PLANT SCIENCE TODAY
Vol x(x): xx–xx
https://doi.org/10.14719/pst.7859

eISSN 2348-1900

RESEARCH ARTICLE

Influence of soil management practices on the arthropod diversity in Moroccan pomegranate orchard

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Received: 21 February 2025; Accepted: 25 March 2025; Available online: Version 1.0: 23 June 2025

Cite this article: Madani M, Eifazazi K, Bouslihim Y, Adiba A, Laaraj S, Bouissane L, Fakhour S. Influence of soil management practices on the arthropod diversity in Moroccan pomegranate orchard. Plant Science Today (Early Access). https:/doi.org/10.14719/pst.7859

Abstract

The main objective of this research is to determine the composition and diversity of weed communities in the inter-rows of pomegranate orchards and to assess their impact on the abundance and diversity of arthropods. Weed diversity was assessed using the quadrat method, while arthropod sampling employed sweep netting, beating and collection shoot methods. Samples were collected weekly during the pomegranate cycle development. The results revealed the identification of a total of 17 weed species from 11 families. In 2022, we found that the three most abundant families were Amaranthaceae, Fumariaceae and Poaceae, which accounted for more than 90 % of the total sampled weeds, with proportions of 74.30 %, 8.09 % and 7.36 %, respectively. In 2023, the most dominant families were Solanaceae (30.03 %), Amaranthaceae (25.11 %) and Poaceae (16.18 %). Arthropods were associated with 12 weed species in 2022 but only 4 species in 2023, with *Sonchus asper*, *Chenopodium album* and *Convolvulus arvensis* hosting the highest arthropod abundance. While sweep netting sampling revealed no significant difference in arthropod abundance between years ($p > 0.05$). In addition, the shoot collection and beating methods revealed a significant positive effect of the weedy treatment on the abundance of beneficial arthropods ($p < 0.05$), with a significant difference observed between the two study years ($p < 0.05$). However, climatic variations also influenced the results across the seasons, with weeds supporting greater arthropod diversity and abundance, compared to bare ground. These findings highlight the role of weeds as a sustainable orchard management practice, promoting arthropod biodiversity and ecosystem services in pomegranate orchards, which may contribute to improving the productivity and management of pomegranate cultivation.

Keywords: abundance; arthropods; pomegranate; soil management; weeds

Introduction

Agricultural intensification is characterized by the increased use of external inputs and resources to boost crop yields, often leading to the simplification of farming systems (1). This production method is characterized by simplifying agricultural landscapes through adopting monoculture systems and using chemicals (2-4). This causes disruptions in the various components of the agroecosystem, leading to a reduction in local biodiversity and thus affecting the balance between pest populations and their natural enemies (5). Among various detrimental effects, agricultural intensification has emerged as one of the main catalysts for global biodiversity loss, threatening 86 % of species at risk of extinction (6). This massive loss of biodiversity also led to a degeneration of important ecosystem services that support agroecosystems (7, 8).

The pomegranate (*Punica granatum,* L) serves as a favorable host for various pests, including mites, thrips, fruit flies and nematodes (9). In addition, the two aphid species including *Aphis punicae Passerini* and *Aphis gosypii* are important pests of pomegranate (10, 11) . They infest and feed on newly developed leaves, tender shoots, flowers, flower buds and developing fruits (12). The presence of this pest can negatively affect both yield and production quality (13). Consequently, current directions in agronomic research aim to develop alternative methods of pest control, specifically focusing on conservative biological control. This technique represents a sustainable means of enhancing the potential of naturally occurring predators and parasitoids to control crop pests (14). Aphid populations and pests are influenced by the presence of natural enemies such as lacewings (Chrysopidae), hoverflies (Syrphidae), ladybugs (Coccinellidae) and gall midges (Cecidomyiidae) allowing their biological control (15) . Its primary objective is to identify potentially significant components of the natural enemy community, categorize agronomic and ecological constraints that appear to limit the effectiveness of these natural enemies and assess their impact on the environment (16). High quality soil is more important than currently acknowledged in determining the plant response to stresses such as pests or parasites (17). Indeed, areas which had weeds provide favorable environment conditions for soil arthropods and in turn enhanced the arthropods diversity (18). In addition, the intensity of cultivation negatively affected the diversity of weeds and arthropods (19).

Weeds play a fundamental role in shaping arthropod communities in agroecosystems. Their diversity and abundance have a direct influence on the composition of arthropod populations. It is demonstrated that the abundance of weeds influences the arthropods diversity in mango trees in previous studies (20). Weeds provide essential resources such as nectar, pollen and shelter, thus promoting the presence of pollinators and natural enemies of pests (21). In addition, insect abundance was greater on apple flowers, suggesting that weeds may increase insect diversity within apple orchards and may sustain pollinators (22). Specifically, the presence of these weed plants in the inter-rows of orchards can serve as a habitat management strategy, increasing the diversity and abundance of natural enemies through various ecological mechanisms (23). Several studies have shown that maintaining a diverse weed flora helps balance populations of herbivorous arthropods and their predators or parasitoids, thereby promoting natural biological control and reducing reliance on chemical pesticides (24). However, some weed species can also act as alternative hosts for pests or pathogens, potentially having negative effects on fruit production (25). This research is the first of its kind in the study area; therefore, it facilitates the identification and management of arthropods in pomegranate orchards. In relation to this situation, the main objective of this study is to identify and quantify plant weeds in the inter-rows of pomegranate orchard and to assess their impact on the abundance and diversity of arthropods.

Material and Methods

Study area

The experiment was conducted over two years (April 6 to June 8 in 2022 and from April 9 to June 12 in 2023) in pomegranate orchards of the 'Sefri Ouled Abdellah' variety, located in the organic agricultural area of Beni Mellal, Morocco. The geographical coordinates of the study site are 32°24'52.0"N and 6°26'22.1"W. The soil in the study area is predominantly silty and consists of 40 % clay, 8.8 % Fine silt, 11.2 % coarse silt, 30 % Fine sand and 9.4 % coarse sand. This region is characterized by an arid to semi-arid climate; the rainfall and the mean temperature during the study period are shown in Fig. 1.

