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Ajerrar A *et al.* (2024)
Notulae Scientia Biologicae
Volume 16, Issue 1, Article number 11594
DOI:10.15835/nsb16111594
Research Article

NSB
Notulae Scientia Biologicae

Diversity and abundance of insect's community associated to *Argania spinosa* (L.) Skeels foliage

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Abstract

Argan tree (*Argania spinosa*) is the unique representative of Sapotaceae family in North-Africa. This family is commonly growing in pantropical areas. The current study focused on the diversity of foliage insect associated to *A. spinosa*, and their seasonality in four sites in Souss region. Insects were trapped using sticky yellow traps installed on each sampled Argan tree. Consequently, 241 morphospecies were identified represented by seven orders. Diptera was the most abundant followed by Hemiptera and Hymenoptera. However, the remains orders represented only less than 4%. A high taxonomic richness was recorded for Hymenoptera (100 morphospecies) followed by Diptera (70) and Coleoptera (39). Data analysis shows a quantitative dominance of some insects' families. Within Hemiptera, Aleyrodidae represented up to 80% of total captures. Coccinellidea was the most abundant family of Coleoptera representing over 62%. Among Diptera and Hymenoptera, more than 60% of total abundance was represented only by five families. Argan foliage insects exhibited seasonal variations. Therefore, high significant diversity parameters were recorded during spring. However, the lowest diversity was recorded during summer in Belfaa and during autumn for the other sites. Five trophic guilds were reported. Their abundance was influenced by seasonal variation. Herbivores abundance was highly significant compared to the others trophic guilds throughout all sampling seasons. Except *Ceratitis capitata* Wiedemann, which infests argan fruits during the two latest stages of maturity, none of its herbivores is known as economic interest to the argan tree. On the other hand, argan trees host a complex structure of functional taxa, including pest regulating (predators and parasitoids) and pollinators.

Keywords: Coccinellidea; herbivores; Hymenoptera; insect's diversity; parasitoids; pollinators

Received: 13 Jun 2023. Received in revised form: 18 Feb 2024. Accepted: 12 Mar 2024. Published online: 22 Mar 2024.
From Volume 13, Issue 1, 2021, Notulae Scientia Biologicae journal uses article numbers in place of the traditional method of continuous pagination through the volume. The journal will continue to appear quarterly, as before, with four annual numbers.

Introduction

Argan tree (*Argania spinosa* (L.) Skeels) is one of the most important endemic fruiting forest trees in the west-central of Morocco covering about 800,000 ha (Msanda *et al*., 2021) and well-adapted to arid and semi-arid climate (Chakhchar *et al*., 2020; Msanda *et al*., 2021). Argan tree is considered as the unique remaining representative of Sapotaceae family in Morocco (Ait Aabd *et al*., 2019). This family is commonly growing in pantropical areas. Since Argan tree is endemic, it is considered as a humanitarian heritage requiring protection, rehabilitation and conservation for current and future generations (Ait Aabd *et al*., 2022). For these reasons, in 2021 the United Nations General Assembly proclaimed 10 May the International Day of Argania. Moreover, according to multifunction roles of Argan, including ecological, economic and social roles (Ait Aabd *et al*., 2019), the Arganeraie was recognized as a Biosphere Reserve by UNESCO since 1998. Argan tree only grows in this part of the world highlighting the singularity of their associated foliage insect community in its ecosystem. Insects play several functions in both forest and agricultural landscape, including pollination, pest regulation, nutrients cycling, and soil engineering (El keroumi *et al*., 2010; Bagyaraj *et al*., 2016; Ollerton, 2017; Ajerrar *et al*., 2020). On the other hand, some insects are pest and can infect directly or indirectly (vector of different disease) different crops and wild plants leading to crop losses (Fegrouche e*t al*., 2012; El Alaoui *et al*., 2013; Haack, 2017).

Recently, the importance of landscapes complexity on arthropods diversity (Bianchi *et al*., 2006; Molina *et al*., 2014) was highlighted. In addition to cultivated plots, non-crop habitats (including, fallows, field margins, wooded margin, etc.) in which higher natural enemy populations and pest pressure lower were found (Bianchi *et al*., 2006). Moreover, several studies show that forest and semi-natural habitats support highly insect diversity compared to subjacent cultivated plots (Bellamy *et al*., 2018) and consequently the important role of these two ecosystems in the insect's conservation. In addition to the impact of habitat type on insect's community, other abiotic factors such as seasonality also influenced the insect community. In arid and semi-arid ecosystems where water is a limiting factor (Wenninger and Inouye, 2008), the supplemental moisture has a positive effect on both abundance and diversity of insects. In central western of Morocco, the argan forests which cover a vast arid ecosystem may play a key role in the insect conservation. Relative to other forest species in Morocco, the entomofauna of the argan tree has received less attention and yet only few studies were done (Ajerrar *et al*., 2020; Ajerrar *et al*., 2023a; Ajerrar *et al*., 2023b; Naamani, 2004; Smirnoff, 1958). However, no studies exist in argan forest of Souss region have examined the diversity and abundance of foliage insect community and their seasonal changes. Thus, the main purpose of the present study was to determine taxonomic composition and functional groups associated to argan foliage in Souss region as well as their seasonal and spatial distribution pattern.

