Influence of Different Citrus Cropping Systems on Insect Diversity in the Northern West of Algeria

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Abstract

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Over the past few decades, the Algerian citrus industry has benefited from significant public subsidies for renewing old plantations. As a result, some growers have switched from the conventional extensive cropping system to new intensive production systems. Management systems have a relevant impact on insect diversity and abundance, as they affect ecological stability and biodiversity. In this context, a comparative study was carried out in two managed citrus orchards in Chlef Valley aimed to assess the insect diversity and abundance in these two areas. Overall, 717 insects belonging to 62 species were identified in the extensive unweeded orchard with a Shannon diversity index of 2.94, whereas only 394 insects belonging to 32 species were recorded in the intensive weeded orchard. Concerning the flora, 10 plant species were identified in the extensively managed orchard, permitting the establishment of diverse insect species compared to the intensively managed orchard. Non-parametric tests analysis of the recorded data showed a significant correlation between cropping systems and arthropod species abundance and richness. Likewise, similarity indices showed clear differences between the studied agroecosystems. However, general linear model tests showed no correlation between weeding methods related to some diversity estimators. Nevertheless, the main diversity parameters indicated that the extensive approach maintained better insect diversity and allowed different insect functional groups to live and interact, enhanced by naturally occurring plants present within and surrounding the studied orchards. Diversity potential in the extensive management of citrus crop highlighted during this survey gave a concrete insight that conversion from an extensive to an organic production system will be smooth, safe, and promising.

Keywords: Citrus, cropping system, conversion, insect diversity, Algeria.

Introduction

Citrus represents one of the most important fruit crops in the world. Their fruits contribute to nutritional balance for overall populations due to their nutritional and organoleptic qualities. Citrus is nowadays produced in various climatic zones with different social and cultural habits (Lacirignola & D'Onghia, 2009). The Mediterranean area controls no less than 60% of the world trade in fresh oranges and lemons. Algeria is one of the main citrus producing countries in the Mediterranean basin (Schimmenti *et al.*, 2013).

Over two decades, the citrus industry in Algeria has benefited from significant state subsidies for renewing the old plantations and the creation of new citrus areas. As a result, citrus growers and investors have switched from the conventional extensive cropping system to a new so-called intensive production system, the latter inspired by the Spanish citrus industry. Because of the promising results of the new cropping system in terms of outcome, almost all new citrus orchards in Algeria are being created by adopting this approach, which has an impact on biodiversity in agroecosystems, and can modify some ecological processes (Altieri, 1999; Vandermeer ,1995).

This situation raised the question of the impact of this new agroecosystem on insect diversity and abundance, which are vital to maintaining a stable insect equilibrium, thus avoiding pest outbreaks and ensuring sustainable crop protection in arable fields.

In order to evaluate the impact of this new agroecosystem on entomofauna in citrus groves, the present study was carried out to determine the entomofauna composition, diversity and abundance in extensive and intensive citrus agroecosystems, with the following objectives: first, to survey and identify the entomofauna associated with two differently managed citrus orchards (intensive and extensive cropping systems), and second, estimation of the insect diversity and abundance in both agricultural systems, considering different functional feeding groups.

Materials and Methods

In order to evaluate the impact of two different cropping systems (extensive unweeded and intensive weeded) on the entomofauna in the citrus agroecosystem, insect composition, diversity and abundance were assessed in a citrus orchard following an extensive farming system, in comparison with another orchard pursuing intensive farming system, both are located in a citrus area northwest of the country (Figure 1). This area is predominantly by a

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Mediterranean climate characterized by cold winter, hot summer and around 400 mm of annual rainfall.

The first selected orchard (site A) is located amid a very large area in which fruit trees are the main cultivated crops. This orchard follows the new so-called intensive production system (Figure 1-A), with high density of trees (600 to over 1,000 trees/ha), raised bed planting, drip irrigation coupled with high production inputs (fertilizers, herbicides and pesticides) provided in high frequency in order to reach maximum yield. Moreover, weeding was done permanently by using chemical herbicides. However, the second selected orchard (site B) is located amid a large area of very old citrus orchards and some vegetable crops. This orchard adopted an extensive conventional cropping system (200 to 250 trees/ha), with a low frequency of input application and without weeding (Figure 1-B). During the period from December to June (2020-2021), the farmer did not apply any kind of pesticides (Table 1).

Insect diversity assessment

Every 15 days, a regular passive trapping was carried out in both studied environments (orchards A and B) for data collection; using the Barber pitfall traps and color traps (Aidoo *et al.*, 2016). For each sampling, five Barber pitfall traps were used to capture the above-ground fauna (Pearce *et al.*, 2005), five blue and five yellow traps were placed in a regular rectangle (sampling plot) in a perimeter of 100 meters in the two sites (A and B). Hence, one blue trap, one yellow trap, and one pitfall trap were set in the middle of the four sides of the rectangular sampling plot and along one of its diagonals. Captured insects were collected every 15 days and stored in tubes containing 70% alcohol, before being processed in the laboratory. After each collection date, sampling plots of each site (A and B) were changed in order to survey the whole orchard and avoid over-exhaustion of the surrounding entomofauna (Mohammedi *et al.*, 2019). In both citrus groves (A and B), a total of seven collection plots were sampled during the survey carried out on seven dates from March 1 to June 15. Captured insect species were identified and then counted. Their identification reached the taxonomic level of order, family, genus, and to the species level when possible, with a special emphasis on species of agricultural interest such as pests, disease vectors, natural enemies, and pollinators using identification guides (Blackman & Eastop, 2000; Capinera, 2008; Chouibani *et al.*, 2001; Roth, 1974; Turpeau et *al.*, 2018). Identified specimens were photographed before their deposit in collection boxes at the zoology lab (Department of Agronomy. Chlef University, Algeria).

Diversity and abundance assessment at each site

The data analyses were carried out by using the following ecological indices:

Centesimal frequency (Fc): $Fc = Ni \times 100/N$

where Ni is the ratio of the number of individuals of a species found in a given environment and N is the total number of individuals of all combined species (Dajoz, 1985).

Shannon-Waever diversity index (H):

$$H = -\Sigma i\ Pi\ (\log Pi)$$

where P_i is the proportion of a total number of samples represented a species i. It provides both information on species richness and abundance (Barrantes & Sandoval, 2009); evenness (equitability) index (E): represents the ratio of the calculated Shannon index to the theoretical maximum index in the population

$$E = H/H_{max},$$

where H_{max} (maximum diversity possible) = ln (S) (S is a number of species or species richness)] (Blondel, 1979).

