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Diversity of hymenopteran families associated to quinoa crop in Algeria (case of Biskra province)

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Abstract: The quinoa (*Chenopodium quinoa*Willd.) crop is originated from Andean region (South America). Its nutritional values as well as its drought climate and water salinity tolerant character have motivated many countries such as Algeria to adapt such a plant culture. This study aims to assess entomofauna from Hymenoptera order in terms of composition and functional diversity. We aim also to evaluate the consequences of the expansion and uncommon crop on the hymenopteran composition. For the first field trial, the survey was carried out in Biskra province during 2018-2019. The Shannon Wiener index and evenness indices were used to measure family's diversity. The results revealed that 1737 specimens were identified into forty families and 166 species. Formicidae species were the most abundant with 68 % of total number of individuals, followed by Braconidae with 7 % and Crabronidae with 5 %. As well, diversity collected with yellow pan traps was more important in winter and spring seasons. As the functional groups, results indicated the presence of three major groups; parasitoids, pollinators and predators. The parasitoid group is the richest one.

Key words: quinoa crop; hymenoptera order; abundance; Shannon Wiener index; Biskra

Raznolikost družin kožokrilcev v posevkih kvinoje v Alžiriji (primer province Biskra)

Izvleček: Kvinoja ali perujski riž (*Chenopodium quinoa* Willd.) je poljščina, ki izvira iz območja Andov v Južni Ameriki. Njena velika hranilna vrednost kot tudi odpornost na sušo in slanost so motivirale številne države, med njimi tudi Alžirijo, da jo uvedejo v pridelovanje. Name te raziskave je bil oceniti favno žuželk iz reda kožokrilcev v posevkih te poljščine glede na sestavo in funkcionalno raznolikost. Namen raziskave je bil tudi ovrednotiti posledice razširjanja te nenavadne poljščine na sestavo favne kožokrilcev. Prvi poljski pregled je bil izveden v province Biskra, v rastni sezoni 2018-2019. Kot merili raznolikosti družin sta bila uporabljena Shannon Wienerjev indeks in indeks izenačenosti. Rezultati so pokazali, da je bilo določenih 1737 primerkov, ki so pripadali 40 družinam in 166 vrstam. Vrste iz družine Formicidae so bile najbolj pogoste, s 68 % deležem vseh osebkov. Tem so sledile Braconidae s 7 % in Crabronidae s 5 % deležem. Raznolikost, ki je temeljila na ulovu z rumenimi ploščami je bila bolj pomembna pozimi in spomladi. Rezultati so pokazali, da so bili med funkcionalnimi skupinami prisotni parazitoidi, opraševalci in plenilci kot glavne skupine, med njimi je bila skupina parazitoidov najbogatejša.

Ključne besede: kvinoja; redovi kožokrilcev; pogostost; Shannon Wienerjev indeks; Biskra

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1 INTRODUCTION

Insects represent the major component of terrestrial ecosystems (Weisser and Siemann, 2004).In trophic interactions (insect-plant), plants serve as resources for insects. They tend to interact with similar partners and they show a stronger conservatism levels for insect pollinators and herbivorous insects (FontaineandThébault , 2015). However, this relationship between insects and plants is not stable and in several cases, native insects have adapted to the introduced crops(Morrill, 2004).Hymenoptera order is one of the largest orders (Gaston, 1993), it ranks the third after Coleoptera and Lepidoptera (Stork, 1997), important members of hymenopteran species belong to higher trophic levels, they are more sensitive to any change of their habitats. Three main groups, ants, bees and parasitoids play crucial role in preserving diversity (Rot et al., 2021).Quinoa ((L.)Willdenow) crop is a pseudo-cereal with high nutritional value; it can be grown in dry climates and tolerates high levels of irrigation watersalinity. To improve food security, it was introduced in Algeria in 2014.It has been the subject of some field trials in arid regions. In Biskra province, quinoa crop was firstly sown in September 2015 on El-Outaya site. There are various reasons for studying diversity related to an exotic plant species.Firstly, know the taxonomy of local hymenoptera reservoir and understand the influence of quinoa crop on species behaviors.This study aims to carry out an exhaustive inventory of hymenopteran families associated with this introduced crop and to evaluate their diversity and abundance.