Materials and Methods

Study sites

Four argan tree localities in Souss valley located in central-west of Morocco were surveyed. The sites of Tameri, Aoulouz and Argana covered forest areas, while the fourth site which located in Belfaa is an argan orchard (Figure 1). The first site is located at Tameri (30.70672N, -9.76643W) in Agadir district. The Arganeraie in this area consists of a relatively dense forest; the main anthropogenic activities are occasional cereals cropping including barley in plots developed for grazing. The second site is located in Aoulouz (30.62352N, -8.14542W) in Taroudant district. The density of trees was about 100 trees per hectare. The third site is located in Argana (30.7519869N, -9.1529756W), which is located in north-west of Taroudant district, goat livestock frequent this site daily. The fourth site is an Argan orchard at an experimental farm of the

National Institute for Agronomic Research (INRA) located in Belfaa (30.0434N, -9.55635W). The orchard was planted in 2010 as an experiment of Argan tree domestication. The orchard's area is about two hectares with a density of 150 trees per hectare. The Argan trees height ranged from 3 to 5 meters. Irrigation and fertilization are carried out with drippers and organic manure. The four studied sites belong to Mediterranean arid climate with less than 300 mm / year rainfall (Mokhtari *et al*., 2013). Aoulouz, Argana and Belfaa have a cold winter and very hot summer. However, Tameri which was influenced by Atlantic Ocean, having a mild winter and summer.

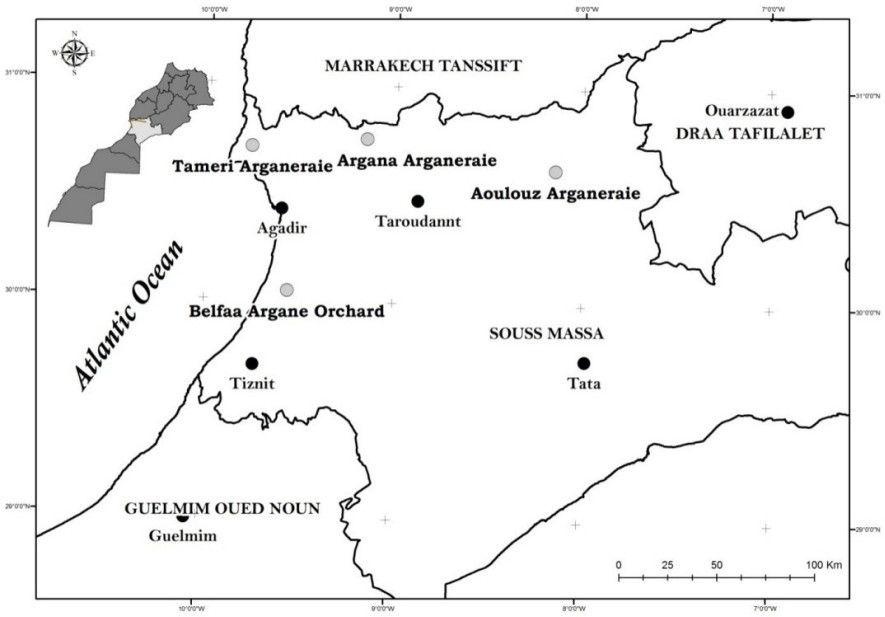

Figure 1. Map of the studied area and site's locations (Grey spots)

Insects sampling

In each studied site, ten Argan trees were selected for the trap's installation. The traps consist of the sticky yellow traps measured 25 cm by 10 cm (IPM Russell, UK) which suspended at a height of 1.5-2 m from the ground on the south-east side of the tree sheltered from the prevailing wind in the foliage (Calabuig *et al*., 2015; Gkisakis *et al*., 2018). The traps were retrieved after 24 hours and transferred to laboratory for insects score and for identification. Identification was conducted to family and then morphospecies, using a stereomicroscope and several keys (Unwin, 1981; Goulet and Huber, 1993; Ebrahim and Salem, 2010; Marshall *et al*., 2017).