The orchard was managed organically without the application of phytosanitary products. The pomegranate trees at this experimental site are all mature ten years-old trees with deep taproots. The orchard consisted of 29 rows of trees, each row containing 30 trees, with 5.5 m between rows and 4.5 m between trees within rows. The pomegranate orchard was divided into two treatments to evaluate soil management methods: weedy and weed-free. The plot with weedy treatment consisted of ten consecutive inter-rows with spontaneous vegetation (weeds), while the plot with weed-free involved maintaining ten inter-rows as bare soil through mechanical vegetation removal. Inter-row vegetation was managed by mowing, which was performed once per month from late March to late June. The two treatments were separated by two inter-rows. The method in question is widely implemented for sustainable pomegranate orchard management. Weedy and weed free management techniques were specifically chosen, as local farms prioritize organic production, strictly prohibiting the use of synthetic pesticides.

Weed sampling

The diversity of weeds in the rows of pomegranate trees was evaluated by randomly placing a 0.25 m^2 (50 cm × 50 cm) quadrat in the tree row between the central trees ten times. The percentage of ground cover within each ring was then visually estimated (26). The total number of individuals for each species was determined weekly for all the quadrats. All weed identifications were carried out at the Plant Protection Laboratory, Tadla Regional Agricultural Research Center, Morocco. Weeds were identified at the family, genus, or species level and classified into dicotyledonous or monocotyledonous plants and perennial or annual grasses based on their morphology and life cycle. Weed and bare soil management techniques are selected in area as the farms produce bio-products where the use of pesticides is prohibited.

Arthropod sampling

The study of abundance was conducted in the weed plants associated with pomegranate orchards, as well as on the pomegranate trees themselves. Arthropod samples from the spontaneous vegetation were collected using quadrats and sweep netting; while beating and shoot collection methods were employed for sampling on the pomegranate trees. Samples were collected weekly from April 6 to June 8 in 2022 and from April 9 to June 12 in 2023. All samplings took place between 9:00 a.m. and 2:00 p.m. on each collection date. Additionally, the sampling locations within the study area are selected randomly. The collected arthropods were preserved in 70 % ethanol for identification at the Plant Protection Laboratory of the Tadla Regional Agricultural Research Center, Morocco. This analysis revealed the presence of several arthropod families, including Aphididae, Coccinellidae, Cecidomyiidae, Syrphidae, Formicidae, Miridae, Acari and Chrysopidae. Specific sampling procedures are detailed below.

Community composition of arthropods on weeds

Collection of arthropods on wild plants

To study the diversity of arthropods in the weeds associated with the pomegranate orchard, a quadrat of 0.01 m^2 (10 cm × 10 cm) was used on the weed plants between the rows of pomegranate trees. In each quadrat, the same weed species were cut and then brought to the laboratory in plastic bags

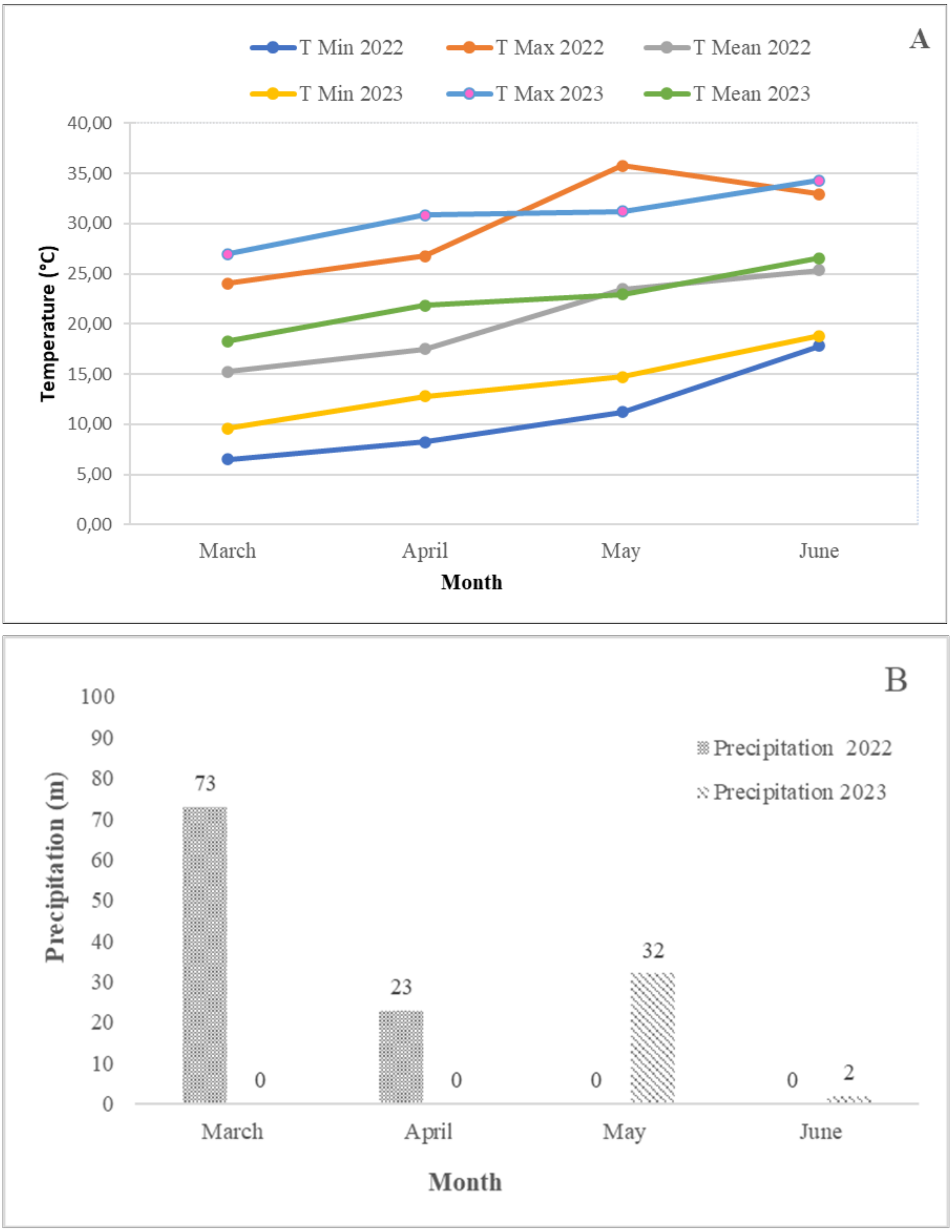

Fig. 1. Monthly temperature [A] and precipitation [B] during the study periods.

