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Study of the predatory action of some Carabidae against some Aphididae in the region of Ouargla

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Abstracts

Study of the predatory action of Coleoptera against some pests of the phylum Arthropoda in Saharan regions

This work aimed to carry out an inventory of the coleopterofauna in some agricultural envirnments of the region of Ourgla, to study some bioecological traits, the bioecology and the spatiotemporal variations of a coleopteran predator family, the Carabidae, and to testify the role of some carabids in aphids' biocontrol. The study sites (three palm groves with different maintening conditions, a wheat and an alflfa culture) were densely vegetated, presenting 11 botanical families, and characterized with sandy-loam soils, low levels of soil moisture and organic matter and pH values varying between 8.5 and 8.75. Their Arthropodologoical species belonged to 4 classes and 16 orders between which Hymenoptera, Heteroptera and Coleoptera dominated.

Coleoptera inventory showed that palm groves were the most diversified while alfalfa culture terrain were the less diversified. Among the families, Carabidae, Tenebrionidae and Coccinellidae were the most diversified. However Cybocephalidae, Coccinellidae, Carabidae and Tenebrionidae families were the most abundante. In termes of species abundances, *Cybocephalus seminulum, Pharoscimnus numidicus* and *Pharoscimnus ovoideus* were the most dominante in the palm groves, while *Lophyra flaxuosa* dominated in the two other sites. These beetles belong to 7 diet categories clearly dominated with predatory species. Of the 117 Coleopteran species inventoried in the study sites, 28 species were carabids. They belonged to thirteen sub-families among which Harpalinae was the most diversified, Lebiinae came in second, followed by Scaritinae then Carabinae. In terms of abundance, the Cicindelinae sub-family predominated. The Harpalinae subfamily ranked second, than the Lebiinae and Scaritinae. Among Carabidae genera, *Harpalus* and *Scarites* were the most diversified while *Lophyra* and *Cicindela* were the most dominant.

Coming to carabids sptial distribution, diversity and abundances were at their maximun in the first three sites. The Shannon-Weaver index H' in the five sites varied between a minimum of 0.98 bits (site 5) and a maximum of 1.25 bits (site 4), while the values of H'max varied between 3 bits and 3.49 bits. The very similar values of the equitability index at almost all sampling levels (0.25 and 0.42) testified to a high degree of irregularity in the Carabidae population. The Sempson index results, which tend remarkably towards 0, were better able to show the great dominance of one or more species over the others. Hill's values, which were very close and tended towards 0 in the sites 1, 2 and 3, confirmed a higher level of diversity in terms of species richness than in terms of number of individuals. The IndVal analysis revealed the presence of only one species characteristic of the the region of Ouargla in all the study sites (*Lophyra flexuosa)*. Most of the specimens were captured between Spring and Summer.

Concernind aphids inventory, *Aphis craccivora* was the most abundant species then came *A. fabae, A. gossypii* and *M. percicae* respectively, with a maximum of catches recorded on March. The results obtained from the efficacity of some carabid species on aphids biocontrol tests have shown three main points: the number of aphids and the cumulative temperature are closely related, the population density of the predators is one of the factors determining their predation efficiency, the efficacity increases from the big sized species to the small sized ones.As for perspectives, we have to make more efforts to betterstudy the diversity and spatiotemporal distribution of ground beetles in arid ecosystems. That will allow us to identify and locate endemic, rare, or endangered species for conservation. In the future, pest management, particularly aphid control, should take carabids into consideration.

Key words: Carabidae, agricultural environments, Ouargla, diversity, bioecology, biocontrol

Etude de l’action prédatrice des coléoptères contre quelques ravageurs de l’embranchement Arthropoda dans les régions sahariennes

Ce travail visait à réaliser un inventaire de la coléoptérofaune dans certains environnements agricoles de la région d'Ouargla, à étudier certaines caractéristiques bioécologiques, l’appartenance biogéographique et les variations spatio-temporelles de l’une des familles de coléoptères prédateurs, les Carabidae, et à tester le rôle de certains carabidés dans la lutte biologique contre les pucerons.

Les sites étudiés (trois palmeraies présentant des conditions d'entretien différentes, une culture de blé et une culture de luzerne) sont densément végétalisés, présentent 11 familles botaniques et se caractérisent par des sols sableux-limoneux, de faibles niveaux d'humidité et de matière organique et des valeurs de pH variant entre 8,5 et 8,75. Leurs espèces arthropodologiques appartiennent à 4 classes et 16 ordres, parmi lesquels dominent les hyménoptères, les hétéroptères et les coléoptères.

L'inventaire des coléoptères a montré que les palmeraies sont les plus diversifiées, tandis que la culture de luzerne est la moins diversifiée. Parmi les familles, les Carabidae, les Tenebrionidae et les Coccinellidae étaient les plus diversifiées. Cependant, les familles Cybocephalidae, Coccinellidae, Carabidae et Tenebrionidae étaient les plus abondantes. En termes d'abondance des espèces, *Cybocephalus seminulum*, *Pharoscimnus numidicus* et *Pharoscimnus ovoideus* étaient les plus dominantes dans les palmeraies, tandis que *Lophyra flaxuosa* dominaient dans les deux autres sites. Ces coléoptères appartenaient à 7 catégories alimentaires clairement dominées par les espèces prédatrices. Sur les 117 espèces de coléoptères répertoriées sur les sites étudiés, 28 espèces étaient des Carabidae. Elles appartenaient à treize sous-familles, parmi lesquelles les Harpalinae étaient les plus diversifiées, suivies des Lebiinae, puis des Scaritinae et enfin des Carabinae. En termes d'abondance, la sous-famille des Cicindelinae était prédominante. La sous-famille des Harpalinae se classait en deuxième position, devant les Lebiinae et les Scaritinae. Parmi les genres de Carabidae, *Harpalus* et *Scarites* étaient les plus diversifiés, tandis que *Lophyra* et *Cicindela* étaient les plus dominants.

En ce qui concerne la distribution spatiale des carabidés, la diversité et l'abondance étaient maximales dans les trois premiers sites. L'indice de Shannon-Weaver H' dans les cinq sites variaient entre un minimum de 0,98 bits (site 5) et un maximum de 1,25 bits (site 4), tandis que les valeurs de H'max variaient entre 3 bits et 3,49 bits. Les valeurs très similaires de l'indice d'équitabilité à presque tous les niveaux d'échantillonnage (0,25 et 0,42) ont témoigné d'un degré élevé d'irrégularité dans la population de Carabidae. Les résultats de l'indice de Sempson, qui tendent remarquablement vers 0, permettent de mieux montrer la grande dominance d'une ou plusieurs espèces sur les autres. Les valeurs de Hill, qui étaient très proches et tendaient vers 0 dans les sites 1, 2 et 3, ont confirmé un niveau de diversité plus élevé en termes de richesse spécifique qu'en termes de nombre d'individus. L'analyse IndVal a révélé la présence d'une seule espèce caractéristique de la région de Ouargla dans tous les sites étudiés (*Lophyra flexuosa*). La plupart des spécimens ont été capturés entre le printemps et l'été.

En ce qui concerne l'inventaire des pucerons, *Aphis craccivora* était l'espèce la plus abondante, suivie respectivement par *A. fabae*, *A. gossypii* et *M. percicae*, avec un maximum de captures enregistré en mars. Les résultats obtenus à partir du test de l'efficacité de certaines espèces de carabidés pour faireune lutte biologique contre les pucerons ont mis en évidence trois points principaux : le nombre de pucerons et la température cumulée sont étroitement liés, la densité de population des prédateurs est l'un des facteurs déterminant leur efficacité de prédation, l'efficacité augmente des espèces de grande taille vers les espèces de petite taille.

Comme perspectives, nous devons redoubler d'efforts pour mieux étudier la diversité et la distribution spatio-temporelle des carabes dans les écosystèmes arides. Cela nous permettra d'identifier et de localiser les espèces endémiques, rares ou menacées afin de les préserver. À l'avenir, la lutte contre les ravageurs, en particulier les pucerons, devrait prendre en considération les carabes.

Mots clés : Carabidae, milieux agricoles, Ouargla, diversité, bioécologie, lutte biologique

الملخص

دراسة النشاط الافتراسي للخنافس ضد بعض الآفات من فصيلة مفصليات الأرجل في المناطق الصحراوية

هدفت هذه الدراسة إلى إجراء جرد لغمديات الأجنحة في بعض البيئات الزراعية في منطقة ورقلة، ودراسة بعض السمات البيئيةالحيوية، والتغيرات المكانية والزمانية لفصيلة من غمديات الأجنحة المفترسة، وهي فصيلة Carabidae ، وإثبات دور بعض أنواع هذه الفصيلة في المكافحة البيولوجية لحشرات المن.

مواقع الدراسة (ثلاث بساتين نخيل ذات ظروف عناية مختلفة، ومزرعة قمح ومزرعة برسيم) كثيفة النباتات، وتضم 11
عائلة نباتية، وتتميز بتربة رملية طينية، ومستويات منخفضة من رطوبة التربة والمواد العضوية، وقيم pH تتراوح بين 8.5 و 8.75. تنتمي أنواع مفصليات الأرجل فيها إلى 4 فئات و 16 رتبة، تهيمن عليها رتبة غشائيات الأجنحة، ورتبة غير متجانسات الأجنحة، ورتبة غمديات الأجنحة.

أظهر جرد غمديات الأجنحة أن بساتين النخيل هي الأكثر تنوعًا، بينما كانت أراضي زراعة البرسيم الأقل تنوعًا. من بين العائلات، كانت عائلات
Carabidae و Tenebrionidae و Coccinellidae هي الأكثر تنوعًا. ومع ذلك، فإن عائلات
الأكثر Cybocephalidae و Coccinellidae و Carabidae و Tenebrionidaeوفرة الأكثر هي . الأنواع، وفرة حيث من
فإن *Cybocephalus seminulum*و *Pharoscimnus numidicus*و *Pharoscimnus ovoideus*هي
انتشارًا في بساتين النخيل، بينما تهيمن *Lophyra flaxuosa* في الموقعين الآخرين. تنتمي هذه الخنافس إلى 7 فئات غذائية تهيمن عليها بوضوح الأنواع المفترسة .من بين 117 نوعًا من أنواع غمديات الأجنحة التي تم جردها في مواقع الدراسة، كان هناك 28 نوعًا من أنواع الكارابيدات. وهي تنتمي إلى ثلاث عشرة فصيلة فرعية، كان أكثرها تنوعًا هي فصيلة Harpalinae، تليها فصيلةLebiinae ، ثم فصيلةScaritinae ، ثم فصيلة Carabinae. من حيث الوفرة، كانت فصيلةCicindelinaeهي الأكثر انتشارًا. احتلت الفصيلة الفرعية Harpalinae المرتبة الثانية، تليها Lebiinae و Scaritinae . من بين أجناسCarabidae ، كانت *Harpalus* و *Scarites* الأكثر تنوعًا، بينما كانت *Lophyra* و *Cicindela* الأكثر انتشارًا

.بالنسبة للتوزيع المكاني الكرابيدات، كان التنوع والوفرة في أعلى مستوياتها في المواقع الثلاثة الأولى. يتراوح مؤشر شانون-ويفر 'H في المواقع الخمسة بين 0.98 بت (الموقع 5) كحد أدنى و 1.25 بت (الموقع 4) كحد أقصى، بينما تتراوح قيم H'max بين 3 بت و 3.49 بت. وتشهد القيم المتشابهة جدًا لمؤشر التكافؤ في جميع مستويات العينات تقريبًا (0.25 و0.42) على درجة عالية من عدم الانتظام في تعداد خنافس الكارابيد. وتُظهر نتائج مؤشر سيمبسون، التي تميل بشكل ملحوظ نحو 0، هيمنة كبيرة لواحد أو أكثر من الأنواع على الأنواع الأخرى. تؤكد قيمHill ، التي تميل نحو 0 في المواقع 1 و 2 و 3، على وجود مستوى أعلى من التنوع من حيث ثراء الأنواع مقارنة بعدد الأفراد. كشف تحليل IndVal عن وجود نوع واحد فقط مميز لمنطقة ورقلة في جميع مواقع الدراسة .(*Lophyra flexuosa*) هذا وقد تم التقاط معظم العينات بين الربيع والصيف.

فيما يتعلق بجرد حشرات المن، كان *Aphis craccivora* هو النوع الأكثر وفرة، ثم جاء *A. fabae* و *A. gossypii* و *percicae* *M.*على التوالي، مع تسجيل أقصى عدد من الصيد في شهر مارس .أظهرت النتائج التي تم الحصول عليها من اختبارات المكافحة البيولوجية لفعالية بعض أنواع الكارابيد على حشرات المن ثلاث نقاط رئيسية: يرتبط عدد حشرات المن ودرجة الحرارة التراكمية ارتباطًا وثيقًا، وتعد كثافة تعداد المفترسات أحد العوامل التي تحدد كفاءة افتراسها، وتزداد الفعالية من الأنواع كبيرة الحجم إلى الأنواع صغيرة الحجم.

أما بالنسبة للآفاق المستقبلية، فيجب بذل المزيد من الجهود لدراسة تنوع وتوزيع خنافس الأرض في النظم البيئية القاحلة بشكل أفضل. سيسمح لنا ذلك بتحديد مواقع الأنواع المتوطنة والنادرة أو المهددة بالانقراض من أجل الحفاظ عليها. في المستقبل، يجب أن تأخذ إدارة الآفات، ولا سيما مكافحة حشرات المن، خنافس الأرض بعين الاعتبار

الكلمات المفتاحية: Carabidae، البيئات الزراعية، ورقلة، التنوع، البيئة الحيوية، المكافحة الحيوية.

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INTRODUCTION

Introduction

Saharan crops face a number of problems that hinder their development and reduce their yields. These problems can be abiotic, such as winter cold, spring frosts, heat, and salinity, or biotic, such as weeds, fungal and viral diseases, nematodes, and insect pests (MAATOUGUI, 1996).

The use of pesticides is one of the primary methods used to combat crop pests (ESMAIELI VARDANJANI et al., 2013). However, after about a century since the first work on plant pathology, the use of chemical weapons has proven its efficiency in terms of yields, certainly; but the negative impact on environmental health is certain and very often irreversible over long periods of time. It is time to let nature heal itself by giving regulators the time and conditions to do their job and accomplish the task for which they are intended.

It should be remembered that these treatments often prove to be insufficiently effective, or that certain species even develop strains that are resistant to synthetic organic products. To overcome these drawbacks, several researchers are currently looking into biological control methods with the aim of limiting the proliferation and harmfulness of various crop pests.

Among the biological models that can provide us with remedies, we can mention the Carabidae family, one of the best known and most studied groups of beetles in the world. This species-rich family is found in most terrestrial habitats (DAJOZ, 2002).

Currently, around 40000 species of Carabidae have been recorded worldwide, and an estimated one hundred new species are discovered each year (GBIF, 2025).

Carabidae are well known in some North African countries, particularly in Morocco (ANTOINE, 1955-1962; CHAVANON & MAHBOUB, 1998), in Tunisia thanks to investigations by GHANEM and BOUMAIZA (2016) and GHANEM et al. (2017).

In Algeria, the Carabidae were studied in the past by BEDEL (1895-1914), and more recently by OUCHTATI et al. (2012), SAOUACHE et al. (2014), CHENCHOUNI et al. (2015), MATALLAH et al. (2016), DAAS et al. (2016) AMRI et al.(2019) and IBOUD (2023). However, no studies have been conducted to examine the diversity of carabidae in the arid regions of Algeria.

On the other hand, ground beetles are a key group among soil arthropods due to their abundance, their mostly predatory diet, and their often polyphagous feeding habits. They therefore play an important role in controlling insect pests (KOTZE et al., 2011).

These insects include aphids (NIETUPSKIL et al., 2015). The latter cause significant financial losses and are responsible for yield losses in many crops (TAGU et al., 2004). Several studies around the world have focused on the biodiversity of aphids and their natural enemies, including those by FRANCIS et al. (2003); LEROY et al. (2009), CHENGOUROU et al. (2012); MOHAMED et al. (2015); TENDENG et al. (2017); and BELLO et al. (2018). In Algeria, we note the work of LAAMARI and HEBBAL (2006), BENOUFELLA-KITOUS et al. (2014, 2015, 2016, 2019); BOUABIDA et al. (2019). However, none of these studies focused on Carabidae as natural enemies of aphids.

To address the gaps already mentioned, we have attempted to address the following points:

- Draw up an inventory of Carabidae species in order to understand the composition and ecology of the Carabidae community collected in some agricultural envirnments of Ouargla (une des regions arides de l'Algérie)

- To describe the structure of the community using index studies as well as analyses of the spatio-temporal distribution of species abundances.
- To define some bioecological and biogeographical traits of Carabidae
- To testify the role of these insects in the biocontrol of aphids.

This thesis is presented in a classical manner and is divided into 2 chapters:

- The first chapter is devoted to the methodology adopted and the equipment used for the soil analysis, the floristic procession and the methods and equipment that helped us to collect the results and carry out this work.

- The second chapter brings together the results and their discussion, setting out in turn:
    - The soil properties, vegetation characteristics, and arthropods diversity in five chosen agricultural environments of the region of Ouargla.
    - Then, the Coleoptera diversity, spatial variation and their different diet based categories are presented.
    - After that, the biogeography of the Carabidae captured in the study sites, some of their bioecological traits, their structure and spatial and temporal organization are described.
    - Finally, the role of some carabids in controlling the aphids populations is presented and discussed.

A conclusion and perspectives conclude this work.

Chapter I
Material and methods

Chapter I - Material and methods

The first aspects to be considered in this chapter concern the description of the study area as well as the various sites chosen at its level, the presentation of the equipment and methods used, and finally the techniques for exploiting the results.

I.1. - Description of the study area and sampling sites

In the following, we will give a brief overview of the study area, then describe the sites chosen at its level, then explain why they were chosen.

I.1.1. - Presentation of the study region

The northern Sahara, covering 1 million km², is a transition zone between the North African Mediterranean steppes and the Central Sahara (LE HOEROU, 1989). At the tip of the Algerian Sahara, on the northern edge of the great eastern erg, are the oases of Ouargla (Fig. 1). The soil cover of Ouargla is highly heterogeneous and comprises the following classes: crude mineral soils, soils with little development, halomorphic soils and hydromorphic soils (DAOUD and HALITIM, 1994). According to the same author, the mineral fraction consists almost entirely of sand, the organic fraction is very low (less than 1%) and does not permit good aggregation, and water retention. Geomorphology in there takes five forms: erg, reg, sebkha, wadi bed and hamada (DAOUD and HALITIM, 1994). The geological formations of Ouargla contain two main sets of aquifer formations: the intercalary continental at the base and the terminal complex at the top. A third formation of more modest importance is added to the two previous ones: The water table or surface water table (IDDER, 1998).

Ouargla's climate is caracterised with low precipitation, intense light, dry air, frequent winds high evaporation and a wide temperature range. More data from the M.N.O. (2020) are grouped in Tab. 1, APPENDIX). GAUSSEN's umbrothermal diagram for the region of Ouargla, between 2013 and 2022, show the existence of a single dry period spread over the whole year (Fig. 2). According to the Emberger's pluviothermal climagram that enables us to classify a given region into the bioclimatic stage that corresponds to it, based on its temperatures and precipitations, we can see that the bioclimatic stage of Ouargla, during the fortnight 2013 - 2022 is of the Saharan type with mild winter, since the Q3 is equal to 7.06 (Fig.3).

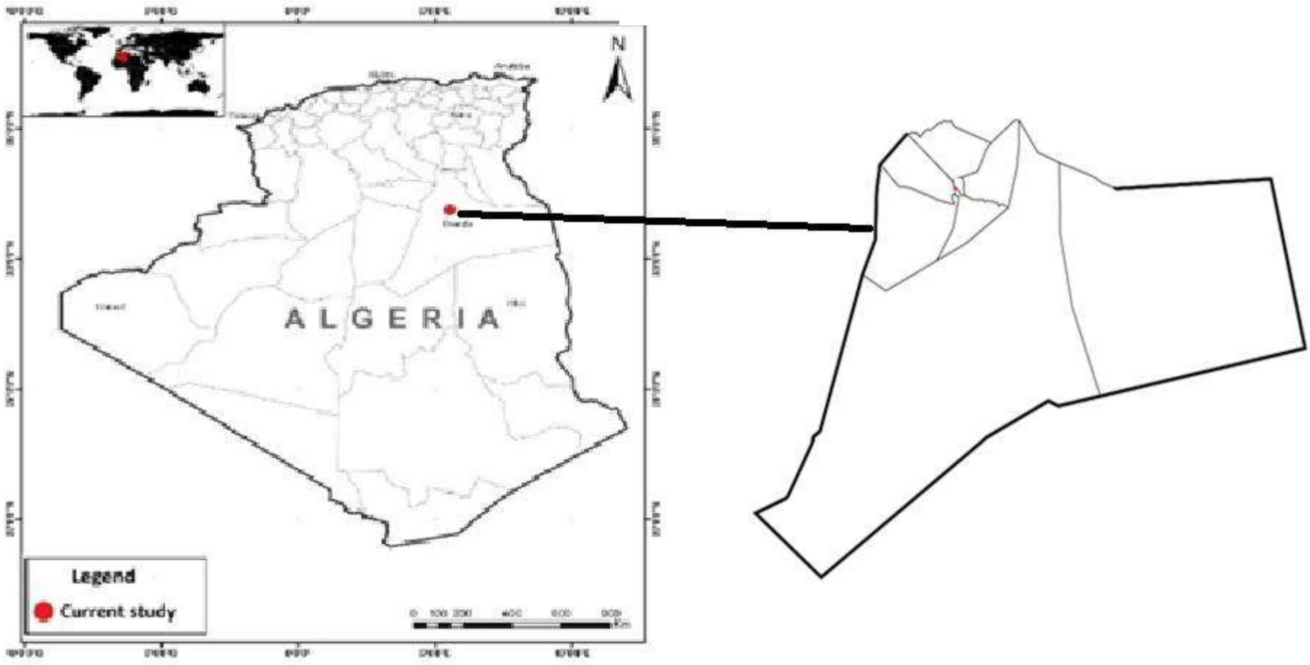

Fig. 1 – Geographical map of the region of Ouargla (COTE, 1998 modified)

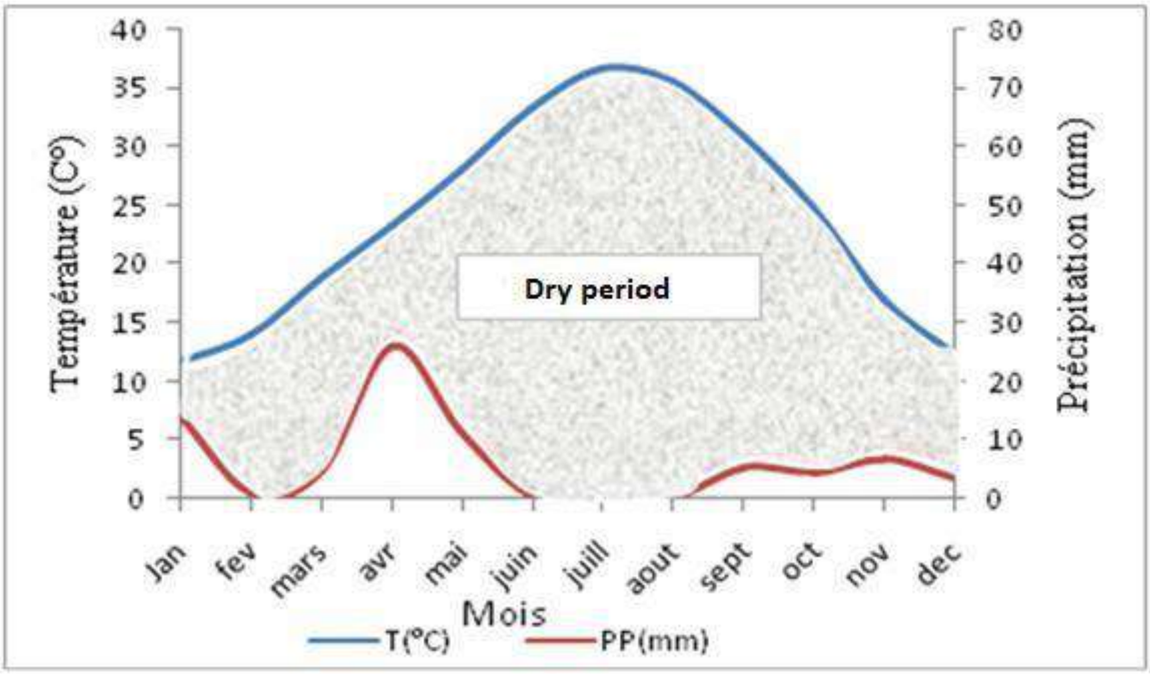

Fig. 2 - Presentation of the GAUSSEN ombrothermical diagramm applied to the region of Ouargla between 2013 and 2022

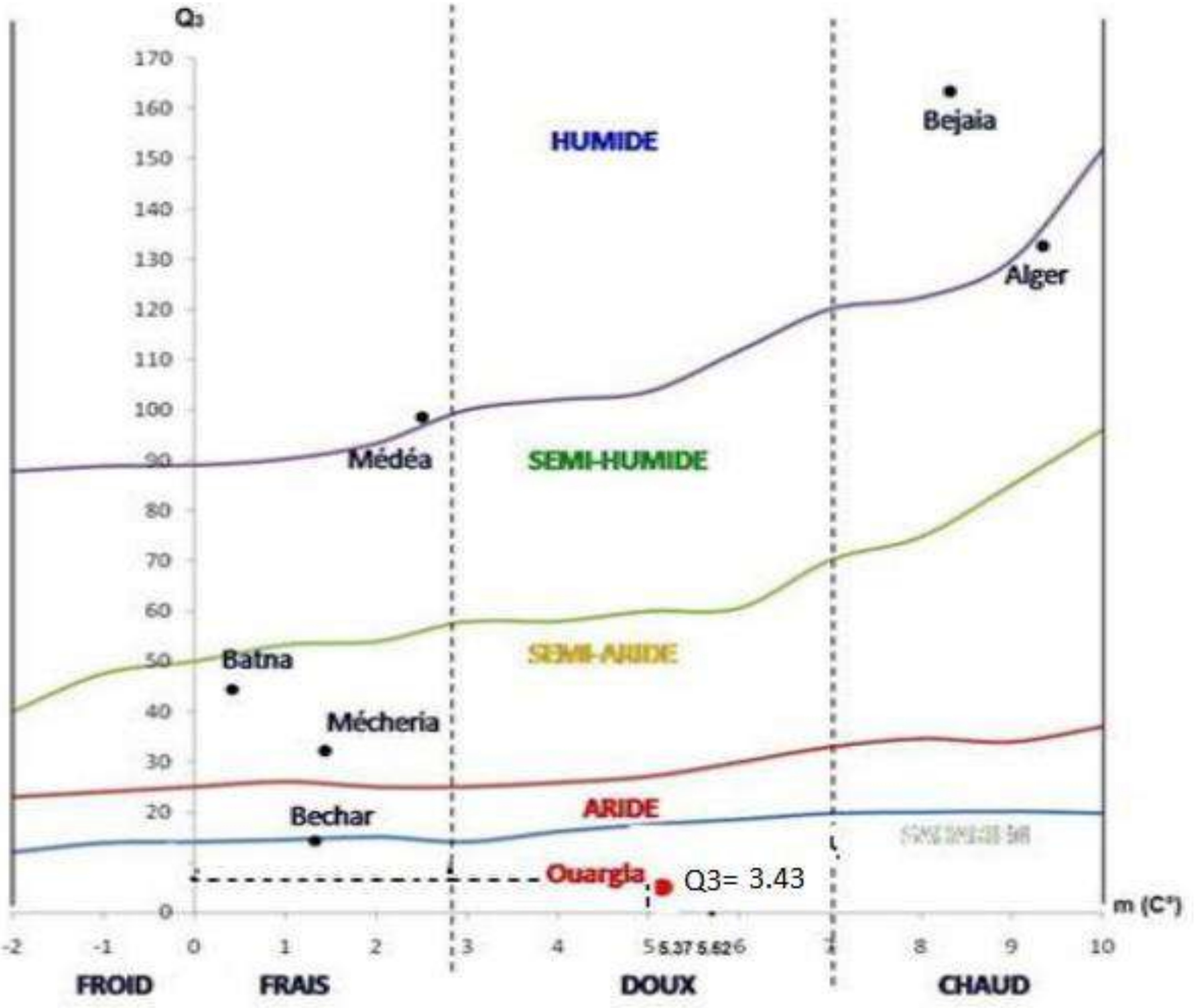

Fig. 3 - Place of the region of Ouargla in the climagramm of Emberger between 2013 and 2022

I.1.2. - Choice of study stations

In order to address the distribution and composition of Coleoptera populations, and its associated arthropods in the region of Ouargla, spatio-temporal monitoring is prescribed. To this end, five agricultural environments were selected. These were the palm grove of Said Otba (named site 1), U.K.M.O. (site 2), M'khadma (Ssite 3), the wheat culture terrain (site 4) and the alfalfa culture terrain (site 5). These sitesdiffer widely, especially in terms of the vegetation that occupies them (nature of plants and overall cover), their maintenance (maintained, semi-maintained and unmaintained phoenicultural gardens) and the method of irrigation. This design reflects an ecosystemic diversity that may reveal comparative elements between the different species inventoried within each habitat. In fact, each sitehas its own intrinsic ecological characteristics. This will later enable us to understand the distribution and ecological preferences of the Coleopteran population (Fig. 4).