2 MATERIALS AND METHODS

2.1 STUDY REGION

Fieldwork was conducted in El-Outayalocated in the north of Biskra province (34°55'58.27 '' N, 5°39'34 41" E, altitude,207 m) (Figure1). This region is characterized by an arid climate with mild winter and wet spring. Survey was done from February 2018 to February 2019 during plant life cycle. Collections were done every week to twice a month depending on the season.

2.2 SAMPLING METHODS

Two trap types were chosen for this study: yellow pan traps and pitfall traps. They were known to be good in catching insects. First trap type is a yellow colored plastic rectangular pan with 30 cm of diameter and a height of 20 cm.The pitfall traps were a plastic jar with a diameter of 10 cm and a height of 10 cm-16 cm. Each trap was filled with an immersing medium composed with a mixture of half liter of clean water and some detergent drops. Three traps of each trap type were distributeover crop area of 250 m^2 at a distance of about 2.5-5 m from each other.

2.3 IDENTIFICATION OF INSECTS

Collected insects were preserved in Eppendorf tubes that contain 70 %ethanol and taken to Entomological laboratory, Department of Agronomy, Biskra for identification. Several available keys of identification were used with reference to Delvare and Aberlenc, 1989; Goulet and Huber, 1993; Amiet et al., 2001; Amiet et al., 2004; Mikó et al., 2007, 2013; Farahani and Talebi, 2012; Paukkunen et al., 2015; Wu et al., 2016; Zi and Zaifu, 2016; Ghafouri Moghaddam et al., 2016; Farahani et al., 2016; Rousse and Villemant, 2012; Edmardashand et al., 2011; Schmid-Egger et al., 2017; Ferrer-Suay et al., 2015; Choi et al., 2012; Chen et al., 2017; Izadizadeh et al., 2015; Mokrousov, 2017; Aguirre et al., 2015; Yari et al., 2016; Zargaretal, 2019; Mikó et al., 2013; Prous et al., 2014, 2019. In order to justify insect trophic relationships, different plant species nearby the quinoa crop were sampled (Table1).

2.4 ANALYSIS

To evaluate insect biodiversity, the common measures were used, like species richness, Shannon-Wiener index and evenness measure.

2.4.1 Species richness (S)

It is a simple measure of total number of species in each sample in a given area. Thismeasurement is strongly dependent on sampling efforts.

2.4.2 Shannon-Wiener index (H')

It takes into account the number of individuals of each species within the local community.

$H' = -\Sigma Pi \log Pi$

Where:
H' = Shannon Wiener index
Pi = proportion of "ith" species and is calculated as

"ni/N", where, "ni" is the number of individuals in "ith" species and N is the total number of individuals in the sample.

2.4.3 Measure of evenness (E: Equitability)

It can be calculated by using species richness (S) and Shannon Wiener index (H').It represents an important component of the diversity indices. It indicates how individuals are distributed among the different species.

$$E = H' / \log(S)$$

3 RESULTS

During this study, 1737 specimens were collected from quinoa crop. They were identified into 40 families and 166 species (Table2). Values of different indices calculated over all the seasons were: Shannon-Wiener index, H' = 3.72bits, Evenness (E) = 0.50. In the collection, 32 families were collected withpitfall traps and 29 families with yellow pan traps. Among these 1737specimens, 1377 were collected with thepitfall traps and represented 95 species, most of 1377 individuals belonged