Similarity analysis of arthropod communities

Comparisons of arthropods diversity were performed by computing classic indices of similarity, including qualitative (Jaccard $I_J= N_c/(N_A+N_B-N_c)$, where N_c is the number of a common taxon in both orchards, N_A and N_B is the total number of a taxon present in orchard A and orchard B, respectively, and quantitative indices (Bray–Curtis $BC_{AB}= 2C_{AB}/S_A + S_B$), where A and B are the two studied orchards, C_{AB} is the sum of only the lesser counts of each species found in both orchards, S_A and S_B is the total number of specimens counted in orchards A and B, respectively. In addition, the similarity was determined using Chao's abundance-based indices; in our case, the adjusted Sorensen abundance-type index $I_S=2UV/\ (U+V)$ (Chao *et al.*, 2006; Krebs, 2009) was preferred, where U and V are the total relative abundance of the shared species in orchards A and B, respectively. Similarity indices were calculated using Estimates® (Colwell, 2013).

Figure 1. Experimental sites (A and B), geographical location of the study area (C).

Table 1. Characteristics of the selected citrus orchards.

Characters	Benadji Farm	Kaizane Farm
Geographical coordinates	Lat: N 36.14.31/Long: E 1.26.00	Lat: N 35.55.45/Long: E 00.08.00
Code of orchard	Site (A)	Site (B)
Variety	Orange (Washington Navel)	Orange (Washington Navel)
Rootstock	*Citrus Volkameriana*	*Citrus aurantium*
Cropping system	Intensive on raised bed	Extensive
Weeding method	Chemical/Mechanical (permanently)	unweeded
Type of irrigation	Drip irrigation	Drip irrigation
Soil's texture	Sandy clay loam	Sandy clay loam
Age (years)	10	>60 years
Surface (ha)	1 hectare	1 hectare
Planting distance (m)	3×4	5×6

Statistical analysis

Abundance count's data was assessed for normality by Shapiro-Wilk test, and then effects between the studied cropping systems on arthropod's abundance was done using the non-parametric Kruskal-Wallis ANOVA test. Variation between biodiversity parameters recorded in orchards A and B were tested using generalized linear models GLM with different distribution errors and link functions (family= Gaussian and link= identity for H', H_{max} and N/S ratio; family = quasi-binomial and link= logit for equitability E'; and finally, family= poisson and link=log for N and S. Within variables, effect between diversity parameters was assessed through the Standard Pearson correlation coefficient. The effect of cropping system on the mean arthropod's abundances recorded along the sampling dates was calculated using two-factor ANOVA with repeated measures. When ANOVA showed significant correlation, Tukey's (HSD) test was performed (P<0.05) to group treatment means. Statistical analysis was carried out with the software Statistica®.

Results

Floristic diversity in A and B sites

Wild flora recorded in the study area included different species. Ten species were identified in the extensive un-weeded citrus orchard B, whereas those identified in the intensive weeded citrus orchard A were only five with 2 monocotyledonous species in common (*Bromus sterilis* L. and *Hordeum murinum* subsp. *Leporinum* L. 1753). In the un-weeded extensive citrus orchard B, eight flowering species that may provide various services to entomofauna were identified, *Fumaria capreolata*, *Calendula arvensis*, *Sinapis alba, Sinapis arvensis*, *Convolvulus arvensis*, *Oxalis cernua, Urtica dioica, Sonchus oleraceus*.

Insect richness in A and B sites

The adopted trapping system has collected during the monitoring period a meaningful number of insects' species. Those species belonged to nine orders in the intensive citrus weeded orchard A and ten orders in the extensive un-weeded citrus orchard B. Relatively, 32 species were identified in site A, whereas 61 species were identified in site B (Table 2).

The highest number of insects (717) were captured in site B, whereas only 397 individuals were recorded in site A (Table 2). In both sites, insect species belonging to the Diptera order were dominant (45), 59% in site A and 44.49% in site B, followed by 34 hymenopteran species in site A (76%) and 25 in site B (24%). Species of the order Coleoptera were ranked third with 10.6% in site B, and less common in site A where it reached only 4.28%. Members of the order Lepidoptera represented 8.56%, in site A, and 1.39% in site B. In addition to the previous orders, the Thysanura order was represented mainly by the Thripidae family, was common in site B (8.51%) and less so in site A (2.77%). Neuroptera was represented in both sites by two species belonging to the family of Chrysopidae, reaching 3.35% in site B scarce in site A (0.50%). Dermaptera and Hemiptera were also present in both sites but with very low numbers, whereas insects belonging to the Psocoptera order were found only in site B.

Diversity of entomofauna in citrus orchard A and orchard B

The total Shannon diversity index calculated in site A was H=2.46 and the equitability (evenness) index was E=0.71. Unlike site A, the total Shannon diversity index calculated in site B was higher (H=2.93); however, equitability index was of the same value (E=0.71). Consequently, in the weeded intensive citrus orchard A, the midlevel of the Shannon diversity index indicated that the specific diversity was at a medium level, translated by the richness in insect species (32) and their relatively high number of individuals (397). In contrast, The Shannon diversity index calculated in the unweeded extensive citrus orchard B was larger due to the high arhropod's frequency and abundance. The non-parametric Kruskal-Wallis ANOVA and general linear models GLM tests revealed highly significant effect of farming system on the abundance N, richness S and N/S ratio (p < 0.05). However, it did not show correlation between cropping systems and diversity indices (H, $Hmax$, E) in addition to abundance and richness of beneficial arthropods N_b and S_b, respectively, of both sites (p > 0.05) (Table 3). Whole estimates of richness and diversity (Table 4) were higher in site B than in site A.

Table 2. Number and proportions of different orders in agroecosystems A and B.

Orders	No. of species	No. of individuals	centesimal frequency (%)	Orders	No. of species	No. of individuals	centesimal frequency (%)
Site A				**Site B**			
Diptera	7	181	45.59	Diptera	10	319	44.49
Thysanura	1	11	2.77	Thysanura	1	61	8.51
Nevroptera	1	2	0.50	Nevroptera	2	24	3.35
Psocoptera	0	0	0.00	Psocoptera	1	17	2.37
Lepidoptera	2	34	8.56	Lepidoptera	3	10	1.39
Dermaptera	1	1	0.25	Dermaptera	1	7	0.98
Coleoptera	5	17	4.28	Coleoptera	15	76	10.6
Heteroptera	1	1	0.25	Heteroptera	2	4	0.56
Homoptera	2	12	3.02	Homoptera	4	18	2.51
Hymenoptera	13	138	34.76	Hymenoptera	22	181	25.24
Total	**32**	**397**	**100.00**	**Total**	**61**	**717**	**100.00**

Table 3. Indices of diversity of arthropod populations sampled recorded in intensive weeded citrus orchards (A) and extensive unweeded citrus orchard (B).

