employing these methods, we aimed to understand the arthropod species in the study area comprehensively. Using pitfall traps, sight hunting, and sweeping nets ensured a thorough examination of ground-dwelling and flying arthropods. This approach allowed us to obtain valuable insights into the biodiversity and distribution of these species. The specimens were identified using the primary morphological characteristics of each taxon, such as thorax pattern, wing venation, abdominal appendages and features, legs, antennae, color patterns, etc. The specimens of the insects were divided into various orders and families and designated as morphospecies before being preserved in 70% alcohol.

Data analysis

Biodiversity indices such as Shannon Wiener diversity, equitability index, and relative abundance were used to determine and explain insect species diversity in the study area. These analyses were graphically represented using Microsoft Excel.

Relative abundance

Relative Abundance (RA) is the percentage of individuals of one species (ni) divided by the total number of individuals (N)

$$RA = \frac{ni}{N} \times 100\% \qquad (1)$$

Shannon-Weaver Diversity (H')

This index is considered to be the best way to reflect diversity. The formula calculates the index:

$$H' = -\sum qi \log2 qi \qquad (2)$$

Where :
H' : Diversity index expressed in bit units
qi : Relative frequency of species i relative to individuals in the stand as a whole
Log2 : Logarithm based on 2

Equitability index (E)

Equitability or evenness index (E) is the relationship between diversity H' and maximum diversity H' max.

$$E = \frac{H'}{H_{max}} \qquad (3)$$

Where :
E : Regularity index
H' : Shannon diversity index expressed in bits
H' max: Index of the maximum diversity expressed in bits

RESULTS AND DISCUSSION

The study of the composition of the population revealed the existence of 83 species distributed among 7 orders. Insect species varied from one habitat type to another; we identified 61 species in the undisturbed field, 52 in the cereal field, and 33 in the beans field. The highest number of recorded species belonged to the orders of Coleoptera, followed by Hemiptera, and the order of Orthoptera in third position. The remaining species were divided over the other orders (Table 1).

Insect richness differs between disturbed and undisturbed areas (Table 1). Habitat type has an impact on insects' biodiversity. In cereal fields, insect species belonging to the order Coleoptera had the highest prevalence, representing an impressive 63.4% of the observed population. The order of Hemiptera was second, with a relative abundance of 13.4%. In the undisturbed field, we have recorded 62.30% of Coleoptera and 13.19% of Hemiptera. In the beans field, the dominant insect species belonged to the Coleoptera order, representing 66.6%, followed by Orthoptera and Hemiptera, each accounting for 9.09%. Other insect orders, such as Odonata, Hymenoptera, Lepidoptera, and Orthoptera, were also present in all agrosystems, although their relative abundance was comparatively lower. Surprisingly, Diptera were scarce and completely absent in the bean field (Table 1).

Insect richness was higher in the undisturbed field but lower in the cereal field, whereas the beans field was the poorest habitat regarding insect richness (Figure 2).

In analyzing the ecological structure indices, it becomes evident that the specific habitat type influences the diversity of insects. The undisturbed field emerges as the most diversified area, supported by Shannon-Wiener's Diversity index and equitability values. The cereal field secures the second position, while the beans field lags with relatively lower results (Table 2).

These results shed light on the detrimental effects of human intervention on insect populations. The data unequivocally demonstrate that our agricultural practices profoundly impact the delicate balance of insect diversity. Specifically, pesticides, coupled with intensive farming techniques such as tillage and specific harvest periods, reduce the presence and variety of insects. Conversely, when human activities are absent and natural habitats are allowed to flourish, we observe a remarkable increase in insect species. This phenomenon is closely linked to the presence of diverse flora and the existence of weeds, which provide essential resources and habitats for insects (Figure 3).

Climatic seasonality also impacted insects' diversity (Table 3). Insect diversity was higher in spring and summer than in autumn and winter. The Shannon-Wiener index values and equitability values indicate that diversity reached its peak during the spring season, followed by summer, winter, and finally autumn (Table 3).