Table 1: Cultivated and spontaneous plants collected infield-work

Plant species	Cultivated	Spontaneous
*Atriplex halimus*L.	-	+
Casuarina equisetifolia L.	+	-
Chenopodium vulvaria L.	-	+
Cupressus sempervirens L.	+	-
Diplotaxis harra (Forssk.) Boiss.	-	+
Hordeum vulgare L.	+	-
Malva parviflora L.	-	+
Medicago sativa L.	+	-
Moricandia arvensis DC.	-	+
Moringa oleifera Lam.	+	-
Olea europaea L.	+	-
Pinus halepensis Moulin	+	-
Salsola vermiculata L.	-	+
Sesbania aculeata (Willd.) Poir.	+	-
Sonchus asper L.	-	+
Suaeda mollis Delile	-	+
Tamarix gallica L.	-	+
Vitis vinifera L.	+	-
Zea mays L.	+	-

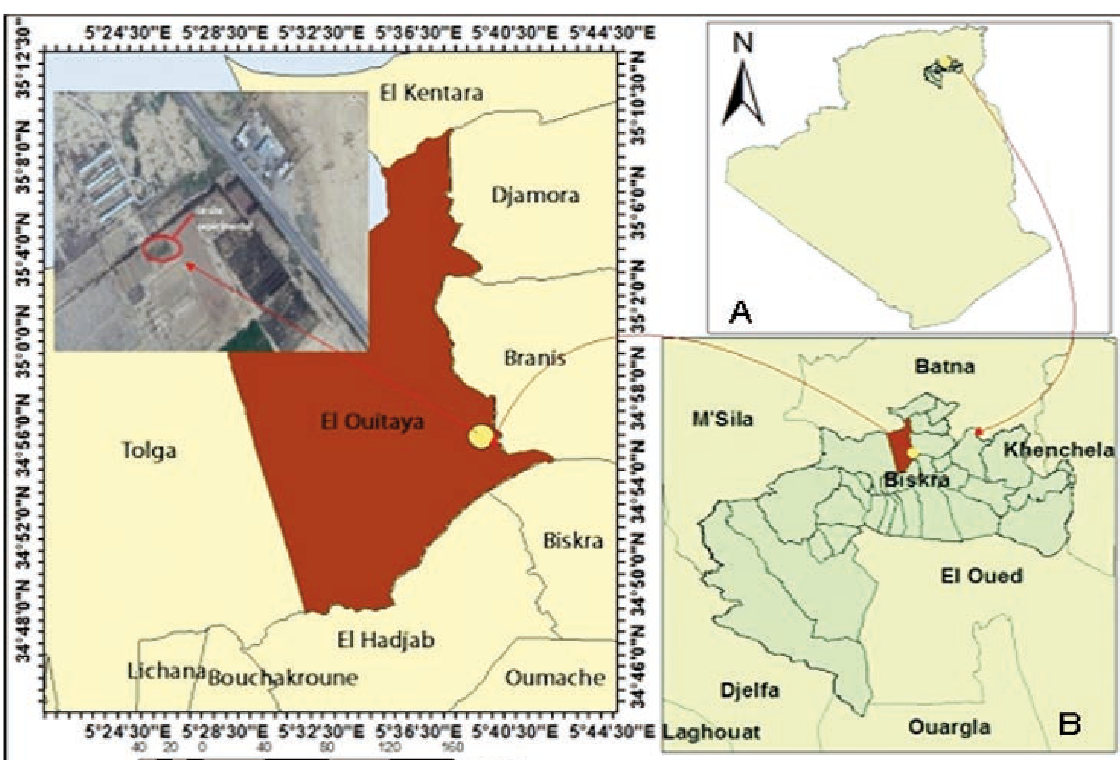

Figure 1: Situation of study site: Map of Algeria (A) showing the study province (B) and the study region

to Formicidae family with 1088 specimens. The rest 360 specimens were collected with the yellow pan traps. In this trap type, 126 species were recorded. 40 species were found in all trap types. The dominant family was Formicidae with 1175 specimens, followed by Braconidae with 124, Crabronidae with 80, Ichneumonidae with 55, Diapriidae 43 and Andrenidae with 35, whereas 17 families were represented with less number of specimens and 11 families with only one specimen (Figure 2). During autumn (17/10-22/12) 136 specimens were collected while 261 insects were collected inwinter (23/12-22/3) and 1340 in spring (23/3-17/5). The calculate values of various indices were presented in Table 3.