for the identification of the arthropods inhabiting them. A total of 10 quadrats of vegetation samples were collected each week (26). In the laboratory, we examined the plants in detail to collect and identify the arthropods that inhabit them.

Sweep netting

Every week, samples of arthropods living in the weeds were collected using a nylon sweep netting (30 cm in diameter and 90 cm deep) to assess the population of pests and beneficial species in this vegetation. Fifteen samples were taken from the central ten rows of the ground cover plot. Each sample consisted of four mows covering the randomly selected area between four trees in two rows. One double sweep is defined as moving the net from the left to the right and back perpendicular to the walking direction (27).

Effect of soil management practices on arthropod abundance in the canopy

Beating

A common method for collecting foliage samples is beating, which is also frequently used to collect tree arthropods. On each sample date, fifteen pomegranate trees were randomly selected in the center of each treatment. One branch per pomegranate tree was struck three times in a 30 cm diameter threshing net and the arthropods that fell on the beating net were quickly collected in plastic boxes (28).

Shoot collection

In each treatment, twenty pomegranate trees of similar height were selected for continuous sampling to monitor the dynamics of arthropod populations. Each tree was sampled from four directions (East, South, West and North) on each sampling day. On each side 30 cm shoots were selected to examine for the presence of arthropods (29). The sampled shoots were covered in a plastic box to collect highly mobile arthropods and these arthropods were transported to the laboratory for identification.

Data analysis

Abundance was calculated based on weed species and the number of arthropods of each morphospecies for each management system year and sampling method, both on the weeds and the canopy. Data on weed infestation and arthropod abundance were tested for normality using the Shapiro-Wilk test. This test allows us to assess whether the data follow a normal distribution. Since the data do not follow a normal distribution the Kruskal-Wallis test is implemented. The Kruskal-Wallis test is a non-parametric method used to determine if there are statistically significant differences between the medians of three or more independent groups. It is an alternative to one-way ANOVA when the assumption of normality is violated.

Results and Discussion

Diversity and composition weed on pomegranate orchard

A total of 17 weed species belonging to 11 families were recorded during the two consecutive years of the study (Table 1). Dicots were represented by 10 families and 15 taxa, while monocots were represented by 1 family and 2 taxa. The majority of the identified weed species are annuals, representing 80.02 % of the total in 2022 and 54.43 % (12 species) in 2023. On the other hand, of the plant species that have been reported, 10.98 % in 2022 and 45.57 % in 2023 (four species) are perennial. The life forms of the recorded species were divided into four different categories: therophytes, geophytes, graminoids and nano-phanerophytes. Within these categories, therophytes proved to be the dominant life form, with 12 species accounting for 80.02 % and 54.433 % of the total species in 2022 and 2023, respectively. Graminoids were the next most common life form with one species (6.42 %), followed by nano-therophytes with one species and geophytes with 2 species.

In terms of species richness, the Amaranthaceae family had the highest species richness with three species, followed by the Portulacaceae, Asteraceae, Convolvulaceae and Poaceae families with two species each. In contrast, the families Fumariaceae, Solanaceae, Brassicaceae, Malvaceae, Polygonaceae and Geraniaceae were each represented by only one species.

In 2022, the three most abundant families were Amaranthaceae, Fumariaceae and Poaceae, which accounted for more than 90 % of the total sampled weeds with proportions of 74.30 %, 8.09 % and 7.36 %, respectively. The dominant weed species were *Amaranthus albus* and *Chenopodium album* from the Amaranthaceae family with a percentage of 39.85 % and 26.04 %, respectively. They were followed by *Solanum eleagrifolium*, *Fumaria parviflora*, *Sorghum halepense*, *Setaria viridis*, *Portulaca sp*, *Sonchus asper, Sinapis alba* and *Convolvulus arvensis*. All other species have rates of less than 1 %. In 2023, the families with the highest species rich were Solanaceae, Amaranthaceae, Poaceae and Portulacaceae, which represent over 90 % of the total species. The most abundant species were *Solanum eleagrifolium, Amaranthus albus, Portuloca sp, Setaria viridis, Convolvulus arvenis, Chenopodium album, Sorghum halepense* and *Sonchus asper.* All other species have rates lower than 1 %.

Table 1. Diversity of weed species associated with the pomegranate orchard, their abundances and percentage over two years