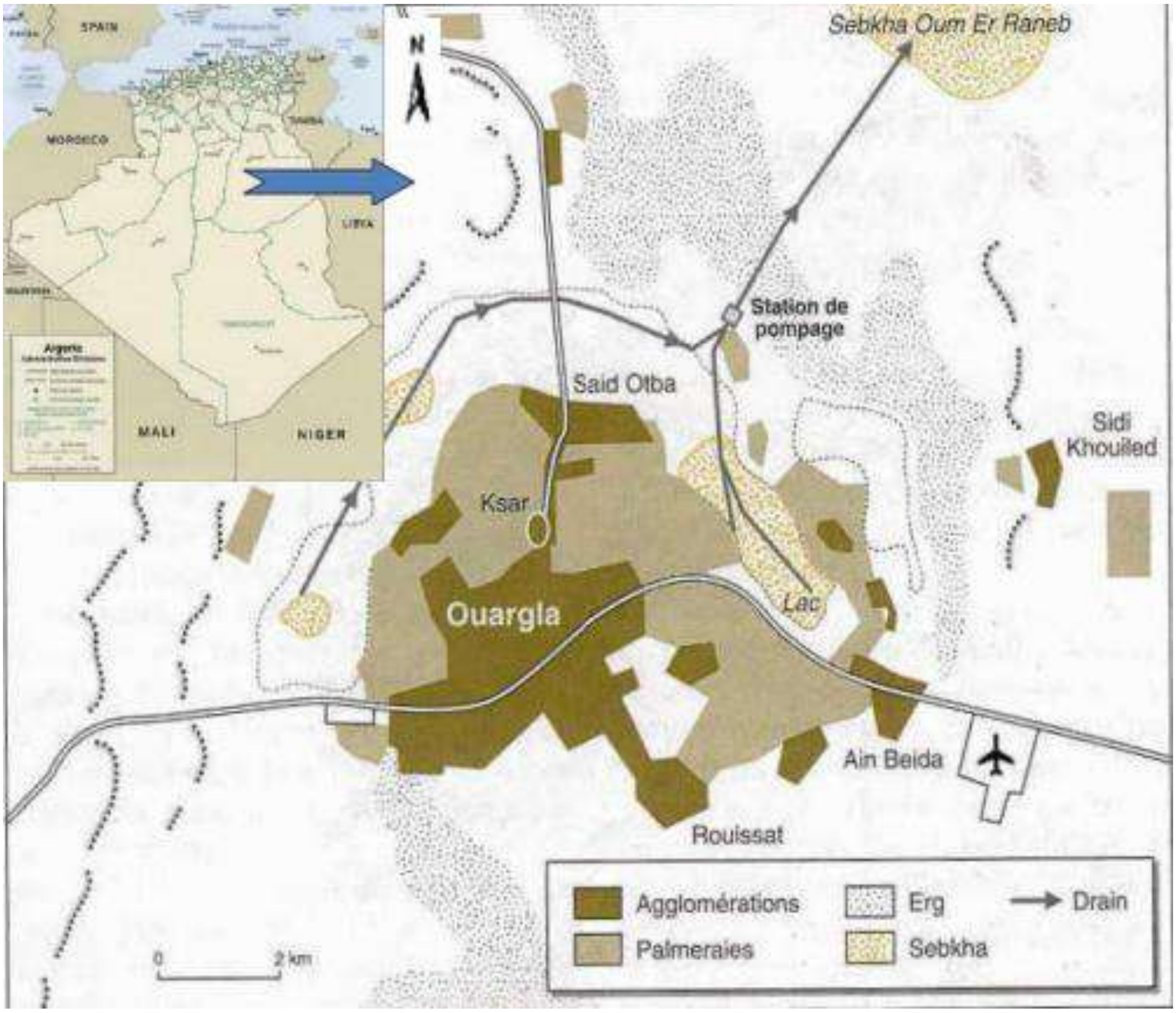

Fig. 4 – Situation of the staudy sitesin the region of Ouargla

I.1.3. - Description of the study sites

The five sites selected in Ouargla are described in detail below.

I.1.3.1. – Palm grove of Said Otba (site 1)

The palm grove of Chott (31°56'N; 5°18'E) is located at the south-eastern end of the Said Otba commune, 10 km from Ouargla town center at an altitude of 137 m. It is bordered to the east by a road leading to other palm groves, to the north by national road number 49, and to the south and west by neighboring palm groves.

Covering an area of no more than 70 m², this garden is considered as a family garden, maintained with anarchic planting and irrigated by submersion (Fig. 5). It contains 33 date palms, of which 54.6% are represented by the Deglet Nour cultivar, 33.3% by the Ghars cultivar and 12.1% by the Takarbouchte cultivar.

I.1.3.2. - Palm grove of the KASDI Merbah University in Ouargla (site 2)

The phoenicultural environment of KASDI Merbah Ouargla's University (31°,57' N and 5°,20'E) is located south-west of Ouargla, 6 km from the town center at an altitude of 132.5 to 134 m. It covers a total surface of 32 ha, of which 14.6 ha are cultivated and divided into four sectors, A, B, C and D, each occupying an area of 3.6 ha. Sectors E, F, G and H make up the remainder, which is uncultivated. The soil has a sandy-loam texture and a distinctive structure, with some gypsum encrustations at certain levels (EDDOUD, 2003). The cultivated areas (A and C) are semi-maintained, with organized planting and flood irrigation (Fig. 6).

I.1.3.3. - Palm grove of M’khadma (site 3)

The palm grove of M’khadma (31°56'N; 5°16'E) is located at the southern end of the M'khadma palm grove, 5 km from Ouargla town center and 136 m above sea level. It is an untended garden with anarchic planting, irrigated by submersion and covering an area of 1 hectare (Fig. 7). It contains 196 date palms (151 Deglet nour, 15 Ghars, 10 Dokkar and 20 Aoula.

I.1.3.4. – Wheat culture terrain of Rouissat (site 4)

Bordered by the town of Ouargla to the east and north and by the national highway to the west and south, the commune of Rouissat covers a total area of 7331 km2, 918 km2 of which is farmed by 1300 farmers. This commune is subdivided into 6 areas: Gara Krima 1, Gara Krima 2, Ain zora, Ain remtha, Djalli gharbi and the ouasis. The latter includes the wheat culture terrain (31°57'N; 5°22'E), with a surface area of around 300 m² at an altitude of 137 m. This terrain is irrigated by sub-mersion (Fig. 8).

I.1.3.5. – Alfalfa culture terrain of Hassi-Ben-Abdellah (site 5)

The palm grove of Hassi-Ben-Abdellah (32°.5 "N and 5°.25 "E), is located in the south-eastern sector of the Hassi Ben Abdellah commune, 26 km from the Ouargla wilaya administrative center at an altitude of 157 m. It comprises 100 date palms (80% Deglet nour and 20% Ghars) and a few crops such as tomatoes, peppers, chillies, cucumbers and alfalfa (Fig. 14). Alfalfa is grown all year round, covering a total area of 200 m2 and located more than 100 m from the palm trees. It is irrigated by a drip system (Fig.9).

Fig. 5 - Palm grove of Said Otba

Fig. 6 - Palm grove of KASDI Merbah Ouargla University

Fig. 7 - Palm grove of M’khadma

Fig. 8 – Wheat culture terrain of Rouissat

Fig. 9 – Alfalfa terrain culture of Hassi-Ben-Abdellah

I.2. - Overview of the applied methods

In this section, we will explain the methods adapted for this work and the equipment used.

I.2.1. - Vegetation analysis

The botanical inventory of the study area was carried out during the first year of the study. All the sites chosen for the fauna inventory were visited as far as possible. Species in flower, fruit or seed were identified. Identification was carried out in several stages: firstly, by referring to the flora of Algeria by QUEZEL & SANTA (1963), supplemented by the flora of North Africa by MAIRE (1952-1987), then the nomenclature was adjusted according to the synonymic index of DOBIGNARD & CHATELAIN (2010 2013) and its updated online version (APD 2023).

In addition, a transect was carried out at each of the selected sites (at the beginning of April

2019) in order to characterize their vegetation typology in terms of structure, composition, physiognomy and land use. For that, we have used the Mayer method cited by MORDJI (1988). This involves scanning individuals belonging to different floristic species in a 500 m² area (50 m by 10 m). The rate of vegetation cover is calculated for each species using the formula :

$$\mathbf{RG = Ss\ x100/S}$$

When - RG: overall cover rate of the species in question ;

- S: surface area of plant transect, i.e. 500 m2 ;
- Ss: Area occupied by a plant species projected orthogonally onto the ground, calculated by the formula: $Ss = \pi r2\ n$ (n: number of clumps in the 500 m2, r: average clump radius).

The overall cover of all plant species is the sum of the covers of each species expressed as a percentage (DURANTON et al., 1982), its formula is as follows: $\mathbf{RG = \sum Ss/S\ x\ 100}$

- RG: Overall cover ;
- S : Area considered (500 m²).

DURANTON et al. (1982) classify plant environments according to their overall cover as follows:

- Open vegetation → R≤ 5% ;
- Very open vegetation → 5 < R≤ 40 ;
- Open vegetation environment → 40 < R ≤ 60% ;
- Dense vegetation environment → 60 < R≤ 95% ;
- Contained vegetation environment → R> 95%.

I.2.2. - Soil analysis

Along the five transects, 10 soil samples were taken from the top ten centimetres of soil (1dm3). Soil samples were analyzed for four parameters: texture, moisture, pH and organic matter content.

The texture of a soil is revealed by its granulometric analysis. Its principle is based on the sedimentation rate of particles separated and dispersed by the destruction of organic matter through hydrogen peroxide attack. These particles are fractionated using a Robinson pipette to determine the fine clay and silt fractions. Fine and coarse sands are then measured by sieving (URBANSKI et al., 2011).

Moisture is the amount of water contained in a soil. This parameter is measured using the Boyoucos method. It is the weight loss after drying at 105°C expressed as a percentage of fresh soil. This is easily determined by simply weighing the soil after it has been oven-dried for a sufficiently long time (constant weight check).

Organic matter content is estimated by measuring organic carbon. It is arbitrarily assumed that soil organic matter is double the organic carbon in uncultivated soil and 1.73 times the organic carbon content in cultivated soil (DUCHAUFOUR, 2001). Carbon content is determined by the ANNE method, which involves oxidizing organic matter with an excess of potassium dichromate (K2Cr2O7) in a sulfuric medium at controlled temperature or boiling. The quantity reduced is in principle proportional to the organic carbon content. Oxygen consumption is assumed to be proportional to sample carbon. Excess dichromate is measured with a solution of MOHR salt, which reduces the dichromate, in the presence of a color indicator (diphenylamine) whose color changes from dark blue to blue-green. Organic carbon content is expressed in elements, percent or per thousand (AUBERT, 1978).

pH is measured on a soil/water extract (1:5) by the electrometric method, using a laboratory pH meter (AFNOR, 1999; MATHIEU and PIELTAIN, 2009).

I.2.3. - Capture of Coleoptera and associated arthropods

Arthropod and coleopterafauna were recorded using interception traps, Mowing net and beating. Obtaining a complete list of the Coleoptera of the region of Ouargla is one of our objectives and one of the most common research questions, which justifies the choice of these methods.

1.2.3.1. - Interception traps

Interception traps are frequently used for studying the fauna of soil arthropods, particularly terricolous beetles (RAÏNO AND NIEMELÄ, 2003). It is a passive capture method, linked to the activity of the species on the soil (SOUTHWOOD, 1988). Using simple pots 12 cm deep and 10 cm in diameter, the technique consists in burying the pots in the soil so that the top edge of the pot coincides with the soil level (fig. 10). The soil is compacted around the trap, so that even small arthropods fall easily into the trap without encountering obstacles (DAJOZ, 2002). A total of 10 interception traps per transect were installed and visited after a whole week to catch as much arthropods as possible. This operation has been repeated monthly for 3 successive years (from September 2019 to August 2022). However, the obtained results came from the identification of only 8 interception traps per month. In order to avoid the effect of the external ecological factors on insects’ distribution, the pots has been installed at the midle of each siteon the same transect.

Fig. 10 - Interception traps technic

I.2.3.2. - Mowing method

The mowing net is used to collect insects that live in tall grass and shrubs, such as grasshoppers, bugs, and ladybugs. It has a sturdy handle approximately 1 m long. The pocket is slightly longer than the diameter of the circle, which measures approximately 40 cm (Fig. 11a) BENKHELIL (1991). This net is used in much the same way as a scythe. It must be wielded vigorously, with both hands if necessary, in order to sweep through the vegetation with rapid sideways movements (Fig. 11b). In this study, we limited ourselves to applying 3 sets of 10 strokes with the scythe net, covering a sample area of 5 m². A single monthly outing was carried out.

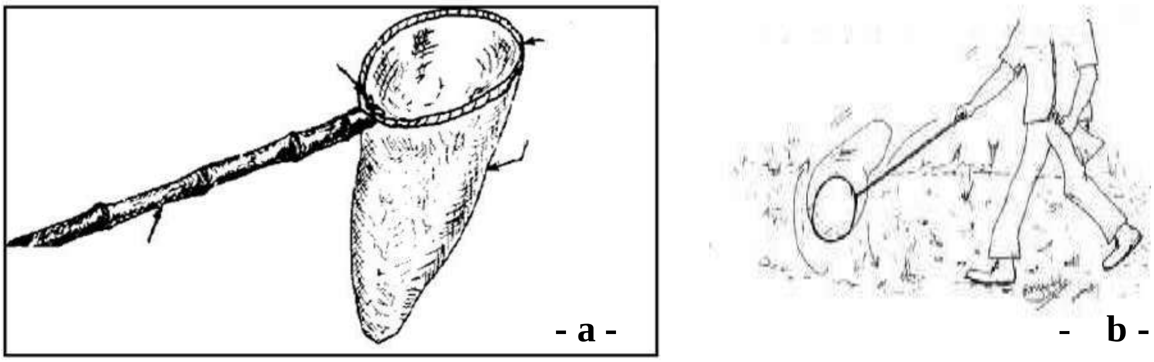

Fig. 11 – Mowing method **(**a- Presentation of the mowing net (FAURIE *et al.*, 1980) ; **b-** Use of the mowing net (DEHINA, 2004)

I.2.3.3. - Beating method

The beating technique consists of striking tree or shrub branches a few times with sharp blows to knock down the insects that are on them. It is recommended to strike the branch twice in the same place to ensure better results. Beating is an excellent method for collecting caterpillars, but also hemiptera, beetles, and other phytophagous insects, as well as many spiders (FRANCK, 2008). As part of this work, we used this method once a month spending one hour per outing. The only tools needed are a stick for beating and a sheet for collecting the catches. The individuals captured in this way are kept in ventilated boxes labeled with the necessary information (date, location, substrate, etc.) (Fig. 12).

Fig. 12 – Beating method (Original)

1.2.4. - Aphids capturing

Aphids observed on the leaves of herbaceous plants are collected once a week, at a rate of ten plants per transect. The samples are collected using a fine brush and placed in Petri pots, that will be then sealed and labeled (Fig. 13).

Fig. 13 – Aphids captiring technique (Original)

I.2.5. - Determination of Coleoptera, Aphids and associated arthropods

The Coleoptera collected are sorted, then preserved in labeled tubes containing 70% ethanol. They were then identified under binocular magnifying glass (up to x40) using reference books (mainly those of BEDEL (1895), JEANNEL (1941 1942), ANTOINE (1962) and DU

CHATENET (2005)) and dedicated websites. Some of the samples needed the expertise of Prof. Salaheddine Doumandji, from the National School of Agronomy in El Harrach (Algeria), to be determined. We also used the reference insect collection of that national school.

Aphids trapped and collected from plants are sorted and identified using the identification keys provided by JACKY & BOUCHERY (1982), AUTRIQUE & NTAHIMPERA (1994), REMAUDIERE et al. (1985), LECLANT (1999) and BLACKMAN & EASTOP (2000, 2006).

Arthropods associated with the coleopterofauna were preserved in petri dishes and determined up to family rank using the following determination keys (PERRIER, 1923, PERRIER, 1927, PERRIER, 1932 and CHOPARD, 1943). The aim of the census of arthropodological species associated with the Coleoptera was to gain an idea of the food availability of these species and the place of this family in relation to the other arthropodological families present at the study sites.

I.2.6 - Efficacity of carabids in controlling aphids populations

In order to follow some Aphis species poputalions growth in presence of some Carabidae species, alfalfa was planted in pots and put in an ambere area under date palms. Three weeks later, Once the alfalfa plants grow, we begin inoculating aphids, then we cover them with tulle to isolate them from other insects. The conditions of the experiment are therefore semi-controlled. The temperature is the same as that received by other plants grown in the field, while humidity is completely controlled by irrigation.

In order to obtain a standard size the pattern of aphid population growth, each pot was inoculated with one mature female per alfalfa plant and per day during three days. During the experiment, the aphids were counted every week on each alfalfa plant in each pot. Aphid stages were not distinguished. Each mounth, one pot is reserved as control meaning that they did not received any carabids . For each Carabidae species, three different densities were tested, 1 individual per pot, 2 individuals per pot and three individuals per pot. Mean temperature were recorded weekly in the experimental field (Fig. 14).

Fig 14. – Experience of aphids biocontrol using carabids (Original)

I.2.6. - Determination of some bioecological traits

The elements presented here concern a few key points in the biology and ecology of Carabidae, enabling us to understand the link between the living environment (its characteristics, the disturbances it undergoes and the context in which it is located) and the species assemblages present there. In particular, this concerns the diurnality of Carabidae, their size, moisture requirements and dispersal capacity, as well as their trophic mode.

I.2.6.1. - Determining the size of Carabidae

The body length of each species is measured from the tip of the clypeus (or labre) to the tip of the abdomen. According to COLE et al (2002), carabid beetles have been classified into 3 size categories: small (<9mm), medium (9 to 15mm) and large (>15mm)

I.2.6.2. - Diurnality

Carabidae inventoried were classified according to their diurnality into diurnal and nocturnal species.

I.2.6.3. - Dispersal capacity

The study of adult dispersal capacity allows us to examine the influence of wing morphology on the ability to colonize new environments. For this reason, one of the most interesting characteristics of the Carabidae as an object for zoogeographic research is the fact that they are both capable and incapable of flight (LINDROTH, 1986). Their dispersal ability is equally variable and, on the basis of the state of wing development, 4 groups can be distinguished: brachypterous, macropterous, dimorphic and polymorphic species.

I.2.6.4. - Trophic groups

The feeding habits of Carabidae are partly linked to the stage of the insect's life cycle. For some species, both adults and larvae are essentially entomophagous, earning them a reputation as highly voracious predators (TENAILLEAU et al .2011). We have subdivided the species collected into three trophic modes:

- Predatory species that mainly consume preys,
- Phytophagous species that feed mainly on plant matter (particularly seeds), which are very few in number and can generally be considered as crop pests,
- Polyphagous species that have a mixed plant and animal diet at the same time.

I.2.6.5. - Moisture requirements

Analysis of all Carabidae in the study area according to their moisture requirements has enabled us to classify them into three categories:

- Hygrophilous species: species requiring soil moisture without being closely linked to the shoreline wetland.
- Mesophilic species: species living in a biotope with neutral soil and major temperature and humidity conditions.
- Xerophilous species: species adapted to biotopes marked by prolonged intense drought.

I.3. - Methods for analyzing stand structure

The various diversity indices currently used in stand ecology enable us to study stand structure with reference to a specific spatio-temporal framework. They enable rapid assessment of stand biodiversity. However, according to GRALL & HILY (2003), their synthetic nature can be a handicap, as much of the information is missing. The description and assessment of general stand structure is based on the use of two variables: species richness and abundance (GRALL & HILY, 2003).

I.3.1. - Specific richness S

This is the total number of species present in a given stand, at a given time, at a given study site (BOULINIER et al., 1998). Species richness is frequently used as a variable reflecting the state of a system, and is often involved in biodiversity management and conservation efforts, as well as in assessing the impact of human activities on biodiversity (NICHOLAS et al., 1998).

I.3.2. - Mean richness (Sm)

The mean richness (Sm) is used to calculate the homogeneity of the stand (RAMADE, 1984). It corresponds to the average number of species contacted during each survey (BLONDEL, 1979). $\mathbf{Sm = S/N}$ where Sm : Average richness ;S: Total richness; N: Number of surveys.

I.3.3. - Shannon-Weaver H' index

This index makes it possible to quantify the heterogeneity of biodiversity in an environment, and to observe its evolution over time (DAGET, 1976; BLONDEL, 1979; LEGENDRE & LEGENDRE, 1979;). This index has the advantage of not being conditional on any prior hypothesis concerning the distribution of species and individuals (BARBAULT, 1992). $\mathbf{H' = -\Sigma\ (Pi\ x\ log2\ Pi)}$ where $\mathbf{Pi = ni\ /N}$ S= Number of species contained in the sample; Pi

= frequency of species i; ni: number of individuals of a species of rank i.

Its value depends on the number of species present, their relative proportions and the logarithmic base. H' is minimal (equal to zero) when the sample contains a single species. It is maximal (theoretically infinite) when all individuals belong to different species, in which case H' is equal to log2 (S).

I.3.4. - The equitability of Piélou J'

The equitability of Piélou J' (1966) accompanies the Shannon index, also known as the equi-repartition (BLONDEL, 1979) or regularity (FRONTIER, 1976) index. This index is used to estimate the distribution of species within a survey by assessing the proportion of dominant and dominated species. It is calculated from the value of H' and the species richness S, and is written as follows: $\mathbf{J' = H'/H\ max = H'/\log(S)}$

Equitability J' varies from 0 to 1, tending towards 0 when almost all the species are concentrated in one or two species (one or two dominant species), and around 1 when all species have the same abundance.

I.3.5. - Simpson D index

This index is essentially linked to variations in abundance between dominant species. The formula for this index is as follows: $\mathbf{D = \Sigma\ Ni\ (Ni - 1)\ /N\ (N - 1)}$ where Ni: number of individuals of the given species. N: total number of individuals. This index tends towards a value of 0 to indicate maximum diversity, and a value of 1 to indicate minimum diversity.

I.3.6. - Simpson's equitability

Noted ES, Simpson's equitability is the ratio between diversity D and species richness S. It varies between 0 and 1 (RAMADE, 2003) and is written $\mathbf{ES = (D - 1)\ /\ (S - 1)}$

I.3.7. - Hill's index

This is a measure of proportional abundance, combining Shannon-Weaver and Simpson's indices: $\mathbf{Hill = (1/D)\ /\ eH'}$ where 1/D: the inverse of Simpson's index.

The closer the Hill index is to 1, the lower the diversity. Hill's index is the most relevant, since it integrates the other two indices. However, it may be useful to use all three indices together to extract maximum information and gain a better understanding of community structure.

I.3.8. - Abundance and relative abundance

Abundance is the number of individuals of a given population present per unit area or volume (RAMADE, 2003). The relative abundance of species in a stand characterises the faunal diversity of a given environment (FRONTIER, 1983). It is calculated using the

BLONDEL (1979) formula:

$\mathbf{AR}\ (\%) = \mathbf{ni\ x\ 100\ /\ N}$ When AR (%): Relative abundance of species in a stand; ni: Number of individuals of species i considered; N: Total number of individuals of all species combined.

I.3.9. - INDVAL index and identification of indicator species

The identification of indicator species is a very common activity in ecology and biogeography. DUFRENE & LEGENDRE (1997) have developed a simple, practical method for identifying indicator species and assemblages of species characteristic of sample groupings. The combination of the relative abundance of a species and its relative frequency is the main innovation of this method. The index is maximal when all individuals of a species are found in a single group and when this species appears in all sites belonging to this group.

For each species i in each survey group j, the indicator value (IndValij) of species i in survey group j is calculated as follows:

$\mathbf{Indvalij = Aij\ x\ Bij\ x\ 10}$ Where $\mathbf{Aij = Nindividuals\ ij\ /\ Nindividuals\ j}$; $\mathbf{Bij = Nsites\ ij - Nsites\ j}$; Aij represents the average abundance of species i within the records of record group j compared to all groups = a measure of specificity Bij represents the number of records occupied by species i among those of record group j = a measure of constancy or fidelity.

Specificity is highest (100%) when the species occupies only one group, and fidelity is highest (100%) when the species is present in all the records of a group. The indicator value of the species is maximum (100%) when specificity and fidelity are maximum

I.3.10. - Statistical analyses

The methods used in this work are based on Correspondence Factor Analysis (CFA), Kruskall-Wallis test and Hierarchical Ascending Classification (HAC). The software used for these analyses was XLSTAT Version 7.5.2 and ESTIMATE S Version 9.0.

I.3.10.1. - Correspondence Factorial Analysis

The term Correspondence Factorial Analysis, reduced to the initials CFA, covers a range of theoretical results, statistical practices and examples of use that have given rise to a great deal of reflection on how it works (CHESSEL et al, 2007).

This analysis is introduced into ecology because it plays an important role for one essential reason: factorial ecology, in its aim of describing fauna, flora and their relationships with the environment, relies on the practice of surveys and provides a number of so-called ecological tables (CHESSEL et al, 2007)L. In the rows, you'll find surveys (plot, sampling, trap, survey, station, point, district, surface, quadrat, segment, point sample, volume of water, soil, air, etc.). The columns show the species of fauna or flora studied (presence-absence of the taxon, number of individuals, conventional abundance score, quantification in percent, logarithmic scale, etc.). Flora-fauna tables (taxon surveys) can be analyzed by AFC: most environments and taxonomic groups have provided analyses of this type (ROUX, G. & ROUX, M., 1967). The method is particularly popular in phytosociology (GUINOCHET, 1973). The analysis was introduced in hydrobiology (LEVEQUE & GABORIT, 1972), ornithology (LEBRETON, 1973) and (IBANEMZ & SEGUIN, 1972). The representation of factorial coordinates as a function of time (DESSIER & LAUREC, 1978) or space (ESTEVE, 1978) introduces the notion of CFA discrimination into ecology. The reciprocal ordination model was identified by HILL (1973) and used, for example, by BATES & BROWN (1981) in phytoecology or by PRODON & LEBRETON (1981) in ornithology.

I.3.10.2. - Classification Ascendante Hiérarchique (CAH)

This consists of progressively assembling individuals according to their similarity, measured using an index of similarity or dissimilarity (DUCHEZ & LOY, 2005). This classification method produces groupings described by a certain number of variables or characters (LEBART et al., 1982). There are several CAH methods and several ways of calculating the distance between two objects, two classes or one object (BENZECRI, 1973). The Bray-Curtis index has been chosen, with the mean agglomerative grouping technique, as recommended by LEGENDRE & LEGENDRE (1984).

I.3.10.3. - Kruskall-Wallis test

A Kruskal-Wallis test is used to determine whether or not there is a statistically significant difference between the medians of three or more independent groups. This test is the nonparametric equivalent of the one-way ANOVA and is typically used when the normality assumption is violated. The Kruskal-Wallis test does not assume normality in the data and is much less sensitive to outliers than the one-way ANOVA (OSTERAGOVA, 2014).

I.3.10.4. - Evaluation of sampling effort

Sampling effort is a measure that is moderately collected during entomological inventories and is difficult to evaluate in any case. Thus, the number of surveys conducted, the number of days or years of prospecting, or the cumulative number of species and individuals could be used. When biological information comes from data sources based on different methodologies, the best solution is clearly to use the number of data points as an indicator of sampling effort. The trend of the curve follows a logarithmic equation (CHAO, 2020).

Chapter II

Results and discussion

II. - Results and discussion on the coleopteran spatiotemporal variations, bioecological traits, bioecology and spatiotemporal variations of the coleopterofauna inventoried in some agricultural environments of Ouargla and the role of some carabids in aphids biocontrol

The content of this chapter is divided into three main parts. The first part contains a characterisation of the microhabitats in which the Coleoptera are inventoried, followed the presentation of spatiotemporal variations of their species. The second part is about some bioecological traits, the bioecology and the spatiotemporal variations of a coleopteran family, the Carabidae. Finally the role of some carabids in aphids biocontrol is presented. The results are both presented and discussed.

II.1 - Characterisation of the microhabitats and spatiotemporal variations of coleopteran species

In this part we will charachterize the microhabitats in which the Coleoptera are inventoried, then we will present their spatiotemporal variations in the region of Ouargla

II.1.1. - Characterisation of the coleopterofaunal microhabitats

An ecosystem is essentially made up of physical, biological or chemical elements such as the environment, fauna, flora and nutrients (DAVIS, 1996). In order to carry out our study, it was necessary to identify the environment in which our coleopterofauna was inventoried. The edaphic conditions of the microhabitats with the characteristics of their plant cover and their arthropodofauna are therefore studied and presented in the following paragraphs.

II.1.1.1. - Soil of the study sites characteristics

Soil is a living environment that contains a particularly rich flora, fauna and microflora that interact with each other. Soil ‘quality’ depends on a number of factors that affect carabid beetles: depth, soil type, pH and moisture content (e.g. DESENDER1982; HOLLAND & LUFF 2000; PFIFFNER & LUKA 2000). Soil moisture is one of the most important factors for most carabid species (HOLLAND et al. 2007). To this end, we carried out a small characterisation of the soils at the study sites by means of granulometric analysis and the measurement of a number of physical parameters, namely organic matter content, moisture content and soil pH.

According to the particle size analysis, and based on the limits of the particle size classes used in the USDA/FAO system, our soils present a textural similarity (sandy-loam type textural class) with a predominance of the coarse sand fraction. In general, soils with a high percentage of sand have good porosity, but low water retention capacity. The results of the various measurements carried out on the soils at the study sitesare shown in Table 2.

Tab. 2 - Results of measurements of organic matter, moisture and pH of soils at the study sites

	Organic matter (%)	**Moisture (%)**	**pH**
Maintained palm grove	0,57	30,62	8,75
Half-maintained palm grove	0,48	10,02	8,69
Non-maintained palm grove	0,59	8,32	8,61
Wheat culture	0,66	11,24	8,64
Alfalfa culture	0,49	9,57	8,50

According to this table, pH values vary between 8.5 and 8.75. In arid regions, soils are generally alkaline (7.5 < pH < 8.5) (DAOUD and HALITIM, 1994). We can also note that soil moisture levels are low in all the environments studied. Generally speaking, and according to DADDI BOUHOUN (2010), humidity is low on the slopes of the Ouargla basin. This low level can be explained on the one hand by the aridity of the climate (the rate of evaporation is higher than the rate of rainfall), and on the other hand by the low water retention capacity of the soil and its texture, which contains a low percentage of clay. At the same time, a relatively high level of humidity has been recorded in the maintained palm grove palm grove. This is due to its location near a built-up area affected by rising groundwater levels. This rise is due to the discharge of drainage water and urban wastewater (IDDER, 2007).

A low level of organic matter was also measured in the soils of the study stations. This is essentially due to the low vegetation cover in these areas. Organic matter has a favourable effect on the soil improving its structure and thus counteracting the effect of sodium (U.S.S.L., 1954). It influences soil structure, promotes the establishment of good physical conditions, increases water retention in sandy soils (STEVENSON, 1994; CRASWELL and LEFROY, 2001; ANNABI et al., 2007) and cation exchange capacity (CEC) (CRASWELL and LEFROY, 2001) and, above all, is a major source of energy and nutrients for fauna and microflora (PELLETIER, 1992).

These edaphic factors are closely interrelated and it is difficult to distinguish the predominant causal factors, especially as they condition the microclimatic characteristics of habitats, which seem to play a fundamental role in distributions (THIELE, 1977). It is therefore highly likely that regional climate, vegetation structure, soil moisture and texture all play a part in creating the specific microclimates that determine local distributions. Even within a seemingly homogeneous station, these factors are the source of heterogeneity, which will be observed in the catch results.

II.1.1.2. - Floristic composition of the study sites

The microclimate is affected not only by the soil, but also by the vegetation, both cultivated and adventitious. Indeed, the floristic composition of a geographical area is the most important biotic component (OZENDA, 1982). Having described the study site and analysed the edaphic parameters, it is essential to assess the floristic composition of the transects where the carabid fauna was surveyed. In what follows, we will present the results of the plant transects applied at the five study stations, as well as the list of the main plant species found there, with a brief characterisation of each of them.