In autumn, in yellow pan traps two most abundant families were Ichneumonidae with 37 % and Vespidae with 20 %, but in pitfall traps, the Formicidae is the most abundant family with 58 %. In winter, the Diapriidae family was the most abundant with 21 % in yellow pan traps and the Braconidae family with 25 % in pitfall traps. In spring, in yellow pan traps; three families were the most abundant Formicidae with 40 %, Crabronidae

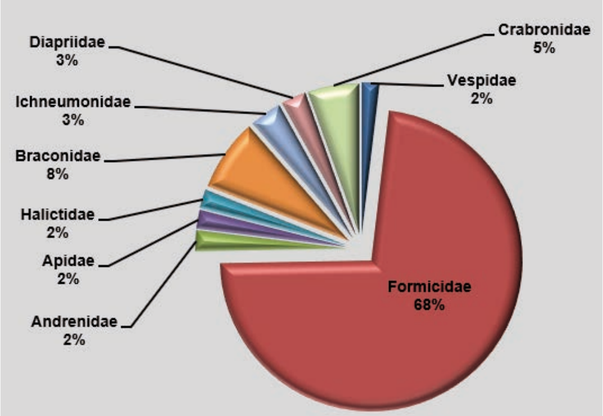

Figure 2: Population pie chart of abundant families given in relative abundance (percent)

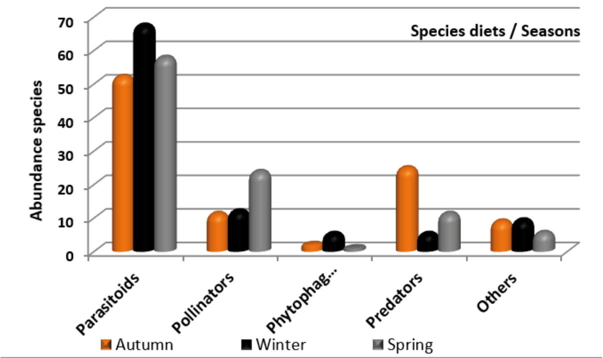

Figure 3: Hymenoptera species abundances of different functional groups

with 20 % and Braconidae with 10 % but in pitfall traps, there was an almost total dominance of Formicidae family with 83 %. Values of Shannon-Wiener index (H') and Evenness (E) indices presented in Table 4 and Table 5 indicate that yellow pan traps were more efficient.Spring and winter remain the best seasons of insect activity in study site. About the functional groups, results indicated the presence of three big groups; parasitoids, pollinators and predators Table 2. The parasitoid group is richer in all seasons. In collected data Crabronidae was the most abundant family of predator. Pollinator families showed no differences in abundance. However, various parasitoid species numbers were observed in all season (Figure3).