Years					2022		2023	
Weed Species	**Family**	**Division**	**life span**	**Life form**	**N**	**(%)**	**N**	**(%)**
Amaranthus albus	Amaranthaceae	Dicot	Annual	Therophyte	6052	43.87	472	1832
Chenopodium album	Amaranthaceae	Dicot	Annual	Therophyte	4092	29.66	171	664
Solanum eleagrifolium	Solanaceae	Dicot	Perennial	Nano-Phanerophyte	461	3.34	774	30.03
Fumaria parviflora	Fumariaceae	Dicot	Annual	Therophyte	1116	8.09	12	0.47
Sorghum halepense	Poaceae	Monocot	Perennial	Graminoid	886	6.42	145	5.63
Portuloca sp	Portulacaceae	Dicot	Annual	Therophyte	0	0.00	402	15.60
Setaria viridis	Poaceae	Monocot	Annual	Therophyte	130	0.94	272	10.55
Sonchus asper	Asteraceae	Dicot	Annual	Therophyte	330	2.39	61	2.37
Convolvulus arvenis	Convolvulaceae	Dicot	Perennial	Geophyte	162	1.17	221	8.58
Sinapis alba	Brassicaceae	Dicot	Annual	Therophyte	171	1.24	6	0.23
Emex spinosa	Polygonaceae	Dicot	Annual	Therophyte	130	0.94	0	0.00
Amaranthus retroflexus	Amaranthaceae	Dicot	Annual	Therophyte	107	0.78	4	0.16
Malva sp	Malvaceae	Dicot	Annual	Therophyte	102	0.74	0	0.00
Convolvulus althaeoides	Convolvulaceae	Dicot	Perennial	Geophyte	7	0.05	31	1.20
Chrysantemum segetum	Asteraceae	Dicot	Annual	Therophyte	29	0.21	6	0.23
Portuloca olearcea	Portulacaceae	Dicot	Annual	Therophyte	18	0.13	0	0.00
Erodium sp	Geraniaceae	Dicot	Annual	Therophyte	3	0.02	0	0.00
				Total	13796	100,00	2577	100,00

N: Total abundances of weeds %: Relative percentages of weeds

Table 2 illustrates the statistical analysis, which indicates that the Kruskal-Wallis test revealed significant differences between the two years (p < 0.05) in the abundance of eight weed species, including *Amaranthus albus*, *Chenopodium album*, *Emex spinosa*, *Solanum eleagnifolium*, *Fumaria parviflora*, *Malva sp.*, *Sonchus asper* and *Setaria viridis*. However, species such as *Convolvulus arvensis*, Erodium sp. and *Chrysanthemum segetum* showed no significant differences in abundance (p > 0.05) across the two years, indicating consistent presence.

Table 2. Statistical analysis of variations in weed species abundance between 2022 and 2023 in the pomegranate orchard (H-statistic and p-value from the Kruskal-Wallis test)

Weed Species	H-statistic	P-value
Amaranthus albus	60.536	0.000
Amaranthus retroflexus	17.713	0.000
Chenopodium album	90.402	0.000
Chrysanthemum segetum	5.025e-05	0.994
Convolvulus althaeoides	11.856	0.000
Convolvulus arvensis	2.861	0.091
Emex spinosa	18.441	0.000
Erodium sp.	1.000	0.317
Fumaria parviflora	41.375	0.000
Malva sp.	41.738	0.000
Portulaca oleracea	39.644	0.000
Portulaca sp	3.326	0.068
Setaria viridis	6.598	0.010
Sinapis alba	10.667	0.001
Solanum elaeagnifolium	41.513	0.000
Sonchus asper	37.340	0.000
Sorghum halepense	28.327	0.000

Community composition of arthropods on weeds

Arthropod observations in each weed species

In the spontaneous vegetation of pomegranate orchard inter-rows, 17 weed species were identified. In 2022, 12 weeds hosted arthropods, including *Setaria viridis*, *Amaranthus albus*, *Malva sp.*, *Solanum eleagnifolium*, *Chenopodium album*, *Amaranthus retroflexus*, *Convolvulus arvensis*, *Sorghum halepense*, *Sonchus asper*, *Erodium* sp., *Emex spinosa* and *Fumaria parviflora*. Conversely, *Portulaca oleracea*, *Portulaca* sp., *Sinapis alba*, *Convolvulus althaeoides* and *Chrysanthemum segetum* showed no arthropod presence (Table 3). Among the host species, *Sonchus asper* attracted the highest number total of arthropods, followed by *Chenopodium album*, *Convolvulus arvensis*, *Malva sp.* and *Sorghum halepense*. In 2023, only four weeds hosted arthropods: *Solanum eleagnifolium*, *Sorghum halepense*, *Setaria viridis* and *Amaranthus retroflexus*. *Solanum eleagnifolium* recorded the highest mean number of arthropods, followed by *Malva sp.*, *Sonchus asper* and *Chenopodium album*. The results demonstrate that the weed diversity is significant during the first year (2022), while it declines during 2023.

A Kruskal-Wallis test was conducted to analyse the abundance of arthropods on different weed species between the two years (Table 3). The statistical results showed significant differences in the number of arthropods hosted by weeds between 2022 and 2023, especially in *Chenopodium album*, *Convolvulus arvensis*, *Erodium sp.*, *Malva sp.* and *Sonchus asper*. On the other hand, *Amaranthus albus*, *Amaranthus retroflexus*, *Setaria viridis*, *Solanum eleagnifolium*, *Sorghum halepense* and *Convolvulus althaeoides* showed no significant differences (p > 0.05), suggesting stable arthropod-host interactions for these species across the years.

Arthropod community on the ground cover

The mean abundance of arthropods collected by sweep netting over two consecutive years (2022 and 2023) is shown in Fig. 2. The results reveal a remarkable stability in the abundance of arthropod populations between the two years. The mean abundance was 4.98 arthropods per sample in 2022 and 4.80 in 2023. The Shapiro-Wilk test results indicate that the data for both 2022 and 2023 significantly deviate from a normal distribution, with p-values < 0.05. This confirms that the arthropod counts for both years are not normally distributed. The Kruskal-Wallis test statistic shows no statistically significant difference in arthropod counts between the years (H= 1.47; p = 0.224).

Table 3. Arthropod abundance on weed species in a pomegranate orchard over two years, with H-statistic and p-value (Kruskal-Wallis test) for each species.