Data analysis

To characterize foliage insects' communities, the diversity parameters of taxonomic abundance (N), taxonomic richness (R) and Shannon diversity index (H') per sample unit were calculated using PAST Software version 4.03 (Hammer *et al*., 2009). All statistical analysis was performed by One-way ANOVA and two-way ANOVA test at $p<0.05$ using Statistica Software (Version 6, StatSoft, USA). Tukey test at 95% confidence limit was used to compare mean values if significant differences are found. At community level, we performed two-way ANOVA to assess the difference in the three diversity parameters of the foliage insects between the four studied sites throughout the sampling periods (seasons). Principal component analysis (PCA) was performed by PAST to generate ordination diagrams leading to compare how closely the different sites are related to each other in terms of species composition and how the species composition varies between sampled periods (seasons).

Results

Composition of foliage insect community

A total of 5080 insects individual were captured (polled data of all samples in the four studied sites), representing 241 morphospecies, and 61 families. Seven orders were represented and their overall relative abundance was as follows: Diptera (45.08%), Hemiptera (39.44%), Hymenoptera (9.86%), Coleoptera (4.14%), Thysanoptera (0.55%), Psocoptera (0.35%) and Neuroptera (0.14%). Table 1 presents a summary data of insects collected. More insect species were trapped in Belfaa site compared to the other sites; however, the lowest insects' species were recorded in Argana site.

Table 1. Summary of foliage insect trapped from *Argania spinosa* in the four studied sites: Belfaa, Aoulouz, Tameri and Argana

	Belfaa	Aoulouz	Tameri	Argana	Total catch	R. A (%)	R. A (%) of family within order
Diptera					1591	45.08	
Tephritidae	412	51	81	1	545	15.44	34.26
Tachinidae	15	36	4	4	59	1.67	3.71
Anthomyiidae	260	8	5	2	275	7.79	17.28
Caliphoridae	88	10	7	4	109	3.09	6.85
Chloropidae	9	11	1	0	21	0.60	1.32
Syrphidae	7	4	1	0	12	0.34	0.75
Agromyzidae	12	6	1	0	19	0.54	1.19
Asilidae	0	0	12	0	12	0.34	0.75
Bibionidae	10	0	0	0	10	0.28	0.63
Empididae	233	0	9	14	256	7.25	16.09
Cecidomyiidae	48	0	6	0	54	1.53	3.39
Scenopinidae	9	0	0	1	10	0.28	0.63
Conopidae	0	0	0	2	2	0.06	0.13
Muscidae	66	14	0	4	84	2.38	5.28
Sciomyzidae	0	0	1	0	1	0.03	0.06
Xylophagidae	0	0	0	2	2	0.06	0.13
Xylomyidae	2	0	0	0	2	0.06	0.13
Lonchaeidae	39	0	0	0	39	1.11	2.45
Sarcophagidae	11	0	6	1	18	0.51	1.13
Stratiomyidae	0	0	1	0	1	0.03	0.06
Fanniidae	30	0	0	0	30	0.85	1.89
Nematocera	0	3	1	26	30	0.85	1.89
Hymenoptera					348	9.86	
Formicidae	0	0	1	3	4	0.11	1.15
Chrysididae	17	2	1	3	23	0.65	6.61
Halictidae	19	4	4	12	39	1.11	11.21
Braconidae	17	5	2	2	26	0.74	7.47
Chalicididae	4	2	0	4	10	0.28	2.87
Myrmaridae	19	2	22	2	45	1.28	12.93
Aphelinidae	0	5	2	2	9	0.26	2.59
Eulophidae	2	2	0	3	7	0.20	2.01
Pteromalidae	32	14	2	3	51	1.45	14.66
Vespidae	3	3	0	2	8	0.23	2.30
Carbonidae	2	2	1	3	8	0.23	2.30
Evaniidae	0	0	2	0	2	0.06	0.57
Scoliidae	0	0	0	2	2	0.06	0.57
Ichneumonidae	1	8	0	1	10	0.28	2.87
Apidae	5	3	3	1	12	0.34	3.45
Pompilidae	1	15	15	23	54	1.53	15.52