4 DISCUSSIONS

Available literature provides less information about entomofauna diversity of quinoa agro-ecosystem in native regions (Valoy et al., 2015). In Algeria, Biskra province is one of few production areas of quinoa and the only inventory done by Deghiche et al. (2021) in 2015-2016 at El-Outaya field may not reflect the true diversity at regional level. Deghiche et al. (2021) reported 5 hymenopteran families, 6 species and 174 specimens. As the second entomofauna listing on quinoa crop at the same site, present study showed a total of 40 hymenopteran families, 166 species and 1737 specimens. Among the collected families, the highest frequency was obtained for Formicidae (68 %). General calculate diversity indices (H'=3, 72 bits and E = 0.50) according to literature range indicated high rich hymenopteran families diversity and moderate distribution throughout the site study. In an ecosystem, various vegetation and favorable climatic conditions also maintain a high diversity of insect (Rasheed and Buhroo, 2018). At the trial site, different vegetation strata and types were present.Our results suggest that this agro-ecosystem harboured an important hymenopteran fauna. Comparison of the diversity indices between yellow pan traps and pitfall traps revealed that hymenopteran fauna composition collected by yellow pan is more important and evenly distributed (in terms of specimen abundance) than collected by pitfall traps. An analysis of the composition of hymenopteran families indicated that 77.77 % of the total specimen abundance is formed by 28 hymenopteran families but in the case of the pitfall traps, we found that 83.07 % of the total specimen abundance is formed by a single family (Formicidae). The winter and spring season results could be explained, in part, due to the key role of temperature as environmental factor ininsect's live cycle and in other part to high plant diversity nearby quinoa crop. Nonetheless, similar diversity could be not found in autumn, when all crop and spontane-

Table 2: Total number of species and specimens of Hymenoptera by families and their diets collected from Biskra province. Nomenclature of all hymenoptera families is follows that orders in Fauna Europaea (2021)

Order	Super-family	Families	Species Number	Specimen effectif	Diets
Hymenoptera	Pamphilioidea Cameron, 1890	Megalodontesidae Konow, 1897	1	4	phytophagous
	Tenthredinoidea Latreille 1803	Tenthredinidae Latreille, 1802	1	2	phytophagous
	Chrysidoidea Latreille, 1802	Chrysididae Latreille, 1802	7	7	Parasitoids
		Dryinidae, Haliday, 1833	1	1	Parasitoids
		Bethylidae, Forster, 1856	1	1	Parasitoids
	Scolioidea Latreille, 1802	Scoliidae, Latreille,1802	6	7	Parasitoids
	Vespoidea Latreille, 1802	Vespidae, Latreille, 1802	5	30	Predators
		Mutillidae, Latreille, 1802	1	1	Parasitoids
		Formicidae Latreille, 1809	8	1175	Variable diets
		Pompilidae, Harris, 1987	2	2	Parasitoids
	Apoidea Latreille, 1802	Crabronidae, Latreille, 1802	3	80	Predators
		Sphecidae, Latreille, 1802	10	1	Parasitoids
		Andrenidae, Latreille, 1802	3	35	Pollinators
		Apidae, Latreille, 1802	9	32	Pollinators
		Megachilidae, Latreille, 1802	6	7	Pollinators
		Melittidae, Michener, 2000	2	9	Pollinators
		Halictidae, Thomson, 1869,	5	32	Pollinators
		Colletidae, Lepeletier, 1841	1	6	Pollinator
	Ichneumonoidea Latreille, 1802	Braconidae, Latreille, 1829	21	124	Parasitoids
		Ichneumonidae, Latreille, 1802	29	55	Parasitoids
	Cynipoidea Latreille, 1802	Figitidae,Thomson, 1862	1	1	Parasitoid
	Diaproidea Halliday, 1833	Diapriidae, Haliday, 1833	3	43	Parasitoids
	Proctotrupoidea Latreille, 1802	Proctotrupidae, Latreille, 1802	2	6	Parasitoids
	Platygastroidea Haliday, 1833	Platygastridae, Haliday, 1833	5	12	Parasitoids
		Scelioninae, Haliday, 1839	5	6	Parasitoids
	Ceraphronoidea Haliday, 1833	Megaspilidae, Ashmead, 1893	2	23	Parasitoids
		Ceraphronidae, Haliday, 1833	3	5	Parasitoids
	Mymarommatoidea Debauche, 1948	Mymarommatidae, Debauche, 1948	2	2	Parasitoids

