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Diversity of cereal pests (wheat and barley) grown in arid climate in Ziban region (provence of Biskra – southeastern Algeria)

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Abstract. This study investigated cereal pests (wheat and barley) grown in southeastern Algeria's arid climate. Using three sampling techniques (yellow pan traps and Pitfall traps, a comprehensive collection of insect specimens was obtained, comprising 2526 individuals taxonomically classified into 20 distinct species, 15 genera, ten families, and six orders. Homoptera and according to quantitative analysis, Thysanoptera was the most dominant taxa, with six and four occurrences, respectively. In contrast, the dominant species were Mayetiola destructor (Say 1817) (Diptera, Cecidomyiidae) with 412 specimens, *Rhopalosiphum maidis* (Fitch 1856) (Homoptera, Aphididae) with 404 specimens then *Oulema melanopa* (Linné 1758) (Coleoptera, Chrysomelidae) with 342 specimens. The observed and expected species richness diversity parameters were comparatively more significant in the cereal ecosystem cultivated in the El Outaya location than in the Sidi Okba location. (Kruskal–Wallis, df = 3, P = 0.019). The results obtained from the Generalised Linear Models (GLM) indicated a statistically significant variation in species richness across the different sites and crops (wheat and barley) (df = 3, Mean Square = 47.70, F = 3.58, P = 0.020).While there were very significant differences in the average number of individuals per species (N/S ratio) (df = 3, mean square = 22.08, F = 5.526, P = 0.002).

Species richness extrapolation revealed that diversity is anticipated as the number of individuals captured increases, however, at a slower rate as the sampled population increases. The species distribution showed that some insect species are found at all phenological stages and all sampling sites.

Keywords: insect, crop, biodiversity, dry climate, richness, extrapolation.

Introduction

Since antiquity, cereals have been the main staple food and are strategically important in human nutrition and animal feed. As well as cereal farming has played an essential role in the development of various civilizations (rice for Asian civilizations, maize for pre-Columbian civilizations, and wheat for the Mediterranean basin and the Near East) (Boulal *et al*., 2007).

Cereals are the staple diet in most southern Mediterranean countries. They are therefore considered strategic in the food security of populations (Lemeilleur *et al*., 2009). In Algeria, cereal growing plays a leading role in the national economy. It occupies the first place in strategic crops; most farmers practice it; according to statistics from the Ministry of Agriculture, the general census of agriculture (RGA) in 2013 gives us about 600.000 cereal farmers, or nearly 60% of all farms without taking fallow land into account. According to the FAOSTAT database (2021), the area occupied by cereals is 1.941.863 ha. This agricultural area is very narrow compared to the total area of Algeria which amounts to 238 million hectares of which 191 million are unproductive. Additionally, cereal production in Algeria is affected by various factors, including changes in weather patterns, which constitute the critical factor in determining the profitability of production. This strong correlation between climatic conditions and production causes a significant irregularity in cereal yields from year to year. Furthermore, according to figures from the Minister of Agriculture quoted by the official agency (APS, 2016), the national production of cereals (barley, oats, durum wheat and common wheat) decreased to 34.750 million quintals during the 2015/2016 campaign. The estimated yield rate was 16 quintals per hectare. It was 40 million quintals in 2014/2015, 35 million quintals in 2013/2014 and 49.1 million quintals in 2012/2013.

Despite the application of several programs to develop the agricultural sector in Algeria, in particular the national agricultural and rural development plan (PNDAR) in 2001/2002, cereal yields are still low and very irregular: 14.337 quintals/ha during the 2020-2021 agriculture campaign (FAOSTAT, 2021). Thus, in terms of productivity, Algeria is lagging behind Mediterranean countries, North Africa and Europe. This can be explained by various constraints such as environmental conditions (soil and climate), technical (seeds, cultivation practices) or human (organization and training of producers).

Besides, cereals in Algeria are frequently attacked by several pests that can damage the crop and reduce their yields. The most significant damages are due to insects; Indeed, these latter can cause severe crop losses by direct and indirect damage (some species are vectors of viruses and other diseases). Several authors have studied cereals entomofauna as well as the population dynamics of certain pests, such as Boujite (2007); Boughida & Dif (2010); Kellil (2019) and Bakroune (2021). Nevertheless, limited research was conducted in Algeria regarding pests affecting cereal crops, especially in arid regions under drought conditions and desertification. Thus, the present study presents a comprehensive inventory of pests that inhabit cereal ecosystems cultivated in the arid Ziban region (Biskra, southeastern Algeria). The aims of the investigation are: (i) assessment of species richness of insects pests in a cereal agrosystem in arid climat; (ii)determine the influence of varieties (wheat and/or barley) on insects diversity and (iii)determine the influence of phenological stages of crops on the diversity and the distribution of insects.

Materials and methods

Study area

This investigation was carried out from January to May 2016 in four sites across the Ziban region in Biskra province (Southeast Algeria), the study area is located at (34° 50′ 13.326′′ N, 5° 45′ 3.7728′′ E at an elevation: 97.623 m a.s.l.) (Fig. 1). Meteorological data for two decades (2000-2020) in Biskra indicated a dry climate in the region; with a maximum temperature of 41.76 °C in July (hottest month) and a minimum temperature of 17 °C h in December (coldest month). Rainfall has been scarce recently, with a maximum in winter (20.33 mm in January) and a minimum in summer (0.80 mm in July).All these factors led to a prolonged dry period; characteristic of North Africa's arid zones (Le Houérou, 1992). The ombrothermic diagram shows a six-month dry period, starting from May and ending in October (Fig.1). According to Emberger's climagram, the Biskra region is in an arid climatic stage (with a mild winter) characterized by low rainfall, high temperatures, high luminosity, and intense evaporation.

Insects sampling

Our work was carried out from January to May 2016. Samplings were done on four plots located in two different zones in Biskra region (southeastern Algeria). Two in El Outaya and two others in Sidi Okba. The plots for wheat and barley at every site are situated 5 kilometers apart from each other. During our experiment, three methods were used for trapping insects: (i) sight hunting (Colas, 1974), which involves random summation, (ii) yellow pan traps, which are commonly used in faunistic and entomological studies of agricultural environments due to their effectiveness, simplicity, and low cost. These traps can be used on a large scale, and (iii) pitfall traps. In this method, the traps are filled to a level of two-thirds with a solution of soapy water, which reduces the surface tension of the water and dissolves the layer of fat that envelops the bodies of the captured insects (Winchester, 1999). This layer of fat is known to hinder the escape of the insects from the trap. A total of 05 yellow pan traps and 05 Pitfall traps were placed at each field on a homogenous square parcel of land measuring 20 by 20 meters, with a total area of 400 square meters (Benkhelil, 1992), at least 50 meters away from the edges to prevent the edge effect. The experimental traps are filled with soapy water up to two-thirds of their capacity. Samples are collected every ten days throughout the experiment (Fig. 1).

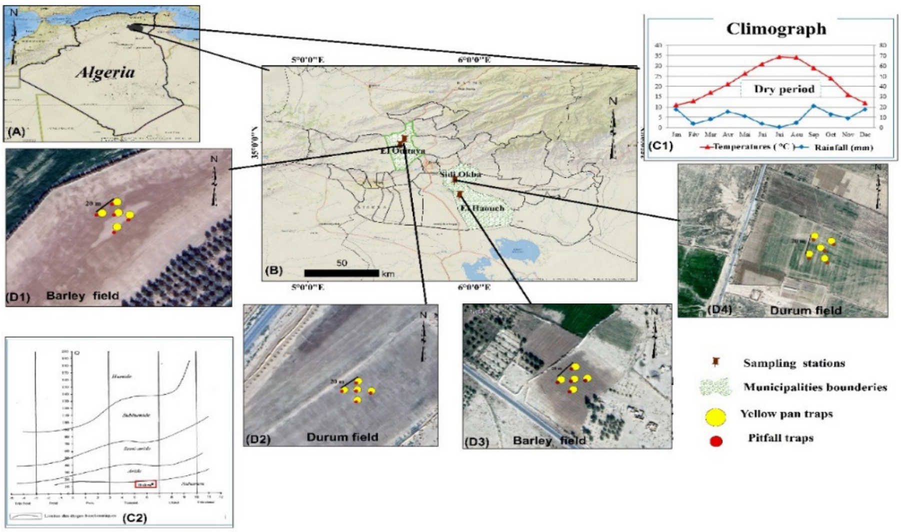

Figure 1. Geographical location of study sites (D_1, D_2, D_3, D_4) located in arid climate in the Ziban region (C_1, C_2) in the Province of Biskra (B) in southeastern Algeria (A).