Cimbicidae	0	0	0	1	1	0.03	0.29
Argidae	2	3	2	1	8	0.23	2.30
Bethylidae	4	23	2	0	29	0.82	8.33
Coleoptera					146	4.14	
Coccinellidea	77	10	2	1	90	2.55	61.64
Anthicidae	1	0	0	0	0	0.00	0.68
Mordellidae	0	0	2	0	2	0.06	1.37
Scolytidae	0	0	4	0	4	0.11	2.74
Oedemeridae	0	0	1	0	1	0.03	0.68
Buprestidae	0	0	0	5	5	0.14	3.42
Chrysomelidae	6	0	1	0	7	0.20	4.79
Dermestidae	0	0	2	0	2	0.06	1.37
Malachiidae	0	1	0	0	1	0.03	0.68
Curculionidae	1	0	0	0	1	0.03	0.68
Other beetles	4	5	13	10	32	0.91	21.92
Hemiptera					1392	39.44	
Aleyrodidae	193	18	532	400	1143	32.39	82.11
Aphididae	39	3	11	3	56	1.59	4.02
Cicadillidae	3	1	2	8	14	0.40	1.01
Membracidae	0	0	5	1	6	0.17	0.43
Psyllidae	71	1	0	0	72	2.04	5.17
Miridae	28	34	3	28	93	2.64	6.68
Rhopalidae	0	0	1	0	1	0.03	0.07
Other Hemiptera	0	3	1	3	7	0.20	0.50
Other families					53	1.50	
Chrysopidae	2	5	0	0	7	0.20	
Psocoptera	8	0	5	5	18	0.51	
Aloethrips	6	0	1	21	28	0.79	

Despite the high relative abundance of Hemiptera which represent more than 39% of overall trapped insects in the four sites, this order is less diverse compared to the other orders such as Coleoptera, Diptera and Hymenoptera. It is represented only by 7 families, the most important of which is the Aleyrodidae which alone represents more than 80% of Hemiptera, followed by Miridae (8.20%), Aphididae and Psyllidae (4.1% and 5.1%) respectively. While, the other families represented less than 2% together (Table 1).

Among Coleoptera, Coccinellidea were the most abundant families representing up to 62% of total Coleoptera collected in the four studied sites, followed by Curculionidae (10 %) and Chrysomelidae (5%). On the other hand, low relative abundance was recorded for Scolytidae and Buprestidae which represented 3% each; while Anthicidae, Malachidae, Dermestidae, Oedemeridae, and Cantharidae represented less than 1% each (Table 1).

Diptera -which represented the most abundant group - was the richest order regarding the number of family. Therefore, it is represented by 21 families whose relative abundance was unequal, and more than 70% of the total relative abundance was represented by four families: Tephritidae (34.24%), Anthomyiidae (17.28%), Empididae (16.09%) and Calliphoridae (6.85%). However, Tachinidae and Muscidae both represented around 9%. On the other hand, the other families were less abundant; several represented less than 2% (Table 1).

Although that Hymenoptera represented only 9.86% of the total relative abundance of foliage insects' community, they were the most diversified group (more than 100 morphospecies have been identified, represented by 19 families). Five families represented more than 60% of total relative abundance: Pompilidae (15.5%). Pteromalidae (14.7%), Mymaridae (12.9%), Halictidae (11.2%), and Bethylidae (8.3%). However, the other families were less abundant: Evaniidae and Scoliidae represented 0.6% each and Cimbicidae represented only 0.3% (Table 1).

Response of foliage insect diversity and abundance to seasonal and spatial variation

Diversity parameters computed for insect community of Argan foliage showed a significant difference between seasons within each studied site (Table 2). A highly significant difference of taxonomic richness was recorded during spring in the four studied sites, while the low richness was recorded during summer at Belfaa and during autumn in the other sites (Table 2). Also, a highly significant difference of taxonomic abundance was recorded during spring in Belfaa, Tameri and Argana. However, a highly significant taxonomic abundance was recorded in both spring and summer compared to the other seasons in Aoulouz. Shannon diversity index computed for foliage insects showed a highly significant difference between seasons: Highest value per trap was recorded during spring in Belfaa (2.59±0.18), Aoulouz (1.86±0.22) and Argana (1.48±0.32). On the other hand, in Tameri, the highest Shannon diversity index was recorded during winter and spring which is significantly different from the other seasons (Table 2).

Table 2. Diversity parameters computed for foliage insects in the four studied sites according to sampled seasons