		Cropping system of citrus orchard			
Indices	**Sample Type**	**Intensive weeded (A)**	**Extensive unweeded (B)**	**Generalized linear models tests**	
Abundances (*N*)	Pooled	397	717		
	Based	62.57±26.63	102.42±27.68	X^2= 5.70	P= 0.017
Abundances beneficials (N_b)	Pooled	169	350		
	Based	24.14±19.36	50.00±26.46	X^2= 2.98	P= 0.084
Species richness *(S)*	Pooled	32	61		
	Based	11.57±4.27	18.00±3.90	X^2= 5.67	P= 0.017
Species richness beneficials (S_b)	Pooled	20	36		
	Based	6.57±3.20	9.85±5.75	X^2= 1.343	P= 0.246
Shannon diversity index *(H)*	Pooled	2.46	2.93		
	Based	1.84±0.50	2.07±0.33	F= 1.188	P= 0.275
H_{MAX}	Pooled	3.47	4.12		
	Based	2.37±0.42	2.90±0.22	F= 7.343	P= 0.006
Evenness *(E)*	Pooled	0.71	0.71		
	Based	0.77±0.13	0.71±0.07	F= 1.156	P= 0.282
Ratio (*N/S*)	Pooled	12.40	11.75		
	Based	6.00±2.08	6.22±1.95	X^2= 0.285	P= 0.593

Poisson type I likelihood ratio test X^2 and Normal generalized linear models (type II F-test) were used for biodiversity parameters in relation with the two weed management systems

Insect species richness rarefaction and extrapolation

The average of total species accumulation was translated by rarefaction curves to estimate the cumulative specific richness within arthropod's community in both samples and giving insight about the sampling coverage carried out for further processing, rarefaction and extrapolation (R/E) sampling curves were generated by iNEXT online software (Hsieh & Chao, 2016). Analyses were based on species richness sampled of both olive orchards.

Through non-asymptotic analysis, we display in Figure 2, the sample-size- and coverage-based rarefaction and extrapolation curves for measures: q = 0 and 1 (a, b and c, d), respectively, for the coverage-based sampling curve plotted in Figure 2 represented the sample completeness curve as a function of sample size. For species abundance, the sample completeness of site A (intensive weeded orchard) was 98.93%, which is lower than 99.45 % for site B (extensive unweeded orchard) (Figure 2-B).

When both sample sizes were extrapolated, they tended to reach the plateau as predicted by extrapolation illustrated by the dashed lines, indicating optimal sampling coverage. Estimator of the sample coverage of species richness is up to 82.6% for orchard A sample and 86.3% for the orchard B sample (Figure 2-D).

In rarefaction and extrapolation (R/E) sampling curves of species diversity, both plots exhibited a consistent pattern, with the diversity parameters for the extensive un-weeded citrus orchard B was above the curve of the intensive weeded citrus orchard A. In all plots, the 95% confidence intervals for the two samples in both rarefaction/extrapolation curve were disjoint, implying a significant difference (Figure 2-A and 2-C).

Similarity indices

Similar tests using Estimates$^{\circledR}$ (Colwell, 2013) showed the impact of farming systems on arthropod communities in the two citrus orchards investigated. Intensive weeded citrus orchard shared 26 out of 32 species with the extensive un-weeded citrus orchard that harbored 61 species. Estimates$^{\circledR}$ displayed clear dissimilarity in terms of abundance and richness between the selected orchards (Table 4). Low values (0.39 and 0.47) of incidence-based similarity indices (Jaccard classic), were similar to values of abundance-based similarity index (Bray-Curtis), respectively, which illustrated that different conditions in the two habitats sheltered different arthropod species (Table 5).

Table 4. Total estimates of species richness and diversity indices of insect communities subservient to olive groves grown under semiarid and arid climates in northeastern Algeria.

	Cropping system of citrus orchards	
Diversity statistics	**Intensive weeded (A)**	**Extensive unweeded (B)**
Samples	56	56
Number of individuals (N)	397	717
Analytical S_{est} (± SD)	67.00±3.60	46.5±3.20
S_{est} (95% CI Lbounds)	59.92	40.22
S_{est} (95% AI Ubounds)	74.07	52.77
Singletons (mean)	10.00	10.00
Doubletons (mean)	8.00±0.00	7.00±4.24
Uniques (mean)	41.00±0.23	46.50±20.50
ACE (mean) [completeness]	72.25±0.00	54.97±15.99
ICE (mean) [completeness]	152.15±0.00	46.50±20.50
Chao 1 (mean ± SD)	71.99±4.31	53.03±5.59
Chao 1 [completeness]	68.15	48.02
Chao 1 (95% CI bounds)	88.55	74.46
Chao 2 (mean ± SD)	82.18±0.00	46.50±6.81
Chao 2 [completeness]	73.55	73.56
Chao 2 (95% CI bounds)	102.16	73.56
Jack 1 (mean ± SD)	87.50±14.50	46.50±0.00
Bootstrap (mean) [completeness]	77.25	46.50
Shannon (mean)	2.92±0.00	2.65±0.43
Shannon exponential (mean)	18.59	14.64
Simpson (mean)	7.62	7.02
Cole Rarefaction	67.00±1.21	58.54±2.30

Species richness estimators and diversity statistics are given, when applicable, as mean, standard deviation (SD), lower and upper bounds of 95% confidence intervals (CI) based on 100 randomization runs. Values expressed in brackets are inventory completeness of observed richness as a percentage of total expected richness according to the corresponding estimator. ACE, abundance coverage-based estimator; ICE, incidence coverage-based estimator. Colwell (2013) for a full explanation of diversity indices and statistics.

Functional biodiversity

Categorization of insect species was carried out as a set of homogeneous phenotypic traits that are related to the expression of a given agroecosystem service, as reported by Constanzo & Barberi (2014). In the intensive weeded citrus orchard A, the results obtained indicated that the predators were represented by eleven species, parasitoids by 8 species, pollinators by 7 species, phytophagous insects by 6 species, and finally hyperparasitoids and vectors were represented by 2 species each (Table 6). In citrus orchard B, where wild plants occurred permanently, the occurrence of 61 insect species belonging to various agroecosystem functional groups was documented. Predators, highly important in pest regulation, were ranked first with a specific richness of 24 species and an abundance value of 139 individuals belonging to five orders, followed by 12 species of parasitoids, 13 herbivore species, 7 species of hyperparasitoids, 8 pollinators, and 2 vector species, in addition to 236 neutral species (Table 7). Variations of beneficial species abundance and richness in selected orchards were not correlated to cropping system as shown by generalized linear models GLM ($p > 0.05$) (Table 3).

Table 5. Similarity values between arthropod populations in weeded and unweeded citrus orchards (A and B).