Insects identification

Captured insects are retrieved using a filter that allows us to collect only insects. The filter designed specifically for collecting entomofauna. The insects are kept in pill boxes containing 70% alcohol and labeled with trap type; collection date, location, and species of cereal. After collecting the insect samples, they are taken to the laboratory for analysis under a binocular microscope. The insects are then sorted in a systematic order to help with identification and counting. To accurately identify the insects, we consulted with specialists from the Department of Agricultural and Forestry Zoology of El-Harrach and the C.R.S.T.R.A. of Biskra.

We collected insects from cereals during different growing stages are counted and examined them under a binocular microscope in the laboratory. To identify these insects, we referred to keys from Remaudiere and Seco Fernandez (1990); Leclant (1999); Leraut (2007).

Data analysis

Biodiversity analysis

- Taxonomic diversity (species diversity). Diversity of insect pests of cereals in each plot was evaluated by calculating the following ecological indices: (i) the relative frequency (RF) of each insect, which was determined by calculating the percentage of the number of individuals of a species in each station relative to the total number N; (ii) the Density/400m^2 (D), which was computed as $D = N/P$, where N represents the total number of individuals of a species collected on the surface considered, and P is the total number of samples; (iii) species richness *(S)*, which represents the overall number of determined species;(iv) Frequency of occurrence *(FO%)*, according to Dajoz (1985), it shows the proportion of species appearances to all species for a specific species it is calculated by the following formula: *F.O % = ni1 / N2 x 100*. To determine the number of constancy classes (N.c.), we used the Sturge index (Scherrer, 1984). The formula is as follows: N.c. = 1 + (3.3 log 10 N3), where N3 represents the total number of captured individuals.;(v) The Shannon diversity index (*H*): *H = ((ni/N) log2(ni/N))*, where ni denotes the frequency of a species and N denotes the total number of individuals in a sample; (vi) evenness (*E*): *E = H/ Hmax*, where *Hmax = log2S*; and (vii) the Simpson reciprocal index, *SRI* = (*1/D*), with *D = Σ(ni(ni −1)/N(N−1))*. (viii) Menhinick's diversity index is calculated as the number of species (S) in the sample divided by the square root of the total number of individuals (N) in the sample written as IMn=S/√N. (ix)The Margalef richness index (RMg) estimates absolute species richness, regardless of sample size. RMg index used to assess diversity across various sites. It does not have a

defined threshold and allows for weighting of sample sizes. Despite being easy to calculate, this index can be greatly influenced by the amount of sampling effort put in (Margalef, 1969). The value of this index is obtained by the following formula: *RMg = S-1/ln (N)*. (x) the value of Fisher alpha index, a diversity index, defined implicitly by the formula S=a*ln (1+n/a), where S is number of taxa, n is number of individuals and a is the Fisher's alpha. (xi) Berger-Parker dominance, this index calculates the proportion of the community represented by the most abundant species. All other species are ignored (Berger, 1970). (xii) the value *1/S*. (xiii) the ration *N/S.*

- *Species accumulation curves.* The impact of the number of captured individuals on the cumulative specific richness observed (S_{obs}) by site and by cereal variety was evaluated. Using the Estimate S program (Colwell, 2013), the diversity index (Richness S, Shannon index H'and Simpson index), were utilized in order to carry out the species richness estimates (S_{est}).

Statistical analysis

The normality of the abundance data was assessed using the Shapiro-Wilk test, followed by the evaluation of species abundance variation using the nonparametric Kruskal-Wallis's test ($\chi 2$). For each sampling site in the study area, the calculated ecological diversity index (N, S, H, E, SRI, and the ratio N/S), and descriptive statistics were displayed in the form of boxplots for each insect family. The study employed generalized linear models (GLMs) to examine the diversity parameters of aphids across different seasons. A one-way analysis of variance (ANOVA) was performed, and a Tukey's HSD post hoc significance test (p 0.05) was used to determine if there was a significant difference in the means of N and S between and within the sampling locations. Statistical analyses was carried out using the free software R (R Core Team, 2019). Principal component analysis (PCA) was employed to investigate the impact of crops on the distribution pattern of insect pests across different locations. A visual representation of the frequency distribution of pest insect species across various phenological stages was presented through Venn diagram.

Results

Inventory

The plots fauna inventory comprised 20 cereal pest taxa that were categorized into six orders and ten distinct families, as presented in Table 1. The order with the highest representation was Homoptera (Fig. 2), which comprised six aphid species dependent on cereals. The aphid community at the

El Outaya location exhibits a higher level of attraction towards cereals than the Sidi Okba site, which only harbours four taxa. The Thysanoptera which ranked second in terms of species diversity exhibited a total of four species belonging to the Tripidae family. Both Lepidoptera and Diptera were comprised of three distinct species each. The Hemiptera taxonomic group comprises two species that rely on cereals as their primary source of sustenance, namely *Aelia germari* and *Aelia acuminata*. The Coleoptera taxa were observed to be comprised of two additional significant cereal pests, namely the Chrysomelidae *Oulema melanopa* and the Scarabaeidae *Geotrogus deserticola*. El Outaya and Sidi Okba sites harbor 18 and 17 species, respectively as determined by the qualitative analysis. Statistically significant difference in insect species diversity was observed among the two sites (Kruskal-Wallis, df = 3, P = 0.019).

The results of principal component analysis (PCA) shown that the ordination structure is divided into three clusters in wheat and four in barely (Fig. 3). The species *Mayetiola destructor*, *Oulema melanopa*, *Rhopalosiphum padi, Limothrips cerealium* and *Rhopalosiphum maidis*are are characterized by high values for the variables Occurence.%, Frequency, N Density Ind/400m^2 (variables are sorted from the strongest) (Tab. 2).

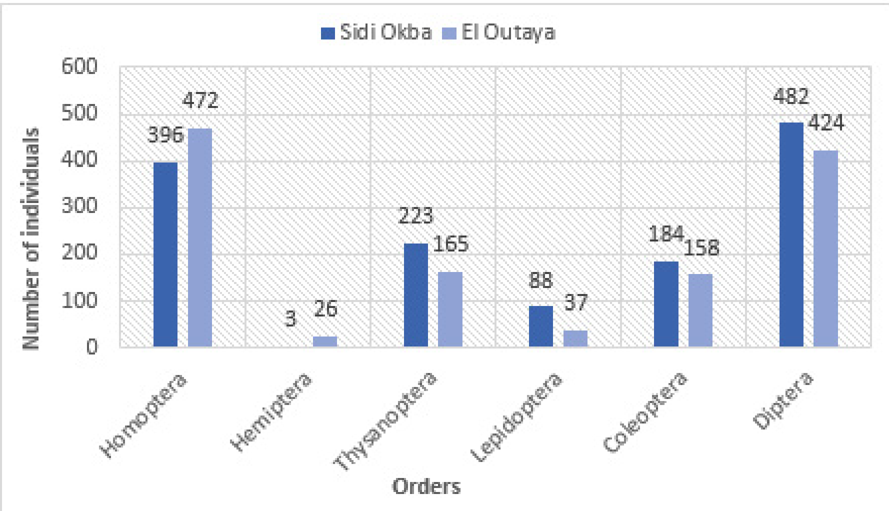

Figure 2. Abundance of the orders of the main cereal pests in the two study sites.

Table 1. Systematic list, abundances (N), frequency and occurrence (occ) of cereals pests (wheat and barley), recorded in an arid climate (El Outaya and Sidi Okba) in the Ziban region (Biskra, Algerian south-east).