Diversity parameters	Sites	Winter	Spring	Summer	Autumn
Richness	Aoulouz	2.8±1^{a}	9.4±1.9^{c}	6.8±2.1^{b}	3.8±1.4^{a}
Abundance		4.2±1.3^{a}	27±10.4^{b}	23.1±13.4^{b}	8.5±4.5^{a}
Shannon index		0.88±0.38^{a}	1.86±0.23^{c}	1.43±0.47^{b}	0.88±0.30^{ab}
Richness	Tameri	3.9±1.3^{a}	10.2±4.3^{b}	3.8±1.1^{a}	2.4±1.2^{a}
Abundance		6.2±2.3^{a}	53.7±29.8^{b}	20.5±16^{a}	6.2±5^{a}
Shannon index		1.1±0.4^{b}	1.1±0.4^{b}	0.6±0.2^{a}	0.5±0.4^{a}
Richness	Belfaa	13.1±2.5^{b}	28±2.5^{c}	6.8±2^{a}	11.4±1.5^{b}
Abundance		49.5±17.3^{b}	138±24.5^{c}	10.6±4.3^{a}	71.7±21.4^{b}
Shannon index		2.1±0.3^{b}	2.5±0.2^{c}	1.6±0.3^{a}	1.8±0.2^{ab}
Richness	Argana	4±2^{a}	10.6±4.1^{b}	3.4±1.4^{a}	3.1±1.3^{a}
Abundance		25.5±17.2^{a}	59.3±20^{b}	8±5.4^{a}	7.2±3.3^{a}
Shannon index		0.7±0.5^{a}	1.4±0.4^{b}	0.8±0.2^{a}	0.7±0.2^{a}

Means (±SE) with different letters indicate significant difference at $P<0.05$

Furthermore, computed diversity parameters of foliage insect show a significant difference between studied sites among sampled seasons (Table 3). Therefore, the highly significant parameters (Richness, Abundance and Shannon index) were recorded in Belfaa orchard during winter, spring and autumn compared to the other studied sites (Table 3). In summer, highly significant taxa richness and Shannon index were recorded in both sites Aoulouz and Belfaa. However, significant taxa abundance was recorded in Aoulouz (Table 3).

To show clearly the spatiotemporal trend of foliage insect's community of Argan tree, the composition and structure of the predominant families based on their relative abundance and their occurrence (only families with occurrence > 10% are represented) were projected according to spatial scale and according to four sampling seasons using PCA (Figure 2). The variation of the composition and the structure of the predominant families according to seasons and localities were observed. Thus, during autumn only few predominant families were registered especially in Argana. However, a high number of families were recorded in Belfaa followed by Aoulouz. Autumn season was characterized by the predominance of Diptera families (including Tephritidae, Empididea, Calliphoridae and Anthomyiidae), Aleyrodidae and Coccinellidae (Figure 2).

In winter, the predominant families were increasing. During this season, the foliage insect's community was characterized by the dominance of herbivores families including Aleyrodidae, Psyllidae, Aphididae, Tephritidae, Aeolothripidae and Cecidomyiidae. Moreover, the appearance of some Hymenoptera families (such as Halictidae, Chrysididae, Braconidae and Apidae) was observed mainly in Belfaa. Positive correlation between herbivores families and Coccinellidae known for preying Aphididae was shown. During spring, mild

climate conditions in the four studied sites result in increasing primary producers, which in turn result in increasing the predominant families of primary consumer (herbivores).

Table 3. Variation of the diversity parameters (Mean ± SD) between sampling sites according to sampled seasons (ANOVA one way at P<0.05)

Diversity parameters	Seasons	P	Belfaa	Aoulouz	Tameri	Argana
Taxa richness	Winter	P <0.0001	13.1 ± 2.5^{b}	2.8 ± 1^{a}	3.9 ± 1.1^{a}	4 ± 2^{a}
	Spring	P <0.0001	28 ± 2.5^{b}	9.4 ± 1.9^{a}	10.2 ± 4.3^{a}	10.6 ± 4.1^{a}
	Summer	P <0.01	6.8 ± 2^{b}	6.8 ± 2.1^{b}	3.8 ± 1^{a}	3.4 ± 1.5^{a}
	Autumn	P <0.0001	11.4 ± 1.5^{b}	3.8 ± 1.3^{a}	2.4 ± 1.1^{a}	3 ± 0.8^{a}
Taxa abundance	Winter	P <0.0001	49.5 ± 17.3^{c}	4.2 ± 1.3^{a}	6.2 ± 2.3^{ab}	25 ± 17.1^{b}
	Spring	P <0.0001	138 ± 24.5^{b}	27 ± 10.4^{a}	53.7 ± 29.7^{a}	39.3 ± 19.9^{a}
	Summer	P<0.05	10.6 ± 4.3^{ab}	23.1 ± 13.4^{b}	20.5 ± 6.2^{ab}	8 ± 5.4^{a}
	Autumn	P <0.0001	71.7 ± 21.4^{b}	8.5 ± 4.5^{a}	6.7 ± 5^{a}	6.7 ± 4.1^{a}
Shannon index	Winter	P <0.0001	2.1 ± 0.3^{b}	0.8 ± 0.3^{a}	1.16 ± 0.3^{a}	0.7 ± 0.4^{a}
	Spring	P <0.0001	2.5 ± 0.1^{c}	1.8 ± 0.2^{b}	1.1 ± 0.3^{a}	1.4 ± 0.3^{ab}
	Summer	P <0.00001	1.6 ± 0.3^{b}	1.4 ± 0.4^{b}	0.6 ± 0.2^{a}	0.8 ± 0.3^{a}
	Autumn	P <0.00001	1.8 ± 0.2^{c}	1.1 ± 0.2^{b}	0.5 ± 0.3^{a}	0.8 ± 0.2^{ab}