Weed Species	2022	2023	H-statistic	P-value
Amaranthus albus	0.03 ± 0.30	0.00 ± 0.00	1.00	0.32
Amaranthus retroflexus	0.03 ± 0.22	0.00 ± 0.00	2.01	0.16
Chenopodium album	1.66 ± 6.04	0.00 ± 0.00	20.82	**0.00**
Chrysantemum segetum	0.00 ± 0.00	0.00 ± 0.00	N/A	N/A
Convolvulus althaeoides	0.02 ± 0.14	0.02 ± 0.20	0.32	0.57
Convolvulus arvensis	1.29 ± 8.20	0.00 ± 0.00	13.81	**0.00**
Erodium sp.	0.10 ± 0.48	0.10 ± 0.00	5.10	**0.02**
Emex spinosa	0.23 ± 1.48	0.00 ± 0.00	3.03	0.08
Fumaria parviflora	0.08 ± 0.71	0.00 ± 0.00	2.01	0.16
Malva sp.	0.92 ± 3.74	0.00 ± 0.00	10.47	**0.00**
Portuloca olearcea	0.00 ± 0.00	0.00 ± 0.00	N/A	N/A
Portuloca sp.	0.00 ± 0.00	0.00 ± 0.00	N/A	N/A
Setaria viridis	0.17 ± 0.88	0.06 ± 0.42	0.55	0.46
Sinapis alba	0.00 ± 0.00	0.00 ± 0.00	N/A	N/A
Solanum eleagrifolium	0.88 ± 3.16	0.26 ± 1.06	1.77	0.18
Sonchus asper	2.74 ± 13.99	0.00 ± 0.00	13.81	**0.00**
Sorghum halepense	0.35 ± 3.01	0.70 ± 4.73	0.12	0.73

N/A: A value implies that the sample data perfectly fits a normal distribution.

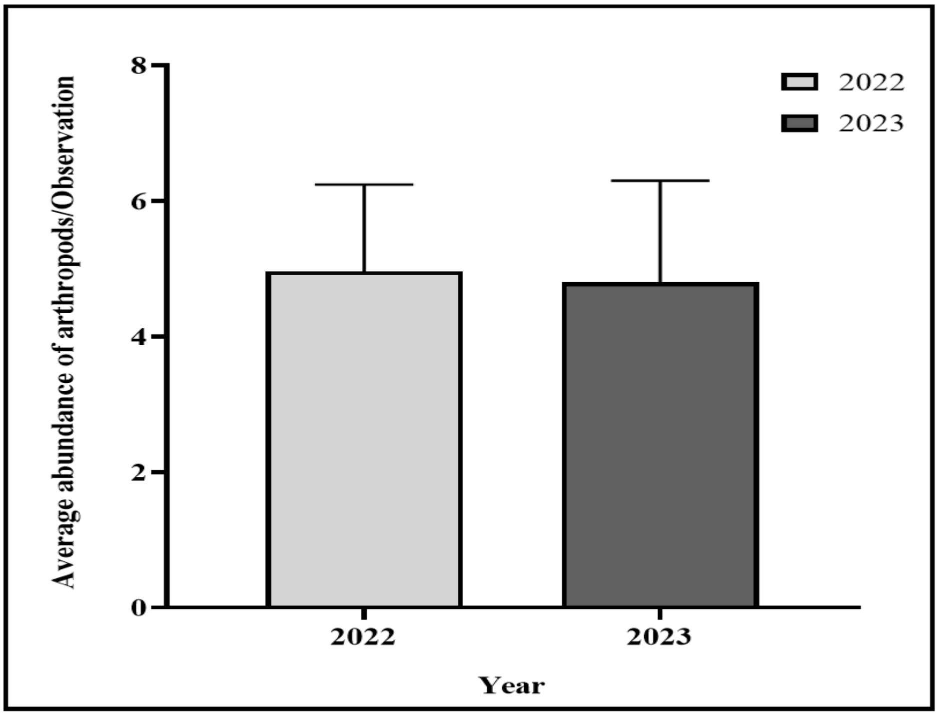

Fig. 2. Abundance of arthropods in weed associated with a pomegranate orchard over two years.

Effect of soil management practices on arthropod abundance in the canopy

Beating

The average abundance of arthropods collected over two years using the beating method is illustrated in Fig. 3. In 2022, the average of individuals of arthropod was higher in weedy plots than in weed-free plots. However, the same trend was observed in 2023, with more arthropods collected in weedy plots compared to weed-free plots. Additionally, the average abundance of arthropods captured in 2023 was lower than in 2022 across both habitat types. The average abundance of arthropods captured significantly decreased in 2023 compared to 2022, across both habitat types and using the beating method.