Ordres	Families	Species	EPPO codes	Sidi Okba								El Outaya							
				Wheat				Barely				Wheat				Barely			
				N	Freq	Occu %	D Ind/ 400m²	N	Freq	Occu %	D Ind/ 400m²	N	Freq	Occu %	D Ind/ 400m²	N	Freq	Occu %	D Ind/ 400m²
Coleoptera	Chrysomelidae	*Oulema melanopa* (Linné, 1758)	*OULEME*	141.00	5.01	83.33	11.75	43.00	1.79	77.78	4.78	97.00	3.53	76.92	7.46	61.00	3.30	84.62	4.69
	Scarabaeidae	*Geotrogus deserticola* (Blanchard, 1851)	*GEOTDE*	7.00	0.25	41.67	0.58	8.00	0.33	66.67	0.88	15.00	0.55	61.54	1.15	0.00	0.00	0.00	0.00
Homoptera	Aphididae	*Metopolophium dirhodum* (Walker, 1849)	*METODI*	0.00	0.00	000	0.00	17.00	0.71	66.67	1.89	25.00	0.91	53.85	1.92	24.00	1.30	53.85	1.85
		Rhopalosiphum padi (Linné, 1758)	*RHOPPA*	71.00	2.52	75.00	11.08	68.00	2.82	100.00	9.11	66.00	2.40	84.62	5.08	55.00	2.98	76.92	4.23
		Rhopalosiphum maidis (Fitch, 1856)	*RHOPMA*	133.00	4.72	100.00	5.92	82.00	3.41	100.00	7.56	101.00	3.67	100.00	7.77	88.00	4.76	92.31	6.77
		Sitobionavenae(Fabricius, 1775)	*SITOAV*	34.00	1.21	75.00	2.83	24.00	1.00	88.89	2.67	58.00	2.11	76.92	4.46	20.00	1.08	61.54	1.54
		Sitobion fragariae (Fabricius, 1775)	*SITOFR*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.00	0.36	53.85	0.77	17.00	0.92	53.85	1.31
		Schizaphis graminum (Rondani, 1852)	*SCHIGR*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.00	0.18	30.77	0.38	3.00	0.16	23.08	0.23
Hemiptera	Pentatomidae	*Aelia germari* (Küster, 1852)	*AELIGE*	0.00	0.00	0.00	0.00	3.00	0.12	44.44	0.33	12.00	0.44	53.85	0.92	6.00	0.32	30.77	0.46
		Aelia acuminata (Linnaeus, 1758)	*AELIAC*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.00	0.11	15.38	0.23	5.00	0.27	30.77	0.38
Thysanoptera	Tripidae	*Limothrips cerealium* (Haliday, 1836)	*LIMOCE*	0.00	0.00	0.00	6.17	50.00	2.08	100.00	5.56	58.00	2.11	100.00	4.46	44.00	2.38	100.00	3.38
		Thrips tabaci(Lindeman, 1889)	*THRITA*	48.00	1.70	83.33	4.00	31.00	1.29	66.67	3.44	44.00	1.60	69.23	3.38	11.00	0.60	38.46	0.85
		Melanthrips pallidior (Priesner, 1919)	*MELAPA*	12.00	0.43	58.33	1.00	0.00	0.00	0.00	0.00	6.00	0.22	30.77	0.46	2.00	0.11	15.38	0.15
		Aeolothrips fasciatus (Linnaeus, 1758)	*AEOLFA*	0.00	0.00	0.00	0.00	8.00	0.33	66.67	0.89	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lepidoptera	Noctuiidae	*Helicoverpa armigera* (Hübner, 1808)	*HELIAR*	13.00	0.46	50.00	1.08	8.00	0.33	44.44	0.89	0.00	0.00	0.00	0.46	6.00	0.32	38.46	0.46
		Agrotis segetum(Denis &Schif., 1775)	*AGROSE*	0.00	0.00	0.00	0.00	9.00	0.37	55.56	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Gelechiidae	*Sitotroga cerealella* (Olivier, 1789)	*SITOCE*	30.00	1.07	66.67	2.50	28.00	1.16	100.00	3.11	15.00	0.55	53.85	1.15	10.00	0.54	46.15	0.77
Diptera	Cecidomyiidae	*Mayetiola destructor (Say, 1817)*	*MAYEDE*	144.00	5.11	100.00	12.00	147.00	6.10	100.00	16.33	121.00	4.40	100.00	9.31	0.00	0.00	0.00	6.77
	Agromyzidae	*Lyriomiza trifolii* (Burgess, 1880)	*LYRITR*	73.00	2.59	91.67	6.08	78.00	3.24	100.00	8.67	124.00	4.51	92.31	9.54	35.00	1.89	76.92	2.69
	Ephydridae	*Hydrellia griseola* (Fallen, 1813)	*HYDRGR*	8.00	0.28	50.00	0.67	32.00	1.33	100.00	3.56	29.00	1.05	69.23	2.23	0.00	0.00	0.00	2.08

N: Number of individuals;Freq: frequency; Occu % : occurrence; D Ind/400m^2 : density.

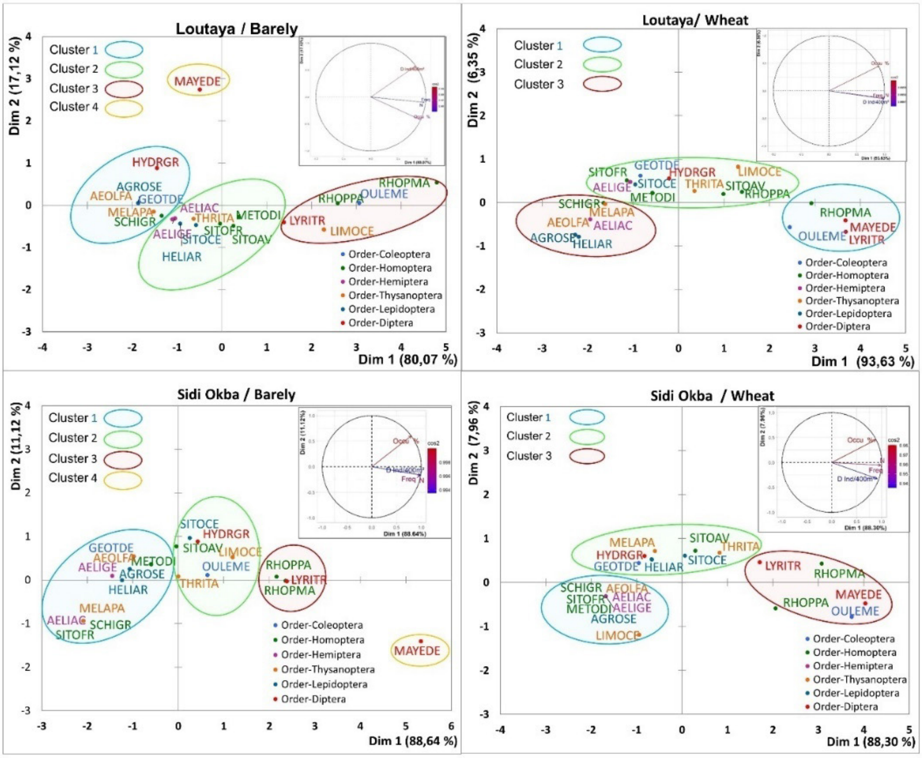

Figure 3. Plot of the results of the principal component analysis (PCA) of the pest/crop/locality ordination in the Ziban region (Biskra, south east Algeria).

Distribution of insects in the sites

The statistical analyses conducted using the Kolmogorov-Smirnova and Shapiro-Wilk tests revealed a significant correlation between species richness, insect abundances, and the N/s ratio in the ecosystems (of the two sites and the four plots), as presented in Table 2, with respective statistical values of S ($F = 3.582$, $P = 0.020$), N ($F = 3.569$, $P = 0.021$) and the ratio N/S ($F = 5.535$, $P = 0.002$) (Fig. 3). Nevertheless, the remaining diversity parameters exhibit no significant variations across the study sites (Shannon diversity index: F = 1.797, $P = 0.160$, Inverse of diversity index: F = 1.311, $P = 0.282$, Evenness: $X^2 = 19.961$, $P < 0.001$) (Fig. 4).