Different letters indicate significant difference tested by Tukey test

As a consequence, other families were recorded (Miridae, Membracidae, Chloropidae and Curculionidae) in addition to the aforementioned ones. As a response to the increase of herbivores families, we observed a parallel increase of parasitoid families including members of Mymaridae and Pteromalidae. Spatial distribution of predominant families was heterogeneous; each studied site was characterized by a dominance of some families. In spring, the dominance of Aleyrodidae and Pompilidae was observed in Tameri and Argana. Belfaa are characterized by a dominance of Diptera families and Hymenoptera (including Pteromalidae and Halictidae). In addition, Tephritidae family was dominant family except in Argana. The summer was characterized by decrease of both Diptera families' number and their dominance; while Hymenoptera families' number (Pompilidae, Aphelinidae and Bethylidae in Aoulouz) increased. Additionally, despite a slight decreased abundance registered for Aleyrodidae, it was the predominant family in Argana and Tameri.

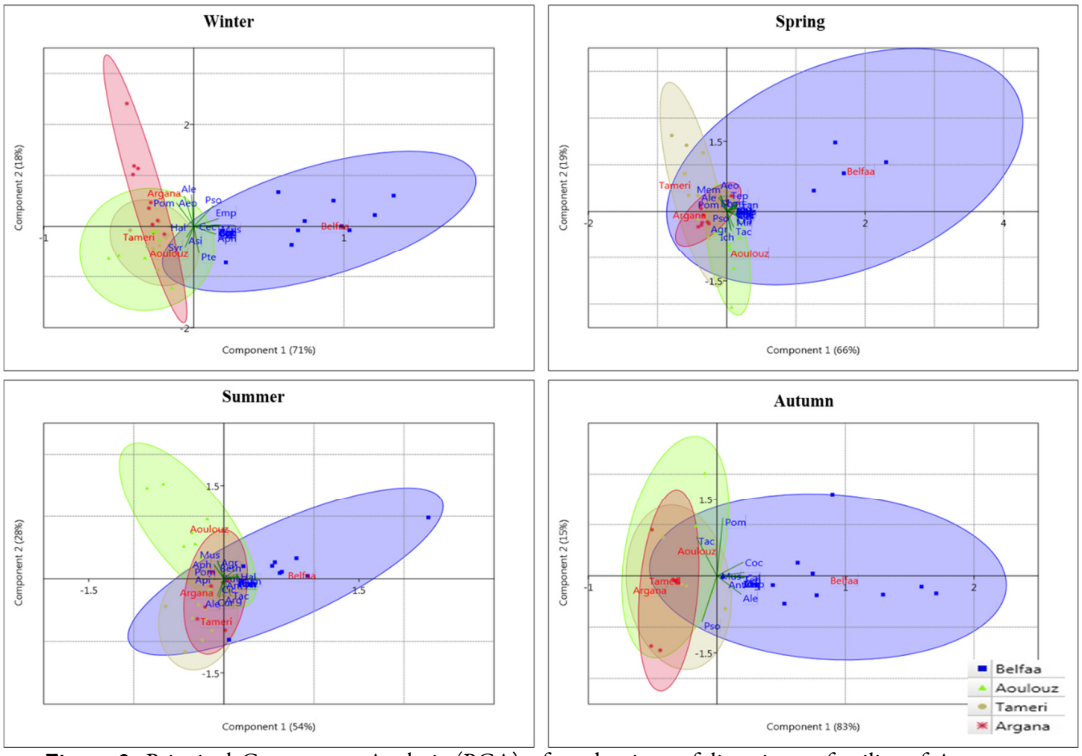

Figure 2. Principal Component Analysis (PCA) of predominant foliage insect families of Argan tree according to studied sites and sampled seasons

Taxa abbreviations. Aeolothripidae: Aeo; Agromyzidae: Agr; Aleyrodidae: Ale; Anthomyiidae: Ant; Aphididae: Aph; Aphelinidae: Aphe; Apidae: Api; Argidae: Arg; Asilidae: Asi; Bethylidae: Bet; Bibionidae: Bib; Braconidae: Bra; Calliphoridae: Cal; Cecidomyiidae: Cec; Chalcididae: Cha; Chloropidae: Chl; Chrysididae: Chr; Cicadellidae: Cic; Coccinellidae: Coc; Crabronidae: Cra; Curculionidae: Cur; Empididae: Emp; Eulophidae: Eul; Fanniidae: Fan; Halictidae: Hal; Ichneumonidae: Ich; Lonchaeidae: Lon; Membracidae: Mem; Miridae: Mir; Muscidae: Mus; Mymaridae: Mym; Pompilidae: Pom; Pteromalidae: Pte; Psocoptera: Pso; Psyllidae: Psy; Scenopinidae: Sce; Scolytidae: Sco; Syrphidae: Syr; Tachinidae: Tac; Tephritidae: Tep; Ves.