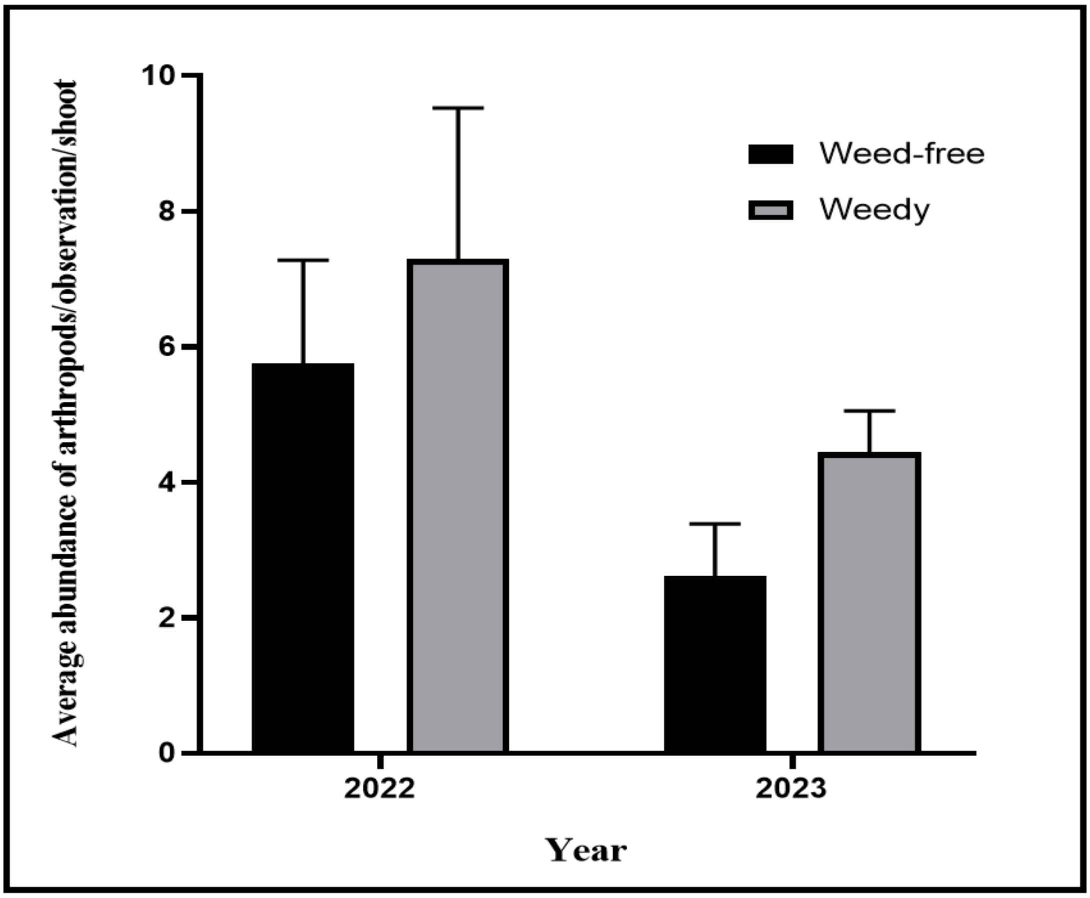

Fig. 3. Arthropod abundance in the canopy of pomegranate trees under soil management practices using the beating method over two years.

Shapiro-Wilk test results confirm that for all combinations of year and treatment, the arthropod counts using beating methods significantly deviate from normality (p-values < 0.05). This indicates that the data is not normally distributed. The Kruskal-Wallis test revealed significant differences in arthropod abundance between years (H= 43.33, $p < 0.05$) and between treatments (H= 7.92, $p < 0.05$) (Table 4).

Table 4. Kruskal-Wallis test for distribution of arthropod abundance data across soil management treatments and years using the beating method

	H-statistic	p-value
Treatment	7.92	0.0049
Year	43.33	$4.61e^{-11}$

Shoot collection

The average number of arthropods collected over the two years of the study using the shoot collection method is presented in Fig. 4. In 2022, the average number of arthropods was significantly higher in weedy plots compared to weed-free plots. In 2023, a sharp decline in arthropod abundance was observed, with a higher average number of individuals in weedy plots compared to weed-free plots. Despite the overall decrease in arthropod numbers, the relative difference between treatments remained consistent across both years.

The Shapiro-Wilk test results confirm that the arthropod count data significantly deviates from a normal distribution for all combinations of year (2022 and 2023) and treatment (Weed-free and weedy), with p-values < 0.05. This indicates that the data does not meet the assumption of normality, necessitating the use of non-parametric statistical tests for further analysis.

Kruskal-Wallis test showed a significant effect of treatment on arthropod abundance (H = 8.94, $p = 0.0028$) and a highly significant difference in abundance between years (H = 1553.99, $p < 0.0001$) (Table 5).

The difference between arthropod abundance between year in shoot collection method is highly significant compared to beating method as revealed by statistical analysis of H-static. While the difference between arthropod abundance and treatments in shoot collection method is highly significant compared to beating method.

In methods, beating and shoot collection, the arthropods abundance is highly important in weedy comparing with weedy-free areas. In addition, the abundance of arthropods is important in 2022 while it is low for 2023; indeed, the precipitation is abundant for 2022 and temperatures are relatively decrease, as a result this increase in temperature and decrease in temperature affect the vegetation cover and arthropods abundance.

Table 5. Kruskal-Wallis test for of arthropod counts using shoot collection method by year and treatment