The number of arthropod species differed between localities and the studied seasons (Figure 4). The species showed a remarkable variation among different seasons.

The diversity of arthropod species varied across different localities and seasons. Notably, there was a variation in species composition observed among different seasons, as depicted in Figure 4. Moreover, a substantial disparity in insect abundance existed among the three distinct environments during each season, with the insect population displaying a diverse pattern across all three habitats.

Regarding insect preferences, undisturbed areas emerged as the most favorable environment, closely followed by cereal fields. The bean field consistently ranked as the least preferred habitat throughout all seasons, exhibiting comparatively low insect numbers, as illustrated in Figure 4.

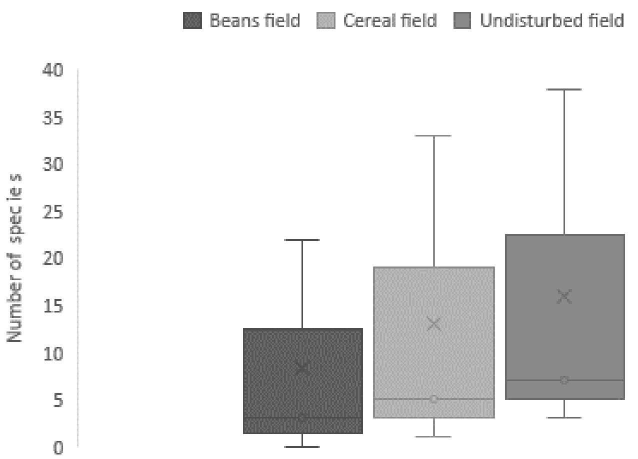

Figure 2. Variation of insect diversity according to habitat type

Table 1. List of number and frequency of different orders in the study station; N_{sp}: number of species; AR%: relative abundance

Order	Beans field		Cereal field		Undisturbed field	
	N_{sp}	AR%	N_{sp}	AR%	N_{sp}	AR%
Coleoptera	22	66,67	33	63,46	38	62,30
Hemiptera	3	9,09	7	13,46	8	13,11
Orthoptera	3	9,09	2	3,85	5	8,20
Lepidoptera	1	3,03	1	1,92	3	4,92
Hymenoptera	2	6,06	3	5,77	3	4,92
Odonata	1	3,03	3	5,77	4	6,56
Diptera	0	0	3	5,77	3	4,92
Total	33	100	52	100	61	100

Table 2. Shannon-Wiever diversity index and equitability calculated for each station

Parameters \ Station	Beans field	Cereal field	Undisturbed field
H'	3,93	4,34	4,4
Hmax	5,04	5,73	5,95
E	0,78	0,76	0,73

Table 3. Shannon-Wiever index and equitability calculated for each station in four seasons

Parameters \ Seasons	Spring	Summer	Autumn	Winter
H'	4,85	3,98	2,46	3,02
Hmax	6,02	5,70	3,81	4,46
E	0,81	0,70	0,65	0,68