Following the Tukey's post-hoc test, and the Dunn's test (for Evenness), the identical letters linked with average values (circles) are not significantly different.

Table 2. Kolmogorov-Smirnov and Shapiro-Wilk normality tests for the ecological indices studied in overall (whole region).

Normality tests						
Ecological indices	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	*df*	Sig.	Statistic	*df*	Sig.
Taxa_S	0.122	46	0.081	0.952	46	0.058
Individuals	0.111	46	0.197	0.940	46	0.019
Dominance_D	0.170	46	0.002	0.817	46	0.000
Shannon_H	0.126	46	0.063	0.927	46	0.006
Simpson_1D	0.170	46	0.002	0.817	46	0.000
Evenness_E	0.135	46	0.036	0.953	46	0.061
Menhinick	0.160	46	0.005	0.952	46	0.057
Margalef	0.093	46	.200*	0.966	46	0.200
Equitability_J	0.080	46	.200*	0.988	46	0.922
Fisher_alpha	0.139	46	0.026	0.918	46	0.003
Berger-Parker	0.146	46	0.015	0.846	46	0.000
1/S	0.128	46	0.055	0.886	46	0.000
N/S	0.114	46	0.167	0.936	46	0.014

df: degree of freedom, Sig.: significance

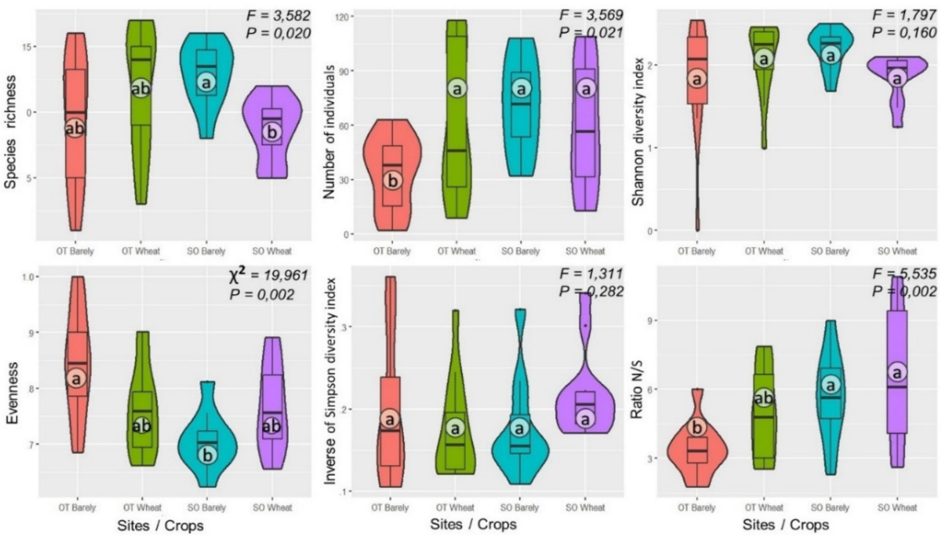

Figure 4. Boxplots representing the Ziban region's (Biskra, *SE* Algeria) various sites' insect diversity parameters.

Variation of insect diversity parameters

Overall, El Outaya site's cereal ecosystem reported higher diversity parameters than Sidi Okba site, with monthly variation values ranging from 4 to 18 in El Outaya and 8 to 15 in Sidi Okba. The abundance of cereal pests captured in Sidi Okba was higher (714 specimens in wheat with a range of 0.268 - 0.143 and 636 specimens captured in barley with a range of 0.243 - 0.105), than El Outaya (789 individuals in wheat with a range of 0,262 - 0,1001 per month and 387 specimens in barley with a range of 0,308 - 0,098) (Tab. 2). The study's findings indicate that there was a significant difference in species richness between the various sites and crops (wheat and barley) as determined by the generalized linear models (GLM) analysis (df = 3, Mean Square = 47.70, F = 3.58, P = 0.020). The N/S ratio exhibited a substantial degree of variation across species, as evidenced by a statistically significant result (df = 3, mean square = 22.08, F = 5.526, P = 0.002) (Tab. 3). The El Outaya site exhibited higher values of Shannon diversity index and evenness in both wheat (H′ = 2.494, E = 0.712) and barley (H′ = 2.473, E = 0.892) compared to the Sidi Okba site (H′ = 2.064, E = 0.877 in wheat and H′ = 2.477, E = 0.793 in barley) (Tab. 4). The Simpson reciprocal index (Simpson_1-D) exhibited a comparable pattern across the various sites, irrespective of the crop type.

In addition, the GLM revealed that the diversity parameters of Menhinick, Margalef, Fisher_alpha and Berger-Parker have no significant variation (P value > 0.05).

Table 3. Variation of diversity indices of pests of cereal sampled in arid lands of southeastern Algeria.

Index	**Sidi Okba**				**El Outaya**			
	Wheat		**Barely**		**Wheat**		**Barely**	
	Min	Max	Min	Max	Min	Max	Min	Max
Taxa_S	5.00	12.00	8.00	15.00	5.00	18.00	4.00	16.00
Individuals	13.00	303.00	37.00	199.00	21.00	197.00	9.00	144.00
Dominance_D	0.14	0.27	0.11	0.24	0.10	0.26	0.10	0.31
Shannon_H	1.48	2.06	1.68	2.48	1.23	2.49	1.27	2.47
Simpson_1-D	0.73	0.86	0.76	0.89	0.62	0.90	0.69	0.90
Evenness_e^H/S	0.66	0.88	0.65	0.79	0.65	0.71	0.70	0.89
Menhinick	0.63	1.39	1.32	1.63	0.98	1.30	0.88	1.37
Margalef	1.35	2.18	1.94	3.15	1.31	3.22	1.34	3.05
Equitability_J	0.83	0.92	0.81	0.91	0.76	0.89	0.87	0.92
Fisher_alpha	1.94	3.04	2.88	5.29	2.08	4.82	2.14	4.70
Berger-Parker	0.18	0.38	0.21	0.41	0.18	0.57	0.18	0.44

Estimation of species richness (rarefaction and extrapolation)

The rarefaction curves exhibited an upward trend as the number of captured individuals increased, eventually attaining a plateau (Fig. 5). As the sampled population grew, the number of species observed S grew, but at a slower rate. The estimated specific richness of the pests captured (S) reached specific stability from 810 and 250 individuals for wheat and barley respectively in El Outaya site, and 700 and 600 individuals for barley, and wheat respectively in Sidi Okba site. The use of three estimators (Richness S, Shannon index H', and Simpson index Simpson_1-D) showed that the estimated species richness curves had a striking resemblance in shape. Additionally, the populations of each site in the three estimators were combined when the total number of samples collected (the reference number) was smaller than the actual number of individuals.

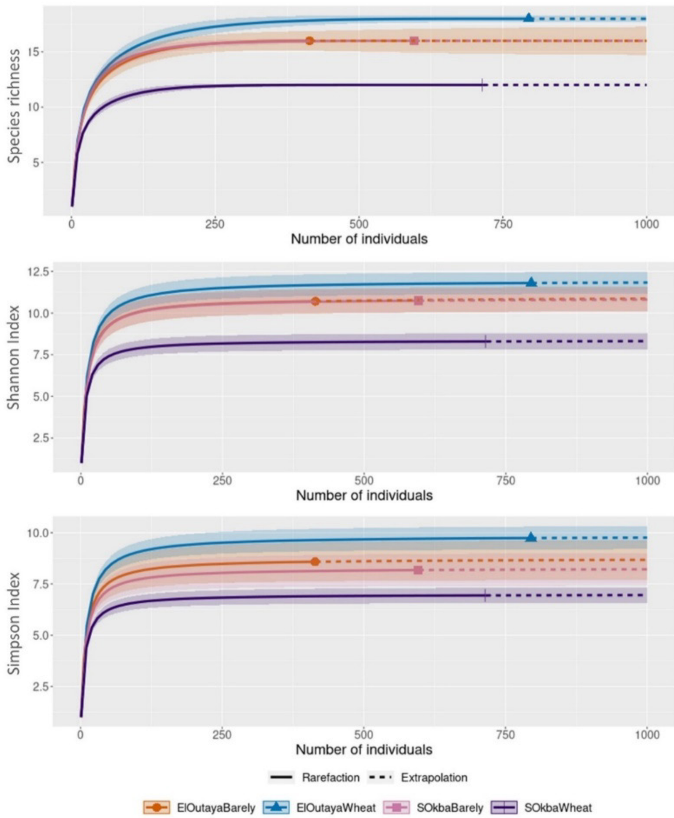

Figure 5. Rarefaction curves of expected species richness in a cereal ecosystem with a dry climate (Biskra, southeast Algeria). The lower and higher limits of the 95% confidence intervals for the number of species (S) are shown by the light-colored areas