II.1.1.2.1. - List and characteristics of the plant species inventoried in the the study sites

Depending on the type of crop, the structure of the vegetation varies greatly, affecting the microclimatic conditions within the plots. The complete list of plant species present in the transects selected at the 5 study sites, their families, their nature (herbaceous, shrubby, arboreal) and the length of the cycle of herbaceous plants (annual, biennial or perennial), are given in Table 3.

The plant species inventoried at the study sitesbelong to 11 botanical families, of which Poaceae is the most diverse (15.38% to 33.33%), followed by Amaranthaceae (16.67% to 26.67%), Asteraceae (11.76% to 25%) and Fabaceae (5.88% to 15.38%), with the other families, notably Frankeniaceae, Convovulaceae, Malvaceae, Moraceae, Boraginaceae, Tamaricaceae, Zygophyllaceae and Caryophyllaceae, showing low diversity (Fig 15 and Table 3). These species were mainly herbaceous (53.85% to 75%), with a few tree species (6.67% to 15.38%) and shrubs (16.67% to 30.77%) (Fig. 16 and Table 2). Among the herbaceous plants, 28.57% to 55.56% were annuals, while 27.27% to 42.86% were perennials, with some plants being annuals, biennials or perennials (Fig. 17 and Table 3).

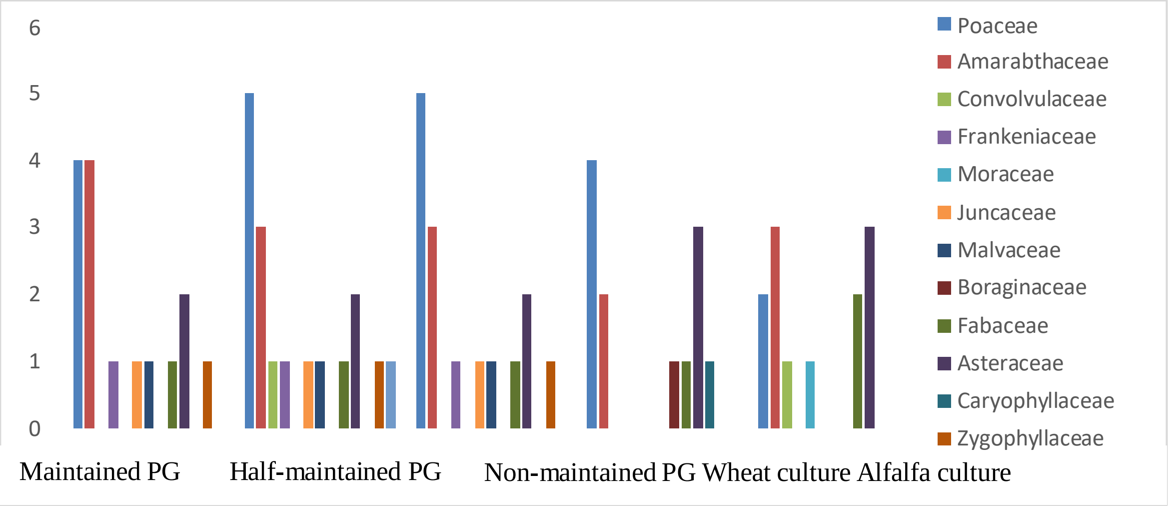

Fig. 15 - Plant families found at the five study sites

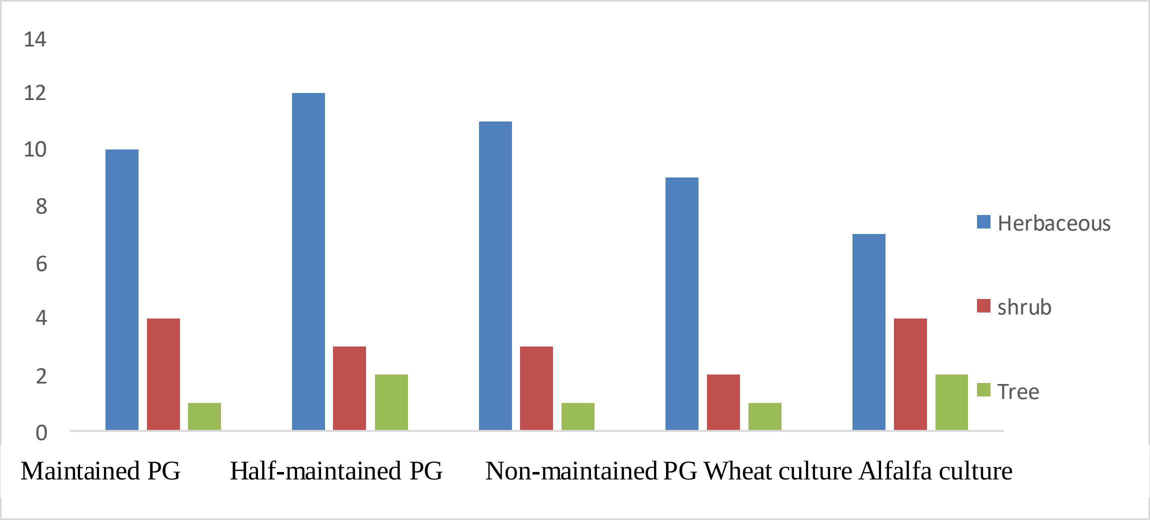

Fig. 16 - Nature of plant species found at study sites

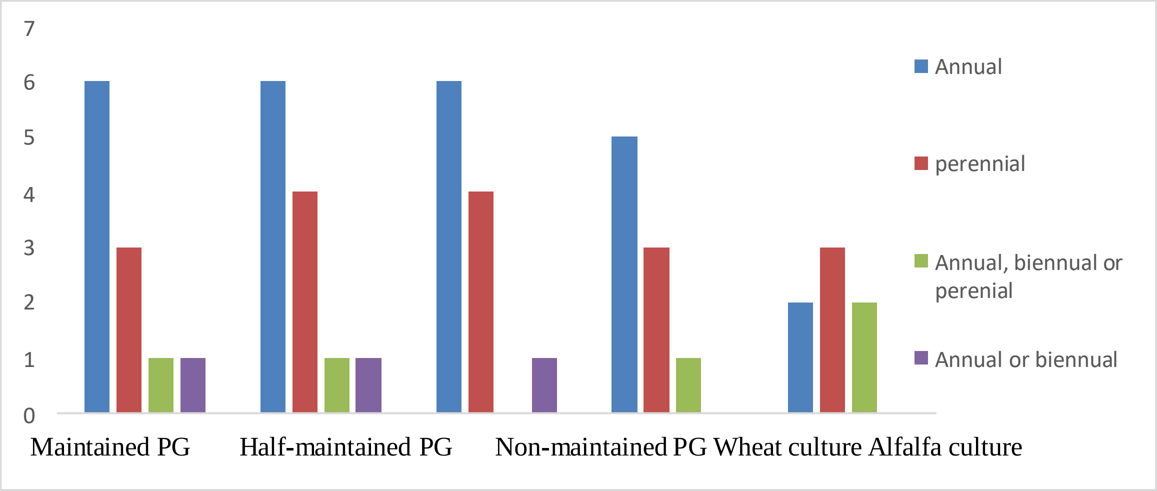

Fig. 17 - Length of vegetative cycle for herbaceous plants at study sites

Tab. 3 - Presence/absence list of some plant species present at the 5 study sitesin 2021

Familly	Species	Nature	Cycle	Site 1	Site 2	Site 3	Site 4	Site 5
Poaceae	*Polypogon monspeliensis*	Herbaceous	Annual	+	+	+	+	-
	Pennisetum clandestinum	Herbaceous	Annual	-	-	-	+	+
	Hordeum vulgare	Herbaceous	Annual	-	+	-	-	-
	Phragmites communis	Herbaceous	Perennial	+	+	+	+	+
	Cynodon dactylon	Herbaceous	Perennial	+	+	+	-	-
	Cutandia dichotoma	Herbaceous	Annual	+	+	+	+	-
	Avena sterilis	Herbaceous	Annual	-	-	+	-	-
Amarabthaceae	*Suaeda fruticosa*	Shrub		+	+	+	+	+
	Beta vulgaris	Herbaceous	perenial	+	-	-	-	+
	Chenopodium murale	Herbaceous	Annual	+	+	+	-	-
	Suaeda fruticosa	Shrub		+	+	+	+	+
Convolvulaceae	*Convolvulus arvensis*	Herbaceous	perenial	-	+	-	-	+
Frankeniaceae	*Frankenia pulverulenta*	Herbaceous	Annual	+	+	+	-	-
Moraceae	*Ficus carica*	Shrub		-	-	-	-	+
Juncaceae	*Juncus rigidus*	Herbaceous	Annual	+	-	-	-	-
	Juncus maritimus	Herbaceous	Perennial	-	-	+	-	-
Malvaceae	*Malva parviflora*	Herbaceous	Annual	+	+	+	-	-
Boraginaceae	*Megastoma pusillum*	Herbaceous	Annual	-	-	-	+	-
Fabaceae	*Medicago sativa*	Herbaceous	Perennial	-	+	-	+	+
	Melilotus indicus	Herbaceous	Annual or biennual	+	+	+	-	-

	Acacia mimosa	Tree		-	-	-	-	+
Lythraceae	*Punica granatum*	Tree		-	-	-	-	-
Asteraceae	*Phoenix dactylifera*	Tree		+	+	+	+	+
	Senecio vulgaris	Herbaceous	Annual	-	-	-	+	-
	Sonchus maritimus	Herbaceous	Perennial	+	+	+	+	+
	Sonchus oleraceus	Herbaceous	Annual	-	-	-	-	+
Caryophyllaceae	*Spergularia salina*	Herbaceous	perenial	-	-	-	+	-
Tamaricaceae	*Tamarix aphylla*	Tree		-	+	-	-	-
Zygophyllaceae	*Zygophyllum album*	Shrub		+	+	+	-	-

+ : Presence, - : Abcence, S. : Site

II.1.1.2.2. - Results obtained from the plant transects applied to the study sites

The transect has the merit of allowing a fairly exhaustive and study of the relationships between species, plant communities and types of environment (DURANTON et al. 1982).

The application of plant transects to the maintained palm grove showed that the latter contains 33 date palms, i.e. 69.5% of the total cover of the station. There are also other spontaneous plants such as *Convolvulus arvinsis* (which contributes for 4.2%), *Suaeda fruticosa* (0.04%), *Juncus rigidus* (0.01%), *Medicago sativa* (0.02%), *Cutandia dichotoma* (2.3%), *Phragmites comminus* (0.1%) and *Sonchus maritimus* (0.1%) (Fig. 18). In the half-maintained palm grove, phoeniculture accounts for 40.01%, while the rest of the surface is occupied by other spontaneous plants such as *Convolvulus arvinsis* (which accounts for 0, 07%), *Suaeda fruticosa* (0.08%), *Medicago sativa* (2.51%), *Cutandia dichotoma* (7.63%), *Phragmites comminus* (0.57%) and *Sonchus maritimus* (0.28%) (Fig. 19). On the other hand, non-maintained palm grove contains 196 date palms (74%) and many spontaneous plants such as *Cutandia dichotoma* (11.77%), *Phragmites communis* (0.39%), *Cynodon dactylon* (05%) and *Juncus maritimus* (0.02%) (Fig. 20). Site The wheat culture is present with other spontaneous plants like *Convolvulus arvinsis* (4.23%), *Suaeda fruticosa* (0.042%), *Juncus rigidus* (0.012%), *Medicago sativa* (0.021%), *Cutandia dichotoma* (2.26%), *Phragmites comminus* (0.12%), *Sonchus maritimus* (0.14%) and *Megastoma pusillum* (0.94%) (Fig. 21). On site 5, the overall rate of soil occupation by vegetation was 33.58% (Fig.18), with *Melilotus indica* contributing for 20.09%, *Acacia mimosa* (7.69%), *Cutandia dichotoma* (5.02%), and other species participating only to a small extent, such as *Zygophyllum album* (0, 42%), *Polypogon monspeliensis* (0.05%), *Cynodon dactylon* (0.01%), *Sanchus oleraceus* (0.1%), *Cheunopodium meural* (0.001%), *Hordeum vulgare* (0.05%) and *Sonchus maritimus* (0.15%) (fig. 22). According to the scale given by DURANTON et al. (1982), all the study sites are classified as densely vegetated environments.

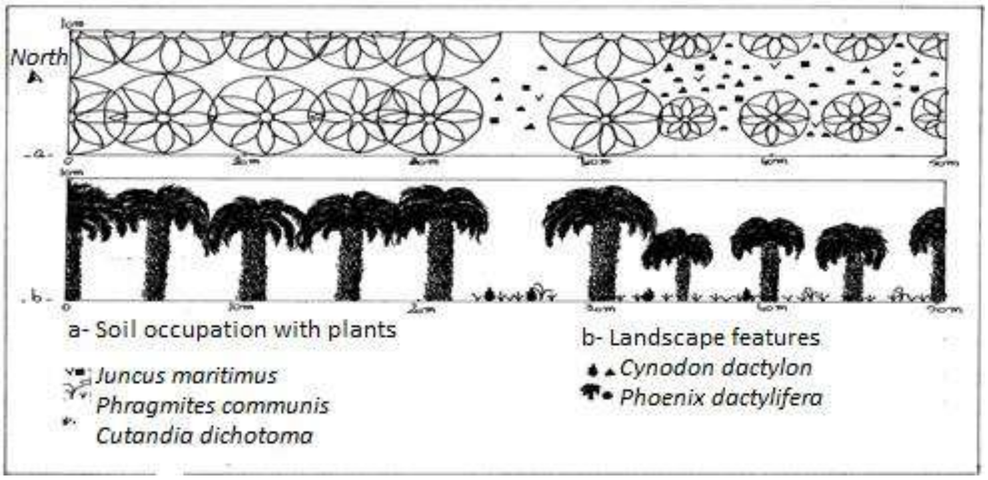

Fig. 18 - Plant transect applied to the maintained palm grove

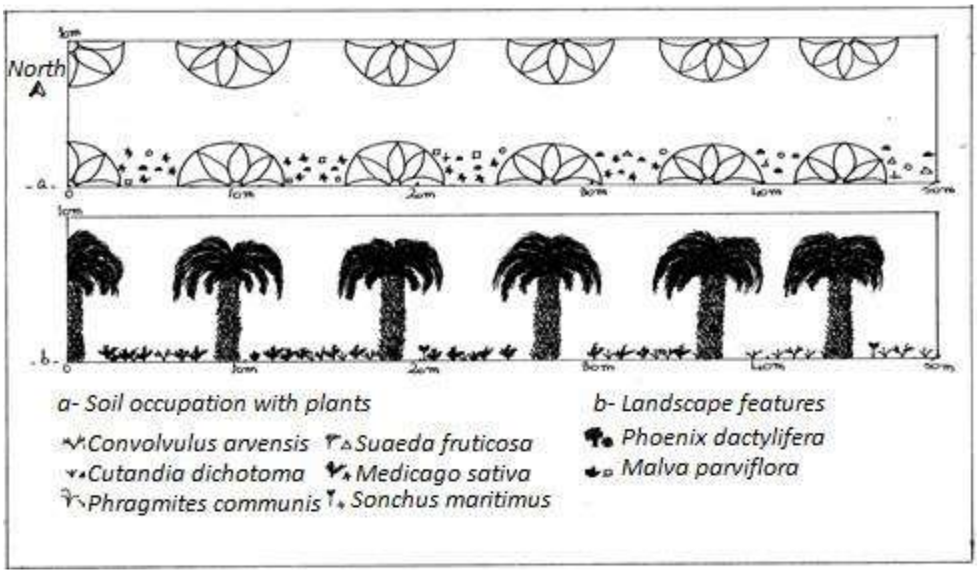

Fig. 19 - Plant transect applied to the half-maitained palm grove

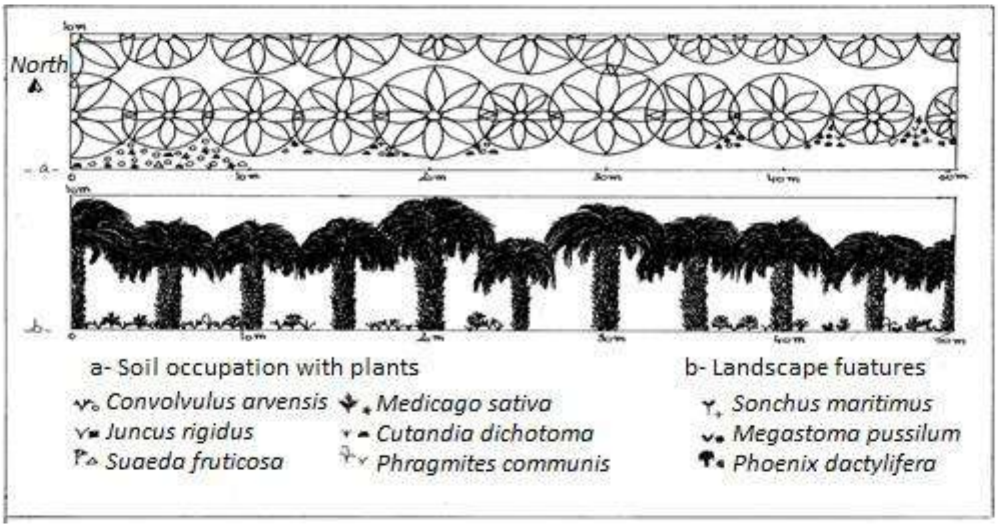

Fig. 20 - Plant transect applied to the non-maintained palm grove

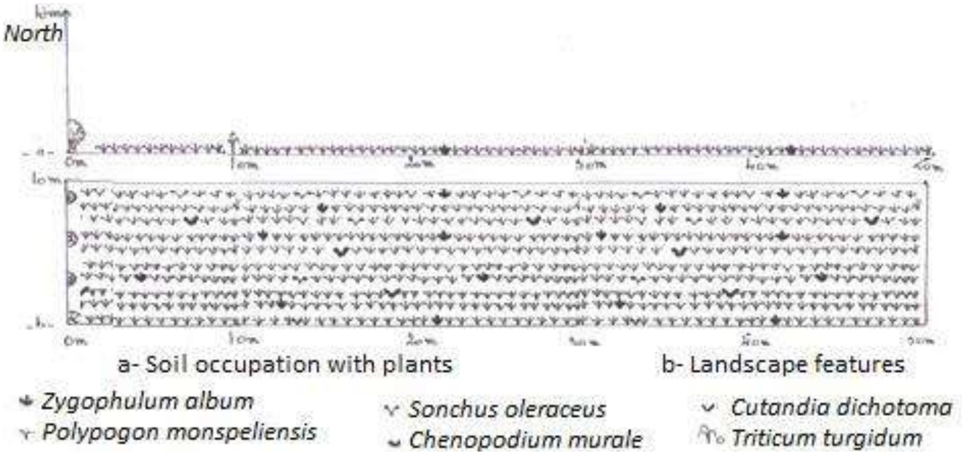

Fig. 21 - Plant transect applied to the wheat culture

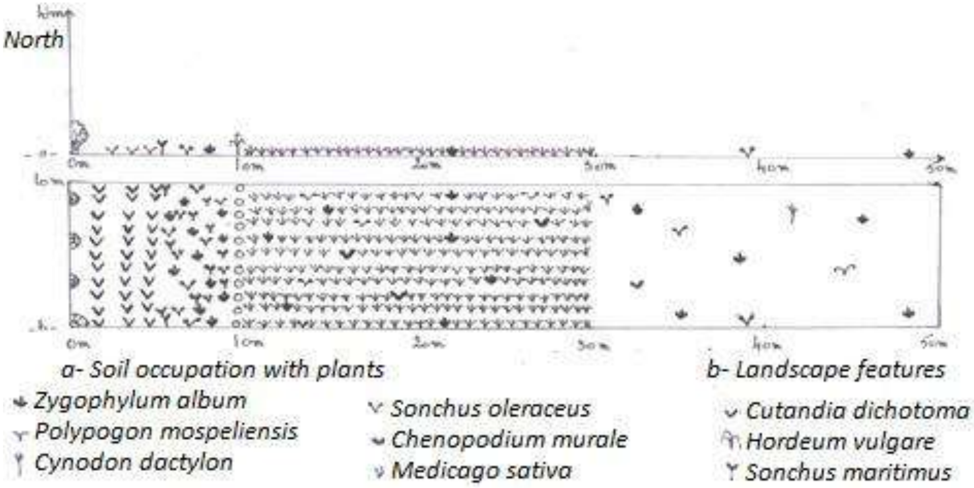

Fig. 22 - Plant transect applied to the alfalfa culture

II.1.1.2. - Composition of arthropods associated with the Coleoptera inventoried in Ouargla

The results obtained from the inventory of arthropods in the five study sitesselected in Ouargla will be presented, exploited and then discussed.

II.1.1.2.1. - Number of individuals and total and average richnesses

The numbers of individuals and the values of total and average richnesses of the arthropods sampled the five study sitesdurin three years (September 2019 to August 2020) are shown in figures 23, 24 and 25. From the figures 23 and 24, we can see that the maximum values of the total richness index and the number of individuals were recorded in the non-maintained palm grove, then the values start to decrease progressively in the other sites until the area planted with alfalfa, where they do not exceed 44 species. Sm values are generally low, not even reaching one species per survey (Fig. 25). The maximum Sm value was recorded in the non-maintained palm grove, making it the most homogeneous environment in terms of species, while the minimum value was found in the alfalfa culture. The results of the other authors depend on the sampling period and environment. CHENNOUF et al (2015), mentioned the presence of 104 arthropod species, divided into 3 classes, 19 orders and 60 families in 3 different environments in the region of Ouargla. Howeaver, AOUIMEUR et al (2015) captured 80 arthropod species in the Mekhadma palm grove in Ouargla. These are divided into 45 families, 14 orders and 4 classes. MEDDOUR et al (2015), using Barber pots on the ERRIAD farm in Hassi Ben Abdellah, recorded only 54 arthropod species belonging to 3 classes, 10 orders and 32 families.

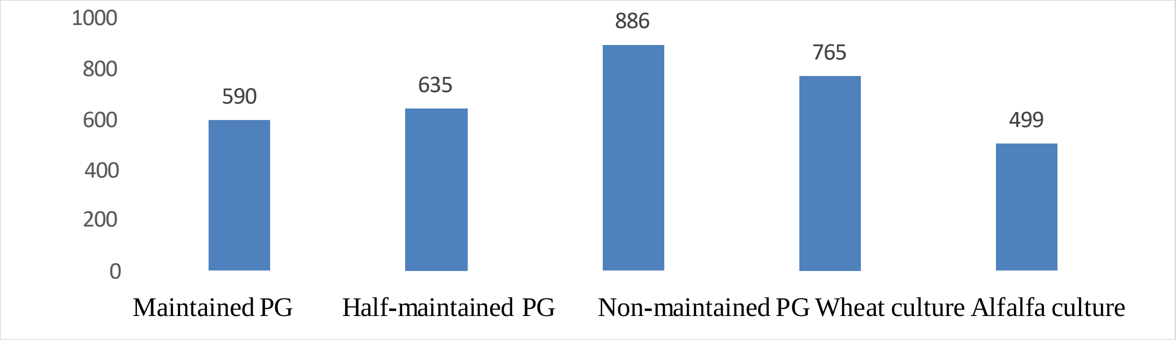

Fig. 23 - Number of arthropods caught in Ouargla

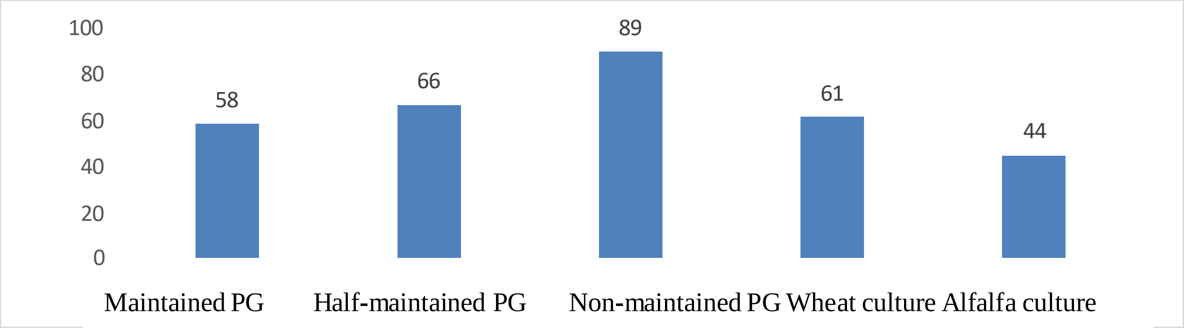

Fig. 24 - Total richness of arthropods caught in Ouargla

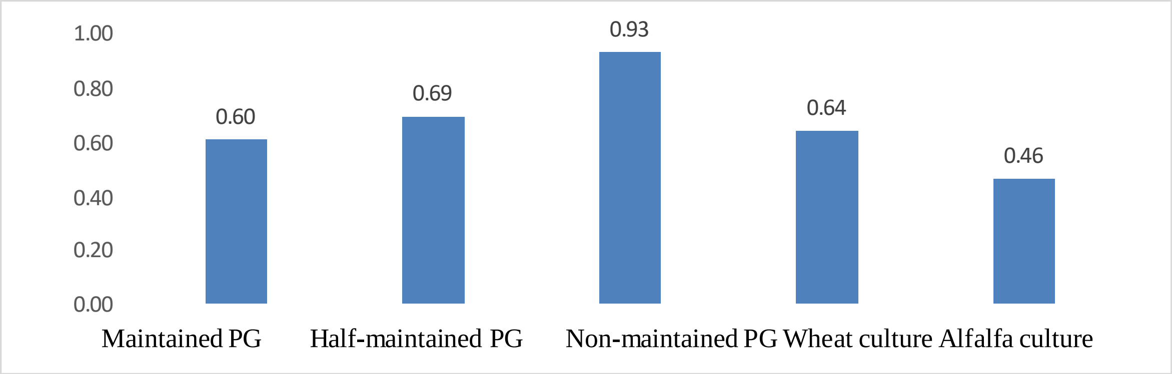

Fig. 25 - Average richness of arthropods caught in Ouargla

II.1.1.2.3. - Relative abundances of arthropod classes

The relative abundances of the arthropod classes sampled at the study sitesare shown in Figure 26. Sampling enabled us to count 4 classes of arthropods. The class Insecta is always the most represented with RA (%) between 87.4% and 93.04%, the class Collembola comes second with RA (%) = 1.53% to 9.82%, then the class Arachnida with RA (%) = 2.05% to 7.46%. The class Malacostraca is the least represented, with RA (%) of no more than 0.2% recorded only on the area planted with alfalfa (Fig. 26).

According to RAMADE (2003), the class Insecta, whatever the ecosystem, is the living group with the greatest species richness. The abundance of Insecta is also mentioned by BENAMEUR-SAGGOU (2009) in three palm groves in Ouargla (80.99% of the total number of invertebrates caught), AOUIMEUR et al. (2015) in the Mekhadma palm grove (S = 67 represented by 1105 individuals) and MEDDOUR et al. (2015) in a cereal-growing environment in Ouargla (AR (%) = 93.4%).

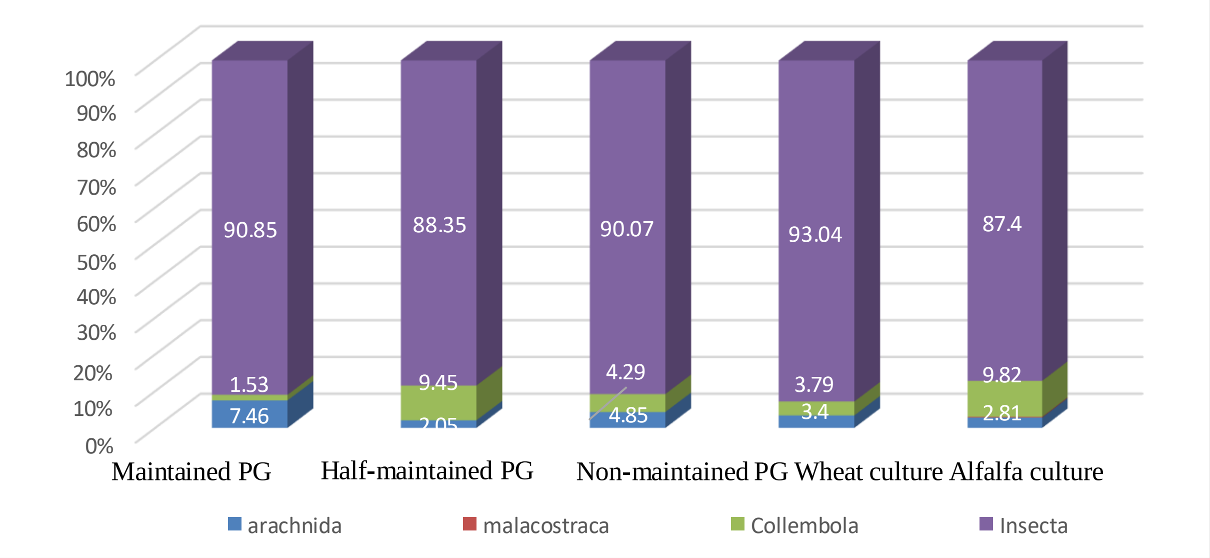

Fig. 26 - Relative abundances of arthropod classes trapped at five agricultural envirments of the region of Ouargla (September 2019- August 2020)

II.1.1.2.3. - Numbers and relative abundances of orders of arthropods

The relative abundances of the orders of arthropods trapped in the Ouargla region between September 2019 and August 2020 are shown in Figure 27.

The inventory resulted in the capture of 16 orders (Fig. 27). In the maintained palm grove, the order Hymenoptera clearly dominated with a rate of 51.69% (Fig. 27). In the same garden, the order Heteroptera is also well represented with an AR% equal to 27.69%, followed by

Coleoptera with 8.14%. The other orders are less represented, either in terms of number of species or number of individuals. In the half-maintained palm grove, the order Hymenoptera was the best represented (AR (%) = 57.95%), followed by the order Coleotera, which accounted for 10.55% of the species caught. The order Heteroptera contributed 10.39%, followed by Podurata with 9.45%.