Indices of similarity	**Similarity**
Incidence based similarity indices	
Jaccard Classic	0.39
SØrensen Classic	0.56
Abundance based similarity indices	
Sobs First Sample	61.00
Sobs Second Sample	32.00
Shared Species	26.00
ACE First Sample	43.66
ACE Second Sample	66.28
Chao Shared Estimated	35.21
Chao Jaccard-Raw Abundance Based	0.66
Chao Jaccard-Est Abundance Based	0.70
Chao-Sorensen-Raw Abundance-based	0.80
Chao-Sorensen-Est Abundance-based	0.83
Morisita-Horn	0.87
Bray-Curtis	0.47

Discussion

The extensive un-weeded citrus orchard B was the most diversified ecosystem. In this regard, it is known that biodiversity is higher in natural or poorly disturbed environments, because the anthropic pressure in agriculture, which is exerted more in intensive agriculture, causes the weakness of faunistic richness. Insecticide applications in agricultural fields can harm both target and non-target species (Hill *et al.*, 2017). Intensive weeded citrus orchard A was a typical example of the intensification of chemical applications in large fields of monoculture crop (citrus) that are strongly linked to external inputs, including synthetic fertilizers and pesticides. Agricultural practices have a relevant impact on the diversity of species and landscapes. This diversity may also vary under certain climatic characteristics, although, in this study, climatic conditions in both experimental sites were similar. The results obtained in the site A confirm results reported earlier (Nemecek *et al.*, 2011), which showed that intensive farming cause little heterogeneity and are unappealing to most wildlife species, excluding crop pests.

The diversity indices of site A were lower than the corresponding values of site B during most sampling dates. Two-factor ANOVA with repeated measures showed that total abundance N, diversity index H and $H_{\max}$ varied significantly between the two-selected citrus orchards (Figure 4). Wild flora within the orchard may have significantly enhanced insect population (Figure 3), as weeds in fact represent food sources and shelters for many insect species (Rahman, 2016). Lower diversity indices recorded in the weeded intensive orchard A can be explained by the effect of insecticide applications and weak density of naturally occurring plants due to the applied systematic weeding. Measurement of the relation between diversity parameters had different correlation in each of the selected orchard; within the intensive citrus orchard A, parameters were positively correlated to each other. Diversity parameters were positively correlated in the extensive citrus orchard B, unless for N/S ratio which was negatively correlated to most diversity parameters (Figure 3). Dissimilarity and diversity contrast between the studied habitats have been well illustrated by the Scatter plot through Pearson correlation patterns between parameters of each site (Figure 3). Categorization of insect species was carried out through species identification, based on their production services in various functional groups; the latter being defined as a set of homogeneous phenotypic traits that are related to the expression of a given agroecosystem service as reported by Costanzo & Barberi (2014). Such classification helps to understand the status of functional biodiversity in both studied agro-ecosystems.

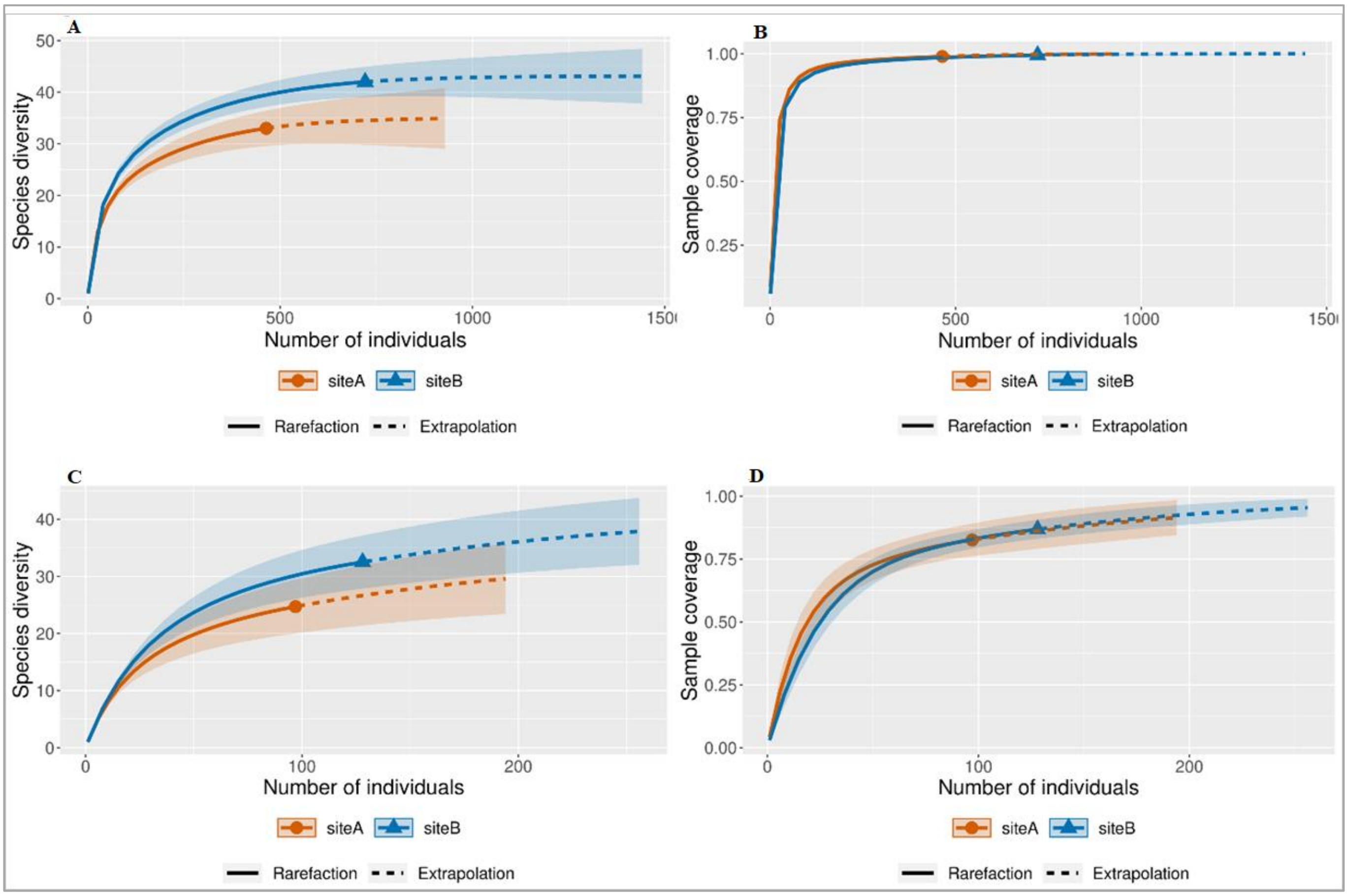


Figure 2. Non-asymptotic analysis: the rarefaction (solid line) and extrapolation (dashed line) sampling curves based on the collected data. Comparison of sample-size-based (A and C) and sample-coverage-based (B and D) rarefaction and extrapolation for species abundance (A, B) and species richness (C, D) for insect populations of the studied citrus orchards (A and B) generated by iNEXT© online software.