Table 4. Evaluation of the fluctuation of insect diversity parameters among sites in Southeast Algeria using generalized linear models

Diversity index	Source	Type III sum of squares		Mean square	F	Sig.
S	Corr. model	143.120[a]	3	47.707	3.582	0.020
	Intercept	5913.547	1	5913.547	444.049	0.000
	site_crop	143.120	3	47.707	3.582	0.020
N	Corr. model	9587.450[a]	3	3195.817	3.570	0.021
	Intercept	165000.7	1	165000.7	184.313	0.000
	site_crop	9587.450	3	3195.817	3.570	0.021
Dominance_D	Corr. model	.049[a]	3	0.016	0.946	0.426
	Intercept	1.774	1	1.774	102.214	0.000
	site_crop	0.049	3	0.016	0.946	0.426
Shannon_H	Corr. model	1.025[a]	3	0.342	1.803	0.159
	Intercept	206.595	1	206.595	1090.104	0.000
	site_crop	1.025	3	0.342	1.803	0.159
Simpson_1-D	Corr. model	.049[a]	3	0.016	0.946	0.426
	Intercept	34.566	1	34.566	1991.904	0.000
	site_crop	0.049	3	0.016	0.946	0.426
Evenness_E	Corr. model	.125[a]	3	0.042	7.487	0.000
	Intercept	30.754	1	30.754	5507.929	0.000
	site_crop	0.125	3	0.042	7.487	0.000
Menhinick	Corr. model	1.051[a]	3	0.350	2.226	0.097
	Intercept	113.073	1	113.073	718.547	0.000
	site_crop	1.051	3	0.350	2.226	0.097
Margalef	Corr. model	4.522[a]	3	1.507	2.535	0.068
	Intercept	304.592	1	304.592	512.222	0.000
	site_crop	4.522	3	1.507	2.535	0.068
Fisher_alpha	Corr. model	21.704[a]	3	7.235	2.228	0.097
	Intercept	976.355	1	976.355	300.617	0.000
	site_crop	21.704	3	7.235	2.228	0.097
Berger-Parker	Corr. model	.015[a]	3	0.005	0.290	0.833
	Intercept	4.242	1	4.242	240.399	0.000
	site_crop	0.015	3	0.005	0.290	0.833
N/S	Corr. model	66.251[a]	3	22.084	5.526	0.002
	Intercept	1355.067	1	1355.067	339.098	0.000
	site_crop	66.251	3	22.084	5.526	0.002

Mean square values: are variance estimates.

Insect diversity depending on phenological stages

The Venn diagram (Fig. 6), indicates that Sidi Okba was host to seven pest species, namely *Hydrellia griseola, Limothrips cerealium, Lyriomiza trifolii, Mayetiola destructor, Rhopalosiphum maidis, Rhopalosiphum padi*, and *Sitotroga cerealella*, throughout the entire sampling period. While only two species shared among the months on wheat in the same site (*Lyriomiza trifolii*, *Mayetiola destructor*), and three species shared between all months of study under barely in El Outaya (*Limothrips cerealium*, *Oulema melanopa* and *Rhopalosiphum maidis*), However, four species were recorded in wheat at El Outaya (*Limothrips cerealium*, *Lyriomiza trifolii*, *Mayetiola destructor* and *Rhopalosiphum maidis*). According to Sturge's rule, all these species are considered omnipresent. Through our study, it was shown that February, March and April are the most diverse months, this coincided with the cereals phenological stages, boot, heading, flowering and grain fill.

Additionally, a notable disparity was observed in the frequency of the species identified during the phenological phases (Kruskal-Wallis, *df*= 4, *P* = 0.045).

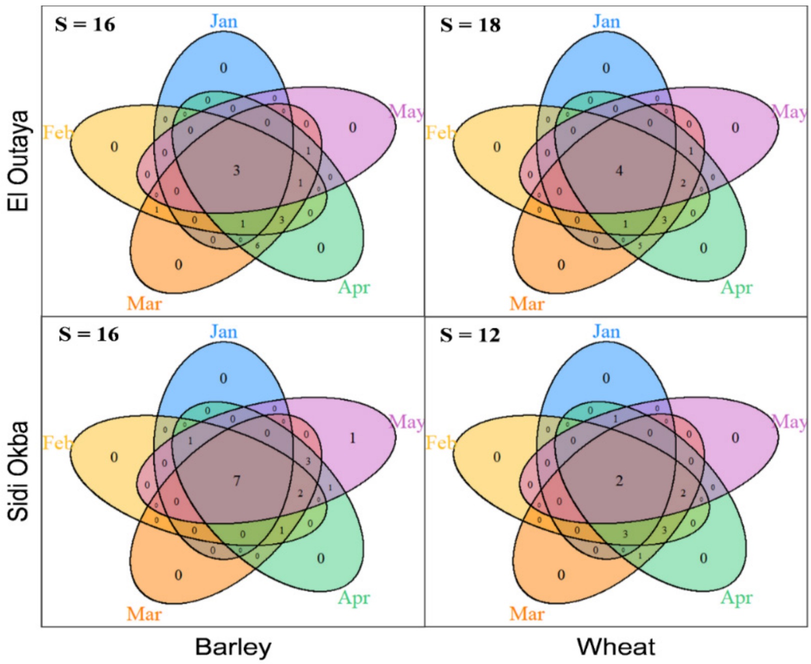

Figure 6. Venn diagram illustrating the distribution of the richness of pests found (S) over the five months of investigation at sample locations for the connected cereal ecosystem of the research area.

Discussion

The census of insect pests we conducted in a cereal agrosystem covered a wide range of bio-aggressor species in the Ziban (Biskra, Algeria) region, were dispersed among six orders, ten families, sixteen genera, and twenty species. Compared to Sidi Okba (17 species), El Outaya location has a higher diversity of 18 species. Homoptera significantly outnumbers the other orders in abundance in both locations, whether on wheat or on barely. Six Aphididae species that depend on cereals are included; they are among the most prevalent pests in Algeria that endanger cereal crops (Laamari, 2004; Assabah, 2011; Saharaoui 2017). Bakroune in 2012 had listed 26 species of aphids in the Biskra region, including 18 in El Outaya. For their part, Laamari *et al*. (2010) mentioned a richness of 30 species in several localities of the Biskra region. Tahar Chaouche (2019) inventoried 32 species in the wild in different localities in the Biskra region. In the region of Sidi Okba, Laamari *et al*. (2009), cited 11 aphid species belonging to the genera *Aphis*, *Brachycaudus* ,*Brevicoryne*, *Capitophorus*, *Dysaphis*, *Rhopalosiphum*and *Sitobion*. Hamidi *et al*. (2013), identified 10 species of aphids in Biskra city. In addition, in the high plain's region of Setif, Kellil in 2019 identified 24 taxa. Additionally, Ketfi (2018) noted the presence of *R. padi, R. maidis,* and *S. avevae* in Constantine region, with a combined total of 508 individuals on durum wheat and 531 individuals on soft wheat. In the sub-humid bioclimatic stage in Oued Smar, Assabah (2011), had inventoried four species of aphids dependent on cereals in a plot of durum wheat, where the species *R. padi* is quantitatively the most dominant with an abundance of 63.53%. Followed by *R. maidis* with 6.87%. The species *S. avenae* and *S. fragariae* represent very low proportions not exceeding 4%. According to Belkahla and Lapierre (1999), *R. padi*, *S. fragariae* and *S. avenae* are among the aphids considered potential vectors of the virus responsible for the incipient jaundice disease of barley in cereal-growing areas in Algeria.