In the non-maintained palm grove the Hymenoptera (62.42%) are still the most abundant. The Coleoptera came second with 9.93%, the Heteroptera contributed with 8.58%, while the other orders were only slightly abundant (Fig. 27). Furthermore, 61.2% of the individuals trapped in site 4 belong to the order Hymenoptera, and 29.28% are Diptera. The other orders were only present at low levels of abundance (Fig. 27). The individuals trapped in alfalfa culture are divided between 10 orders, including Hymenoptera (68.74%), Podurata (9.82%), Coleoptera (7.82%) and Heteroptera (6.41%). The other orders are weakly represented (Fig. 27). The importance of Hymenoptera in all the study sitesis interpreted by the fact that insect behaviour plays a major role in their capture (ROTH, 1963). This importance is also mentioned by CHENNOUF et al (2015), who state that flying insects are 90% dominant in a cereal- growing environment in Hassi Ben Abdellah (Ouargla) and 52.1% dominant in a plant-growing environment in the same region. In second place, these authors found that Coleoptera were most prevalent (31.8%). Also, the dominance of Hymenoptera is cited by MEDDOUR et al. (2015) who used Barber pots in a cereal pivot in Haassi Ben Abdellah. For their part, KOURIM et al. (2011) listed 8 orders of arthropods in the Central Sahara, with a dominance of Hymenoptera and Coleoptera.

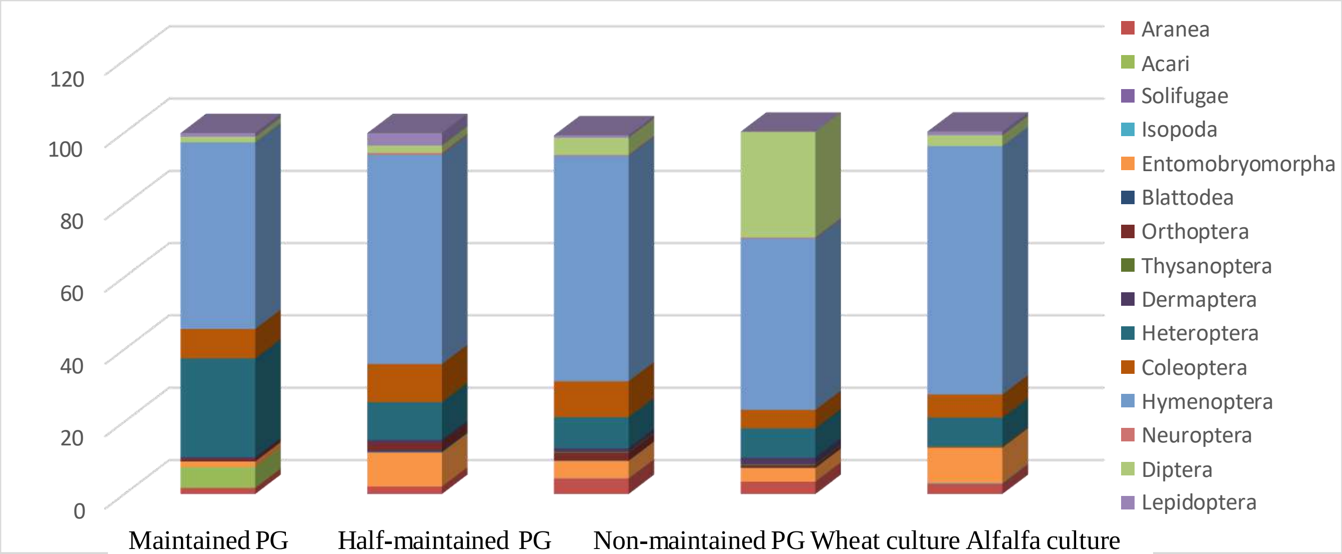

Fig. 27 - Relative abundances of arthropod orders trapped in Ouargla between between September 2019 and August 2020

II.2. – Spatiotemporal variations of the Coleopterofauna inventoried in Ouargla

Looking for a better understanding of the ecological organization of beetles of the five Saharan studied biotopes, we will present all the results that concerne their inventory, than we will classify them according to their nutritional preferences. All the presented results will be illustrated and discussed.

II.2.1. - Total abundances and richnesses of the community of Coleoptera inventoried in Ouargla

The analysis of the overall composition of the coleopterofauna revealed a collection of 117 species belonging to 22 families of unequal importance. The liste, the abundances and the relative abundances of the coleopteran families and species trapped in Ouargla between September 2019 and August 2022 are presented in table 4 (APPENDIX).

Comparing our results on the total richness and abundance of Coleoptera with those obtained by other authors in the humid regions of Algeria, it appears that ours are less significant. Indeed, IBOUD et al. (2024) have identified 83 species belonging to the Carabidae family alone in Lake Tonga (northeastern Algeria). SAHARAOUI et al. (2013) report the presence of 48 species of Coccinellidae in Algeria, of which only 16 species exist in southern Algeria. According to these same authors, the distribution and dispersion of insect populations are influenced by several biotic and abiotic factors that condition their natural behavior. Among these factors, the same authors add, we can cite the distance of the southern regions from the northern regions in relation to the European continent, which reduces species immigration. In their theory, MAC ARTHER & WILSON (1967) assert that distance from the continent reduces immigration, which leads to lower species richness.

In semi arid regions of Algeria, many studies have been carried out. MECHERI et al (2014), using pit traps, air traps, yellow bins and hand harvesting in the forest of Djellal (Djellal), found 29 coleopteran species distributed around 11 families (Géotrupidae, Carabidae, Coccinellidae, Curcuulionidae, Meliodae, Scarabidae, Cetoniinae, Buprestidae, Staphylinidae, Tenebrionidae, Trogidae). Howeaver, GANAOUI et al (2020), analysing the Coleoptera populations of the oak stands of Ouled Bechih Forest, in the province of Souk Ahras, revealed the presence of 76 species, belonging to 21 families. AMOKRANE et al (2020), using pitfall traps, coloured traps, mowing net and sight hunting identified more than 100 species of Coleoptera belonging to 22 different families for a total number of 5698 individuals, while BOUKLI-HACENet al (2012) have yielded 3833 specimens belonging to 140 species thanks to the use of bimonthly trappings in five groups of vegetation chosen in the salt marsh at the mouth of the Tafna River, between october 2009 and september 2010.

The limited research on beetles in palm groves provides an incomplete picture of the diversity of this group. In general, the composition of the beetle fauna collected remains relatively higher in species compared to the results of other studies conducted in the Algerian Sahara. In fact, SEGHIER and DJAZOULI (2018) revealed a beetle community composed of 32 species from 413 individuals caught in two biotopes (Beni Abbès and Tabelbala), belonging to the saharan bioclimatic level at temperate winter, using interception and attractive traps. It is classified into 10 families and 26 genera. Also, BAKROUNE et al (2023) were able to collect a total of 1671 individuals of Coleoptera, belonging to 42 species, 38 genera and 12 families in three durum wheat terrains in the Biskra region.

The presence of a significant number of Coleoptera order species was also indicated by DEGHICHE-DIAB & BELHAMRA (2019) in their generalized entomological inventory. Likewise, CHENNOUF et al (2015) and MEDDOUR et al (2015), found that Carabidae were the most important family after Formicidae. That observed and proved diversity and abundance of coleopteran species can be explained by their large presence in the world (AUBER, 1999) with over 400000 species described (DAJOZ, 2003).

The efficiency of traps against the different orders was also discussed by autors, NIEMELA & SPENCE (1994) reported that the design of used trap can be also another factor that explains their efficiency against different species of Coleoptera order (crawler, flying). Our results agree with those of WINCHESTER & SCUDDER (1993) who tried several methods to capture insects' specimens and found that some of them were mostly present in pitfall traps type. Also, food availability seems to be a key factor for certain species (BAKER & DUNNING, 1977; LOREAU, 1984). This factor is linked to site productivity, but also to microclimatic factors.

On the other hand, the total coleopteran abundances and richnesses were totally different from a site to another. The maximum was recorded in the non maintained palm grove with 6853 specimens belonging to 65 species, followed by the maintained and the half-maintained palm groves with 4369 and 3684 specimens belonging to 52 and 51 species respectively. The velues of abundance are largely different in the remaining sites (wheat and alfalfa cultures) with 539 and 525 specimens belonging to 27 and 23 species respectively (Fig. 28 and Fig 29).

Climatic conditions (Dajoz, 1985) under palm groves as well as the presence of host plants, and the presence of prays favor development of insects and maintain their multiplication ((DEGHICHE-DIAB et al., 2020; BERTOLACCINI et al., 2011; COUTURIER, 1973). HANSKI & COMBFORT (1991) and PONEL (1995) demonstrated that there is a positive correlation between the number of plant species, the abundance of food resources, and the abundance of beetles. Thus, the specific characteristics of each habitat in terms of vegetation composition can lead to quantitative and probably also qualitative differences in the entomofauna present (LAMARRE et al., 2011).

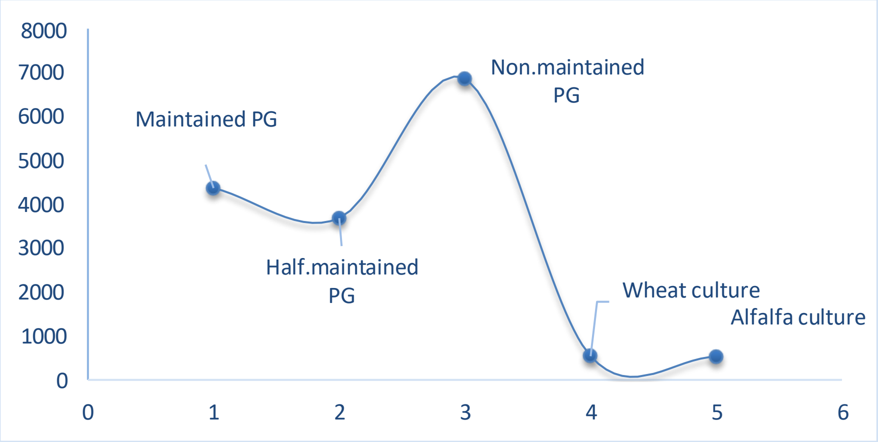

Fig. 28 - Abundances of Coleoptera trapped in the 5 sample sites chosen in Ouargla between September 2019 and August 2022

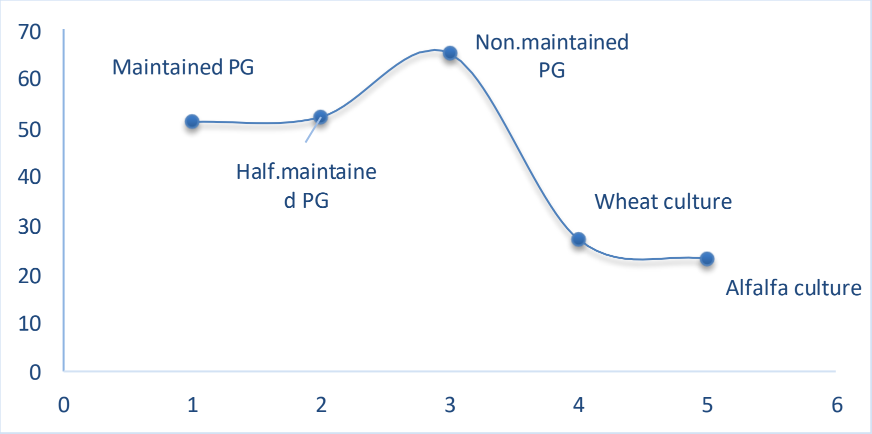

Fig. 29 - Richnesses of Coleoptera trapped in the 5 sample sites chosen in Ouargla between September 2019 and August 2022

II.2.2. – Abundances and richnesses of the coleopteran families inventoried in Ouargla

The abundances and the richnesses of the coleopteran families inventoried in all the 5 sites chosen in the region of Ouargla, between September 2019 and August 2022, using three sampling methods (Barber pots, swepping net and beating) are presented in the figure 30.

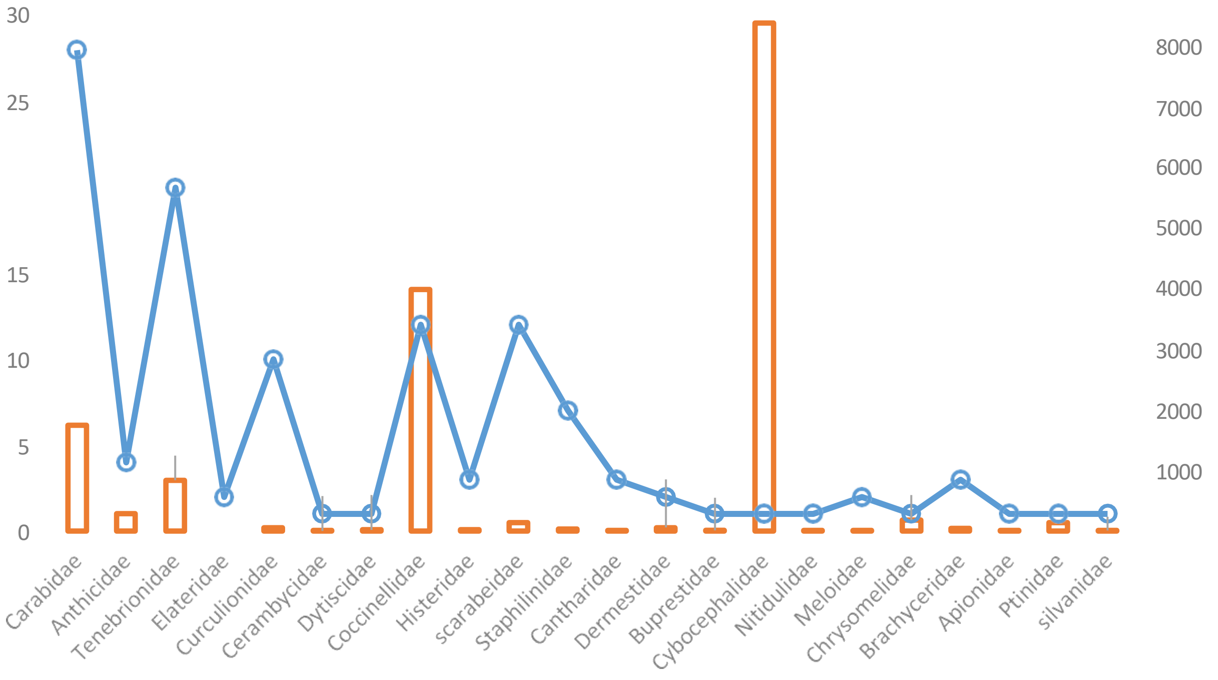

Fig. 30 - Abundances and richnesses of coleopteran families trapped in Ouargla between September 2019 and August 2022

Among the families, Carabidae was the most diversified with 28 species (presenting 23.93 % of the total number of species). Tenebrionidae comes in second with 20 species (17.09 %), followed by Coccinellidae and Scarabeidae with 12 species each (10.25 % each), then curculionidae with 10 species (8.54 % a each) (Fig. 30). In terms of abundance, the Cybocephalidae family predominates and accounts for more than a half of the Coleoptera inventoried (52.48 %). The Coccinellidae family ranks second with 25 %, than the Carabidae and Tenebrionidae with 10.9 % and 5.23 % respectively. The relative abundances of the remaining families (Anthicidae, Curculionidae, Chrysomelidae, Scarabeidae, Dytiscidae, Histeridae, Staphilinidae, Cantharidae, Nitidulidae, Elateridae, Buprestidae, Brachyceridae, Silvanidae, Apionidae, Dermestidae, Cerambycidae, Meloidae, Ptinidae) are relatively low (Fig. 30 and Tab. 4-APPENDIX).

In some inventories done in semi-arid regions of Algeria, the family of Tenebrionidae was the most dominant, but in other studies it was not the case. We can cite here the work of BRAGUE-BOURAGBA et al (2007) who montionned that the abundant four Coleoptera families (Tenebrionidae, Carabidae, Curculionidae and Scarabaeidae) represent 58 species and 2402 subjects, the Tenebriobidae largely dominating among them, with 43.1% of the species and

84.1% of the Coleoptera subjects, followed by the Carabidae (29.3% of the species and 10.6% of the subjects), and the Curculionidae (17.2% of the species and 4% of the subjects), the Scarabeidae representing only 10.4% of the species and 1.3% of the Coleoptera subjects. BRAGUE BOURAGBA et al (2006) making an inventory of four beetle families (Tenebrionidae, Carabidae, Curculionidae and Scarabaeidae) and a study of soil characteristics in nine siteslocated within three phytosociological groups and different soil characteristics during a year, have collected a total of 3142 individuals belonging to 71 species. Tenebrionidae and Carabidae were also the most abundant families. In contrast, GANAOUI et al (2020) revealed that the family wich species richness is the highest was Scarabaeidae (22%), followed by Carabidae (16%) while AMOKRANE et al (2020) found that the Carabidae predominate then come Curculionidae, Chrysomelidae, Scarabidae and Staphylinidae families in a decreasing order.

In arid regions, it was the same. Litterature did not prove the predominance of one family but it was either Tenebrionidae (SEGHIER and DJAZOULI 2018), Coccinellidae or Carabidae (BAKROUNE et al 2023).

Despite the difference, all the authors agree on the dominance of Tenebrionidae, Carabidae and Coccinellidae among all the inventoried coleopteran families. Differently of all of them, we have noted the predominance of Cybocephalidae in the palm groves against Carabidae in the wheat and alfalfa cultures. That can be due to the use of the method of beating while they did not use it. The dominance of Cybocephalidae in the palm groves seems to be favored by the important presence of *Parlatoria blanchardi* which is the main pray of that predator (Fig. 23). The use of beating as a method of sampling has also caused its dominance among the inventoried Coleoptera. The efficiency of traps against the different orders was also discussed by autors, NIEMEL & SPENCE (1994) reported that the design of used trap can be also another factor that explains their efficiency against different species of Coleoptera orders.

The importance of the Carabidae, either in our case or in the works already cited, seems to be favored by the important entomological procession characterizing their living environments and offering them sufficient food availability. Carabids are bioindicators of habitats; they regulate the populations of certain harmful and saprophagous species (slugs, springtails, caterpillars) (CLERGUE et al., 2004; KOTZE et al., 2011). The habitats studied here, due to their structure, great diversity of facies, bioclimates, and soil quality, are conducive to the establishment of fauna that are likely to be prey for this group of insects. The Tenebrionidae turned out to be the second best-represented group of insects, in species' number and the fourth one in subjects' number. That can be due to the dense vegetation cover (Tab. 3) and the considerable entomological diversity (Fig. 26 and 27) that characterizes our study sites, offering these omnivorous insects favorable conditions to live.

Coccinellidae was also one of the most abundant Coleoptera families thanks to the entomological diversity existing in the sampling sites (Fig. 27). In fact, its dominant species were either coccidiphagous (*Pharoscimnus numidicus* and *Pharoscymus ovoideus* feeding on *Parlatoria blanchardi*) or aphidiphagous (*Coccinella algerica* and *Adonia variegate* feeding mainly on Aphis species).

II.2.3. - Spatial variations of the abundances, relative abundances and richnesses of coleopteran species captured in Ouargla

In the palm groves (the maintained, the half-maintained and the non-maintained palm groves) *Cybocephalus seminulum* was the most dominant species among all the coleopteran species inventoried (65.7 %, 55.4 % and 51.7 % respectively). *Pharoscimnus numidicus* (10.7 %,13.2 % and 12.6 %) and *Pharoscimnus ovoideus* come second (5.44 %,9.15 % and 6.17 %). Then come *Lophyra flexuosa* with 4.86 %, 6.7 % and 5.26 % respectively. *Coccinella algerica* and *Adonia variegata* are also well represented (Fig. 31, 32, 33 and Tab. 4- APPENDIX). Differently, in the wheat culture, we have noted the dominance of *Lophyra flexuosa* (34.1 %), followed by *Adonia variegata*, *Anthicus floralis*, *Anthicus antherinus* and *Anthicus quadriguttatus* with 4.17 %, 8 %, 4.17 % and 2.5 % respectively (Fig. 34 and Tab. 4-APPENDIX). In alfalfa culture, we found that *Lophyra flaxuosa* was the most anundant (47 %), followed by *Ouelma melanopus* (25 %), *Adonia variegate* (10.5 %), *Anthicus antherinus* (6.1 %), *Coccinella algerica* (3.34 %), *Brachycerus barbarus* (5.01 %) and *Pheropsophus africanus* (3.06 %) (Fig. 35 and Tab. 4-APPENDIX). Likewise, BAKROUNE et al (2023) studying the ecology of coleopteran species based in three sites of the region of Biskra found that the most represented species were *Coccinella septempunctata* (424 specimens), *Oulema melanopa* (342 specimens), *Hippodamia variegata* (243 specimens) and *Psilothrix viridicoerulea* (238 specimens). However, BELHADID et al. (2014) identified *Calathus fuscipes algericus* as the most abundant species in Djurdjura cedar plantations, while GHANNEM et al. (2017) found that *Chlaenius chrysocephalus*, *Carterus rotundicollis*, and *Amara aenea* dominate beetle assemblages in northern Tunisia.

According to BRUSTEL et al. (2006) and SILVA et al. (2008), the richness and abundance of some families such as Carabidae can be very significant in the most degraded environments. Species require that the food resources offered by the environment in which they live be effectively available for their development (LINDENMAYER et al., 2008).

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.

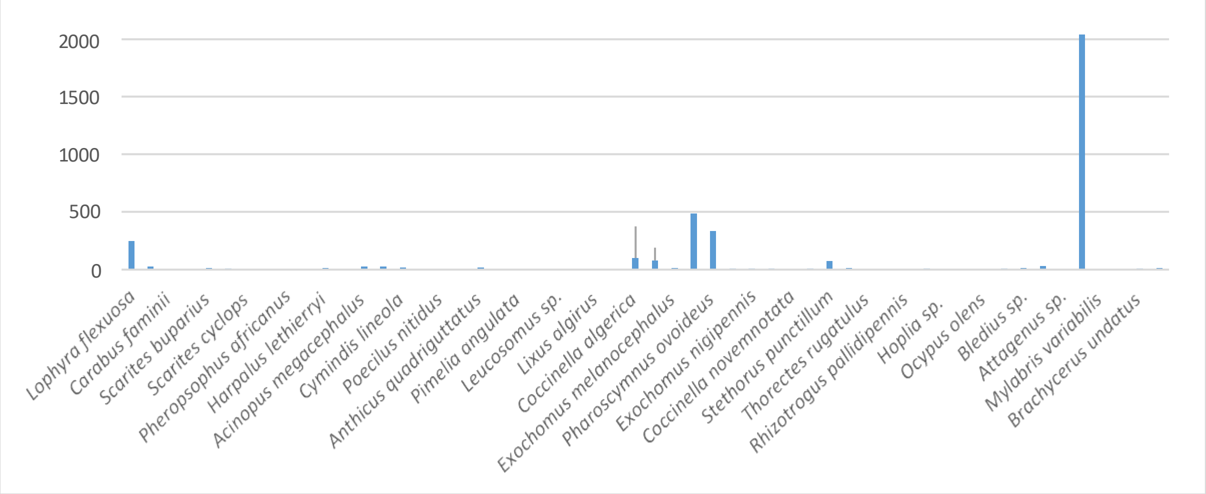

Fig. 31 - Abundances of Coleoptera trapped in the maintained palm grove between August 2021 and September 2024

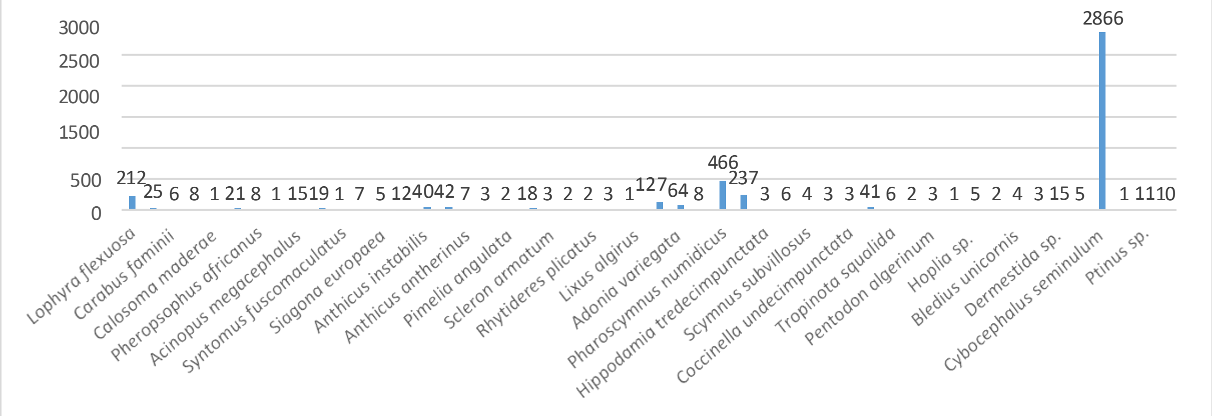

Fig.32 - Abundances of Coleoptera trapped in the half-maintained palm grove between August 2021 and September 2024

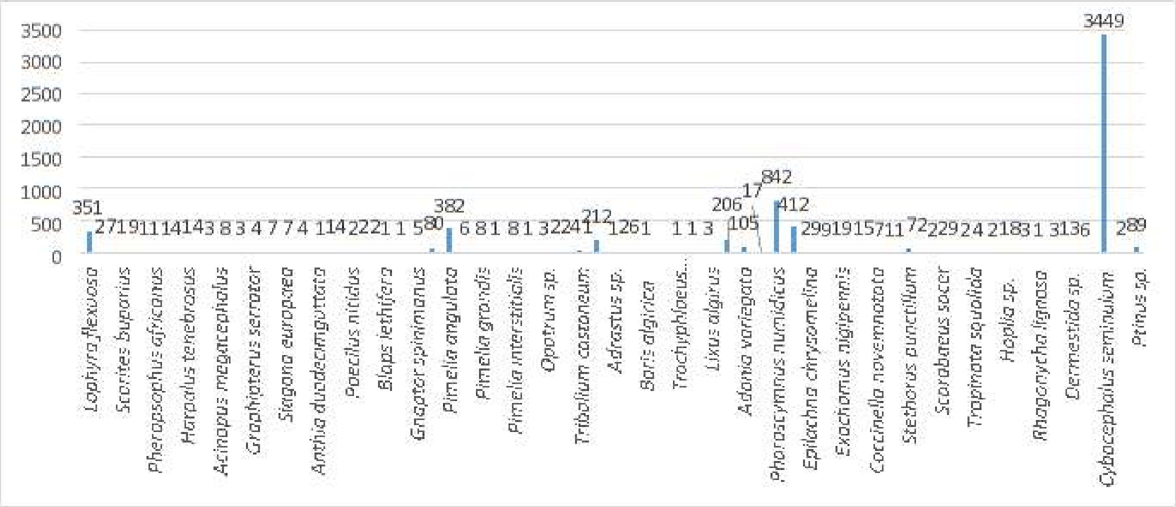

Fig. 33 - Abundances of Coleoptera trapped in the non-maintained palm grove between August

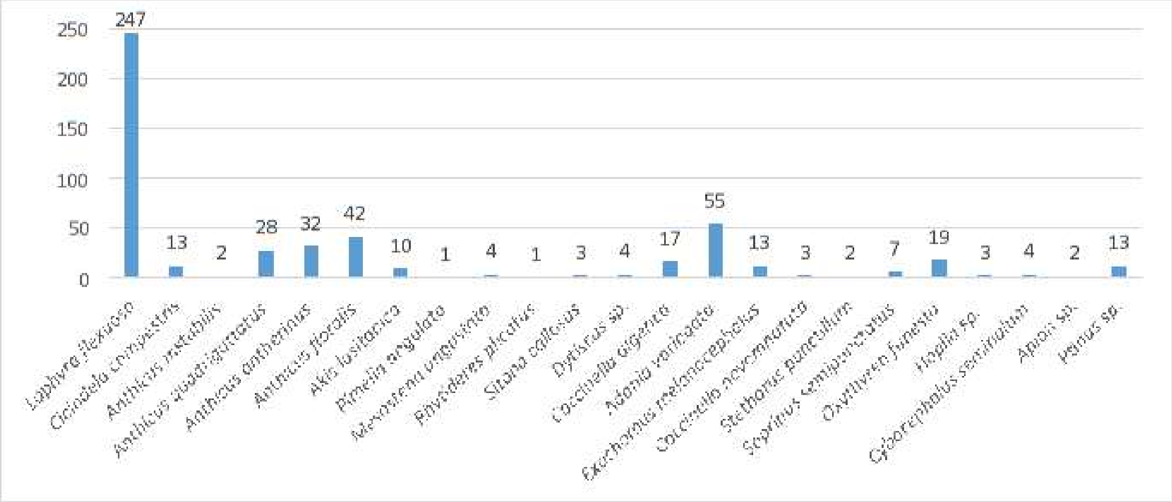

Fig.34 - Abundances of Coleoptera trapped in the wheat culture between August 2021 and September 2024

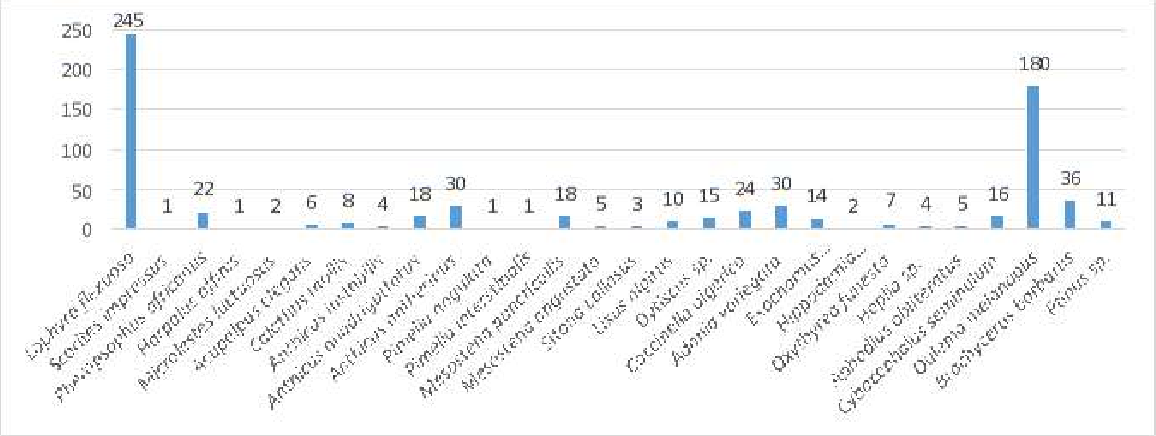

Fig.35 - Abundances of Coleoptera trapped in the alfalfa culture between August 2021 and September 2024

II.2.4. - Estimated species richness

The rarefaction and extrapolation sampling curves based on the collected data of Coleoptera sampled in Ouargla between September 2019 and August 2020 are presented in the figure 36.