Trophic guild's function

Mean of abundance recorded for the five main trophic guilds per trap showed a strong variation among sampled seasons. Except predators, high abundance was recorded during spring compared to the other sampled seasons for the other guilds. During summer, abundance per trap recorded was significantly decreased for all trophic guilds. Therefore, the lowest abundance was recorded during this season. In autumn, a slight increase was recorded for pollinators and herbivores. However, predator's abundance was remarkably increased. On the other hand, abundance of detritivores was decreased. The mean of abundance recorded during winter was almost the same as that recorded during autumn except for predators and pollinators, which slightly decreased. Throughout all sampled seasons, mean of abundance recorded for herbivores was significantly higher than the other trophic guilds ($P < 0.0001$) (Figure 3.).

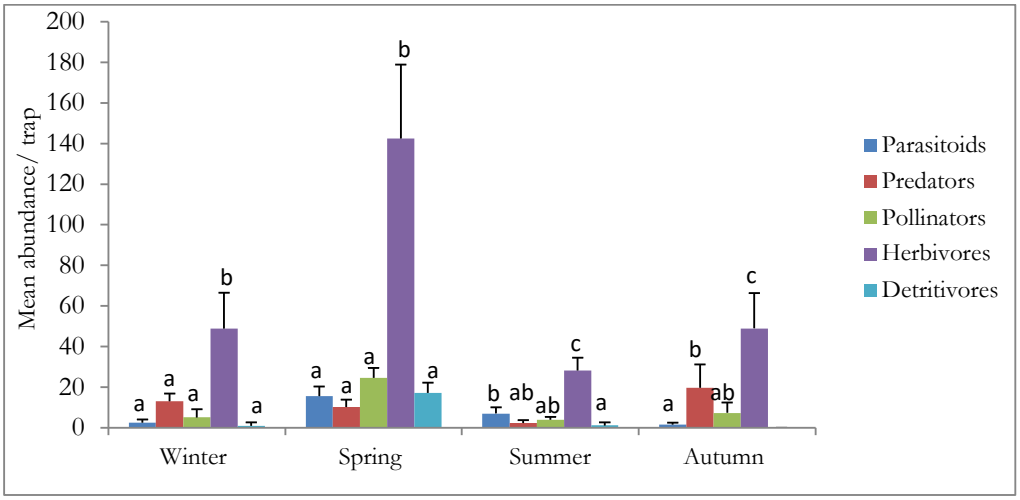

Figure 3. The seasonal abundance of the five trophic groups of foliage insects' community trapped in the four study sites

Means (±SE) with different letters indicate significant difference at P<0.05 followed by Tukey test.

Discussion

This study reported a high diversity and richness of Argan foliage insects. Therefore, 241 morphospecies were identified. Comparing this result with other works conducted in Morocco, we found that the total species richness in this study is slightly lower than that of the arthropod community trapped on Argan foliage in Essaouira (Naamani, 2004) which is represented by 300 species. Again, lower than the species richness of foliage species associated to *Quercus ilex* where Arahou (2010) reported 310 species. This difference may be explained by the beating method used in the two studies, which makes it possible to extract more entomofauna taxa (e.g., Arachnida, Coleoptera, Lepidoptera, Orthoptera and Formicidae). Furthermore, the difference in the sampling method may explain the difference in the entomofauna assemblage structure between the present study and that conducted by Naamani (2004) in Essaouira. In Essaouira, the beating method allowed for a significant abundance of mites and a high taxon richness of Coleoptera (120 species) and Sminroff (1958) reported a high abundance of Coleoptera followed by Hemiptera in Souss region. On the other hand, in the present study, the structure of insect's community of Argan foliage shows the importance of the Hymenoptera, which represents the richest order (100 morphospecies) followed by the Diptera (70), and the Coleoptera (39). The Hemiptera was relatively less rich in species; however, they were the second abundant order (representing over 39 % of total captured insects). The high number of captured Aleyrodidae explains this significant abundance of Hemiptera. Diptera constitute the most abundant group, it represented by 21 families including Tephritidae as the most abundant one, mainly presented by *Ceratitis capitata* Weidemann, which reared perfectly in Argan fruits (Ajerrar *et al.*, 2023b).