The spatiotemporal evolution of each species shows that the species *R. maidis, R. padi* and *S avenae* are present in the two sites on both varieties (wheat and barley); they are constant species present during all the plant phenological phases. The activity of aphids is related to the biological cycle of the species and the phenological stage of the host plant, as well as the influence of climatic conditions. Hulle and d'Acier (2007) reported that the minimum temperature for the development of aphids is 4°C on average, below this threshold, they no longer multiply. According to Ortega (1988), *R. maidis* is a very popular pest worldwide. But in harsh climatic conditions such as winter, it does not survive (Blackman and Eastop, 2007). This species is probably the most important cereal aphid in hot, tropical and subtropical regions of Africa and Asia (So *et al*., 2010).

Four species of thrips were listed in the context of our study, among these taxa only the species *Limothrips cerealium* has the status of pest of cereals. The other taxa *Thrips tabaci*, *Melanthrips pallidior* and *Aeolothrips fasciatus*are much more stretched out by the spontaneous vegetation in or around the plot. The *L. cerealium* species has already been reported in the Biskra region by Rechid (2011) on *Echium parviflorum*, *Asphodelus refractus* and *Beta vulgaris* and by Razi (2017), on onions in several localities. On their part Benmessaoud *et al*. (2011), noted the presence of this species on *Triticum* and *Jasminus* in Algiers. It is also mentioned in North Africa, in Morocco by Zur Strassen (1968), in Tunisia Jenser (1982), in Egypt Preisner (1960). According to Elimen *et al*. (2014), it is a very popular pest in cereal fields in Europe. The appearance of thrips coincides with the first vegetative stages of the host plant (wheat and/or barley).

The infestation of cereal plots by thrips increases over time, especially by *L. cerealium* and *T. tabaci,* to reach the peak of pullulation in the spring (between March and April), it is matched with heading and flowering stages. Several conditions can play a determining role in diversity, abundance and dynamics of thrips such as plant phenology (Mehra and Singh, 2013), climatic conditions (Toapanta *et al*., 2001), the diversity of crops practiced within the study sites (Razi, 2017).

Diptera order occupies the third position with three cereal pests, where the *Mayetiola destructor* (Cecidomyiidae family) is the most dominant species in the two cereal varieties. This species was reported by the National Institute for Plant Protection services (NIPP, Algeria) in the Annaba and Guelma regions (Bakroune, 2021). Other researchers have reported this Diptera in several regions of Algeria (Berchiche, 2004; Saidouni, 2012), in the Mitidja region on soft wheat and barley. Today this pest has spread to all regions of Algeria. In Morocco, *M. destructor* has been observed in all cereal-growing regions (Nadjimi *et al*., 2002; Nsar Ellah and Lhaloui, 2006). According to Roy *et al.* (2008), this pest is recognized as being very harmful for the cultivation of wheat *Triticum aestivum* (Linné, 1753) and *T. turgidium* (Linné, 1753) where the damage can reach 100% of the yield. This species developed at least three generations during the 2015/2016 cereal campaign. Lhalouiet *et al*. (2004) mentioned that the number of generations varies according to climatic conditions. It varies between 2 to 6 generations per year (Elimen *et al.,* 2018). The results of monitoring the Hessian fly (*M. destructor*) in Morocco show that this species has three generations per year, two complete generations and a partial one which can only develop if the end of the growing season is rainy (Lhaloui, 1995). This confirms that the number of generations is related to climatic conditions. The Agromyzidae *Liriomyza trifolii* is the second cereal pest with intense activity in the two study sites. It is a very polyphagous species (Spencer, 1990), it has been observed in 29 taxonomic families (Mujica *et al.,* 2016). *L. trifolii,* is native to North America, Central America and South America. It spread to other parts of the world in the 1960s-1980s (Mujica *et al.,* 2016).

Hydrellia griseola is the third species that deserves to be reported as a critical cereal pest. It was captured in both cereal varieties. It is a Diptera, also called grain fly or grain miner, sometimes the tiny rice miner; it belongs to the Ephydridae family. Hydrellia is cosmopolitan, with more than 120 species identified. Hassan *et al.* (2019), noted that the Ephydridae family has a wealth of 2000 species identified across the world. The damage of this species is mainly due to the larvae (miners), which attack the blade and the sheath of the leaves as well as the roots.

Lepidoptera includes two families, namely the Noctuidae and the Gelechiidae. The Noctuidae predominate with two species, *Helicoverpa armigera* and *Agrotis segetum.* As an indication, more than 35000 Noctuiidae are described worldwide, and perhaps more than 100000 species in total, with more than 4200 genera (Murlis *et al.,* 2000). Gourari (2015) identified 12 species of Noctuidae, representing a present rate of 19% of all entomofauna captured in Séttif region. In addition, Barkou *et al.* (2017), in his study on the diversity of butterflies in the Algerian coastal regions, had cited the species *Agrotis segetum* and *Helicoverpa armigera* in his inventory. The Gelechiidae family is represented by *Sitotroga cerealella* which is considered as a cereal pest. This species showed intense activity in both study sites. According to Athanassiou *et al*. (2005), *S. cerealella* attacks all varieties of cereals (barley, wheat, rice, millet, sorghum); weight loss can reach 50% for wheat. Infestations begin during plant growth and continue during storage (Bushra and Aslan, 2014). This species one of the main pests of stored cereals in Morocco (Benayad, 2013).

According to Akter *et al.* (2013), adult longevity of *S. cerealella* is 2–4 weeks depending on developmental conditions, with 5–6 generations per year. Adjalian *et al*. (2014), indicated that the development of *S. cerealella* populations is maximal in a range of temperatures oscillating between 20 and 30° C.

Among beetles, *Oulema melanopa* is the only key bioaggressor of cereals that predominates. It is a species belonging to the Chrysomelidae family. Adults and larvae consume cereal leaves (Bai *et al*., 2002). In Algeria, Kellil (2019) indicated that studies on the cereal leaf beetle are insufficient, despite the significant damage that this species can cause to production. However, Rouag *et al.* (2014), reported the presence of two species of the genus *Oulema* in the Setif region (*O. melanopus* and *O. hoffmannseggi*).

Heavy infestations of *O. melanopa* occurred during boot, heading and Flowering stages, between the end of February and mid-April. These results are consistent with those obtained by Kellil in 2019 in his study of the population dynamics of *O. melanopa* on cereals in Setif. Kher *et al*. (2011) point out that the beetle's phenology and adaptability differ from region to other. According to Philips *et al*. (2012), many physical and biological factors intervene directly or indirectly in the fluctuations of the beetle population, such as habitat, microclimate, food, quality of the host plant and the abundance of natural enemies or competing species.

Two species of hemipterans of the Pentatomidae family recognized as pests of cereals were identified. These are the bugs *Aelia germari* and *Aelia acuminata*. Our inventory results show that the two *Aelia* species are practically absent on durum wheat in Sidi okba. On the other hand, the species *A. germani* is present only on barley in the same site. In El Outaya the two species are present in the two cereal varieties.

Safavi (1968) in Zair (2016), reports that cereal crops in North Africa are frequently attacked by various species of Pentatomidae belonging mainly to the genus Aelia, and record considerable damage. According to the N.I.P. report (2016), the specie *A. germari*, constitutes a permanent danger in cereal-growing regions (High-Plains). In Constantine, Benaoun and Meziani (2015) captured 15% of the bug of the genus *Aelia*. In the region of Tlemcen, Zair (2016), reported the species *A. germari* in 4 localities of the Wilaya in a total area of 108 ha. The installation of the two species of *Aelia* in cereal plots should be on time. They intervene at the grain fill and maturation stages (mid-March to end of the cereal campaign). At the same time Boutheldja and Orlici (2014) indicated that this insect causes damage in the field, before grain maturity.

Conclusion

The present study allowed us to better understand the diversity and distribution of cereal bioagressors in an arid climate (the region of Ziban, Biskra, south-eastern Algeria). Throughout the cereal campaign, the cereal agrosystem has a varied richness of insect species. A distinct insect community accompanies each phenological stage. The diversity varies according to the cereal varieties (wheat, barley) and the collection sites. The results obtained from this study can potentially function as a benchmark for other ecological inquiries about the interdependent associations between insects and cereal agroecosystems.