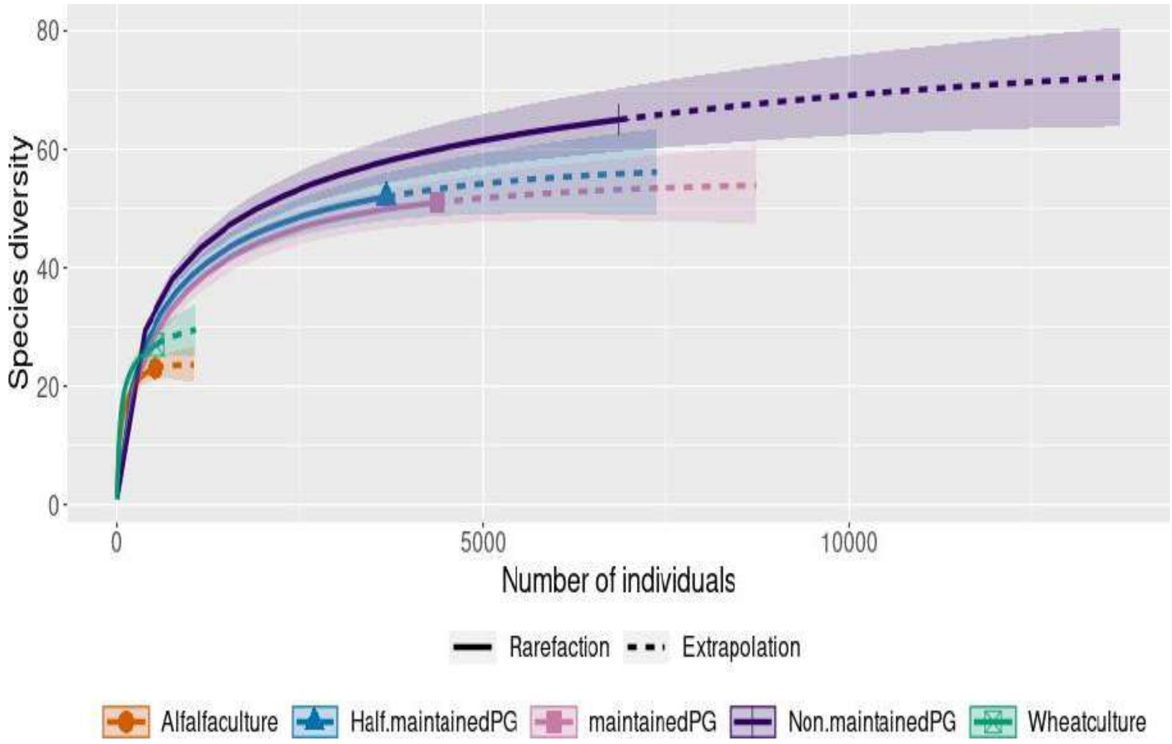

Fig. 36 - Species richness estimates (with 95% confidence intervals) for the estimators Sest (analytical) based on 100 randomized samples (Colwell 2013) for the total data of Coleoptera sampled in Ouargla

In rarefaction and extrapolation (R/E) sampling curves of species diversity exhibited a consistent pattern, with the diversity parameters for the non-maintained palm grove was above the curves of the remaining sampling sites. The 95% confidence intervals for the five samples in rarefaction/extrapolation curves were disjoint, implying a significant difference.

Furthermore, we can observe that the rarefaction/extrapolation curves for the three palm groves kept increasing with the increase of number of individuals (Fig. 36). However, the rarefaction curves for wheat and alfalfa cultures demonstrated that sampling was carried out correctly and that few species were not captured.

II.2.5. - Diet categories of the coleopterofauna captured in Ouargla

The total abundanses and richnesses of diet categories for Coleoptera species caught in Ouargla and their spatial variation are presented here. He results are exploited with some ecological indices and the kruskall-Wallis test.

II.2.5.1. - Total abundances and richnesses of the coleopteran categories diet based

According to MAC ARTHER, 1972 data on the diversity of the coleopterofauna and their temporal and trophic distribution show that in balanced communities, there are close relationships between the quality and diversity of available resources on the one hand, and the diversity of species present on the other. To validate this hypothesis, we monitored the dynamics of Coleoptera and their trophic categories during the three-year period in the study stations. Categorization of coleopteran species was carried out through species identification, based on their production services in various functional groups.

Thus, we determined 7 diets, 56 predatory species, 31 phytophagous species, 24 omnivorous species, 2 carnivous and 2 polleniphagous species, one xyllophagous and one saprophylic species (Fig. 37 and table 4 -APPENDIX). The catches were 89% (14196 specimens) dominated with predatory species, then came omnivorous and phytophagous species with 7% and 3% respectively. The remaining categories are weekly presented (Fig. 38). According to ACHOURA & BELHAMRA (2010), the predator rate is 20.83% of the total catch. They are in second place. They are followed by saprophages and lastly by parasites and polyphages, in a work carried out in the palm grove of El Kantara. However, DEGHICHE-DIAB (2009), mentioned a high percentage of phytophages 41.73%, Zoophages 36.52% and polyphages 21.73% in the Biskra oases.

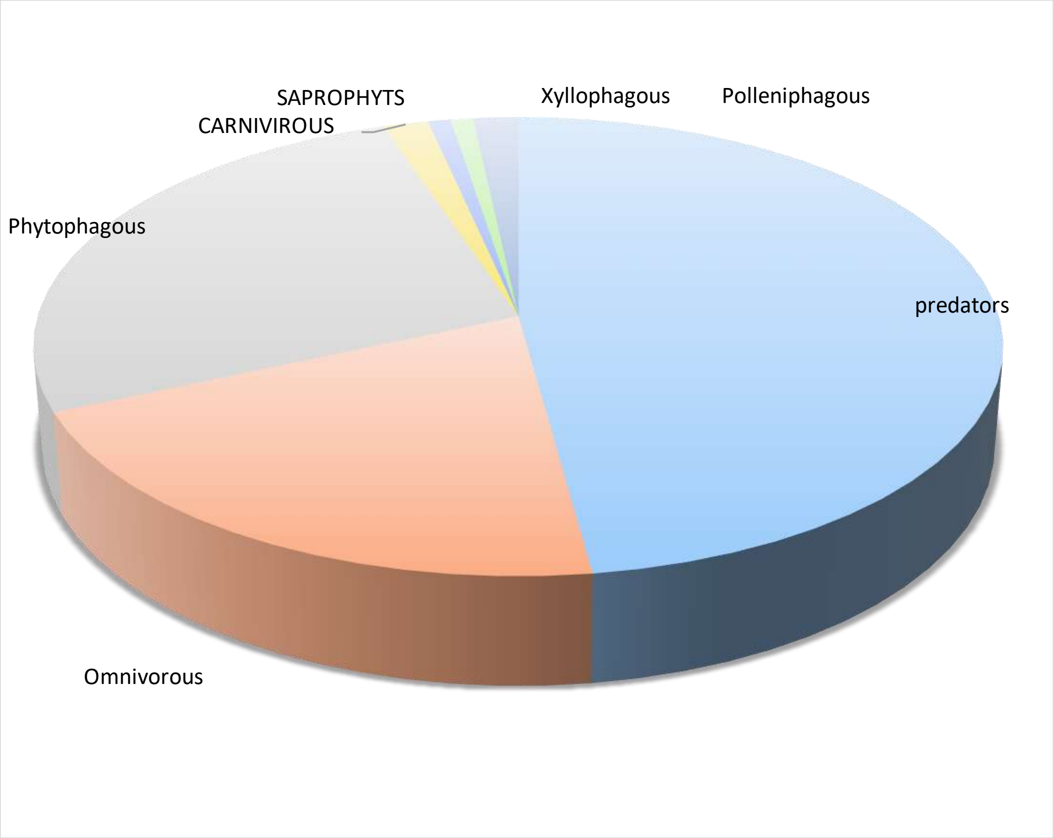

Fig. 37 – Richnesses of the diet categories of the inventoried coleopteran species

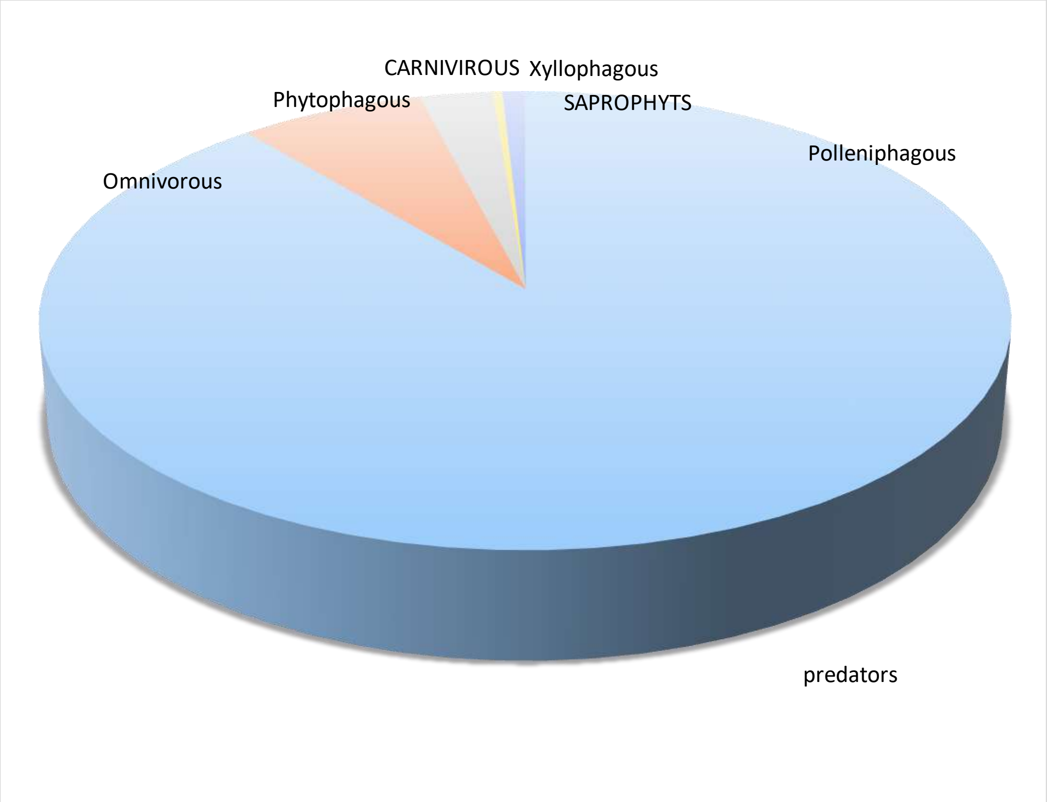

Fig. 38 - Abundances of the diet categories of the inventoried coleopteran species

II.2.5.2. - Spatial variation of the coleopteran species diet categories

It appears that the composition of beetle fauna differs across the five habitats due to their heterogeneity. Predators dominate quantitatively and are recorded in all five sites (Fig. 39 and Fig. 40). These are mainly represented by Carabidae, the majority of which are predatory species. They can therefore be beneficial to crops and limit the impact of certain pests (SASKA, 2007).

On the biodiversity scale, second place is shared between phytophages and omnivores. The presence of phytophages is favored by the dense vegetation cover that characterizes the sampling sites (Fig. 18 to Fig. 22), while the presence of omnivores is favored by the diversity of arthropods and other animal species. The only one Xyllophagous species was present in the half-maintained palm grove attaking the date palms that exist there. However, Saprophyts appear at almost all the sites and play an important role in their orgnic matter decomposition (Fig. 39 and Tab. 4 APPENDIX).

On the abundance scale, we have noted that second place were occupied by omnivores in the maintined and non maintained palm groves and in the alfalfa culture. La large gamme de choix alimentaires que présentent ces insectes semble etre responsable à leur offrir la capacité à s'adapter à des milieux différents. However, in the half-maintained palm grove, carnivores ranked second grace à la richesse faunistique qui caractérise ce milieu agricole. In the wheat culture we have noted the dominance of phytophages suite à la dominance de Oulema connue comme espèce ravageuse du blé (Fig. 40 and Tab. 4 APPENDIX).

Carabidae are known as bioindicators and their distribution can be influenced by the heterogeneity of sites due to the availability of a varied food source consisting mainly of dead wood and small insects. Their high mobility helps them to colonize habitats that suit them well. (GHHANNEM et al., 2017). BAKROUNE at al. (2023) proved that 50% of the coleopteran species collected at Biskra are predators, followed by phytophagous by a relative abundance equal to 36%. Also, AMOKRANE et al. (2020) found that there was an interesting presence of predators (28.15%) mainly formed of Carabidae and Staphylinidae.

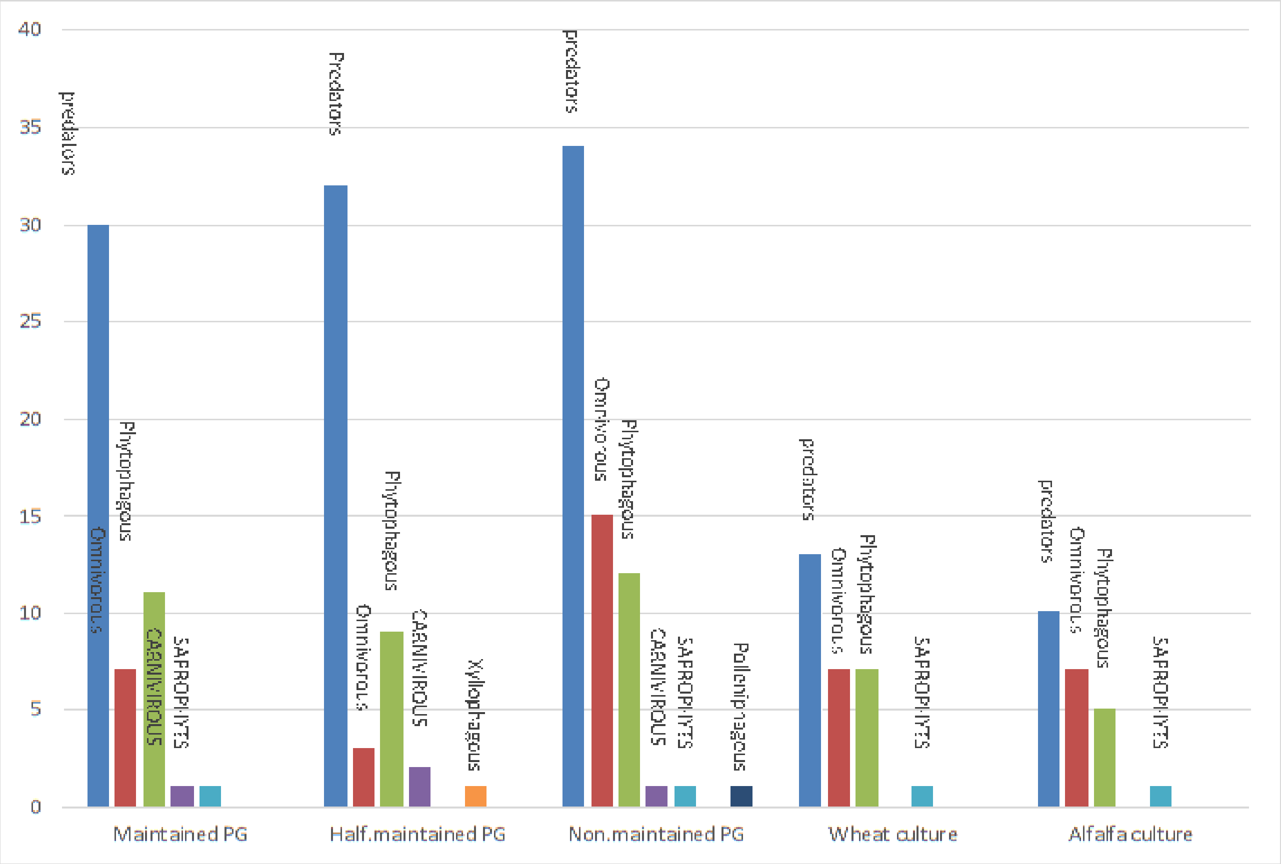

Fig. 39 – Richnesses of the inventorid Coleoptera diet categories

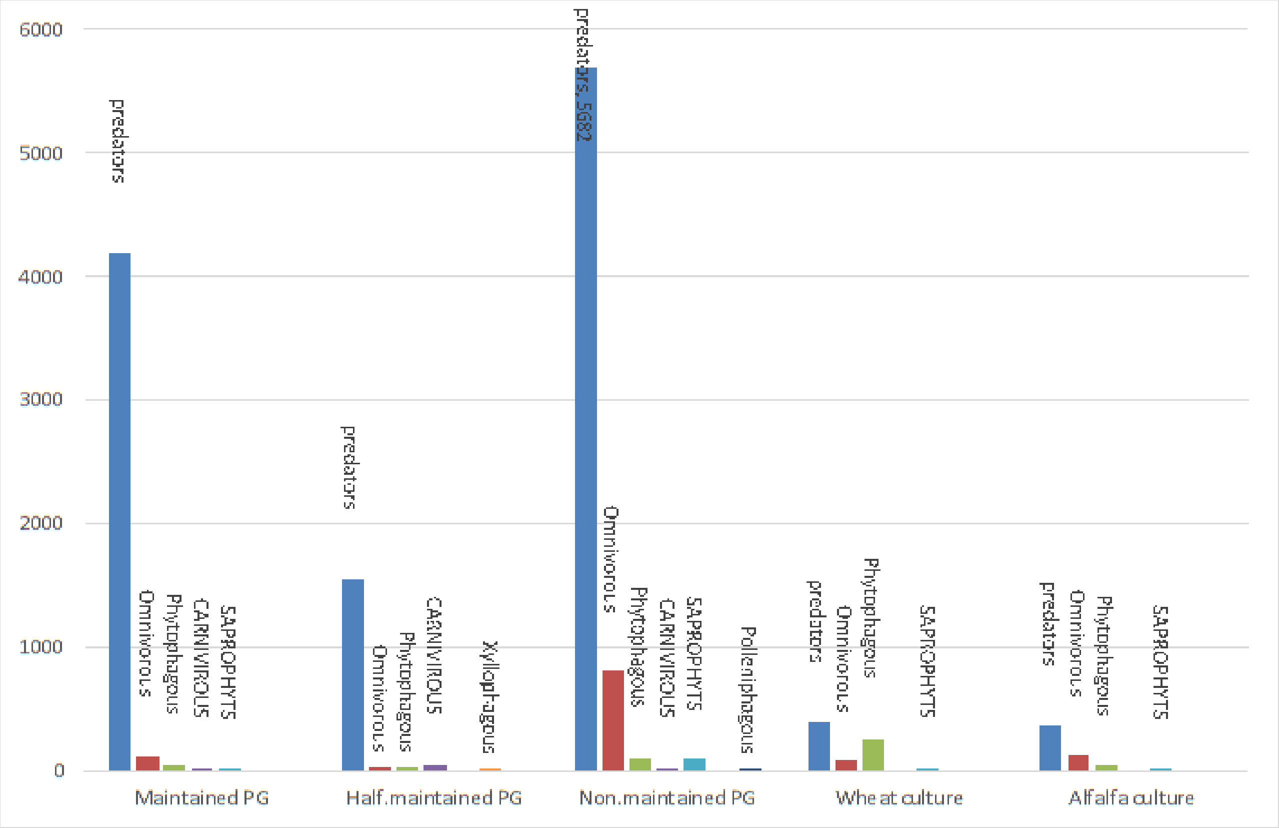

Fig. 40 – Abundances of the inventorid Coleoptera diet categories

II.2.5.3. - Statistical analysis

The existence of any significant difference between the numbers of predator individuals of Carabidae inventoried in the five agricultural environments was checked using the Kruskall-wallis test. The later was chosen after applying the Kolmogorov-Smirnov normality test and finding that the normality is not significant (Tab. 5).

Tab. 5 - Kruskall-Wallis test result

K (Valeur observée)	**10,64**
K (Valeur critique)	8,644
DDL	4
p-value (unilatérale)	**0,000**
Alpha	0,05

In this case, the statistics of the Kruskall-Wallis test give a value equal to 10,64 with a probability smaller than 0.05. We therefore refuse the null hypothesis according to which there is no significant difference between the values of the numbers of predator Carabidae individuals inventoried in the study sites. In other words, the difference between the means of these five groups is statisticaly significant.

This observation can be attributed to the fact that our sampling sites differ greatly in terms of soil conditions, vegetation cover, maintenance conditions, and fauna richness. Predator abundance is related to the absence of chemicals and the abundance of prey (ALI-AROUS et al., 2023). Additionally, the presence of ground vegetation and its density enhance their richness.

II.3. - List, composition, some bioecological traits, biogeographical appurtenance and spatiotemporal variations of the carabidofauna caugnt in some agricultural envirnments of Ouargla

The family of Carabidae has a major role in agriculture and in ecology and needs to be well studied. Here, we will present its list of species, their composition, some bioecological traits characterizing them, the bioecological appurtenance of these species and the analysis of their spatiotemporal variations.

II.3.1. - Commented global list

Of the 117 Coleopteran species inventoried in the study sites, 28 species are carabids (Tab. 4-APPENDIX).

The Executive Decree No. 12-235 of 3 Rajab 1433 corresponding to 24 May 2012 that establishes the list of protected non-domestic animal species shows that our list includes 4 carabid species classified by Algerian law as endemic species. These include *Carabus faminii, Cicindela campestris, Anthia sexmaculata* and *Graphipterus serrator*.

Furthermore, if we compare our list of species with those mentioned by other authors in Algeria during the last 10 years (2016–2025), we find that only five species have been found in the arid regions of the country. These species are *Lophyra flexuosa* in some Saharan localities of Bechar, some durum wheat terrains in Ouled Djellal and some palm groves in Tougourt (SEGHIER and DJAZOULI 2018; DEGHICHE-DIAB et al. 2022; HADJOUDJ et al. 2018), *Scarites occidentalis* in some Saharan localities in Bechar (SEGHIER and DJAZOULI, 2018), *Brachinus explodens* in some durum wheat terrains in Ouled Djellal (DEGHICHE-DIAB et al. 2022), and *Calosoma algiricum* with *Pheropsophus africanus* in some terrains of water melon crops in Ouargla (KACHA et al. 2021), which is in accordance with the data we obtained.

Our list also includes the species mentioned from arid regions in other parts of Algeria, as well. These include *Graphipterus serrator* from Tougourt palm groves and the Central Saharan Atlas of Djelfa (BRAHIMI et al. 2021; HADJOUDJ et al. 2018; BOURAGBA et al. 2020), *Pterostichus nigrita* from some terrains of water melon crops in Ouargla and the national park of El Kala (KACHA et al. 2021; IBOUD et al. 2023), and *Anthia sexmaculata* in some Tougourt palm groves, two Saharan biotopes of Bechar and the Central Saharan Atlas of Djelfa (HADJOUDJ et al. 2018; SEGHIER and DJAZOULI 2018; BRAHIMI et al. 2021).

Other species are not mentioned in the arid regions. These include *Calosoma maderae* found in two types of arboreal terrains in Belezma, two native xerotic shrub species in Tebessa and a ramsar wetland in Chott Tinsilt (OUCHTATI et al. 2021; AMRI et al. 2019; HABBARI et al. 2023), *Harpalus tenebrosus* in some Durum wheat terrains in Oum Bouaghi (AMOKRANE et al. 2020), *Harpalus luctuosus, Calathus encaustus* and *Cymindis lineola* in the Central Saharan Atlas of Djelfa (BRAHIMI et al. 2021), *Bembidion tetracolum* in some saline wetlands of Setif (MOUHOUBI et al. 2018), *Poecilus nitidus* in a Ramsar wetland of Chott Tinsilt and two native xerotic shrub species in Tebessa (OUCHTATI et al. 2021; AMRI et al. 2019), *Harpalus* *lethieryi* in a Ramsar wetland of Chott Tinsilt, two native xerotic shrub species in Tebessa, some olive groves in Batna, some Ramsar wetlands in El Kala and Tlemcen (AMRI et al. 2019; MATALLAH et al. 2016; OUCHTATI et al. 2021; CHAFAA et al. 2019; IBOUD et al. 2023), *Acinopus megacephalus* in Belezma national park, some olive groves in Batna and some Ramsar wetlands in Tlemcen (MATALLH et al. 2016; CHAFAA et al. 2019; HABBARI et al. 2023) and *Siagona europaea* in two native xerotic shrub species in Tebessa some Ramsar wetlands in El Kala and Tlemcen (MATLLAH et al. 2016; OUCHTATI et al. 2021; IBOUD et al. 2023).

Other species are so far found only in the humid regions of Algeria: *Scarites buparius*, *Acupalpus elegans* and *Drypta distinctata* in El Kala national park (IBOUD et al. 2023), *Apotomus rufithorax* in a Ramsar wetland of Tlemcen (MATALLAH et al. 2016), and *Harpalus affinis* in some animal crops in various localities of Tizi Ouzou (MARNICHE et al. 2019).

On the other hand, there are species that have been mentioned in all bioclimatic zones of Algeria, namely: *Carabus faminii* in some step habitats of Ouled Djellal, El Kala national park and Tikedjda forest (DEGHICHE-DIAB et al. 2022; ABBASSEN et al. 2022; IBOUD et al. 2023) and *Cicindela campestris* in some durum wheat terrains of Ziban, some step habitats of Ouled Djellal, Tebessa, some olive groves of Batna, and El Kala national park (DEGHICHE-DIAB et al. 2022; BAKROUNE et al. 2023; OUCHTATI et al. 2021; CHAFAA et al. 2019; IBOUD et al. 2023).

II.3.2. - Composition of the carabids captured in Ouargla

In this part, the composition of Carabidae sub-families, genera and species captured in five different agricultural envirnments of the region of Oargla during three years of sampling.

II.3.2.1. - Total abundance and richness of Carabidae sub-families inventoried in Ouargla

Analysis of the overall composition of the carabid fauna revealed a collection of 28 species belonging to thirteen sub-families of unequal importance. To illustrate the diversity of the faunal composition, the figures 41 and 42 show the spectrum of the various subfamilies expressed in terms of number of species and number of individuals in relation to the community as a whole. Among the subfamilies, Harpalinae was the most diversified with 5 species (presenting 38.46 % of the total number of species). Lebiinae comes in second with 4 species (30.77 %), followed by Scaritinae and Carabinae with three species each (23.08 % each), then Cicindelinae, Brachininae, Antiinae, and Pterostichinae with two species each (15.38 % each). The rest of the subfamilies (Dryptinae, Apotominae, Platyninae, Trechinae, and Siagoninae**)** were composed by only one species each (7.69 % each) (Fig. 41). In terms of abundance, the Cicindelinae sub-family predominates and accounts for more than three-quarters of the Carabidae inventoried (85.43 % of the fauna collected).The Harpalinae subfamily ranks second with 3.78 %, than the Lebiinae and Scaritinae with only 2.56 % and 2.45 % respectively. The relative abundances of the other subfamilies are in the following decreasing order: 1 % for the Carabinae and Brachininae, 0.89 % for the Anthiinae and Pterostichinae, 0.44 % for the Trechinae, Platyninae and Apotominae subfamilies and finaly 0.33 % for Siagoninae and Dryptinae (Fig. 42).

According to BELHADID et al. (2013) the family Pterostichidae is the richest among the seven families of Caraboidea inventoried in the Chréa National Park at Blida (the centre of Algeria). Howeaver, the inventory of LORENZ (2005) has confirmed our finding about the remarkable richness of Harpalinae among the Carabidae sub-falilies, with more than 19,000 species. This observation is similar to the works of ANDUJARE et al, 2001; OUCHTATI, 2013; TEOFILOVA, 2015; MATALLAH et al, 2016 and AMRI, 2019. According to ANDERSEN (2000), this sub-family is associated with highly disturbed crops and is able to find a suitable habitat in anthropogenic agricultural ecosystems, which is the case of our study sites, disturbed by anthropogenic activities.

Although only two species from two different genera, *Lophyra flexuosa* and *Cicindela campestris*, made up Cicindelinae, it was the most abundant subfamily. JASKULA and REWICZ (2015) have also noted the presence of only two species of Cicindelinae in the desert regions of Tunisia. According to them, Cicindelinae occurring in these areas inhabit predominantly river banks and oases, because they prefer to live in sandy humid terrains and can colonise a large number of microhabitats the oases offer. The same authors have also noted that the desert regions are characterised by a much lower diversity than the region that is adjacent to the Mediterranean Sea coastline. However, the subfamily Harpalinae was the most diverse with 5 species. Also, LORENZ (2005) has reported that the subfamily Harpalinae is the most diverse among the carabids with approximately 19,000 species.