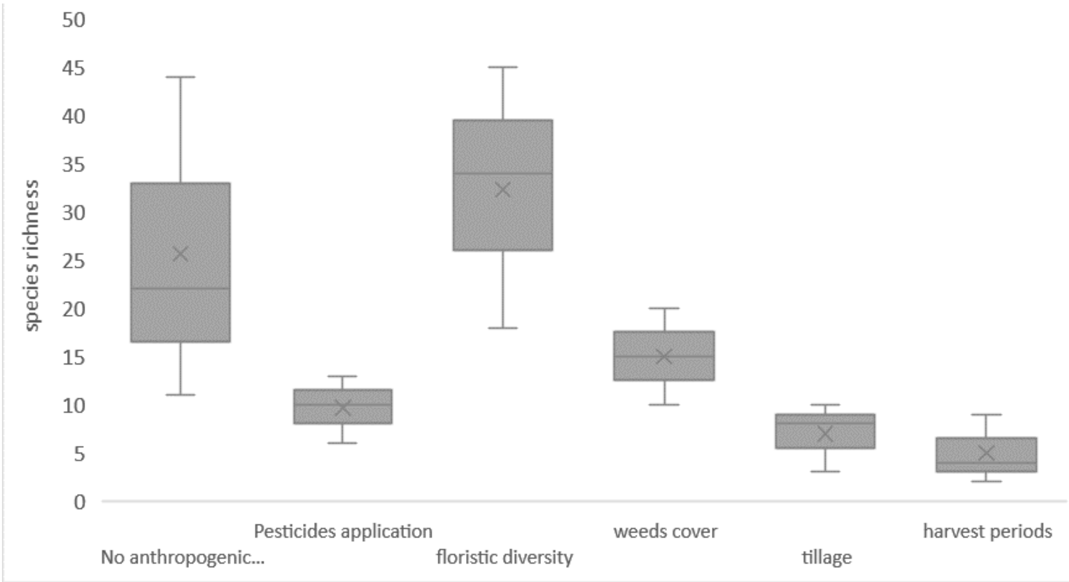

Figure 3. Insect species richness under the influence of certain factors at the three study sites

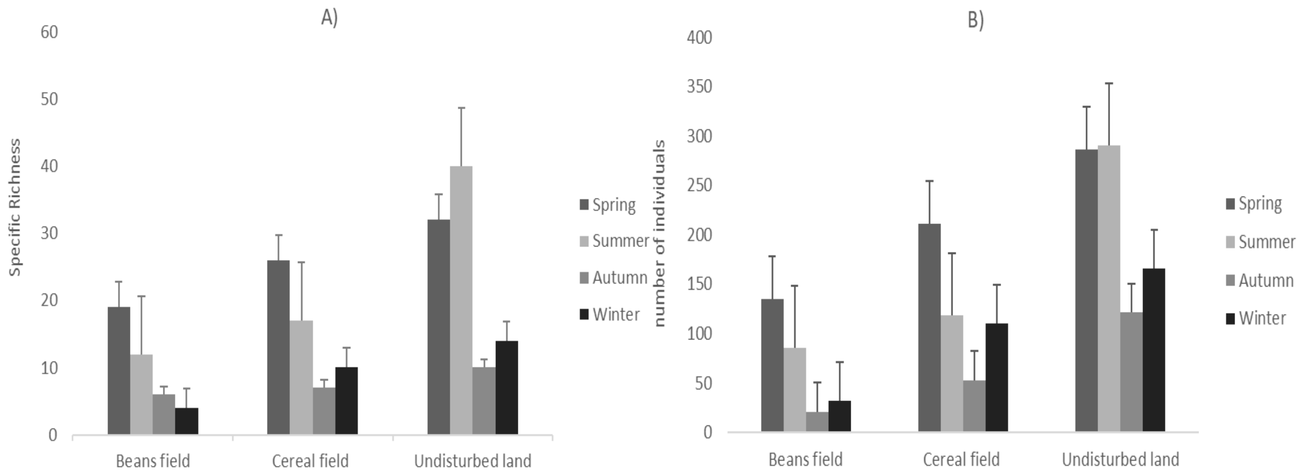

Figure 4. A) Species richness. B) Number of individuals per season

Discussion

The effect of habitat type and anthropic factors on the biodiversity and abundance of arthropods

. The study revealed that the richness of insects was higher in undisturbed land, with a total of 61 species. This can be attributed to the favorable conditions in this area throughout the year. These are (i) the absence of anthropogenic factors that cause disturbances in the reproduction and development of insects. (ii) the vegetative cover (heterogeneity of plant species). Insect diversity is favored when the heterogeneity of plant species is increased (Song et al. 2023). According to Liebhold et al. 2018 and Horák et al. 2022, the diversity of plant communities influences the diversity of other groups, such as butterflies, carabids, and bees. Floristic diversity directly affects phytophagous species, which contribute to the presence of predators and parasites and, thus, maintain their natural enemies. Numerous studies have shown that the richness and abundance of insects in the heterogeneous landscape is greater than in the homogenous landscape (Medeiros et al. 2019; Ortega et al. 2023). Our results are consistent with these previous studies. Thus, we can confirm our hypothesis that the diversity of arthropods will be different in each field tested in the study area. Our results show that in the undisturbed field, the diversity of insects was higher than in the cultivated fields.