References

Akter, T. & Jahan M. (2013). Toxicité effet de la plante indigène couramment utilisés des extraits contrôle de la teigne du riz, *Sitotroga cerealella* Oliv. En stockée grain de riz. *Int. J. Sust. Agr., 5*(1), 10-15

Assabah, M. (2011). Evolution de peuplement aphidian et de ses ennemis naturels de blé dur (var. vitro) dans la station de Oued Smar (El Harrach – Alger). Thèse Magister, E.N.S.A. Alger.

Athanassiou, C.G., Kavallieratos, N.G., Palyvos, N.E., Sciarretta, A. & Trematerra, P. (2005). Spatiotemporal distribution of insects and mites in horizontally stored wheat. *J. Econ. Entomol. 98,* 1058-1069. https://doi.org/10.1603/0022-0493-98.3.1058

Bai, B.B., Worth, R.A., Johnson, K.J.R. & Brown, G. (2002). Detection survey and population monitoring of cereal leaf beetle in Oregon, 2001. *Proc. 61st Ann. Pacific NW Insect Manag. Conf*. Portland, Oregon.

Bakroune, N. (2012). Diversité spécifique de l'aphidofaune (Homoptera, Aphididae) et de ses ennemis naturels dans deux (02) stations : ElOutaya et Ain Naga (Biskra) sur piment et poivron (Solanacées) sous abris - plastique. Thèse Magister, Université de Biskra.

Bakroune, N. (2021). L'entomofaune des céréales dans la région de Biskra. Ecologie des populations des principaux bioagrésseurs. Thèse doctoret. Université de Biskra. http://thesis.univ-biskra.dz/5343/

Barkou, H., Benzehra, A. & Saharaoui, L. (2017). Diversity of moths (Lepidoptera, Noctuiidae) and the flight curves of the main species in Algeria, *IDOSI. 18* (3), 158-167. https://www.idosi.org/gv/gv18(3)17/2.pdf

Belkahla, H. & Lapierre, H. (1999). Serodetection of viruses associated to barley yellow dwarf (BYD) on cereals in Algeria. *Phytoprot. 80*(3), 169-177. https://id.erudit.org/iderudit/706190ar

Benaoun, A. & Meziani, A. (2015). Inventaire des punaises des céréales (Hemyptera) dans deux stations d'étude: Oueldjet el Kadi Ibn Ziad (Constantine) et El Khroub (Constantine). Mémoire de Master, Université de Constantine.

Benayad, N. (2013). Extraction de métabolites secondaires des champignons endophytiques isolés de plantes Marocaines et activité anticancéreuse. Thèse de doctorat, Université Mohammed V – Agdal. Rabat, Maroc.

Benkhelil, M. (1992). Les techniques de récoltes et de piégeages utilisées en entomologie terrestre. Ed. Office Publications Universitaires, 68 pp.

Benmessaoud, B.H., Mouhouche, F., & Belmazouzi, F.Z. (2011). Inventory and identification of some thrips species in coastal and sub-coastal regions of Algeria. *Agr. Biol. J. N. Amer. 1*(5), 755-761. Doi: 10.5251/abjna.2010.1.5.755.761

Berchiche, S. (2004). Entomofaune du Triticum aestivum et Vicia faba. Etude des fluctuations d'Aphis fabae Scopoli, 1763 dans la station expérimentale d'Oued-Smar. Mém. Magister, Inst. Nat. Agro., El-Harrach, Alger, 245 pp.

Boughida, S. (2010). Puceron russe du blé Diuraphisnoxia (Mordvilko, 1913) (Homoptera, Aphididae): Répartition et ennemis naturels à travers quelques localités dans l'Est algérien. Mém. *Ing. Agro. Dép. Agro. Batna*, 38 pp.

Boujite, A. (2007). Contribution à l'étude éco-biologique des pucerons des céréales dans la région d'El-Khroub (W. de Constantine). Mém. Ing. Université de Batna.

Boulal, H., Zaghouane, O., EL Mourid, M. & Rezgui, S. (2007). Guide pratique de la conduite des céréales d'automne (blés et orge) dans le Maghreb (Algérie, Maroc, Tunisie). *Ed. TIGC, INRA, ICARDA, Algérie,* 176 pp.

Boutheldja, K. & Orlici, B. (2014). Les pentatomidae (Hémiptères) dans le nord d'Algérie. Mémoire de master, Universoté de Constantine.

Bryan, F. & Manly, J. (2007). Texts in statistical science, randomization, bootstrap and Monte Carlo methods in biology. *Taylor & Francis Group*.

Bushra, S. & Aslan, M. (2014). Management of *Sitotroga cerealella* in stored cereal grains: a review. *J. Arch. Phytopathol. Plant Prot., 47.* https://doi.org/10.1080/03235408.2013.877191

Colas, G. (1974). Guide de l'entomologiste. N. Boubée, Paris, France.

Colwell, R.K. (2013). EstimateS: statistical estimation of species richness and shared species from samples. Version 9. Available from http://purl.oclc.org/ estimates [accessed 14 April 2019].

Dajoz, R. (1985). Précis d'écologie. Ed*. Dunod, Paris*, 505p.

Elimem, M. & Chermiti, B. (2013). Thrips species composition and seasonal dynamic populations in an organic citrus orchard in the central eastern coast of Tunisia. In: Garcia-Mari, F. 2013. *Proc. Meet. Adana, Turkey, 07 - 09 May, IOBC-WPRS Bulletin, 95:* 77-82.

Gourari, B. (2015). Étude de la biodiversité faunistique urbaine et périurbaine de la ville de Sétif. Mémoire de Magister, Université de Sétif.

Hamidi, W., Laamari, M. & Tahar Chaouche, S. (2013). The parasitoidhymenoptera of aphids associated with the ornamental plants of the city of Biskra. USTHB-FBS-4th International Congress of the Populations & Animal Communities "Dynamics & Biodiversity of the terrestrial & aquatic Ecosystems""CIPCA4"TAGHIT (Bechar) – ALGERIA.

Hassan, A., Dawah-Syed, K., Mohammed, A. & Zatwarnicki, T. (2019). An overview of the Ephydridae (Diptera) of Saudi Arabia*. Zootaxa, 4711*(3). *https://doi.org/10.11646/zootaxa.4711.3.1*

Hulle, M. & Cœur D'acier, A. (2007). Les pucerons, indicateurs de changements globaux? *Biofuture 297:* 44-47.

Jenser, G. (1982). Data to the *Thysanoptera* fauna of Tunisia. *Fol. Entomol. Hung., 43*(1), 55-57.

Kellil, H. (2019). Contribution à l'étude de la bioécologie fonctionnelle des peuplements entomologiques inféodés aux agro-écosystèmes céréaliers dans la région du nord-est algérien (Sétif, Constantine). Thèse Doctorat., Université de Biskra, 135pp.

Ketfi, H. (2018). Bioécologie des insectes nuisibles (Classe Insecta) du blé (*Triticum* Desf 1889) dans la région de Constantine, Algérie. Mém master, Université des Frères Mentouri Constantine.

Kher, S.V., Dosdall, L.M. & Cárcamo. H.A. (2011). The cereal leaf beetle: Biology, distribution and prospects for control, *Insects and Diseases*. *Prairie Soils Crops J. 4*.

Laamari, M. (2004). Etude éco-biologique des pucerons des cultures dans quelques localités de l'Est algérien. Thèse Doctorat, E.N.S.A. El Harrach, Alger.

Laamari, M., Jousselin, E. & Coeur D'acier, A. (2010). Assessment of aphid diversity (Hemiptera: *Aphididae*) in Algeria: a fourteen-year investigation. *Faunistic Entomol. 62* (2), 73-87. https://popups.uliege.be/2030-6318/index.php?id=1286&file=1&pid=1272

Laamari, M., Khenissa, N., Merouani, H., Ghodbane, S. & Stary, P. (2009). Importance des Hyménoptères prasitoïdes des pucerons en Algérie. In *Proc. Colloque Int. Gestion Risques Phytosanitaires*, du 9 au 11 Novembre 2009, Merrakech, Maroc, 581-587.