Table 6. Processes related to production services affected by various functional groups recorded in orchard A.

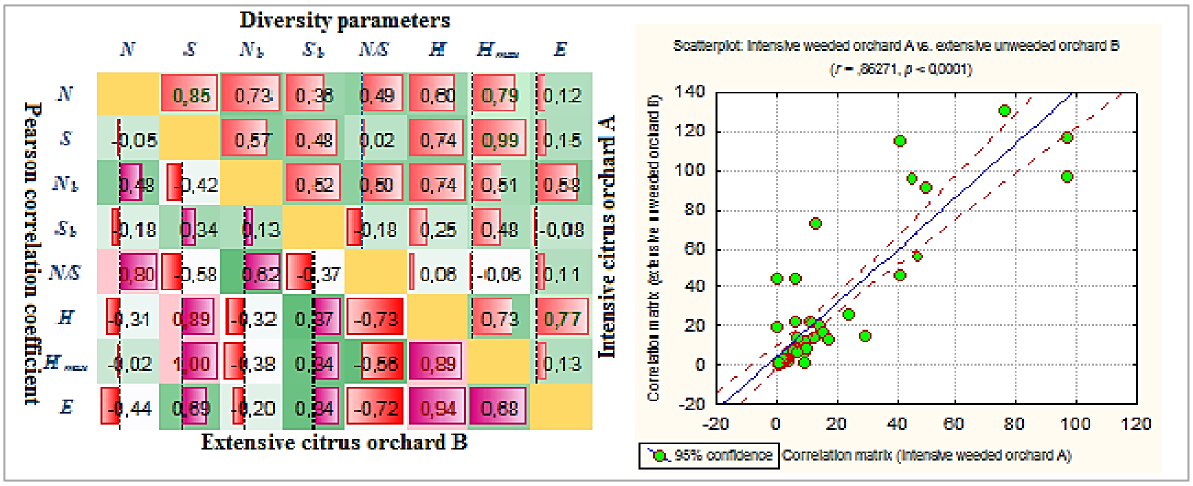
Suborder	Family	Genus/species	Number	Pest	Parasitoid	Hyper-parasitoid	Predator	Pollinator	Vector	Neutral	References
Hereidae	Hereidae	Hereidae	22							x	Roth, 1974
Muscidae	Muscidae	Muscidae	132							x	Roth, 1974
Diptera											
Brachycera	Trypetidae	*Ceratitis capitata*	15	x							Chouibani *et al.*, 2001
Brachycera	Syrphidae	*Syrphus ribesii*	7				x	x			Correa, 2019
Brachycera	Syrphidae	*Episyrphus Balteatus*	2				x	x			Turpeau *et al.*, 2018
Brachycera	Syrphidae	*Scaeva* sp.	2				x	x			Turpeau *et al.*, 2018
Brachycera	Syrphidae	*Eupoedes* sp.	1				x	x			Turpeau *et al.*, 2018
Hymenoptera											
Parasitica	Eulophidae	*Citrostichus* sp.	2		x						Chouibani *et al.*, 2001
Parasitica	Eulophidae	*Pnigalio* sp.	1		x						Chouibani *et al.*, 2001
Parasitica	Braconidae	*Aphidius ervi*	10		x						Turpeau *et al.*, 2018
Parasitica	Braconidae	*Aphidius matricariae*	13		x						Turpeau *et al.*, 2018
Parasitica	Braconidae	*Lysiphlebus fabarum*	39		x						Turpeau *et al.*, 2018
Parasitica	Ichneumonidae	Ichneumonidae	7		x						Turpeau *et al.*, 2018
Parasitica	Chalcidoidea	Aphelinidae	5		x						Turpeau *et al.*, 2018
Parasitica	Trichogrammatidae	*Aphytis* sp.	1		x						Chouibani *et al.*, 2001
Parasitica	Encyrtidae	Syrphophagus sp.	3			x					Turpeau *et al.*, 2018
Parasitica	Megaspilidae	*Dendroderus* sp.	6			x					Labdaoui, 2019
Aculeata	Apidae	*Apis millefica*	50					x			Roth, 1974
Aculeata	Vespidae	*Vespa* sp.	1					**x**			Roth, 1974
Nevroptera											
Hemerobioida	Chrysopidae	*Chrysoperla* sp.	1				x				Roth, 1974
Coleoptera											
Haplogastra	Staphylinidae	Staphylinidae	3				x				Roth, 1974
Haplogastra	Staphylinidae	*Tachyporus* sp.	11				x				Turpeau *et al.*, 2018
Cryptogastra	Curcurlionidae	Curcurlionidae	1	x							Roth, 1974
Haplogastra	Scarabaeidae	Scarabaeidae	1				x				Roth, 1974
Haplogastra	Silphidae	Silphidae	1				x				Roth, 1974
Thysanoptera											
Terebrantia	Thripidae	Thripidae	11	x							Chinery, 2007
Lepidoptera											
Tineoidea	Yponomeutidae	*Prays citri*	33	x							Chinery, 2007
Heteroneura	Pieridae	*Pieris brassicae*	1					x			Roth,1974
Homoptera											
sternorryncha	Aphididae	*Aphis spiraecola*	3	x					x		Stoetzel, 1995
sternorryncha	Aphididae	*Aphis gossypii*	9	x					x		Blackman & Eastop, 2000
Dermaptera											
Forficuloida	Forficulidae	*Forficula* sp.	1				x				Roth, 1974
Heteroptera											
Geocorisa	Anthocoridae	Anthocoridae	1				x				Turpeau *et al.*, 2018
	24	**32**	**396**	**72**	**78**	**9**	**27**	**64**	**12**	**154**	

Table 7. Processes related to production services affected by various functional groups recorded in orchard B.

Suborder	Family	Genus/species	Number	Pest	Parasitoid	Hyper-parasitoid	Predator	Pollinator	Vector	Neutral	References
Diptera											
Hereidae	Hereidae	Hereidae	11							x	Roth, 1974
Muscidae	Muscidae	Muscidae	208							x	Roth, 1974
Nematocera	Cecidomyiidae	*Aphidoletes aphidimyza*	4				x				Turpeau *et al.*, 2018
Brachycera	Trypetidae	*Ceratitis capitata*	51	x							Chouibani *et al.*, 2001
Brachycera	Syrphidae	*Syrphus ribesii*	21				x	x			Correa, 2019
Brachycera	Syrphidae	*Episyrphus Balteatus*	15				x	x			Turpeau *et al.*, 2018
Brachycera	Syrphidae	Syrphidae	3				x				Turpeau *et al.*, 2018
Brachycera	Syrphidae	*Scaeva* sp.	3				x	x			Turpeau *et al.*, 2018
Brachycera	Syrphidae	*Eupoedes* sp.	2				x	x			Turpeau *et al.*, 2018
Brachycera	Syrphidae	*Merodon* sp.	1				x				Correa, 2019