	H-statistic	p-value
Treatment	8.94	0.0028
Year	1553.99	0.000

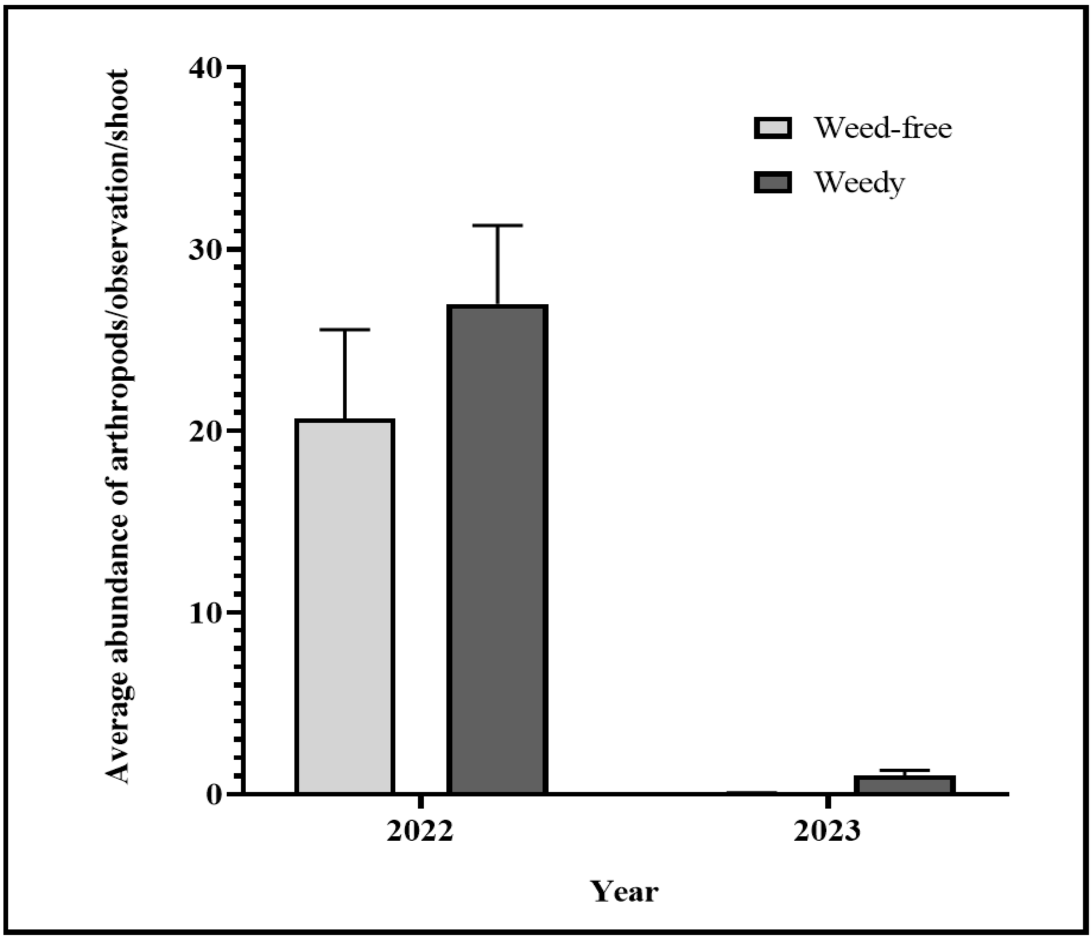

Fig. 4. Arthropod abundance in soil management collected by shoot collection over two years.

Discussion

Abundance and diversity of weed species on pomegranate orchard

The present study revealed a total of 17 weed species belonging to 11 families, indicating a relatively high diversity of weeds in the pomegranate orchard. Annual species were found to be dominant, with therophytes representing the prevailing life form. Similar findings have been reported in various agricultural environments (30-33). The prevalence of therophytes over other life forms appears to be influenced by the Mediterranean climate, variations in topography and biotic factors (34). Additionally, plant life forms showed a characteristic distribution in the different vegetation patterns (35). The short life cycles of annual weeds, in addition to the harsh climate and insufficient moisture, favor the presence of annuals during favorable seasons (36).

The number of families and plant species observed in this study differs significantly from those observed in numerous previous studies conducted on other crops and in various regions worldwide. In contrast, the number of floristic families identified in this study is lower than the 30 botanical families reported in citrus orchards located in the Mediterranean region of Turkey (37). In addition, it was shown that weeds in legume plantations consist of 29 families (38). The results showed that the predominant plant families were Amaranthaceae, Fumariaceae and Poaceae. Similar results have been obtained in earlier studies (39) and Amaranthaceae was the most abundant family in Townes Harvest Farman and apricot orchards (40). In contrast, Asteraceae, Amaranthaceae, Caryophyllaceae, Solanaceae, Poaceae and Primulaceae were the most predominant families, accounting for more than 50% of the species in a citrus orchard in Morocco (41). These differences in the number and richness of weed families compared to other studies highlight the importance of local environmental factors, such as soil properties, climate and land use, in shaping the floristic composition of weed communities (42).

On the other hand, the number of weed species was higher than usually recorded in conventional or no-till fields. Less than 14 species were found in Hayathnagar Research Farm, India (43) and species richness was ranging from 6 to 9 species (44). Species richness varied from 2 to 15 species (45), depending on the country and the agricultural system used (conventional or reduced tillage). In contrast, the number of weed species observed in this study was lower than the 29 species reported in citrus orchards in the Western Mediterranean region of Turkey (37). In the present study, the dominant weed species were *Amaranthus albus*, *Chenopodium album*, *Fumaria parviflora* and *Sorghum halepense*. Similarly, a comparable floristic composition in an apricot orchard, including *Amaranthus retroflexus*, *Convolvulus arvensis*, *Sorghum halepense* and *Chenopodium album* was reported in another study (40). This discrepancy in species richness and the dominance of weed species documented in this study compared to that in other studies can be attributed to numerous factors, with the most crucial factor being the distinction between native flora and the numerous environmental factors that influence each specific region (33). Additionally, this disturbance often leads to distinct local variation in soil properties which meet the edaphic requirements of many species within communities (46).

The results show that differences in the abundance and diversity of weed species could be related to different climatic factors. The variation in the abundance and composition of weeds in the pomegranate orchard between 2022 and 2023 are probably due to changes in precipitation. Data from the study region indicate that precipitation was higher in March and April 2022 than in the same period in 2023 (Fig. 1). These changes in precipitation likely influenced the germination, growth and reproduction of weeds, leading to shifts in species composition (47, 48). Furthermore, climatic conditions influence important plant functions such as flowering, fruiting and seed dormancy, which in turn contributes to changes in weed communities (49-51).

Community composition of arthropods on weeds

Insect observations in each flowering plant

The results from the quadrat sampling method revealed that *Sonchus asper*, *Chenopodium album*, *Convolvulus arvensis* and *Malva sp* supported the highest total arthropod abundance, with significant differences observed among these species over the two years. In contrast, no significant differences were found for *Amaranthus albus*, *Amaranthus retroflexus*, *Setaria viridis*, *Solanum eleagnifolium*, *Sorghum halepense* and *Convolvulus althaeoides*. The variation in arthropod infestation across different weed plants may be related to the chemical composition of these plants. These results are consistent with previous investigations (52) highlighting the most relevant aspect of the chemical basis of plant-arthropod interactions may be the role of weeds' secondary chemicals as determinants of the nature and composition of the weed-associated fauna. In addition, the detection of arthropods associated with host weed species can be influenced by several factors, including the structure the morphological characteristics of the leaves and flowers of weed species, which play a role in the association of arthropods with these plants. The current results are consistent with findings showing that insect groups respond differently to specific characteristics of plant species, with factors such as flower abundance, seed mixture, vegetation structure influencing insect abundance and diversity (53).