Lazaro, G.A., Williams, L. & Carpinntero, D.L. (2005). Plant bugs (Heteroptera: Miridae) associated with roodside habits in Argentina and Paraguay : host plant, temporal and geographic rang effects. *Ann. Entomol. Soc. Amer. 98,* 694-702. https://paperity.org/p/96193307/plant-bugs-heteroptera-miridae-associated-with-roadside-habitats-in-argentina-

Leclant, F. (1999). Les aphides et la lutte intégrée en vergers. *Bulletin Technique d'Information France, 249*: 264–273.

Legendre, P. & Legendre, L. (1998). *Numerical Ecology*, Elsevier, Amsterdam, 853 pp. Doi: 10.1016/S0304-3800(00)00291-X

Lemeilleur, S., Selma, Tozanli, S. & Bencharif, A. (2009). Dynamique des acteurs dans les filières agricoles et agroalimentaires. Paris : *CIHEAM. Options Méditerranéennes*: *Série B. Etudes et Recherches, 64*, 93-141. http://om.ciheam.org/option.php?IDOM=567

Leraut, P. (2007). Le guide entomologique, plus de 5000 espèces européennes. Delachaux et niestlé, Paris, France.

Lhaloui, S. (1995). Biology, host preference, host suitability, and plant resistance studies of the barley stem gall midge and the hessian fly (Diptera: Cecidomyiidae) in Morocco. PhD Dissertation. Kansas State University, Manhattan KS, USA.

Lhaloui, S., El Bouhssini, M., Naserlhaq, N., Amri, A., Nachit, M., El Haddoury, D. & Jlibène, M. (2004). Les cecidomyies des cereales au maroc biologie, degats et moyens de lutte*. INRA du Maroc.* https://www.inra.org.ma/sites/default/files/publications/ouvrages/cecidomyies.pdf

Magurran, A.E. (2004). Measuring biological diversity. *Wiley-Blackwell*, Oxford, United Kingdom.

Mehra. K. & Singh, V. (2013). Population dynamics of thrips, Thrips tabaci Lindeman (Thysanoptera: Thripidae) on garlic in an arid ecosystem*. Indian J. Entomol. 75*(2), 171-173. https://doi.org/10.55446/IJE.2022.660

Mujica, N., Khadioli, N., Le Ru, B. & Ongamo, G. & Carhuapoma, P. (2016). American serpentine leafminer, Liriomyzatrifolii (Burgess 1880). In: Kroschel, J.; Mujica, N.; Carhuapoma, P.; Sporleder, M. (eds.). Pest distribution and risk atlas for Africa. Potential global and regional distribution and abundance of agricultural and horticultural pests and associated biocontrol agents under current and future climates. *Lima (Peru). International Potato Center (CIP).* 139-153. https://cipotato.org/riskatlasforafrica/wp-content/uploads/sites/4/2016/11/4.3.3-1.pdf

Murlis, J., Willis, M.A. & Carde, R.T. (2000). Spatial and temporal structures of phéromone plumes in Fields and forests. *Physiol. Entomol. 25*(3), 211-222. https://doi.org/10.1046/j.1365-3032.2000.00176.x

Nadjmi, B., Boukhatem, N., El Jaafri, S., Jlibene, M., Paul, R. & JaxqueminJ, M. (2002). Amplified fragment length polymorphisme (AFLP) analysis of markers associated with H5 and H12 Hessian fly resistance genes in bread wheat. *Rev. Biotechnol. Agron. Soc. Environ. 6*(2), 79-85.

Nasrallah, N. & Lhaloui, S. (2006). Les variétés de blé résistantes à la cécidomye: nouvelle atout pour la céréaliculture au maroc. Bulletin mensuel d'information et de laison du programme national de transfert de technologie en agriculture (PNTTA). *Institut Agronomoque et Vétérinaire Hassan II-Rabat*.

Philips, C.R., Herbert, D.A., Kuhar, T.P., Reisig, D.D. & Roberts, E. A. (2012). Using degree-days to predict cereal leaf beetle (Coleoptera: Chrysomelidae) egg and larval population peaks. *Environ. Entomol. 41,* 761- 767. https://doi.org/10.1603/EN12026

Priesner, H. (1960). A mongraph of the Thysanoptera of the Egyptian deserts. Ed. *Institut du Désert d'Egypte, Elmataria,* 541p.

Razi, S. (2017). Etude éco-biologique des thrips de la région de Biskra. Thèse doctorat, université de Biskra.

Rechid, R. (2011). Les thrips dans la région de Biskra: biodiversité et importance dans un champ de fève. Mémoire de magistère, Université de Biskra, 77pp.

Remaudiere, G., Seco Fernandez. V. (1990). Clés pour aider à la reconnaissance des ailés de pucerons piégés en région Méditerranéenne (Homoptera: Aphidoidae), Universidad de Leon, Leon, France.

Rouag, N., Mekhlouf, A. & Makhlouf, M. (2014). Evaluation de l'infestation par les Criocères des céréales (Oulemaspp.) sur six de variétés de blé dur (*Triticum durum* Desf.) dans les conditions semi arides de Sétif, Algérie. *Revue des Régions Arides, 35,* 1773-1779.

Roy, M., Langevin, F., Légaré, J P.H. & Duval, B. (2008). La cécidomyie orangée du blé *Sitodiplosis mosellana* Gehin (Diptera: Cecidomyiidae). Laboratoire de diagnostic en phytoprotection, MAPAQ. 6 pp.

Saharaoui, L. (2017). Les coccinelles algériennes (Coleoptera, Coccinellidae): analyse faunistique et structure des communautés. Thèse doctorat, Université Paul Sabatier - Toulouse III. Français. https://theses.hal.science/tel-01914941v1/document

Saidouni-Ain Alouane, L. (2012). Diversité de l'entomofaune des céréales et dynamique des populations de la Moche de Hesse (*Mayetioladestructor*) (Diptera-Cecidomydae) dans la région de la Mitidja Occidentale. Mémoire magister. (ENSA). El Harrache-Alger.

Scherrer, B. (1984). Résultats des données. In Biostatique, Gaetan, Morin (eds). Louiseville, Canada; 850 pp.

So, Y.S., Ji, H.C. & Brewbaker, J.L. (2010). Resistance to corn leaf aphid (Rhopalosiphummaidis Fitch) in tropical corn (*Zea mays* L.). *Euphytica, 172,* 373–381. https://doi.org/10.1007/s10681-009-0044-z

Spencer, K.A. (1990). Host specialization in the world Agromyzidae (Diptera). *Series Entomologica 45*. Dordrecht, Pays-Bas, Kluwer Academic Publishers. 444 pp.

Tahar Chaouche, S. (2019). Etude de la biodiversité des Hyménoptères parasitoïdes des pucerons en milieu naturel dans la région de Biskra. Thèse doctoret. Université de Biskra.

Taybi, A.F., Mabrouki, Y., Berrahou, A., Peris-Felipo, F.J. & Chaabane, K. (2016). Contribution à l'étude de la relation «plante-hôte-parasite» entre Elodea canadensis Michx., Hydrelliasp. (Diptera) et Ademondecrescens (Nees, 1811) (Hymenoptera, Opiinae) dans le bassin versant de la Moulouya (Maroc). *J. Mater. Environ. Sci. 7*(7), 2445-2452. https://www.jmaterenvironsci.com/Document/vol7/vol7_N7/261-JMES-2289-Taybi.pdf

Toapanta, M.A., Funderburk, J.E. & Chellemi, D. (2001). Development of *Frankliniella* species (Thysanoptera: Thripidae) in relation to microclimatic temperatures in vetch. *J. Entomol. Sci. 36*(4), 426-437. Doi: 10.18474/0749-8004-36.4.426

Winchester, N.N. (1999). Identification of potential monitored elements and sampling protocols for terrestrial arthropods. *Technical report N° 3:* 227-314.

Zair, N. (2016). Contribution à l'étude de Punaise des céréales dans quelques stations de la région de Tlemcen. Mémoire de Magister.