Suborder	Family	Genus/species	Number	Pest	Parasitoid	Hyper-parasitoid	Predator	Pollinator	Vector	Neutral	References
Hymenoptera											
Parasitica	Eulophidae	*Citrostichus* sp.	2		x						Chouibani *et al.*, 2001
Parasitica	Eulophidae	*Pnigalio* sp.	1		x						Chouibani *et al.*, 2001
Parasitica	Braconidae	*Lysiphlebus fabarum*	3		x						Labdaoui, 2019
Parasitica	Braconidae	*Aphidius colemani*	3		x						Labdaoui, 2019
Parasitica	Braconidae	*Diaeretiella rapae*	4		x						Labdaoui, 2019
Parasitica	Braconidae	*Lysiphlebus testaceipes*	6		x						Turpeau *et al.*, 2018
Parasitica	Braconidae	*Aphidius matricariae*	2		x						Turpeau *et al.*, 2018
Parasitica	Braconidae	*Binodoxys angelicae*	2		x						Turpeau *et al.*, 2018
Parasitica	Braconidae	*Praon* sp.	2		x						Turpeau *et al.*, 2018
Parasitica	Braconidae	*Ephedrus* sp.	2		x						Turpeau *et al.*, 2018
Parasitica	Ichneumonidae	*Ichneumonidae*	5		x	x					Labdaoui, 2019
Parasitica	Megaspilidae	*Dendroderus* sp.	7			x					Labdaoui, 2019
Parasitica	Figitidae	*Phaenoglyphis* sp.	3			x					Turpeau *et al.*, 2018
Parasitica	Figitidae	*Alloxysta* sp.	2			x					Turpeau *et al.*, 2018
Parasitica	Pteromalidae	*Pachyneuron* sp.	3			x					Turpeau *et al.*, 2018
Parasitica	Pteromalidae	*Asaphes* sp.	4			x					Turpeau *et al.*, 2018
Parasitica	Trichogrammatidae	*Aphytis* sp.	5		x						Chouibani *et al.*, 2001
Parasitica	Encyrtidae	*Syrphophagus* sp.	1			x					Turpeau *et al.*, 2018
Aculeata	Apidae	*Apis mellifica*	103					x			Chinery, 2007
Aculeata	Scoliidae	Scoliidae	3					x			Roth, 1974
Aculeata	Eumenidae	*Eumonidae*	9				x	x			Roth, 1974
Aculeata	Vespidae	*Vespa* sp.	9								Roth, 1974
Coleoptera											
Haplogastra	Staphylinidae	*Staphylinidae*	5				x				Bohac, 1999
Haplogastra	Staphylinidae	*Tachyporus* sp.	9				x				Bohac, 1999
Haplogastra	scarabaeidae	*Tropinota hirta*	7				x				Roth, 1974
Haplogastra	Silphidae	Silphidae	12				x				Roth, 1974
Cryptogastra	Elarteridae	*Geotrogus* sp.	6	x							Roth, 1974
Cryptogastra	Coccinellidae	*Adalia decempuctata*	4				x				Turpeau *et al.*, 2018
Cryptogastra	Coccinellidae	*hippodamia variegata*	1				x				Turpeau *et al.*, 2018
Cryptogastra	Coccinellidae	*Coccinella semptempuctata*	2				x				Turpeau *et al.*, 2018
Cryptogastra	Coccinellidae	*Brumus quadripustulatus*	7				x				Biche, 2012
Cryptogastra	Coccinellidae	*Scymnus* sp.	5				x				Labdaoui, 2019
Cryptogastra	Coccinellidae	*Oenopia* sp.	1				x				Labdaoui, 2019
Cryptogastra	Cerambycidae	Cerambycidae	1	x							Roth, 1974
Cryptogastra	Melyridae	*Melyridae*	1	x							Roth, 1974
Cryptogastra	Buprestidae	Buprestidae	10	x							Roth, 1974
Symphigastra	Carabidae	Carabidae	5				x				Kromp, 1999
Homoptera											
Sternorryncha	Aphididae	*Aphis spiraecola*	12	x					x		Stoetzel, 1994
Sternorryncha	Aphididae	*Aphis gossypii*	3	x					x		Stoetzel, 1994
Auchenorryncha	Cicadellidae	*Empoasca vitis*	1	x							Capinera, 2008
Auchenorryncha	Cicadellidae	*Jacobiasca lybica*	2	x							Capinera, 2008
Lepidoptera											
Heteroneura	Hyponomeutidae	*Prays citri*	3	x							Chouibani *et al.*, 2001
Heteroneura	Pieridae	*Pieris brassicae*	1					x			Roth,1974
Heteroneura	Gracillaridae	*Phyllocnictis citrella*	6	x							Chouibani *et al.*, 2001
Dermaptera											
Forficuloida	Forficulidae	*Forficula* sp.	7				x				Roth, 1974
Nevroptera											
Hemerobioida	Chrysopidae	*Chrysopa perla*	5				x				Turpeau *et al.*, 2018

Suborder	Family	Genus/species	Number	Pest	Parasitoid	Hyper-parasitoid	Predator	Pollinator	Vector	Neutral	References
Hemerobioida	Chrysopidae	*Chrysoperla carnea*	19				x				Turpeau *et al.*, 2018
Heteroptera											
Geocorisa	Anthocoridae	*Deraeocoris sp*	3				x				Turpeau *et al.*, 2018
Geocorisa	Miridae	Miridae	1	x			x				Chinery, 2007
Psocoptera											
Psocoptera	Psocoptera	Psocoptera	17							x	Roth,1974
Thysanoptera											
Terebrantia	Thripidae	*Thripidae*	61	x							Chinery, 2007
	38	**61**	**717**	**145**	**45**	**31**	**139**	**166**	**18**	**236**	



Diversity parameters

	N	*S*	N_b	S_b	*N/S*	*H*	H_{max}	*E*
N		0,85	0,73	0,38	0,49	0,60	0,79	0,12
S	-0,05		0,57	0,48	0,02	0,74	0,99	0,15
N_b	0,48	-0,42		0,52	0,50	0,74	0,51	0,58
S_b	-0,18	0,34	0,13		-0,18	0,25	0,48	-0,08
N/S	0,80	-0,58	0,62	-0,37		0,08	-0,08	0,11
H	-0,31	0,89	-0,32	0,37	-0,73		0,73	0,77
H_{max}	-0,02	1,00	-0,38	0,34	-0,56	0,89		0,13
E	-0,44	0,89	-0,20	0,34	-0,72	0,94	0,88	

Figure 3. Correlation matrices of diversity parameters within the intensive weeded citrus orchard A (above the diagonal in pink gradient color) and extensive unweeded citrus orchard B (beneath the diagonal in purple gradient color). Minus r values in red gradient color. Marked correlations are significant at p < 0,05. Scatterplot of variables (diversity parameters) of the intensive orchard (A) vs. the extensive orchard (B).