These shifts in weed species composition and arthropod abundance could be attributed to several factors, including changes in climatic conditions, or the dynamics of the pomegranate orchard ecosystem itself. The variation in arthropod-weed interactions between 2022 and 2023 may reflect the influence of environmental factors such as temperature, precipitation, or the availability of resources for arthropods. This is consistent with previous results showing that increased temperatures reduce nectar production, thereby limiting resources for flower-visiting insects; this response varies across species (54-56). Furthermore, our results are consistent with studies demonstrating that insect abundances are influenced by the temporal availability of resources (53). In addition, the higher average temperatures and lower precipitation in 2022 may have created favorable conditions for thermophilic arthropods and certain weed species, such as *Sonchus asper* and *Chenopodium album*, to host more arthropods. Notably, *Chenopodium album* causes significant indirect costs in agriculture by serving as an alternative host to a number of economically significant pests (57). These differences in infestation may be linked to the weed life cycle. Perennial plants persist longer throughout the season, providing a continuous source of pollen for arthropods. These findings are consistent with previous studies, which have shown that perennial forage plants are valuable sources of pollen for long-tongued pollinator species (58, 59).

Arthropod community on the ground cover

The results show that sweep netting was an effective and reliable method for arthropod collection, with consistent results across both years of the study. Although the mean abundance of arthropods collected in 2022 was slightly higher than in 2023, the difference was not statistically significant, suggesting that annual variation did not have a major impact on the overall arthropod populations in the pomegranate orchard. This finding contradicts with previous studies that found annual variation in arthropod abundance in vineyards orchard in the Croatia (60). Moreover, the consistency of sweep net efficiency in both years confirms its reliability as a sampling method for arthropods in orchards, as highlighted by studies in various agricultural systems (61-63). This finding highlights the stability of arthropod populations in relation to the sampling technique used, indicating that other factors, such as species composition, season and density of vegetation (particularly annual herbs, which can vary significantly within a year), may not have caused large temporal fluctuations in arthropod numbers (63). Further investigation could focus on these other environmental factors to understand their influence on arthropod abundance.

Effect of soil management practices on arthropod abundance in the canopy

The study demonstrated that inter-row soil management significantly affects the abundance of arthropods in pomegranate orchards. The results showed that the of weedy treatment had a positive impact on the abundance of beneficial arthropods compared to weed-free, as shown by data collected over two years using Shoot collection and beating methods. These findings align with previous research indicating that herbaceous ground cover enhances the abundance of ground-dwelling arthropods (64-67). The positive effect is likely explained by the resources provided by weed species, such as shelter, nectar, pollen and alternative prey, which play a crucial role in maintaining the survival and reproduction of natural enemies and pollinators (68-70). In addition, organic farms which maintain a large diversity of weed communities, exhibit a higher abundance of arthropod predators, while non-predatory insects and pests do not show a similar increase (71). On the contrary, these results disagree with previous studies that showed no effect of ground cover between rows on the abundance of arthropods (72). This discrepancy may indicate a lack of synchronization between herbivores and the natural enemies observed in ground cover studies (73). Weedy plots play a key role in integrated pest management strategies by promoting biodiversity and providing habitats for natural enemies of pests, such as predators and parasitoids (74). By maintaining plant diversity in orchards, these plots offer alternative food resources and refuges, which can enhance the effectiveness of biological control agents (75).

The decline in arthropod abundance observed in 2023 compared to 2022 across both habitat types suggests that external factors, such as climatic changes or pest management practices, may have influenced insect populations. These results are consistent with previous studies, which show that higher mean temperatures can accelerate insect growth and reproduction but may also limit dispersal and survival at extreme levels, depending on the species' ecology and plasticity (72). Conversely, precipitation changes can affect plant quality and arthropod performance, with heavy rainfall benefiting insect populations by reducing pest numbers like aphids and mites (76).

Further studies are recommended, such as the characteristics and ecology of arthropods require further elucidation in future research, for example, to accurately determine the role of each species within this agroecosystem. Moreover, the same management methods should be investigated in other fruit trees in the area and additional studies should be implemented to enhance tree productivity in line with arthropod abundance. In addition, the main practical concern for farmers is the management of pests and the abundance of arthropods, which may become invasive and damage crops or reduce their quality. Meanwhile, this study serves as a foundation for future researchers to apply in similar studies and as a valuable resource for building upon in subsequent research.

Conclusion

This study highlights the importance of weeds and soil management practices in the dynamics of arthropods in pomegranate orchards. The observed floristic diversity, dominated by therophytes, is influenced by the Mediterranean climate and local conditions. Weeds, particularly *Chenopodium album* and *Sonchus asper*, play a key role in providing resources for arthropods, while inter-row cover crops promote these interactions by supporting natural enemies and pollinators. Climate variations between 2022 and 2023 altered the composition of weeds and arthropods, emphasizing the impact of rainfall and temperature on these communities. Our findings demonstrate the positive effects of inter-row vegetation management on the abundance of arthropods in pomegranate orchards. These results can inform large-scale orchard management, particularly regarding weed management and inter-row crops, which promote functional biodiversity and ecosystem services. However, future research should explore more in-depth the ecological interactions between these factors, taking into account climatic variations, to optimize large-scale agricultural practices. It would also be relevant to study the dynamics of pollinators and the impact of functional biodiversity on sustainable orchard management.

Acknowledgements

The authors are grateful to Mohamed Benaamar for their great efforts in sampling arthopods in Morocco. We thank Aferji Aymen for technical support, Mr. Yahya Baye, for his expertise and valuable assistance in identifying weed plants. We are thankful to the Director of INRA-Morocco and the Head of Tadla Research Regional Center for the support and facilities. The authors also acknowledge part funding from the PRIMA Carob Research Programme through the PROMEDLIFE project (Section I), Agreement No. 2132.

Authors' contributions

FS devised the research concept, secured funding, and, along with MM and BL, verified the methodology. Software analysis was conducted by BY, MM and FS, while validation involved FS, EK, BY and BL. AA, BY, and LS performed the formal analysis; resources were collected by MM, LS and AA; and the original draft was prepared by MM, FS, BL and AA. Supervision and project administration were handled by FS, BL and EK, with all authors contributing to the review and approving the final manuscript.

Compliance with ethical standards

Conflict of interest: The authors declare no conflicts of interest.

Ethical issues: None

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Additional information

Peer review: Publisher thanks Sectional Editor and the other anonymous reviewers for their contribution to the peer review of this work.

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