The hypothesis which assumed that agricultural activities impact biodiversity has also been proven. Factors such as pesticide application, tillage, and harvest periods affected the biodiversity of fauna. According to the study, the undisturbed field in this area boasts the highest level of diversity, particularly in terms of insect assemblage; the cultivated fields closely follow it. This is also the case in the Chlef area, which is located in northwestern Algiers, where Mohammedi et al. 2019 discovered that the entomological variety was highest in an undisturbed field, which is a less disturbed environment, compared to a cereal field, which is a disturbed habitat. Biodiversity is well recognized to be high in natural or minimally altered settings. On the other hand, the anthropogenic impact on agriculture, particularly pronounced in intensive agriculture, results in a decline in faunistic richness.

In the present study, different orders were found. Coleoptera, with 54 species, is the most well-represented order. After that, 12 species belong to the Hemiptera, 5 to the Orthoptera, 4 to the Odonata, and 3 to Diptera, Lepidoptera, and Hymenoptera. Our findings indicated that Coleoptera species were the most prevalent group across all orders, even in agricultural fields. This variation between orders can be explained by the fact that some species, such as carabids, tolerate mechanical disturbances and can reach high abundances even in agriculturally impacted ecosystems. These species can move and thus escape these disturbances toward the grassy strips at the edges of the agricultural plots (Jones et al. 2019). Furthermore, it has been demonstrated that some Coleoptera can disperse over vast distances within agricultural parcels and to the edges of those parcels (Jones et al. 2019; El Harche et al. 2022). While certain individuals cannot tolerate these alterations, such as the larvae of several dipteran or orthopteran families (Menalled et al. 2007). Indeed, crushing the larvae of these summer breeding groups during deep plowing will result in mortality. Nevertheless, depending on the species, anthropogenic influences like plowing can change the composition of communities by making some taxa more abundant and others less abundant. The presence of beetles, especially carabid beetles, in large numbers as opposed to other families is explained by the fact that most carabids reproduce in the spring and overwinter as adults. Since they spend the winter either in adult or larva form (in the ground), they are not disturbed by the plowing during the summer, which reduces the diversity of other insects that reproduce during this season. If reproduction occurs in the autumn, the larva remains in standby all winter and only resumes its metamorphosis in the following spring. As a result, the response of different taxonomic groups varies, and these responses depend on the practices implemented, such as the date of intervention and the depth of plowing (Holland and Reynolds 2003). Analyses of anthropogenic pressures show that the diversity of insects has been negatively associated with agricultural activities