In the intensive weeded orchard A, predators were represented by eleven species, parasitoids by 8 species, pollinators by 7 species, phytophagous by 6 species, and finally hyperparasitoids and vectors were represented by 2 species each (Table 5). Wasps represented the most numerous groups with 78 individuals, followed by phytophagous species with 72 individuals, pollinators with 64 individuals, and predators with 27 individuals. The remaining two groups, vectors and hyperparasitoids, were represented by 12 and 9 individuals, respectively. Predators recorded in moderate level in this site belonged to Syrphidae *Syrphus ribesii* (L. 1758), and *Episyrphus balteatus* (De geer, 1776) and Staphylinidae *Tachyporus* sp. (Gravenhost, 1802). Two other coleopterans belonging to Scarabeidae and Silphidae were among the identified predators, in addition to one species of Dermaptera, *Forficula auricularia* (L. 1758) (Dermaptera: Forficulidae). The total absence of ladybirds could be explained by the high frequency of chemical treatments used in site A, which affect directly these species mainly because they fly for a short distance. Moreover, the low presence of aphids and the total absence of scales in site A, which are the major food for ladybirds, could further explain the absence of coccinellids. Many scientists today believe that conventional contemporary agriculture is in the midst of an environmental disaster (Altieri & Nicholls, 2018). Six phytophagous pest species were collected in citrus orchards in site A among them two key pests like *Ceratitis capitata* (Wiedemann, 1824) (Diptera: Tephritidae) and *Prays citri* (Milliere, 1873) (Lepidoptera: Yponomeutidae), which was conducted following an intensive management system and included 23 insecticides treatments.

Statistical analysis through kruskal-Wallis Anova test did not show significant effect of farming system on beneficial activity, the survey in site B revealed that predators, highly important in pest regulation, were ranked first with a specific richness of 24 species and an abundance value of 139 individuals belonging to five orders, followed by 12 species of parasitoids, 8 pollinators. Harmful feeding groups were represented by 13 pests, 7 species of hyperparasitoids, and 2 vector species, in addition to 236 neutral species. Contrary to the site A, where predators were much lower in both richness and abundance (11 species and 27 individuals), predator occurrence in site B was very high and ladybirds and hoverflies were the most represented with 6 species each. Predator abundance is related to the absence of chemicals and the abundance of preys; additionally, the presence of the above-ground vegetation enhanced their richness (Ali-Arous *et al.*, 2023).

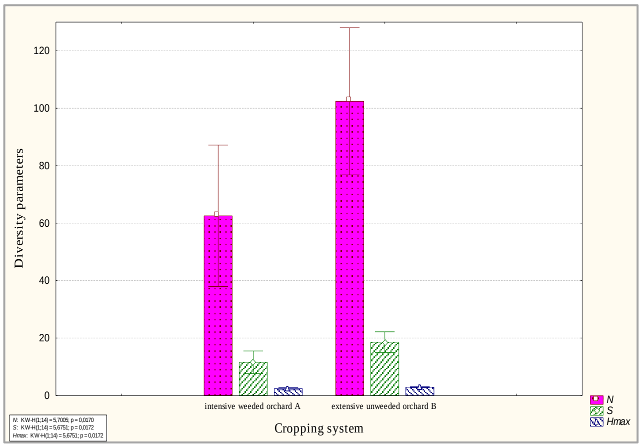


Figure 4. Results of Two-factor Anova with repeated measures applied to the mean arthropod's abundances counted repeatedly in selected orchards (weeded olive orchard A and unweeded olive orchard B).

Most predators at larval stages are directly exposed to chemical sprays, and they are usually found amid their host colonies. Previous studies (Alvis, 2003) proved that the genus Scymnus was the most abundant in European citrus orchards, similar to what was found in Algeria (Saharaoui & Hemptinne, 2009). In Turkey, *Coccinella septempunctata* (L. 1758) was the most abundant ladybird that directly attacks citrus aphid colonies (Yoldaş *et al.*, 2011). During the current study, ladybirds encountered in site B belonged to seven species, the most abundant was *Brumus quadripustulatus* (L. 1758), followed respectively by *Scymnus sp*., *Adalia decempunctata* (L. 1758), *C. septempunctata, Hippodamia variegata* (Goeze, 1777) and *Oenopia conglobata* (L, 1758). (Coleoptera: Coccinillidae). According to Biche (2012), the genus Brumus is very common in cultivated and natural environments in Algeria. The remaining species are widely distributed in all environments. Even hoverfly species were identified during the survey, *S. ribesii*, *E. balteatus*, *Scaeva pyrastri* (L. 1758)., *Merodon equestris* (Fabricius, 1794)., *Eupoedes corolla* L (Fabricius, 1794), and another unidentified species (Diptera: Syrphidae), in addition to *Aphidoletes aphidimyza* (Rondani, 1847) (Diptera: Cecidomyiidae). Syrphids are among the most frequent predators of aphids in citrus orchards, they play an important role in reducing aphid populations in Algeria and in the rest of the Mediterranean basin (Hermoso de Mendoza *et al*., 2012). Coleopteran species, identified as predators, belonged to the families Carabidae, Silphidae, Scarabaeidae, and Staphylinidae, and were of vital importance in pest control, and most coleopteran species were collected from pitfall traps. It seems that the year-round ground cover vegetation available in site B provided the resources they needed throughout their lifecycle. The survey also revealed 22 hymenopteran species belonging to twelve different families. Neuroptearan species belonging to the family of Chrysopidae were represented by *Chrysopa perla* (L. 1758) and *Chrysoperla carnea* (Stephens, 1836); the larvae are active predators and feed mainly on Aphididae, Coccidae and caterpillar species (Turpeau *et al.*, 2018).

Surprisingly, the group of primary parasitoids was particularly lower in terms of abundance (45 individuals) in site B compared to site A (78 individual). The specific diversity of wasps was higher in site B than in site A, with 12 and 8 species, respectively. In site B, the recorded species were specialized on several hosts. *Citrostichus phyllocnistoides* (Narayanan 1960) and *Pnigalio mediterraneus* (Ferriere & Delucchi, 1957) are both larval parasitoids of citrus leafminer. C. *phyllocnistoides* was introduced in 1995 from Australia, whereas *P. mediterraneus* is local (Biche, 2012).