Based on our field observations and monitoring carried out in the field of the different parts of the Argan tree, none of the herbivores, though significant compared to other guilds, is known as economic interest to the Argan tree - except *C. capitata*, which infests Argan fruits during the last two stages of maturity without causing significant quantitative losses for the Argan tree (Mazih and Debouzie, 1996). Moreover, some pests were reported in Argan tree such as *Xylomedes coronata* (Marseul) (Curculionidae) (Aberlenc and Hamlaoui, 2011).

In this present study, diversity indexes (Mean abundance, mean richness, and mean Shannon index) per trap, calculated for foliage insects in the four studied sites, were significantly impacted by season. Results indicated that the structure of argan foliage insects in the present study was affected by seasonality. Overall, in the four studied sites, high significant diversity indexes were recorded during spring, which is the most suitable

season for foliage insect community in this area. The same finding was reported by Smirnoff (1958) on argan foliage, and on terrestrial arthropods (Ajerrar *et al*., 2023a). Significant high diversity indexes reported in spring may be explained by spring season's mild climate in the four studied sites. Moreover, argan blooming (Bani-Aameur, 2000), significant vegetative growth (Zahidi *et al*., 2013) and the annual plants grown in the Argan shade occurred during this season seem to have a positive effect on Argan foliage insect's assemblage. The same pattern was reported elsewhere (Lowman, 1982). On the other hand, autumn was the most unfavorable season for foliage insects of Argan in Tameri, Argana and Aoulouz. However, summer was unfavorable in Belfaa. The same pattern of foliage insects of Argan tree was found while studying terrestrial arthropods within the same studied sites (Ajerrar *et al*., 2023a). Diversity decline during these two seasons may relate to limited food resources during these dry seasons.

Foliage insect's community assigned to trophic guilds also shows the seasonality impact on the abundance of trophic guilds. The seasonal pattern of trophic guilds is almost the same pattern as the overall insects' assemblage. Therefore, we found a high abundance during the spring for all the five guilds which coincide with the high resources' availability and the mild climate as we explained above leading to an increased number of first consumers (including herbivores and pollinators), which leads in turn to increase the second consumers (including predators and parasitoids). Moreover, several insects were found to feed on Argan flowers in a separate study (Ajerrar *et al*., 2020). Over all sampling periods, the abundance of herbivores was significantly higher; the latter can be explained by the high abundance of Aleyrodidae family. The Argan grove covers a large area in the southwest of Morocco with different types of formations. Next to the Argan forest, which covers most of the Argan groves, there are forest fragments, private and communal orchards and new orchards recently planted which gives a mosaic aspect to the agricultural landscape in the Souss region. This complexity of the agricultural landscape provided by the different formations of the Argan groves can contribute to the conservation of insect communities and arthropods in general in this region. This observation has been demonstrated elsewhere (Bellamy *et al*., 2018) while showing that the complexity of the agricultural landscape contributes to a significant stability of communities and to increase the ecosystem services that depend on it. The majority of these studies find positive effects of increased complexity on the abundance of beneficial arthropods (Bianchi *et al*., 2006; Chaplin-Kramer *et al*., 2011). In Souss region, the argan forest offers a refuge where insects and / or arthropods can settle, breed and feed on the various resources offered by the argan tree itself and its undergrowth.

Conclusions

This study indicated that foliage insect communities of argan tree are highly diversified. Despite the significant high abundance of herbivores guild, no leaves pest was recorded for argan tree. The current findings are original and could be a baseline for future studies since the study was done in argan forest. It may further be developed through additional studies under greenhouse or other controlled areas to study each of the identified insect foliage and check for possible pests of argan seedlings at nursery level. On the other hand, further studies are also needed to fully understand the mechanism of high biotic stress resistance observed on adult argan tree.

Authors' Contributions

Conceptualization: R.B. and A.A.; Methodology: R.B., A.A., M.Z., E.H.M., B.C. and R.Q.; Investigation. writing - original draft preparation: A.A. and R.B.; Writing - review & editing: M.Z., B.C., E.H.M. and R.B.; Formal analysis: R.B., H.B., H.L., E.H.M., A.B. and R.Q.

All authors read and approved the final manuscript.

Ethical approval (for researches involving animals or humans)

Not applicbale.

Acknowledgements

This work was supported by National Institute of Agronomic Research. Regional Center of Agronomic Research of Agadir. Morocco (Grant id: PRMT Arganier 2017-20). We acknowledge Pr. Rachid Houmad for his English language editing.

Conflict of Interests

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

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