Continued on next page

		Aphelinidae, Thomson, 1876	1	2	Parasitoid
		Chalcididae, Latreille, 1817	1	1	Parasitoid
		Elasminae (Eulophidae)	1	1	Parasitoid
		Encyrtidae, Walker, 1837	2	2	Parasitoids
		Eulophidae, Westwood, 1829	2	6	Parasitoids
		Eupelmidae, Walker, 1833	1	1	Parasitoid
Hymenoptera	Chalcidoidea Latreille, 1817	Pteromalidae, Dalman, 1820	4	4	Parasitoids
		Tanaostigmatidae, Howard, 1890	1	1	Parasitoid
		Trichogrammatidae Haliday & Walker, 1851	1	1	Parasitoid
		Eurytomidae, Walker, 1832	3	3	Parasitoids
		Mymaridae, Haliday, 1833	3	5	Parasitoids
		Tetracampidae, Förster, 1856	1	1	Parasitoid

Table 3: Indices values of Hymenoptera families' diversity

Indices of Hymenopterafamilies diversity				
Name	Autumn	Winter	Spring	All Season
Richness S	19	28	27	40
Individuals	136	261	1340	1737
Shannon H (bits)	3.04	3.86	1.28	3.72
Evenness E	0.71	0.80	0.26	0.50

Table 4: Indices values of hymenoptera families collected by yellow pan in study seasons

Indices of yellow pan collected Hymenoptera families				
Name	Autumn	Winter	Spring	All Season
Richness S	12	20	22	29
Individuals	51	113	196	360
Shannon H (bits)	2.75	3.48	3.01	3.72
Evenness E	0.76	0.80	0.67	0.76

Table 5: Indices values of hymenoptera families collected by pitfall traps in study seasons

Indices of pitfall traps collected Hymenoptera families				
Name	Autumn	Winter	Spring	All Season
Richness (S)	15	21	21	32
Individuals	85	148	1144	1377
Shannon (H) (bits)	2.45	3.55	0.80	1.47
Evenness (E)	0.62	0.80	0.18	0.29

ous plants were in the early stages of their growth. In El-Outayasite, the average monthly temperatures during study in winter ranged from 12.1 to16.7 (with maximum of 27.1 ^{0}C) and the difference between the maximum and minimum temperature did not exceed 8 ^{0}C.Some observations were recorded in spring with mean monthly temperatures oscillated between 17.5 and 25 (with maximum of 30 ^{0}C).

With the exception of spring data collected by pitfall traps, various diversity indices calculated in all season (Tables 4 and 5) showed that great hymenopteran diversity were recorded and the detected families were evenly distributed throughout areas trial. At the quinoa field, scares infestation were observed. Moth was found on leaves in early stages, but the presence of aphid species and thrips were later. In the quinoa native region (Andes), aphids and thrips are considered occasional pests (Cruces et al., 2021).In trial field, quinoa harbours important hymenopteran diversity with different diets. The natural enemy complex formed by parasitoids and predatorsplays an essential role in plant protection. This crop-system proved very favorable for pollinator because they need good foraging resources.Surrounded by low use of pesticides and a variety of crops and herbs, the quinoa crop allows insects to have food and refuge Burgioet al. (2006).The results may also explain the greater diversity of entomophagous hymenopteran families. Parasitoids were the dominate group (Table 2).According to Rasmussen et al. (2003) in Andean region, up 45 % of quinoa pests were naturally controlled by parasitoids and predators. Apparently, our results were relatively similar to those in Cruces et al. (2020 a, 2020b); the introduced quinoa crop appears with positive impact on local insects' diversity.

5 CONCLUSIONS

This study is the first research to emphasize the diversity of hymenopteran families present in the Biskra province. It has been shown the presence of 40 hymenopteran families and 166 species. Thus, the found richness may give more information about herbivore identity and entomophagous guilds function in relation to local plant diversity and introduced crops us quinoa at locality scale. It may be important to survey the component of each family. This data can be used as example for integrate pest management of quinoa cultivation in the future.

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