Many primary endoparasitoids of aphids were recorded, such as *Lisyphlebus fabarum* (Marshall, 1876), *Lisyphlebus testaceipes* (Cresson 1880), *Aphidius Colemani* (Viereck, 1912) *Aphidius.matricariae* (Haliday, 1834), *Bynodoxys angelicae* (Haliday, 1833) *Praon volucre* (Haliday, 1833), and *Epherdus plagiator* (Nees von Esenbeck, 1811) (Hymenoptera: Braconidae). These species were already recorded in the study area (Labdaoui, 2019). The family of Ichneumonidae is the largest within the Hymenoptera order with about 30,000 species, they attack mainly caterpillars, pupae of Lepidoptera, and larvae of Diptera and coleoptera (Roth, 1974). The Aphytis genus belongs to Aphelinidae family, and it is mentioned in the study of Chouibani *et al*. (2001) that it is specialized in parasiting various Diaspididae species occurring in citrus orchards, including the Californian red scale *Aonidiella aurantii* (Maskell 1879).

The low abundance of primary parasitoids of aphids in site B compared to site A could be explained on one hand by the high abundance of hyperparasitoids (secondary parasitoids) which develop at their expense inside mummified aphids, causing the reduction of the population of primary parasitoids (Labdaoui, 2019), and on the other hand the high abundance of predators probably played a role in reducing aphid parasitoids. The higher insect diversity in site B could be linked to the high floristic diversity in this site, which provided refuge and food for many insect species, not only natural enemies, but also pests (Simon *et al.*, 2010). As a result, one of the best solutions would be the adoption of integrated weed management. Most studies (Altieri & Nicholls, 2018; Rahman 2016) have explored the effects of the manipulation of ground cover vegetation on insect pests and associated enemies. The available data indicated that orchards with rich floral cover exhibited a lower incidence of insect pests than clean cultivated orchards, mainly because of an increased abundance and efficiency of predators and parasitoids. In some cases, ground cover directly affected herbivore species, which discriminate among trees with and without vegetative cover underneath. The role attributed to weeds should be included in future research questions formulated by weed scientists (Fernández-Quintanilla *et al.*, 2008). For example, weed management may enhance biodiversity conservation. On the one hand, this includes the protection of rare weed species. On the other hand, this means that weed scientists should contribute more actively to the production of knowledge and know-how on the management of weeds to support agroecosystem functional biodiversity for the improvement of the sustainability of agricultural practices (Bàrberi *et al.*, 2010).

The classic debate concerning extensive against intensive cropping system remains among the agricultural issues and requires more research in different agroecosystems to provide accurate results in term of yield as well as human health and environment protection to make the best management decisions. One of the most important agricultural and ecological features is the correlation between the cropping system and insect diversity as well as the impact of each system on natural entomofauna. Citrus orchards are among the arable ecosystems on which this controversy and query are not well solved.

Our study conducted in two orchards following different cropping systems revealed that the cropping system followed in the Algerian citrus agroecosystems has a relevant impact on insect diversity and abundance. The extensive un-weeded cropping system preserves better biodiversity and shows high levels of insect richness in comparison with the intensive weeded one. In addition, the extensive cropping system permits the occurrence of different insect functional groups, which enhances insect diversity. In this context, more than 700 insects belonging to 62 species were identified in the studied extensive citrus orchard. This insect diversity is critical to keep the insect balance steady, minimizes pest outbreaks and consequently provides long-term protection for citrus orchards.

On the other hand, an intensive cropping system can affect negatively the insect diversity in citrus groves. This system alters the citrus agroecosystem equilibrium because it limits the activity of beneficial insect species as ladybugs and hoverflies. Furthermore, floral diversity and abundance in citrus orchards favor the activity of natural enemies but also pests. However, the lack of ground cover vegetation in the intensive orchard has affected the occurrence of flying and above ground entomofauna. Hence, the adoption of new approaches of selective weed management in production system is highly recommended. Considering that, the intensive production system is economically important for citrus producers in Algeria, but the extensive production system is more sustainable. On one hand, it is of utmost importance to extend research studies to other areas and orchards, in order to reduce the expensive inputs used by the farmers, preserve the biological control agents as an alternative to insecticides allowing the farmers to switch to more sustainable approaches. In the other hand, arthropod's potential explored through this study gives a concrete insight that conversion from extensive to organic production system will be fluent, safe and economically promising.

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الملخص

علي-عروس، سمير، زين الدين العبداوي، مونة بن الحاج جلول وخالد جلواح. 2024. تأثير النظم المحصولية المختلقة لبساتين الحمضيات/الموالح في تباين المجتمع الحشري في شمال غرب الجزائر. مجلة وقاية النبات العربية، 42(4): 406–418. https://doi.org/10.22268/AJPP-001263

استفادت زراعة الحمضيات الجزائرية من الدعم الحكومي الكبير لتجديد المزارع القديمة، ونتيجةً لذلك، تحول معظم المزارعين من نظام المحاصيل الموسع التقليدي إلى أنظمة إنتاج تكثيفية جديدة. ضمن هذا السياق، أجريت دراسة مقارنة في بساتين الحمضيات في وادي الشلف بهدف تقييم تنوع ووفرة الحشرات في هاتين المنطقتين. بشكل عام، تمّ التعرف على 717 حشرة تنتمي إلى 62 نوعاً في البستان التقليدي بدون تعشيب وكان مؤشر تنوع شانون 2.94، بينما تمّ تسجيل 394 حشرة تنتمي إلى 32 نوعاً فقط في البستان المعشب والخاضع لنظام التكثيف. فيما يتعلق بالنباتات، تمّ تحديد 10 أنواع في البستان التقليدي، مما سمح بظهور أنواع حشرية متنوعة مقارنة بالبستان تحت نظام التكثيف. أظهر تحليل الاختبارات غير المعيارية للبيانات المسجلة وجود ارتباطٍ وثيق ومعنوي بين أنظمة المحاصيل ووفرة الحشرات وثرائها، وبالمثل، أظهرت مؤشرات التشابه وجود اختلافات واضحة بين النظم الزراعية البيئية المدروسة. أظهرت نتائج اختبارات النماذج الخطية العامة عدم وجود ارتباط لطرائق إزالة الأعشاب الضارة في بعض مقدرات التنوع. ومع ذلك، أشارت معاملات التنوع الرئيسية إلى أن النظام الزراعي التقليدي قد حافظ على تنوعٍ أفضل للحشرات وسمح للمجموعات الوظيفية المختلفة للحشرات بالعيش والتفاعل، معززةً بالنباتات الطبيعية الموجودة داخل البساتين المدروسة ومحيطها. إن إمكانية التنوع في الإدارة التقليدية لمحاصيل الحمضيات التي تمّ تسليط الضوء عليها خلال هذا المسح، تعطي فكرة ملموسة تفيد بأن التحول من نظام الإنتاج الشامل إلى نظام الإنتاج العضوي سيكون آمناً وواعداً.

كلمات مفتاحية: حمضيات/موالح، تنوع حشري، نظام محصولي، الجزائر.

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