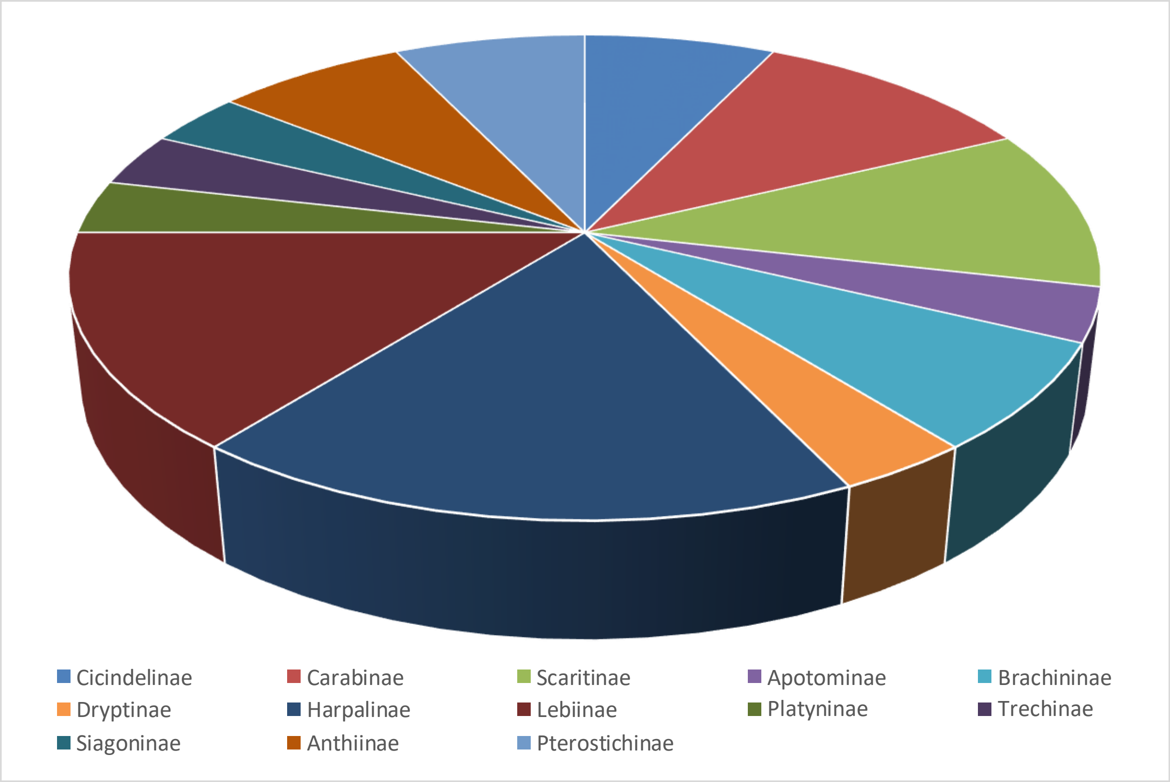

Fig. 41 - Inventoried Carabidae sub-families diversity

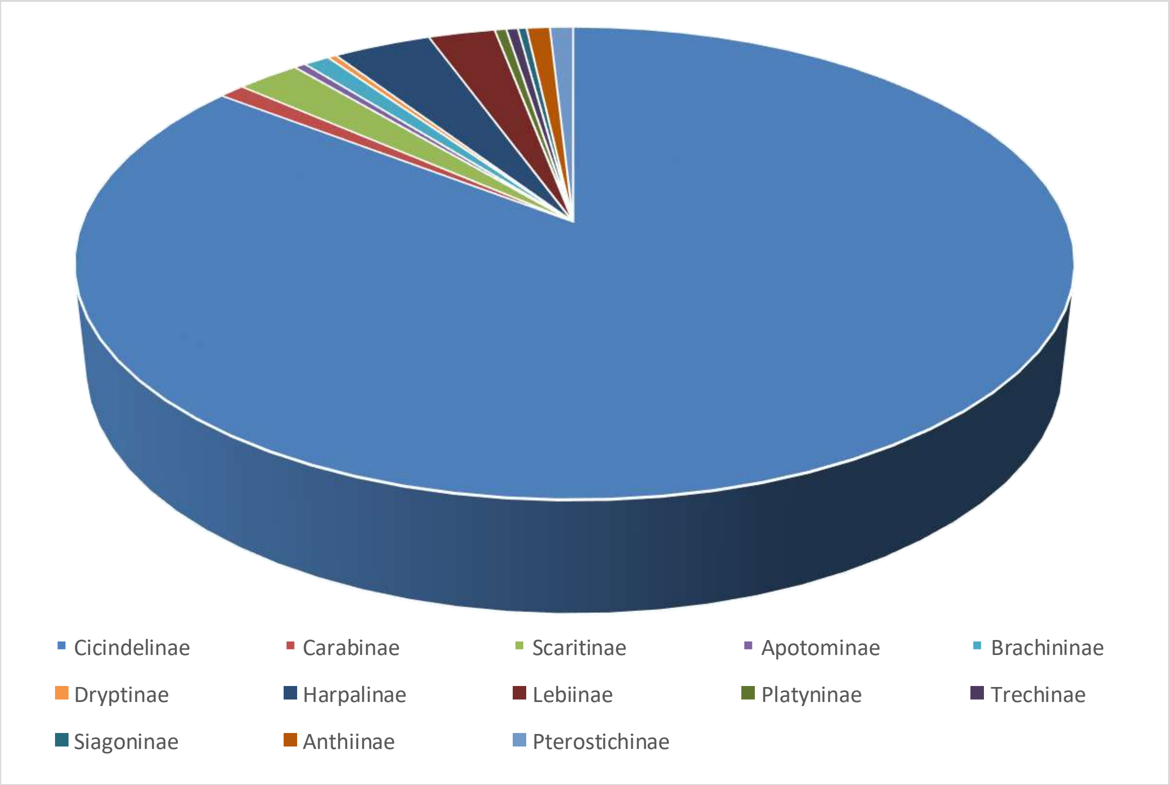

Fig. 42 - Inventoried Carabidae sub-families abundances

II.3.2.2. – Total abundance and richness of carabid genera inventoried in Ouargla

Our inventory has revealed the presence of 22 genera of ground beetles. The spectrum of the various genera expressed in terms of number of species and number of individuals in relation to the community as a whole are illustrated in the figures 43 and 44.

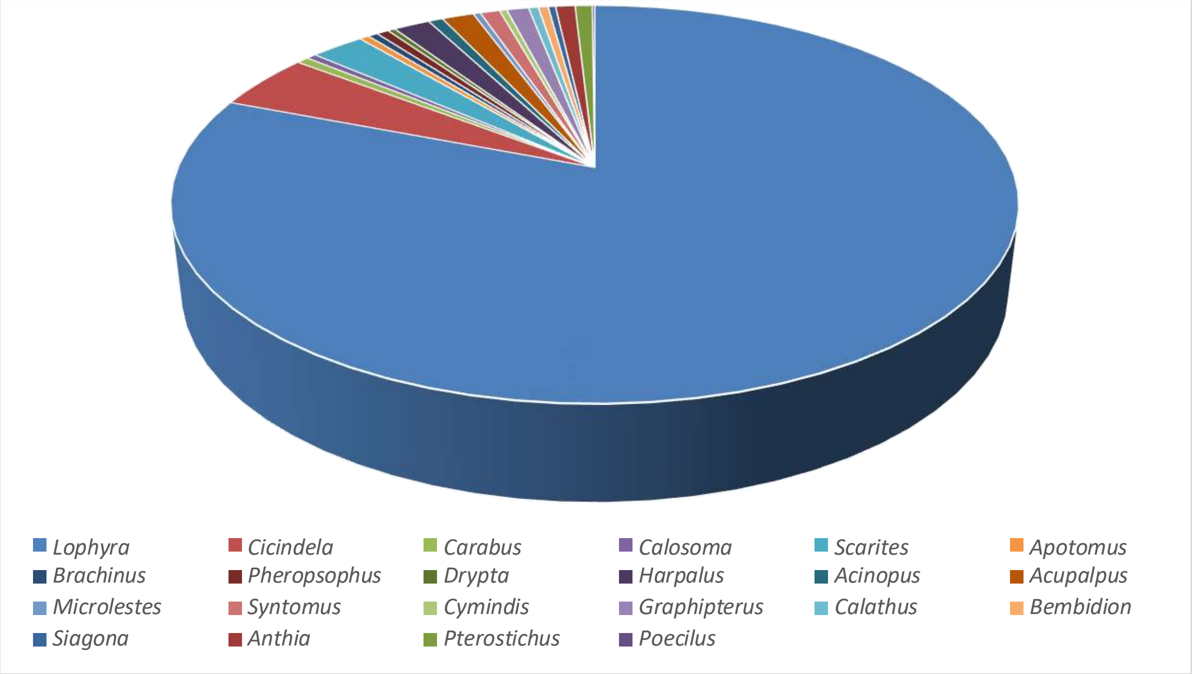

Fig. 43 – Inventoried Carabidae geneta diversity

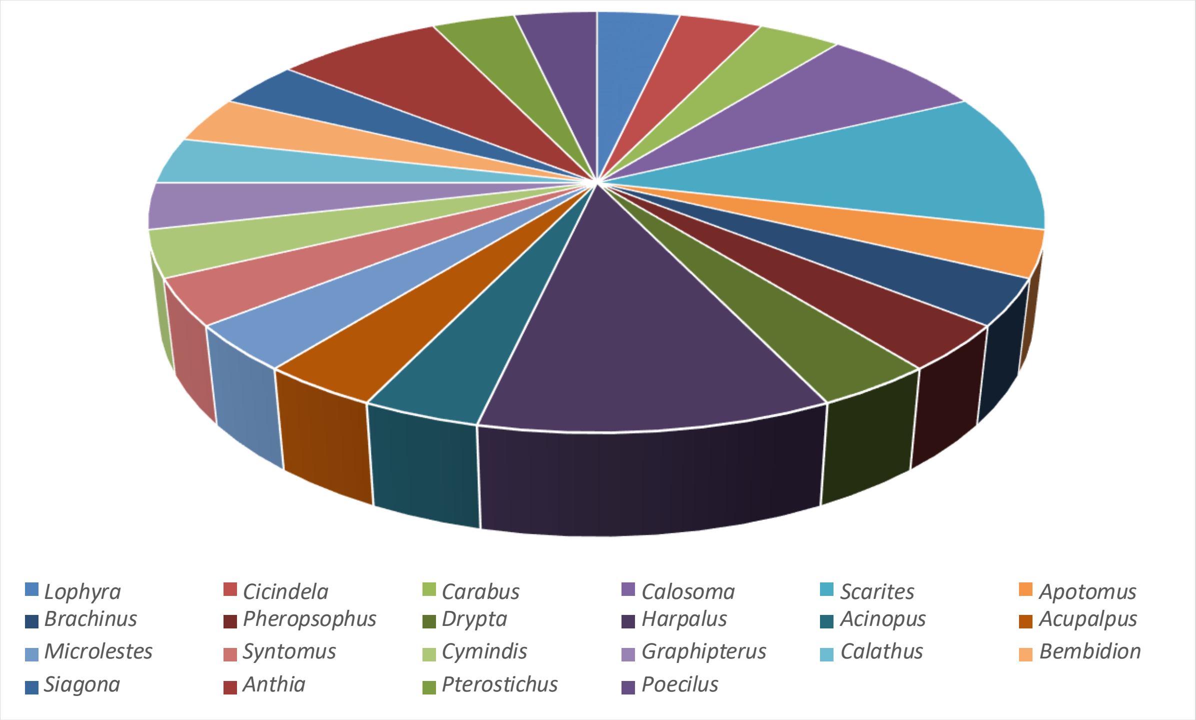

Fig. 44 – Inventoried Carabidae genera abandance

The faunal composition analyzed on the basis of the importance of genera also shows different proportions (Fig 43). *Harpalus* and *Scarites* are the most diverse, with three species each (23.1 %) followed by *Calosoma*, *Brachinus* and *Anthia* with two species each (15.4 %). The other genera are represented by only one species, namely *Lophyra*, *Cicindela*, *Carabus*, *Apotomus*, *Brachinus*, *Pheropsophus*, *Drypta*, *Acinopus*, *Acupalpus*, *Microlestes*, *Syntomus*, *Cymindis*, *Graphipterus*, *Calathus*, *Bembidion*, *Siagona*, *Pterostichus* and *Poecilus* (7.7 %) (Fig. 43). In terms of abundance, *Lophyra* and *Cicindela* are the most dominant, with the highest number of individuals (80.87 % and 4.56 % respectively), followed by *Scarites* and *Harpalus* with 2.45 % and 1.67 % respectively. The genera *Acupalpus* and *Graphipterus* are presented with 1.45 % and 1 % respectively. The other genera are represented by a small number of individuals each (Fig. 44).

II.3.2.3. - Total abundances and richnesses of the inventoried Carabidae species

The inventory of carabid species in 5 agricultural envirnments of the region of Ouargla enabled 28 species presented with 1747 specimens. (Tab. 4 – APPENDIX).

Our findings differ from those of BORGES and MERIGUET (2005), who identified 60 species in the marsh of Frocourt (northern France) between June and July 2005. In addition, GHANNEM and BOUMAIZA (2017) cited 65 species belonging to 45 genera, 24 tribes, and nine subfamilies in northern Tunisia, while CHAVANON and MAHBOUB (1998) have identified 157 species at the mouth of the Moulouya River in the north-eastern part of Morocco. In Algeria, BOUKLI-HACENE et al. (2011) reported the presence of 42 species in the Tafna salt marshes (west of the country), a richness similar to that recorded later by AMRI et al. (2019) at Chott Tinsilt (Est of the country). OUCHTATI (2012) has highlighted the presence of 53 species of Carabidae in the El-Kala National Park, while SAOUACHE et al (2014) and MATALLAH et al (2016) identified 55 species of Carabidae in eastern and western Algeria respectively. Lately, AMOKRANE et al. (2020) and HEBBARI et al. (2023) have caught, respectively, 543 individuals in Oum Bouaghi and 1172 individuals in Batna during a year of study. BRAHIMI et al. (2021) have also registered 4934 specimens during ten years of carabids sampling (between 2000 and 2011) in the region of Djelfa, while IBOUD et al. (2024) have identified 83 species of Carabidae in the lac of Tonga (Estern Algeria). The last authors' findings seem to be more elevated than ours, because they have all carried out their inventories in regions with higher levels of humidity and lower average temperatures than our arid regions (which are hotter and drier). According to SANDERS et al. (2007), all organisms' species richness can be determined by the temperature, as it affects their metabolic reactions. The influence of precipitation on carabids' structure is also remarkable because it provides them with a higher soil moisture and a greater plant diversity (YAN et al. 2015). In addition, the lack or insufficiency of food in Saharan regions, which result in fierce competition between the species, and the emergence of such distribution models could account for this outcome, since it is known that the spatiotemporal distribution of carabids and the structure of communities can be regulated by many factors like competition, predation and parasitism (BAGUETTE 1992; BOUKLI-HACENE et al. 2012; BELHADID et al. 2013).

Howeaver, the quota of species collected (28 species) is the most complete ever carried out in arid regions compared with previous studies carried out on neighbouring sites, such as those by BAKROUNE et al. (2023) and SEGHIER and DJAZOULI (2018) which respectively highlighted the presence of only 6 and 7 species of Carabidae in the regions of Ziban (Northern Sahara of Algeria) and Bechar (southern Algeria). Likewise, KACHA et al. (2021), mentioned only 24 individuals during three years of sampling in a watermelon crops siteat Ouargla. Also, CHAFAA et al. (2019) has inventoried only 23 individuals in an arid region of Batna. The main difference between our study and theirs is that we have chosen to get more than the half of our samples from palm groves when they have chosen to work in other Saharan localities. In fact, the palm groves have provided a dense and diversified vegetation cover (fig. 14 and table 2) that acted as a buffer to maintain stable microclimatic conditions, avoiding sudden rises or falls in temperature or humidity. In addition, the herbaceous stratum existing in our study sites was caracterised by the presence of many perennial species, remaining permanently green (Tab. 3-APPENDIX) and providing shelter and food for herbivores directly and simultaneously, and prey for predators indirectly (TSAFACK et al., 2019). Consequently, a considerable diversity of arthropods was captured at the study sites (Fig. 26), and a wide range of prey choices seemed to be provided to carabids. On the other hand, our study is the first to describ biodiversity and try to detect as many Carabid species as possible, whereas previous cited studies carried out in arid regions have not focused their research on the diversity of Carabidae specifically but rather on coleopterans or arthropods in general. In addition, the large number of transects and pots used for capture and the long sampling period were all efforts we made to capture the maximum number of carabid species present in our study region.Apart from this, the results show that Lophyra flexuosa and Cicindela campestris appear to be the most abundant species in our study region with a small number of individuals representing each other species. The reasons for the abundance of some species and the rarity of others will become clearer in the section dealing with the bioecological traits of carabid species.This is favoured by their characteristics as being xerophytic, mobile species, and voracious. On the other hand, the other poorly represented species (Carabus faminii, Calosoma mderae and others) are known to be hygrophilous, not very locomotor, not very dispersible and apterous (Tab. 4-APPENDIX).

II.3.3. – Some bioecological traits of the inventoried carabids

In the following section we will present some bioecological traits characterizing the inventoried Carabidae species

II.3.3.1. - Body size of Carabidae

The body size of an organism is a fundamental characteristic in ecology (KINGSOLVER & HUEY, 2008). It is linked to ecological processes at different scales, including population biology (WHITE et al., 2007). Indeed, a long-term database on carabids shows that large species, but not small ones, have decreased in size over a period of 30 or 100 years. To illustrate this variation, the fauna has been classified into three classes (Fig. 45): large species (greater than 16 mm), small species (less than 9 mm), and medium-sized species between 9 and 15 mm.

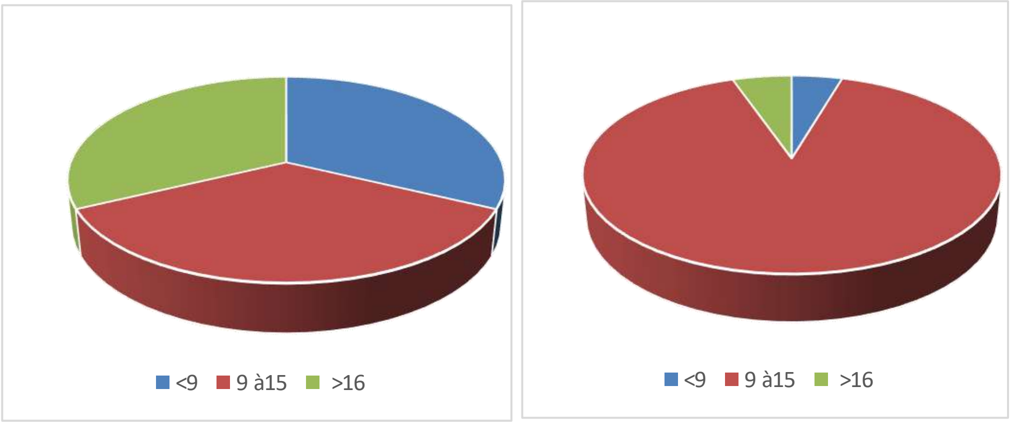

Fig. 45 - Size of carabid species found in different agricultural environments in the Ouargla region

According to our data, this community is clearly dominated (with 90% of abundances and 36% of the total number of species) by the category of medium-sized species, followed by small and large species respectively (Fig. 45).

Given that most of the carabidae inventoried tend to be small or medium-sized, it could be that the disturbance factor, particularly of anthropogenic origin, is present and exerting pressure on the community. Indeed, SZYSZKO'S (1983) hypothesis states that disturbances lead to carabid assemblages characterized by small species. In addition, the size of individuals is related to the amount of organic matter contained in the soil (BLAKE et al., 1994). In the Oargla region, organic matter content recorded low values during the study period (Table 1), which is characteristic of Saharan environments. Therefore, this explanation could be applied to the present case.

II.3.3.2. – Diet categories

Taking into account the food spectrum, several classifications have been proposed, such as the classification by TOFT (2002), which classifies Carabidae as follows: generalist carnivores, generalist insectivores, mollusk specialists, microarthropod specialists, caterpillar specialists, and granivores. In terms of abundance, predators clearly dominate the total fauna collected, accounting for 89 %, followed by polyphagous species with 9% and generalist predators with 3% (Fig. 46). In terms of species richness, we observe that across all agricultural environments, dominance is shared between generalist predators and polyphagous species, with almost identical percentages of 39% and 35% respectively (Fig. 46).

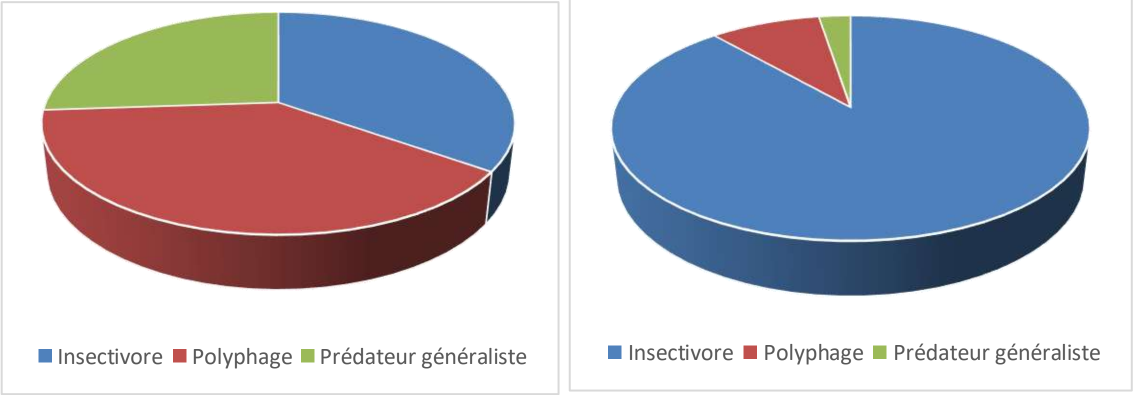

Fig. 46 – Abundance and richness of the different diet categories of inventoried carabids

Our results are consistent with the observations of GOBBI & FONTANETO (2008), which confirm the dominance of predatory and polyphagous ground beetles in open environments. According to GOBBI and FONTANETO (2008), biotopes with a high level of disturbance, especially anthropogenic disturbance, have a low presence of predators. Carabidae have always been considered predators or carnivores, yet the diet of the entire family is very diverse. Given the variation in their food spectrum, DEN BOER & DEN BOER-DAANJE (1990) consider polyphagy to be much more suitable for them than predation. The trophic spectrum includes specialized phytophagous species such as certain *Amara*, *Harpalus*, and *Bradycellus*, and specialized predators such as *Notiophilus*, *Cychrus*, and *Loricera pilicornis*, as well as a majority of polyphagous species (THIELE, 1977). In addition, these insects can explore different strata of vegetation in search of food (YOUNG, 2008), and even during the species' development, feeding habits change. This is the case with the species *Synuchus nivalis*, whose larvae are carnivorous, while adults are mainly phytophagous (LINDROTH, 1986). Omnivorous carabids are strongly affected by local plant diversity, while predators are strongly linked to landscape structure (YUNHUI et al., 2015).

II.3.3.3. – Wing morphology based categories

Carabid beetles mainly move on the ground, but several species are also capable of flying. This latter ability appears to result from a complex and dynamic interaction between the physiology of the species, environmental conditions, and the mode of transmission of flight-related traits (KAMENOVA, 2013). Differences in wing morphology could therefore be a proxy for dispersal ability (KOTZE et al., 2011). Depending on the state of wing development, four groups can be distinguished: brachypters (wingless individuals), macropters (winged individuals), dimorphic individuals, and polymorphic individuals (individuals with wing plasticity) (KAMENOVA, 2013). According to DUFRENE (1992), brachypters dominate in forest environments, while macropters inhabit open environments (riparian habitats, salt marshes, limestone grasslands, crops, etc.). Finally, dimorphic species are indifferent and have a very wide range of habitats.

Although Carabidae generally prefer to walk rather than fly to move around (ROUME, 2011), almost all of the species identified in the Ouargla region are macropters (96%) (Fig. 47). This finding is consistent with that of AMRI (2019), with almost similar proportions of 97.61% in Tinsilt and 94.44% in Ezzemoul. According to GOBBI & FONTANETO (2008), the low proportion of brachypterous species is highly sensitive to environmental instability. The same author adds that these species cannot reproduce in open environments and prefer closed, undisturbed habitats.

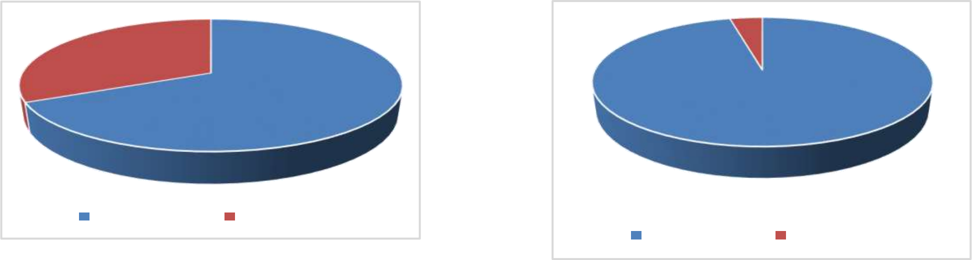

Fig. 47 – Wings morphology based categories of the Carabidae inventoried in Ouargla

II.3.3.4. - Humidity requirements

Analysis of all Carabidae in the study area according to their humidity requirements reveals that our species fall into three categories : hygrophilous species requiring soil moisture without being closely linked to the wetland area, mesophilic species living in a neutral soil biotope with major temperature and humidity conditions, and xerophilic species adapted to biotopes characterized by prolonged intense drought.

In terms of abundance, the species inventoried in the study area are dominated by hygrophilous species, accounting for 43% (Fig. 48). These values could be explained by the fact that the dominant vegetation is perennial, which remains green all year round, thus forming an effective natural shelter for retaining moisture and facilitating the establishment of hygrophilous species. In terms of abundance, xerophylous species dominate (Fig. 48), which is logical given the dry conditions that characterize our study area (Fig. 2 and 3).

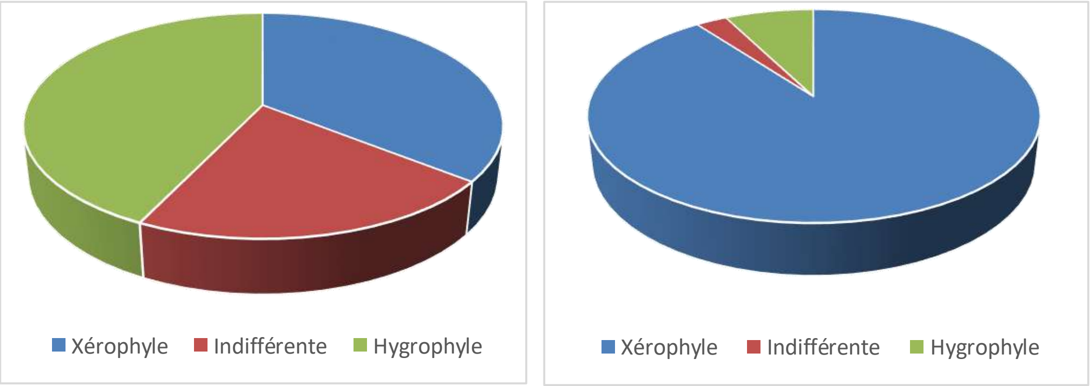

Fig. 48 - Pourcentage des espèces de Carabidae de la région d'Ouargla selon leurs exigences en humidité (Abundances et richesses)

II.3.3.5. - Activity mode based categories

In terms of abundance, diurnal species appear to be the most represented (Fig. 49). This is due to the predominance of *Lophyra flexuosa* and *Cicindela compestris* in the study region. Both species are diurnal, and their abundance will certainly influence the results. In terms of diversity, nocturnal species predominate (Fig. 49). This is consistent with the nature of carabids as soil insects. This characteristic allows them to protect themselves from severe drought and high temperatures, minimize water loss, and escape predators.

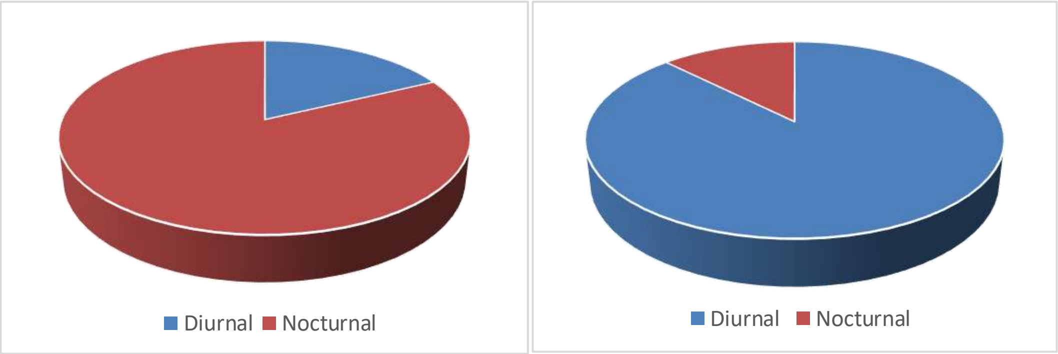

Fig. 49 - Percentages of diurnal and nocturnal carabid species

II.3.4. Biogeography of Carabidae

The Carabidae inventoried are classified according to their bioecological distribution into 8 categories. The number of species present in each category is shown in the figure. The figure shows that the Carabidae community is dominated by Eurasian and Saharo-Arabian species with 63% of the total, followed by species that are Eurasin, Saharo-Arabian and North American and those that are Eurasian, Saharo-African and African with 7% each (Fig. 50). The other categories are equally represented, with 4% each.

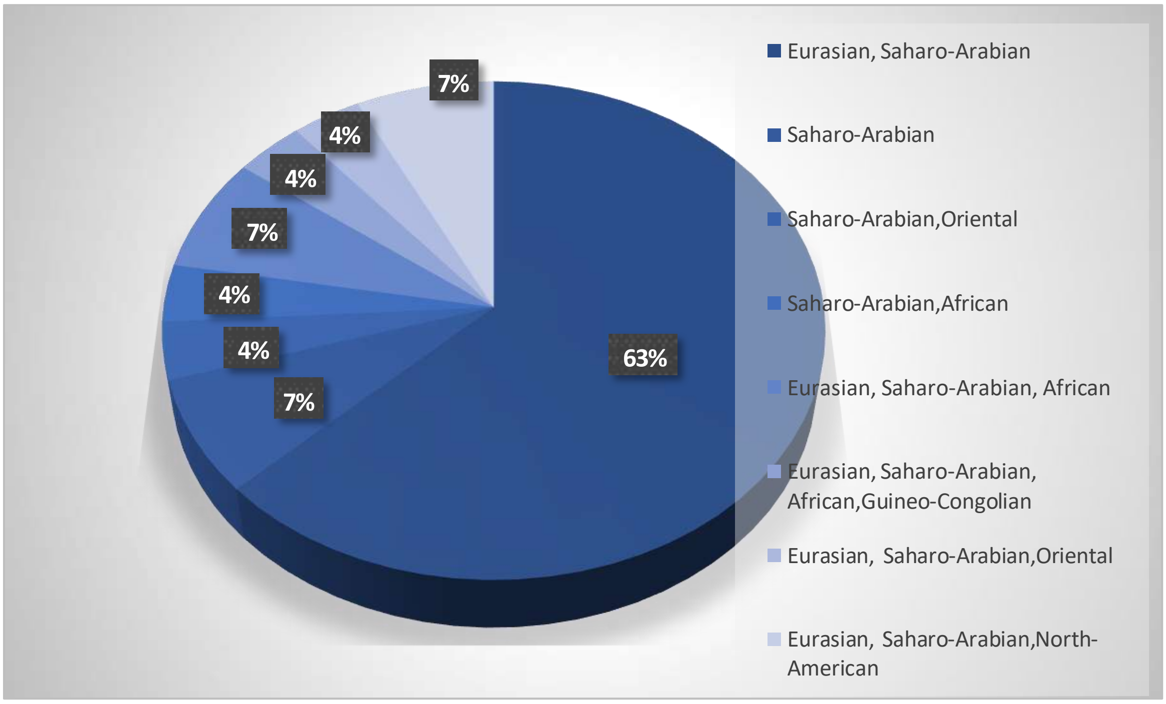

Fig. 50 – Bioecological analysis of the inventoried Carabid species

II.3.4.2. - Hierarchical testing and determination of coenotic units

A hierarchical ascending classification (HAC) was performed on a biogeographical distribution matrix of the biogeographical distribution of the 28 species inventoried (Fig. 51). This classification made it possible to subdivide all the species sampled into two groups according to the type of distribution of each species.