The effect of climatic seasonal variations on arthropods' assemblage structure

The study of the composition of the population revealed the existence of 83 species distributed among 7 orders belonging to 32 families. The present study clearly showed that arthropod assemblages differed among seasons, higher in spring and summer than in autumn and winter. It is also due to the abundant rains that occurred in March, which increased the humidity of the soil and allowed the development, proliferation, and multiplication of a good vegetation carpet, which means more food for groups of phytophagous insects and, consequently, the predators. On the other hand, autumn and winter have a low plant diversity, which influences the presence of phytophagous species, predation, and parasitism (Becerra 2015). Previous research in Mediterranean regions and other ecosystems has revealed similar findings (Doblas-Miranda et al. 2009; Piñero et al. 2011; Majeed et al. 2021). Ajerrar et al. (2022) made the same observation by studying seasonal terrestrial arthropod activity rhythms in the Souss Valley in west-central Morocco. These authors observed significant insect' activity in each season. This activity is probably due to abiotic factors that influence arthropod diversity and distribution (Majeed et al. 2021), directly by alteration of the soil microclimate, or indirectly by affecting resource availability and food webs (Vanhée and Devigne 2018). As well as the cultural activities that occur during the summer and early winter (harvesting, plowing, etc.). A higher specific richness of vegetation maintains a higher specific richness of insects (Knuff et al. 2020). Welti et al. (2017) and Peng et al. (2022) also point out that the increase in plant diversity leads to an increase in the diversity of phytophagous and, consequently, their predators and parasites. During the summer, some species experience higher levels of environmental stress, such as water scarcity and anthropogenic pressure at their peak. The limited food resources may explain the low abundance of species during autumn across sampling sites during this season. The observed herbaceous layer in all sampling sites may explain the slight increase in insects observed during winter. However, these results can also be explained by the fact that most insects spend these two seasons mostly as nymphs or adults, in the soil or sheltered in plant debris or bark under stones (hibernation) (Bale et al. 2002). Their abundance is mainly determined by their life cycle since the reproduction periods differ according to the species, which is manifested by emergence at specific periods (Bohbot and Vernick 2020).

The results of the diversity indices by season show the population's regularity and that the numbers of the different species captured are in balance with each other in the habitat. However, this diversity varies from season to season, with high values in spring and early summer and moderately high values during autumn and winter. These variances are caused by environmental and climatic conditions determining the level of their body temperatures

(Käfer et al. 2020), forcing them to spend the terrible season under the soil as a nymph or adult. The distribution of insects within a habitat is influenced by temperature (Warren et al. 2019). According to Burns et al. (2016) and Sintayehu (2018), environmental changes can have a twofold effect by increasing the diversity of some species while decreasing the diversity of others. Bodlah et al. (2023) specify that temperature regulates all metabolic processes of species and communities and their distribution within the biosphere. This could explain why some insects, such as beetles and Diptera, can survive in extreme environments (above 40°C). The temperature continues to be one of the influencing factors in this insect's activities (Jaworski and Hilszczański 2013). In our study, temperatures influenced insect assemblage (Robinson et al. 2018). Additional environmental parameters, such as diversity of vegetation and deadwood occurrence, are stronger predictors of arthropod structure and environmental interactions (Ashford et al. 2013). Our findings are consistent with research conducted in the Cerrado, which found that an increase in temperature and water availability in the soil due to precipitation are the primary triggers for the restart of insect activity in various orders (da Silva et al. 2011). Changes in the number of species and individuals in an ecosystem are primarily caused by changes in vegetation, food availability, and climatic and edaphic conditions; however, they are stable and well-structured across time.

In conclusion, the present study clearly showed that seasons, habitat type and anthropogenic effect influenced arthropod assemblages. Our results show that insect assemblage in the spring and summer was the most varied. Indeed, more than three-quarters of the harvested species prefer higher temperatures to be active, a pattern probably related to the use of solar radiation to propitiate the passive heating of the body and to complete their metamorphosis. The limited biodiversity in the cultivated areas resulted from disturbances in the interactions of insect communities caused by agricultural practices in these environments. Adopting sustainable farming techniques is another vital step towards creating a favorable environment for insects. Practices such as crop rotation, integrated pest management, and organic farming help to maintain a healthy balance between pests and beneficial insects. This approach reduces the need for chemical pesticides while promoting natural pest control methods that do not harm the overall insect community. This will ensure a sustainable entomological diversity, thus increasing the role of biological control in pest management systems. Furthermore, environmental parameters, such as heterogeneous vegetation, contribute significantly to species richness. The presence of varied plant species provides different habitats and food sources for insects, supporting a wider range of species. This diversity not only enhances ecosystem resilience but also strengthens biological control mechanisms by ensuring a more robust predator-prey relationship. Understanding the interplay between environmental parameters and insect activity is essential for designing effective conservation strategies. By identifying key factors that influence species richness and population dynamics, we can develop targeted interventions to preserve and enhance insect biodiversity.

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