The first group comprises Eurasian and Saharoarabian, Eurasian, Saharo-Arabian and North American, Eurasian, Saharo-Arabian and African species. This group has been subdivided into two subgroups. The first subgroup contains two species with a very limited distribution, and known as endemic to North Africa: *Carabus famini* and *Anthia duodecimguttata*. The second subgroup comprises species with a better distribution (18 species), such as *Lophyra flexuosa*, *Cicidela campestris*, *Acinopus megacephalus* and *Acinopus elegans*. The diversity of this groupe reflects the species' power of dispersal and colonisation, as well as their wide adaptation to fluctuations in climatic conditions, particularly temperature and rainfall, since on a large scale these are the two most widely adopted factors for determining the dispersal power of Carabidae (ANDUJAR et al., 2001). That justifies also their abundance in our study region. The second group comprises 2 species with low distribution, Siagona europaea and Harpalus lethierryi reported only throught Saharo-Arabian countries. The third group, comprises species with a wide distribution throughout Eurasin, Saharo-Arabian and Oriantal countries. These are Bembidion tetracolum and Anthia sexmaculata. A fourth group contains species with awide distribution in African and Guineo-Congolian regions: *Cymindis lineola* and *Drypta distinctata*. The last two groups are represented with one species each. *Calosoma maderae* original of Saharo-Arabian, African and oriental regions and *Harpalus affinis* which is a Saharo-Arabian and African species. These species are totally absent from Europe.

In addition, the presence of this wide variety of zoogeographic elements provides information on the diversity of physiographic conditions in the environment studied. From these observations, it is clear that Ouargla harbours an undeniable faunal capital, attesting to the high heritage value and biological richness of this region.

However, this diversity remains lower than that recorded by other authors in northern Algeria. SAHARAOUI et al. (2013) point out that the distribution and dispersion of insect populations are influenced by several biotic and abiotic factors that determine their natural behavior. Among these factors, the same authors add, we can cite the distance of the southern sectors from those in the north in relation to the European continent, which reduces species immigration. In their theory, MACARHUR & WILSON (1967) assert that distance from the continent reduces immigration, which makes species richness lower.

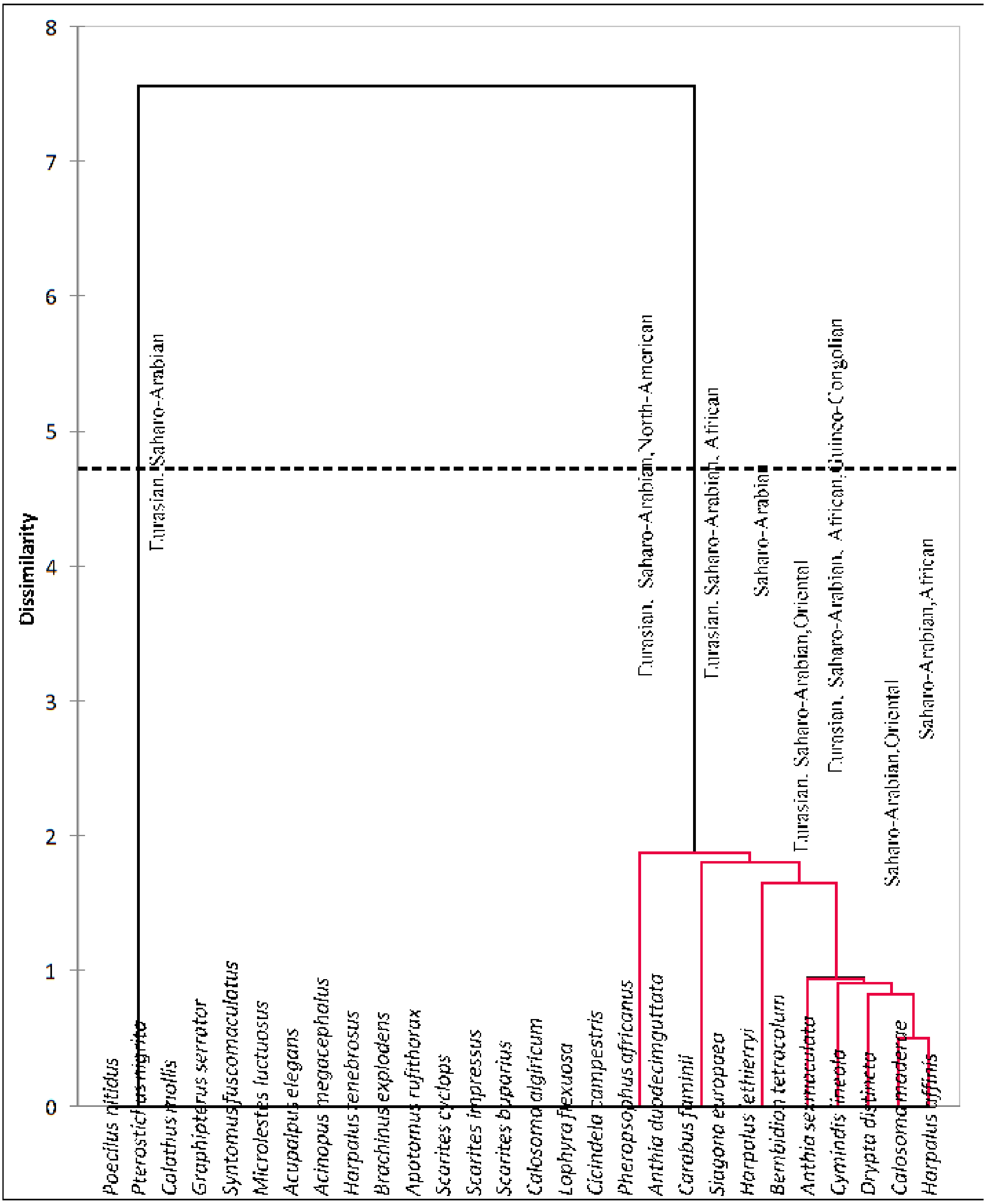

Fig. 51 – Hierarchical Ascending classification applied on the biogeological distribution of carabids

II.3.5. - Spatiotemporal variations of the inventoried carabids

Fluctuation is a basic characteristic of insect populations. Studies of fluctuation are necessary to understand biological control, conservation, and pest species, and to plan pest-management strategies in agroecosystems (PRICE et al. 2011). Population studies are essential for the discovery of carabid species composition, dominant species, the phenology of species, seasonal activity, and habitat selection, among others (FULOP et al. 2020). The spatiotemporal variations of Carabidae sub-families, genera and species inventoried in all the 5 sites chosen in the region of Ouargla, between September 2019 and August 2022, are presented, illustrated and discussed.

II.3.5.1. - Spatial variation of the captured Carabidae species

Analysis of carabid fauna assemblages living in some agricultural envirnments is based on the use of specific richness S, the diversity Shannon-Weaver H', Piélou J' equitability, Simpson D and Hill indices, as well as abundance, Jaccard and Indvel indices. In addition, a Kruskal-Wallis test, a factoriel analysis of correspondence and an evaluation of the sampling effort curve have been done to gain a better insight into the spatial distribution of the Carabidae species in the chosen palm groves.

II.3.5.1.1. - Spatial variation in total species richness and abundances

The inventoried species and specimens were not evenly distributed across the study sites (Fig. 52). In fact, the first four sites were more diverse (between 8 and 16 species) than the last one (only 2 species). At the first four sites, sampling was carried out in the herbaceous stratum beneath the palms, whereas at the last site, sampling was carried out in the alfalfa crop adjacent to the palms. The last sampling site was therefore characterised by different conditions, notably: less dense plant cover with a total absence of plant debris, meaning a smaller number of habitats provided for Carabidae (Fig. 52), irrigation water that met the needs of the alfalfa crop without excess thanks to the use of the drip system, resulting in lower soil humidity (Tab. 1), the continuity of cultural operations, which disrupts the stability of carabid populations, and the more frequent use of pesticides and fertilisers, which, according to several authors (KROMP 1999; LEE et al. 2001; DAJOZ 2002; MELNYCHUK et al. 2003; MENALLED et al. 2007; FOUNTAIN et al. 2009), will have a detrimental effect on Carabidae.

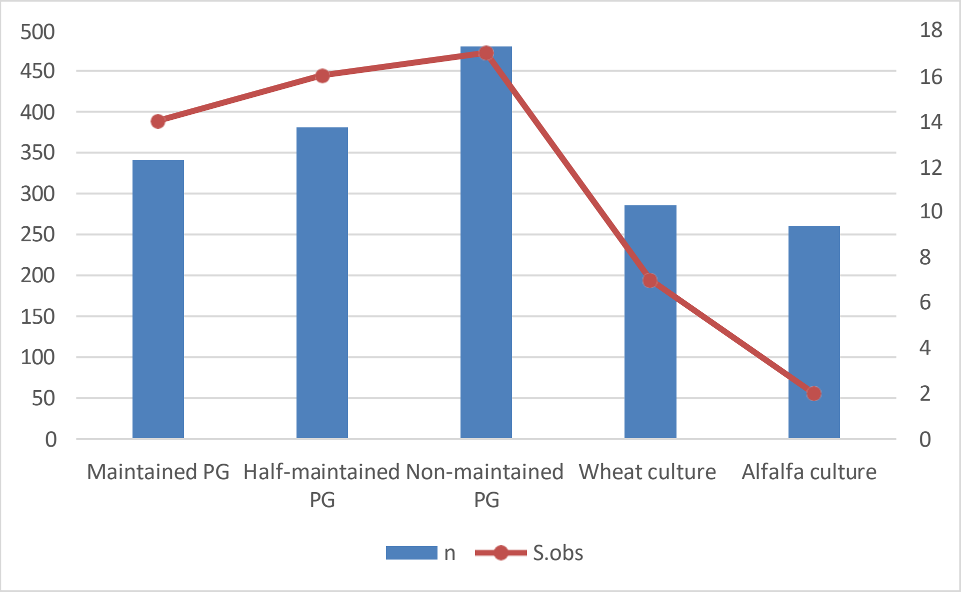

Fig. – 52 - Spatial variation of the richness index and abundance

II.3.5.1.2. - Shannon-Weaver H' index and H' max index

The Shannon-Weaver index H' in the five sites varies between a minimum of 0.98 bits (site 5) and a maximum of 1.25 bits (site 4), while the values of H'max vary between 3 bits and 3.49 bits. The low diversity index are probably due to the the fact that many species are very sparsely represented (less than two individuals) like *Poecilus nitidus*, *Anthia duodecimguttata* and *Scarites impressus*. The other species were also poorly represented, except for *Lophyra flexuosa* and *Cicindela campestris*, which had the highest relative abundances (Fig. 53 and Fig. 54).

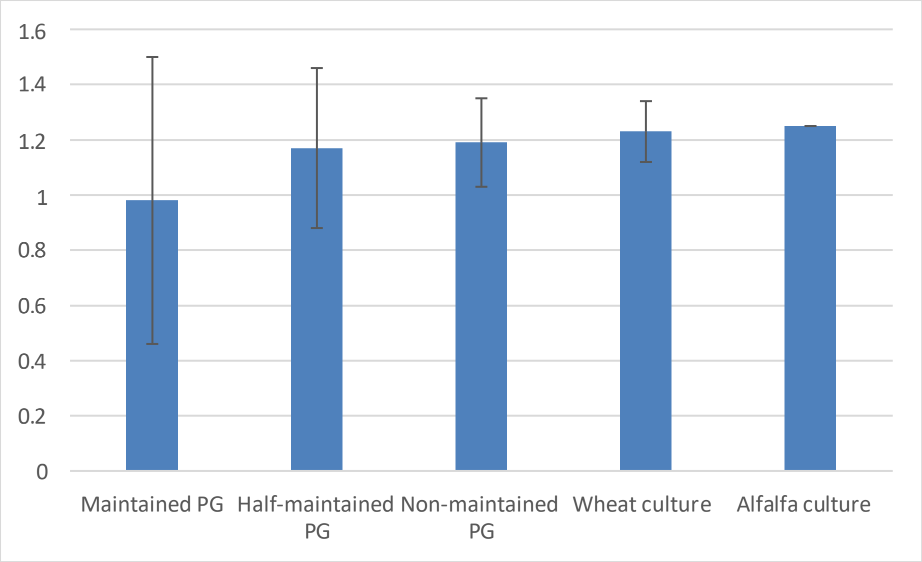

Fig. 53 - H' index spatial variations of ground beetles

Fig. 54- H’amx spatial variation of carabids

II.3.5.1.3. - Piélou's J' equitability index

Figure 58 shows that the spatial evolution of Piélou's equitability J' as a function of H' varies very little across all the sites of the study area. The very low values at almost all sampling levels (0.25 and 0.42) testify to a high degree of irregularity in the Carabidae population in all our sites (Fig. 55). This irregularity is probably due to the two strongly represented species *Lophyra flexuosa* and *Cicindela campestris*.

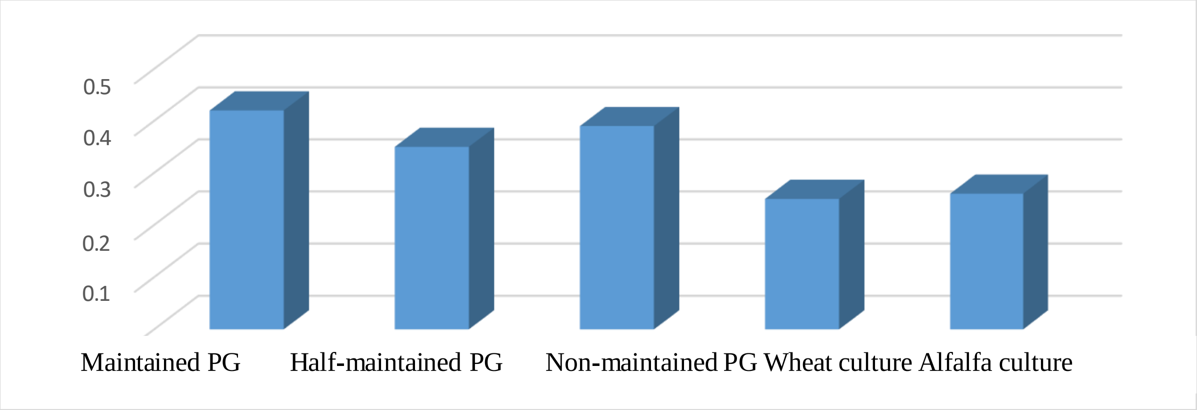

Fig. 55 – Spatial variation of the Piélou's J' equitability index

II.3.5.1.4. - Simpson D index

The values of the Simpson diversity index of the region of Ouargla are shown in figure 61. Simpson's diversity index gives more weight to abundant species than to rare species. The presence of rare species in the stand hardly modifies the value of the diversity index, unlike the much more sensitive Shannon index. This is why it lends itself better to comparisons between given habitats or ecosystems (GUILLAUME, 2020).

Indeed, these results, which tend remarkably towards 0, are better able to show the great dominance of one or more species over the others (Fig. 56). In particular, *Lophyra flexuosa* and *Cicindela campestris* were represented by a markably high number of individuals, while the other species were poorly represented. These results have also confirmed the Pielou's equitability index values, which indicated the dominance of a single species by tending towards 0 (Fig. 56).

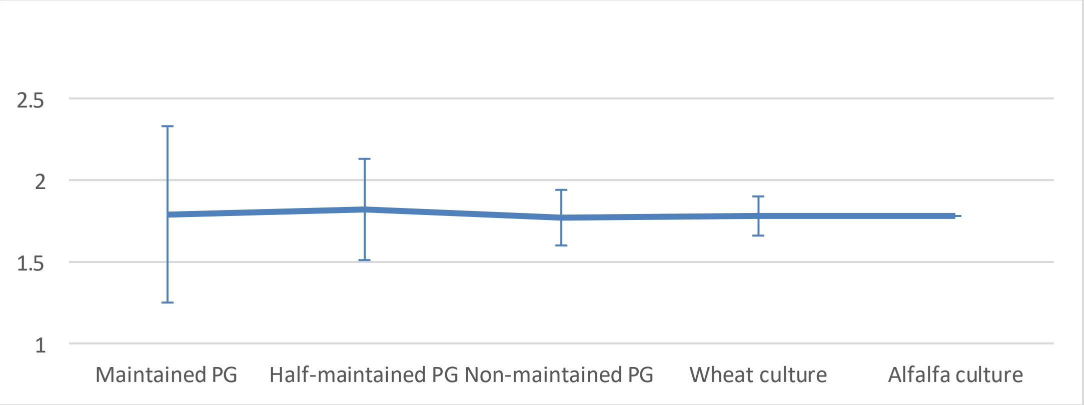

Fig. 56- Spatial variation of Simpson D index

II.3.5.1.5 - Hill's index

For a better comparison of stands in different sites, it is preferable to use the Hill index, which has the advantage of combining the two previous indices H' and D. Several authors (see MOUILLOT, 1999; THOIRON et al., 1988) recommend its use. Hill's values, which are very close and tend towards 0 in the sites 1, 2 and 3, confirm a higher level of diversity in terms of species richness than in terms of number of individuals (Fig. 57). The sites 4 and 5 show higher values of the Hill index (Fig. 57), indicating less diversity with a remarkable dominance of a single species (*Lophyra flexuosa* in our case).

Most of the time, as was the case in our work, it contains a solution that is not attractive to insects, allowing them to be preserved. It is therefore a passive trap that only collects insects that may have fallen into the pot during their natural movements. These traps are therefore useful when we are interested in the assemblage of active Carabidae and wish to locate their activity, but they do not provide information on inactive individuals, such as overwinterers.

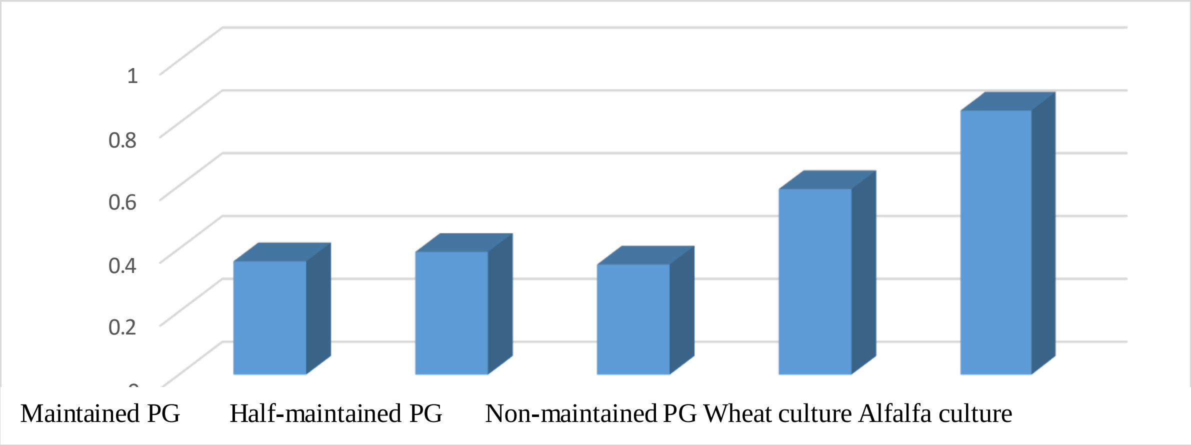

Fig. 57 – Spatial variation of Hill index

II.3.5.1.6. - Abundances and relative abandunce of Carabidae

The number of individuals recorded in the five sites of the study area differs from one site to another. It was the highest in site 1, with 30% of the total stand, followed by site 2 with 24%. The sites 3 and 4 show comparable abundances with 13.12 and 10% of the total, respectively. The site 5 remains the least abundant, with only 176 individuals (10%) (Fig. 58).

Among the sub-families, Cicindelinae was the only one inventoried at site 5 and the most abandoned at the other sites in the study region. The Harpalinae sub-family was ranked second at sites 1, 3 and 4, whereas it was ranked third after the Lebiinae at site 2 (Fig. 58).

Regarding the abundance of different species of Carabidae at the various study sites, we have noted the dominance of *L. flexuosa*, *C. campestris*, *S. buparius*, *A. elegans*, and *A. megacephalus* in the maintained palm grove with 212, 25, 21, 19, and 15 individuals respectively, and in the semi-maintained palm grove with 247, 22, 11, 23, and 22 individuals respectively. However, *L. flexuosa*, *C. campestris*, *S. buparius*, *H. tenebrosus*, and *P. nigrita* dominated in the unmaintained palm grove with 351, 27, 19, and 14 individuals respectively. In the wheat culture, we have noted the dominance of *L. flexuosa* (245 individuals), *C. campestris* (27 individuals), and *S. buparius* (19 individuals), while the alfalfa culture has contained only two species: *L. flexuosa* with 247 individuals and *C. campestris* with 13 individuals (Fig. 59).

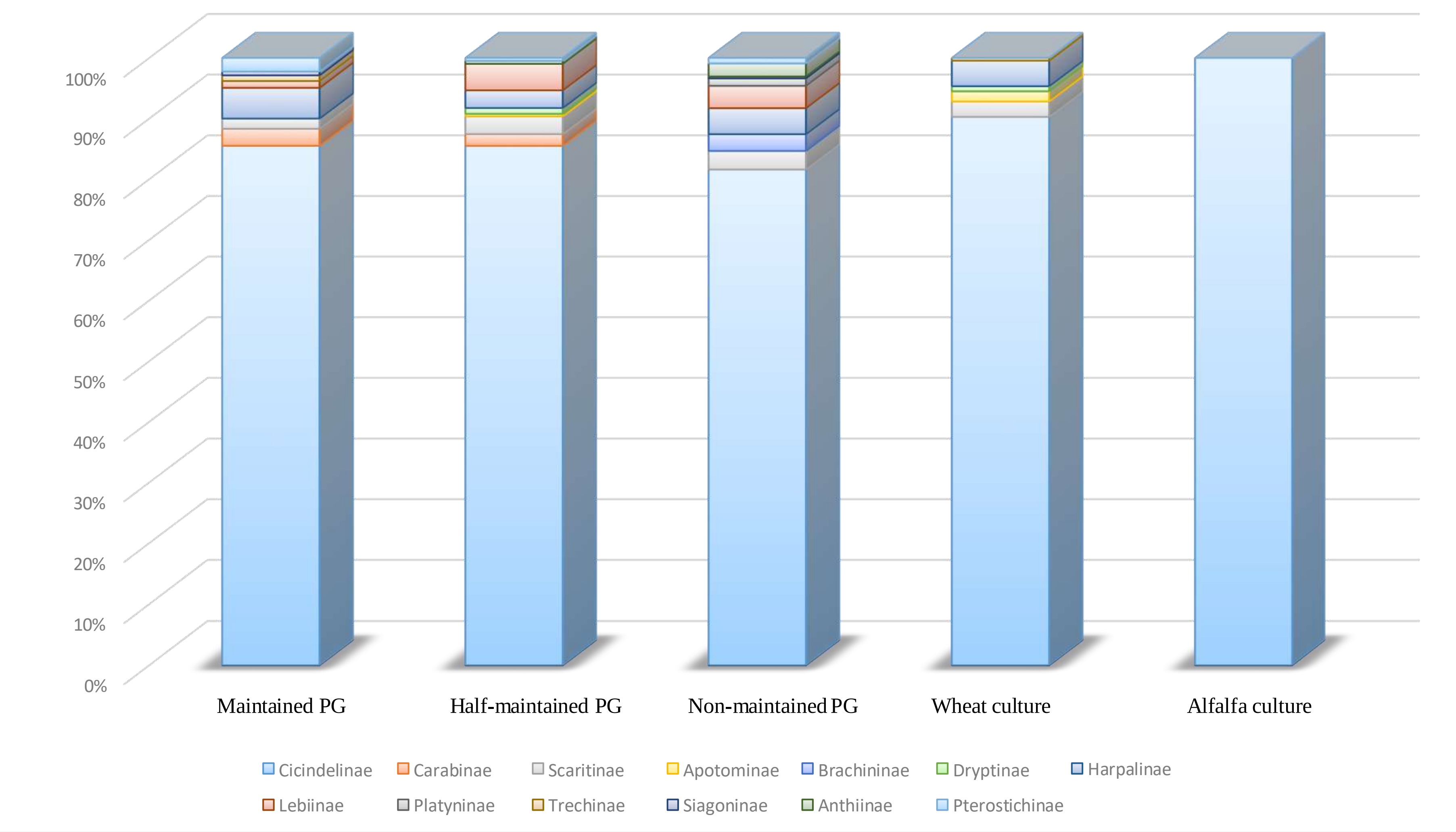

Fig. 58- Spatial variation of Carabidae sub-families abandunces

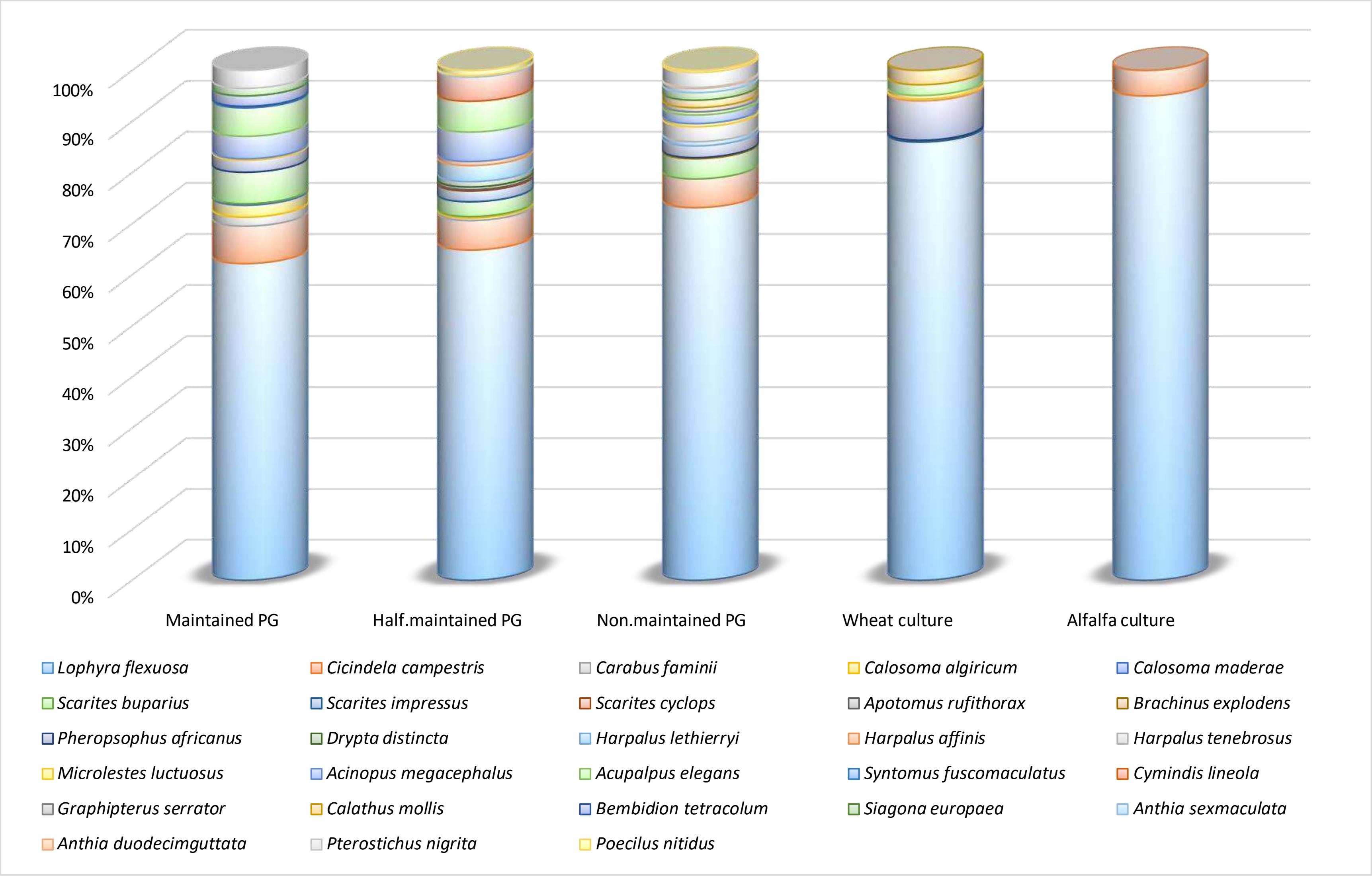

Fig. 59- Spatial variation of Carabidae species abandunces

II.3.5.1.7. - Kruskall-Wallis

The existence of any significant difference between the numbers of individuals of Carabidae inventoried in the five agricultural envirnments was checked using the Kruskall-wallis test. The later was chosen after applying the Kolmogorov-Smirnov normality test and finding that the normality is not significant (Tab. 6).

Tab. 6 - Kruskall-Wallis test result

K (Valeur observée)	20,14
K (Valeur critique)	9,488
DDL	4
p-value (unilatérale)	**0,000**
Alpha	0,05

In this case, the statistics of the Kruskall-Wallis test give a value equal to 20,14 with a probability smaller than 0.05. We therefore refuse the null hypothesis according to which there is no significant difference between the values of the numbers of Carabidae individuals inventoried in the study sites. In other words, the difference between the means of these five groups is statisticaly significant.

Indeed, DAJOZ (2002) argues that animals always look for an area where the ideal conditions for living can gather. In fact, many abiotic and biotic factors like temperature, humidity, light, predator distribution, food supply, and life cycle strategies can lead to the difference in species richness (LOVEI and SUNDERLAND 1996). We would like to point out here that our agricultural environments differ greatly in terms of their biotic and abiotic conditions.

II.3.5.1.8. - Similarity index between palm groves

Jaccard's index was calculated to assess the similarity of arthropods communities between the different palm groves (Table 7).

Matrix obtained for Jaccard similarity index calculated (Table 7), shows that the highest similarity was observed between 1st palm grove and the3rd palm grove with 52%. That indicate a large number of species common between this tow palm groves.In contrast, the lowest similarity value was 16% between the 4th palm grove and the 2nd one. Those results indicate that there were few common species between the two visited palm groves and there were a number of heterogynous specific species in each palm grove.

Tab. 7 - Jaccard's silarity index calculated for the five study sites

U02(i,j)	Maintained PG	Half-maintained PG	Non-maintained PG	Wheat culture	Alfalfa culture
Maintained PG	1.000	0.248	0.334	0.182	0.118
Half-maintained PG		1.000	0.274	0.225	0.110
Non-maintained PG			1.000	0.217	0.105
Wheat culture				1.000	0.100
Alfalfa culture					1.000

II.3.5.1.9. - Indicator species for some palm groves of the region of Ouargla

Indicator species are species that are used as ecological indicators of community or habitat types, environmental conditions or changes ZINSOU et al (2017). The IndVal method has many advantages for ecological bioindication (MCGEOCH and CHOWN 1998). This statistical approach makes it possible to identify an indicator species among species with similar specificity and fidelity, but can also show whether a species is unsuitable as an indicator (MOUILLOT et al. 2002). Several authors have used this method to identify characteristic species (ANTONELLI, 2015; SKLODOWSKI, 2016; ZINSOU, 2017; AMRI, 2019 and LABAT, 2021).

The indicator values (IndVal) of the taxa or combinations of taxa at the sitesare presented in Table 8.

The IndVal analysis of the assemblages of 28 Carabidae species inventoried between 2019 and 2021 revealed the presence of only one species characteristic the region of Ouargla in all the study sites. That was Lophyra flexuosa a xerophylous, macropterous, insectivorous, diurnal, long leged species generally found on sandy soils covered with sparse vegetation. No other species seem to be characteristic of the study region. The non-significant values to be indicators confirm the presence of species that depend on a functional zone ecological transition from open to closed environment (agricultural envirnments to other natural habitats).

Tab 8 - The indicator values of the taxa or combinations of taxa at the stations

Species	Site 1			Site 2			Site 3			Site 4			Site 5		
	Sp.	Fd.	I.V.	Sp.	Fd.	I.V.	Sp.	Fd.	I.V.	Sp.	Fd.	I.V.	Sp.	Fd.	I.V.
Lophyra flexuosa	0,74	0,92	68,2	0,81	0,83	67,2	0,78	1	78,2	0,9	0,88	78,7	0,96	0,88	83,5
Cicindela campestris	0,1	0,58	5,83	0,04	0,38	1,63	0,03	0,33	1,12	0	0	0	0,04	0,13	0,56
Carabus faminii	0,01	0,04	0,02	0,02	0,13	0,24	0	0	0	0	0	0	0	0	0
Calosoma algiricum	0,01	0,04	0,02	0	0	0	0	0	0	0	0	0	0	0	0
Calosoma maderae	0,02	0,13	0,21	0	0	0	0	0	0	0	0	0	0	0	0
Scarites buparius	0,02	0,13	0,21	0,02	0,17	0,32	0,03	0,38	1,15	0	0	0	0	0	0
Scarites impressus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Scarites cyclops	0	0	0	0	0	0	0	0	0	0,03	0,13	0,32	0	0	0
Apotomus rufithorax	0	0	0	0,01	0,08	0,08	0	0	0	0,02	0,08	0,14	0	0	0
Brachinus explodens	0	0	0	0	0	0	0,01	0,17	0,2	0	0	0	0	0	0
Pheropsophus africanus	0	0	0	0	0	0	0,02	0,17	0,26	0	0	0	0	0	0
Drypta distincta	0	0	0	0,01	0,08	0,08	0	0	0	0,01	0,04	0,04	0	0	0
Harpalus lethierryi	0	0	0	0	0	0	0,02	0,21	0,32	0	0	0	0	0	0
Harpalus affinis	0	0	0	0	0	0	0	0	0	0,03	0,08	0,21	0	0	0
Harpalus tenebrosus	0	0	0	0	0	0	0,01	0,17	0,2	0,01	0,04	0,04	0	0	0
Acinopus megacephalus	0,02	0,08	0,14	0	0	0	0,01	0,13	0,12	0	0	0	0	0	0
Acupalpus elegans	0,03	0,25	0,83	0,02	0,13	0,24	0,01	0,08	0,05	0,01	0,04	0,04	0	0	0
Microlestes luctuosus	0,01	0,04	0,02	0	0	0	0,01	0,08	0,05	0	0	0	0	0	0

Syntomus fuscomaculatus	0,01	0,04	0,02	0,03	0,25	0,85	0	0	0	0	0	0	0	0	0
Cymindis lineola	0	0	0	0,01	0,04	0,04	0	0	0	0	0	0	0	0	0
Graphipterus serrator	0	0	0	0	0	0	0,03	0,25	0,69	0	0	0	0	0	0
Calathus mollis	0	0	0	0	0	0	0,01	0,17	0,2	0	0	0	0	0	0
Bembidion tetracolum	0,02	0,13	0,21	0	0	0	0	0	0	0,01	0,04	0,04	0	0	0
Siagona europaea	0,01	0,08	0,09	0	0	0	0	0	0	0	0	0	0	0	0
Anthia sexmaculata	0	0	0	0	0	0	0,02	0,21	0,45	0	0	0	0	0	0
Anthia duodecimguttata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pterostichus nigrita	0,02	0,13	0,28	0	0	0	0,01	0,13	0,12	0	0	0	0	0	0
Poecilus nitidus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Sp. Spécificity Fd. Fidelity I.V. Indicator values

Animals exploit different types of habitat by selecting distinct and heterogeneous microhabitats (JOHNSON, 1980). Species with similar ecological requirements in terms of resources should have the same habitat selection criteria and would congregate in a given habitat to form communities with distinct specific compositions (MENGE & OLSON, 1990). According to HENGEVELD & HOGEWEG (1979), edaphic factors determine the distribution patterns of Carabidae, especially the degree of substrate moisture. This assertion was later refuted by one of the two authors (HENGEVELD, 1985), who revealed in his work on Carabids in the Netherlands that their dynamics and distribution also depend on climatic variables.

II.3.5.1.10. - factorial Analysis of correspondances of the Carabic species inventoried in the five study sites

In addition, the FCA highlighted the distribution of carabid species captured in a plane defined by axes 1 and 2, taking into account their presence/absence at the five study sites(Figure 60). The contribution of arthropods to the construction of the axes was equal to 47.21% for axis 1 and 33.25% for axis 2. The contributions of the various areas to the formation of axes 1 and 2 were as follows:

Axis 1: The site 3 contributed strongly to the construction of axis 1 with 59.8%, followed by site 2 with 24.1% and site 5 with 16.1%.

Axis 2: The site 1 contributed intensively to the formation of axis 2 with 78.1%, followed by the sites 3 and 4 with 8.7% and 8.6% respectively then site 5 with only 4.5% (Figure 60).

Concerning the contribution of the various species to the formation of axes 1 and 2, we cite, for axis 1: *S. fuscomaculatus* (sp. 19) with 16.8%, *G. serrator* (sp. 21) with 15.1%, and *A. sexmaculata* (sp. 25) with 11.7%. In second place came the species that contributed with a 8.4% and 6.7% share. These are respectively *P.africanus* (sp. 11) and *B.explodens* (sp. 10). The remaining species were poorly presented. The species contributing strongly to the formation of axis 2 were: *C. campestris* (sp. 2) with 17.6%, *A. elegans* (sp. 17) with 17%, and *H.tenebrosus* (sp. 14) with 14.2%. *P.nigrita* (sp. 27), *B. tetracolum* (sp. 23) accounted for 8.4% and 6.7% of the total respectively, while the remaining species contributed with small percentages (Figure 60). The codes for the various Carabidae species are given in Table 4.

The graphical representation of axes 1 and 2 shows that the sites 1 is in the first quadrant, the site 4 is in the second quadrant, the site 3 is in the third quadrant, and the sites 2 and 5 are in the fourth quadrant.

For the Carabidae species inventoried in the three palm groves, we noted the presence of six groupings (Figure 60). The group A comprises carabids caught only in the site 5, notably

Siagona europaea (sp. 24), and *Pterostichus nigrita* (sp. 27). Groupe B comprises *Calosoma maderae* (sp. 5) and *Calosoma algiricum* (sp. 4) which are common between the sites 1 and 5. The species forming point cloud C are typical of site 1, notably *Bembidion tetracolum* (sp. 23) and *Acupalpus elegans* (sp. 17), while carabids forming the group D characterised the site 3 mainly *Harpalus lethierryi* (sp. 13), *Microlestes luctuosus* (sp. 18) and *Calathus mollis* (sp. 22). Carabids caught only in the site 4 formed group E. These species are *Carabus faminii* (sp. 3), *Syntomus fuscomaculatus* (sp. 19) and *Poecilus nitidus* (sp. 28) (Figure 62). Group C represents Carabidae species common to all three palm groves, notably *Lophyra flexuosa* (sp. 1), *Cicindela campestris* (sp. 2), *Scarites buparius* (sp. 6), *Acupalpus elegans* (sp. 17) and *Acinopus megacephalus* (sp. 16).

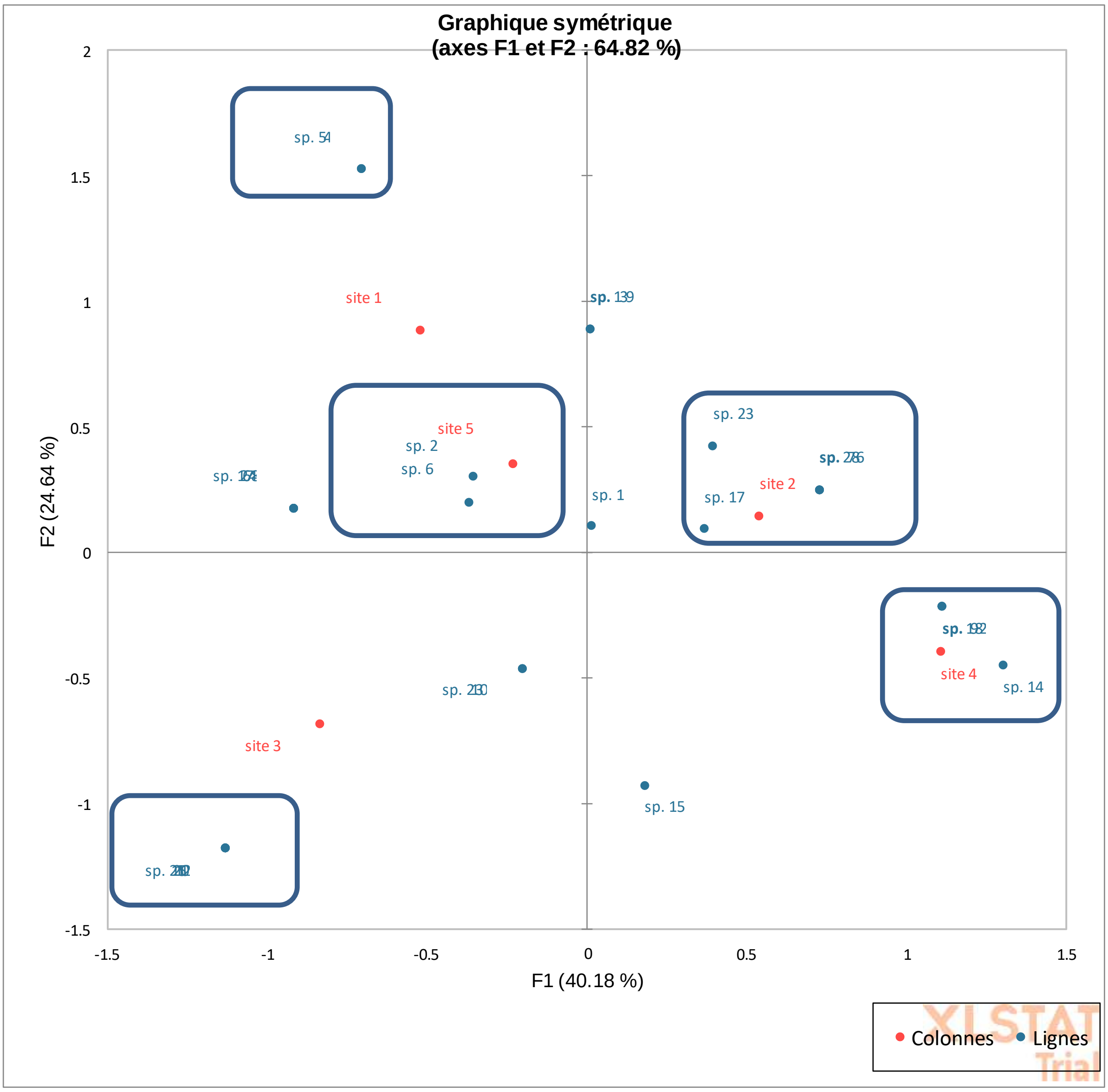

Fig. 60 - Analysis of results obtained on the Carabidae species captured in five selected sites in Ouargla using factorial correspondence analysis.

II.3.5.1.11. - Evaluation of sampling effort

The trend in species number profiles relative to the number of individuals during the sampling period is represented as a curve (Fig. 61).

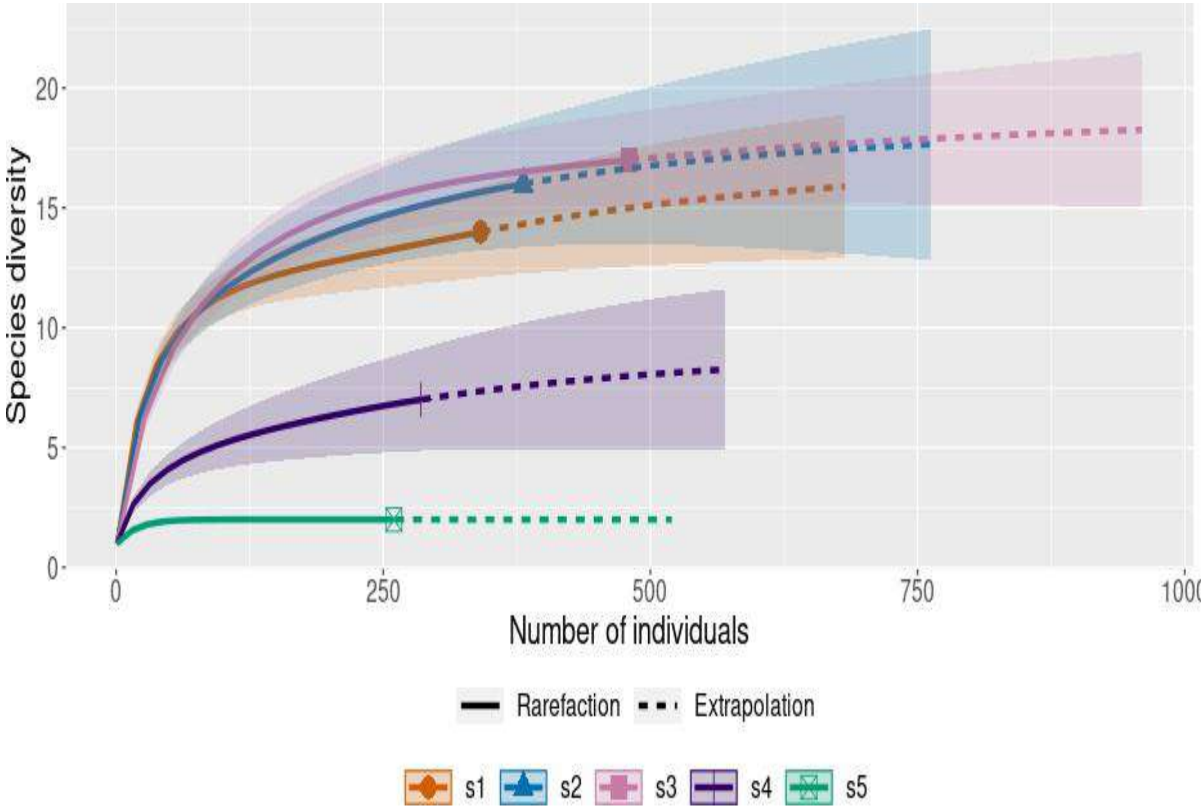

Fig. 61 - Rarefaction curve for estimating sampling effort at the five study sites.

The rarefaction graph below shows a slight divergence in the gradation of the number of taxa. There is a slight dip in the five richness curves, but no plateau can be distinguished. This upward profile of the curves therefore indicates that additional sampling effort is needed to approach completeness of the inventory and reach a plateau in the curves. This trend indicates that common species have been well sampled and that additional species would have been captured with further sampling effort.

Furthermore, palm groves had a higher richness than wheat and alfalfa cultures (Fig. 61). This result could be explained in part by a greater diversity of habitats and food sources attracting polyphagous and entomophagous species. The quantity and quality of food are important factors in the capacity of an environment to sustain a ground beetle population.

II.3.5.2. - Temporal evolution of Carabidae in several agricultural environments in the Ouargla region

A description of the Carabidae collected each month at each site is very important for a better understanding of the temporal organization of Carabidae in the Ouargla region. The captures took place over a period of three years. This period allowed us to track the temporal variation of Carabidae over the twelve months of the year.

II.3.5.2.1. - Temporal variation in species richness

The species richness of the Carabidae community had significant variations in composition during the study period (Fig. 62). Spring and summer are the richest in the entire region, accounting for more than 90 % of the total species richness in the study area (Fig. 62). The winter season shows average diversity with 5 species. Almost all of the species collected in winter are common species that can be found throughout the year, such as *Lophyra flexuosa*, *Cicindela campestris* and *Acupalpus elegans*.

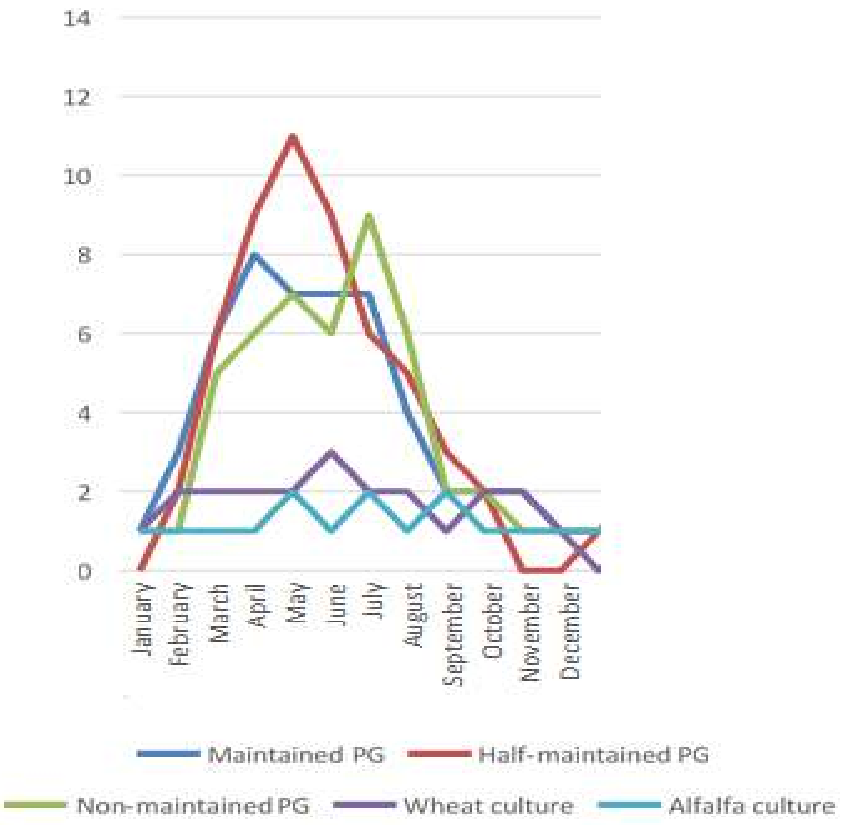

Fig. 62 - Variation temporelle de la richesse spécifique totale des Carabidae inventoriés dans les sitesd'étude

Agricultural envornments are disturbed several times a year by tillage, sowing, possible phytosanitary treatments, and harvesting (ALTIERI, 1999). Over the course of a single year, living conditions in Agricultural envornments therefore change radically and very quickly. These disturbances potentially affect soil structure, chemistry, vegetation structure, microclimate, and food resource abundance, which are crucial determinants for the organisms that may live there.

According to BOURAADA et al (2018), soil moisture is the key factor in the distribution of Carabidae, rather than vegetation composition. According to VANBERGEN et al. (2005), Carabidae may be influenced by air and soil moisture. Based on our results, Carabidae appear to be grouped according to the moisture level of the study area. Our results are consistent with the work of EYRE and LUFF (1990) on European fauna, OUCHTATI (2012) on Carabidae in El-Kala National Park, and AMRI (2019) on Carabid entomofauna in the chotts of eastern Algeria.

These authors indicate that the amount of water in the soil is an important factor influencing the composition of Carabidae. The highest number of Carabidae in terms of abundance and species richness in our community was recorded in the spring and summer seasons, consistent with the findings of PAARMANN (1970) and OUCHTATI (2013). This maximum diversity is associated, on the one hand, by SKARBEK et al. in 2020 with a gradual rise in temperature and, on the other hand, by NEVE, 1994; HONEK, 1997; HOLLAND and REYNOLD, 2003 with the resumption of activity and the emergence of new individuals that have spent the winter season in larval form. Carabidae are more active, which makes them easier to capture and thus allows for the identification of more species. According to THOMSEN et al (2016), high temperatures in the summer have a positive effect on species richness. This variation on number may be also explained by flora diversification during spring period (GREENSLADE & GREENSLADE, 1977; COTES et al., 2009) used as habitats for prey or as an alternative source for food, refuge or for hibernation for larval development (Maisonhaute, 2009).

II.3.5.2.2. – Temporal variation in the Shannon-Weaver diversity index H' and maximum diversity index H'max

The values recorded during the summer and spring seasons are significant and indicate the codominance of several species. The maximum value of H' of 3.46 bits recorded during the summer (July) and spring (May) periods is probably related to the relatively high species richness and the very low number of specimens, followed by the automn season with an equally high value of 2.81 bits (Fig. 63). The lowest Shannon-Weaver diversity is recorded in winter with a value of 0 (January and December).

In direct relation to species richness, H'max of the Carabidae community shows relatively high values (Fig. 63). The maximum value recorded in November is probably due to the low number of specimens captured during that mounth. Otherwise, the relatively low values correspond to the species richness recorded during the spring and summer seasons, followed by the automn season then the winter season (Fig. 63).

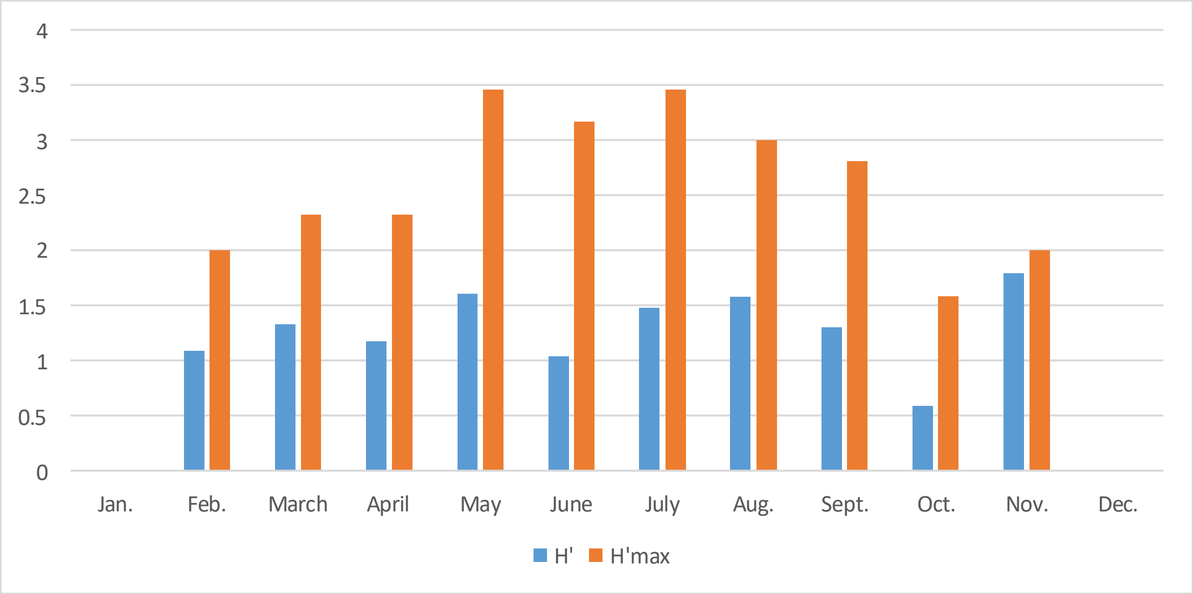

Fig. 63 - The Shannon-Weaver diversity index H' and maximum diversity index H'max temporal variation of the inventoried carabids

II.3.5.2.3. - Monthly variation in abundance

The highest number of specimens was recorded during spring and summer in all the study sites. That can be explained by the increase of activity of the majority of Carabidae species with the increasing degrees of temperatures. The autumn season is marked by a decrease of abundances, which can be interpreted by the fact that the majority of carabids escape the low temperature conditions by getting refuged under the ground, stones and vegetation cover. Finally, the winter season is characterized by a low number of specimens (Fig. 64). This low value is probably due to poor weather conditions, notably very low temperatures, obliging carabids to have a hivernation period.

Furthermore, we have noted that the seasonal variations in carabids abundances still the same for the five agricultural environments but the maximum values of abundance can be earlier in a site or latter in another site (Fig. 65 to Fig. 69). Over the course of the yeare the synchronicity between the phenology of the species and their needs and the phenology of the plants and the availability of resources is not necessarily exact in all the agricultural envirnments. Carabid diversity is highest in agricultural environments that provide plant cover the earliest and where no or few practices are carried out at this period (BAGUETTE & HANCE 1997). In fact, the phenology of cultivated plants, and therefore the period at which they provide favourable conditions, varie from one species to another. Depending on whether they are planted in autumn or spring, they may or may not be able to provide winter shelter or food during the active period.

On the other hand, several authors have shown that Carabidae, or at least certain species, exhibit significant interannual variability in abundance, particularly under the influence of climatic variations or variations in prey populations (BAARS and DIJK, 1984; SYMONDSON et al., 2002a; IRMLER, 2003). This leads us to believe that, although the composition of assemblages may vary due to interannual fluctuations, the structure of the community in terms of the relationship between rank and proportion of species is relatively well preserved, despite different sampling periods and sample plots in the comparisons we conducted. Other studies also show that the spatial distribution patterns of species in stable environments are generally reproduced from one year to the next (JUDAS et al., 2002) and that differences in assemblages between different environments are also preserved (MAGURA et al., 2001b).

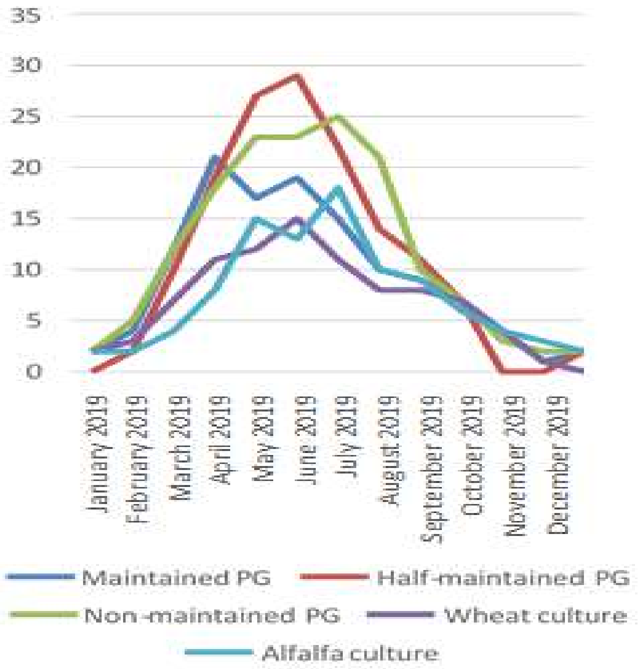

Fig. 64 - Total abundances monthly variation for the captured carabids

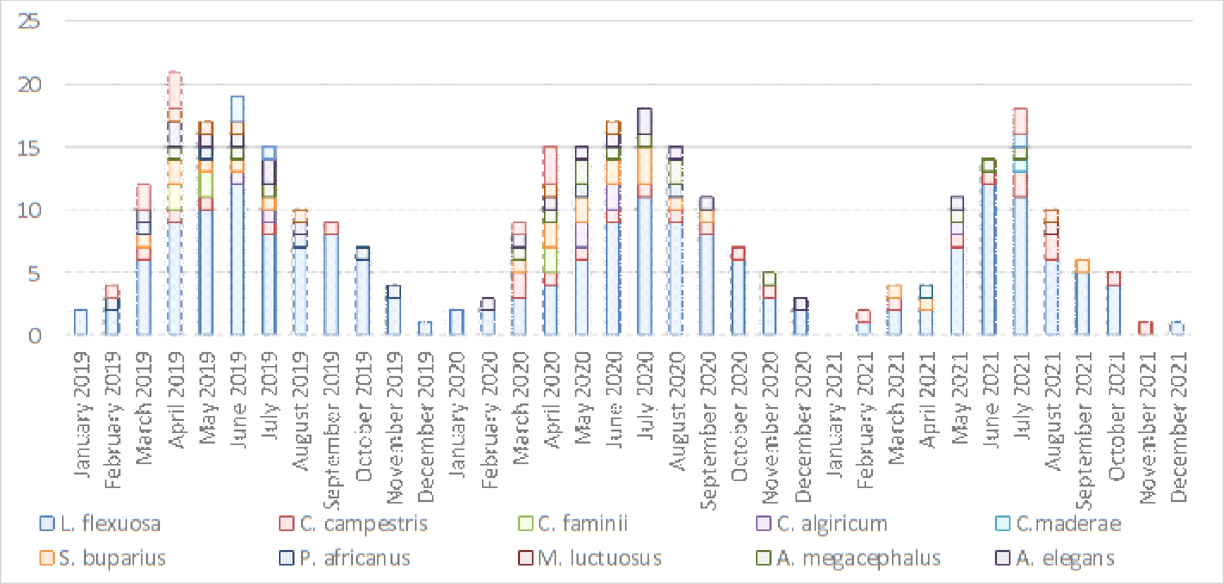

Fig. 65 - Species abundances monthly variation for the captured carabids in the maintained palm grove

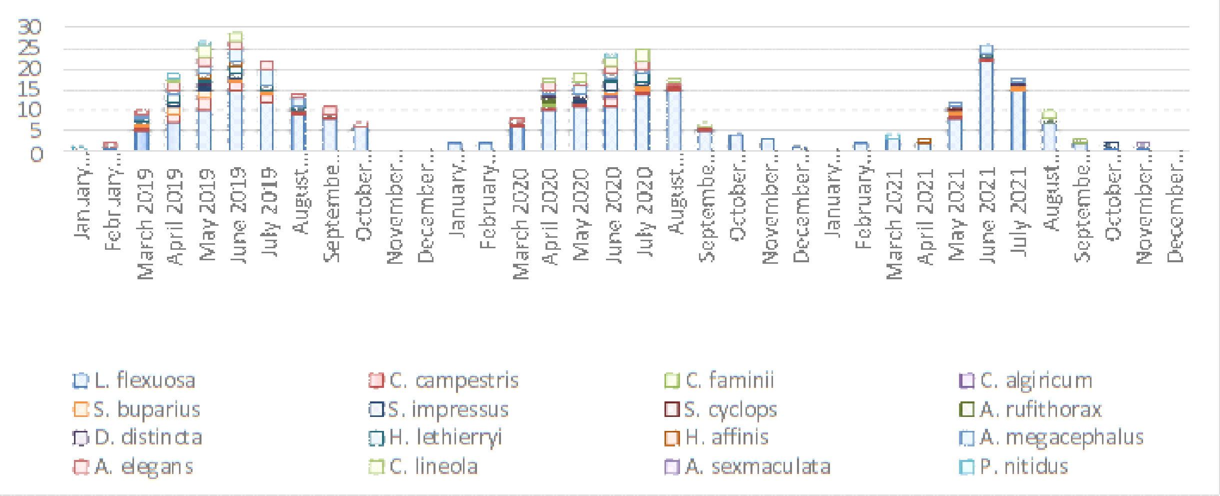

Fig. 66 - Species abundances monthly variation for the captured carabids in the half-maintained palm grove

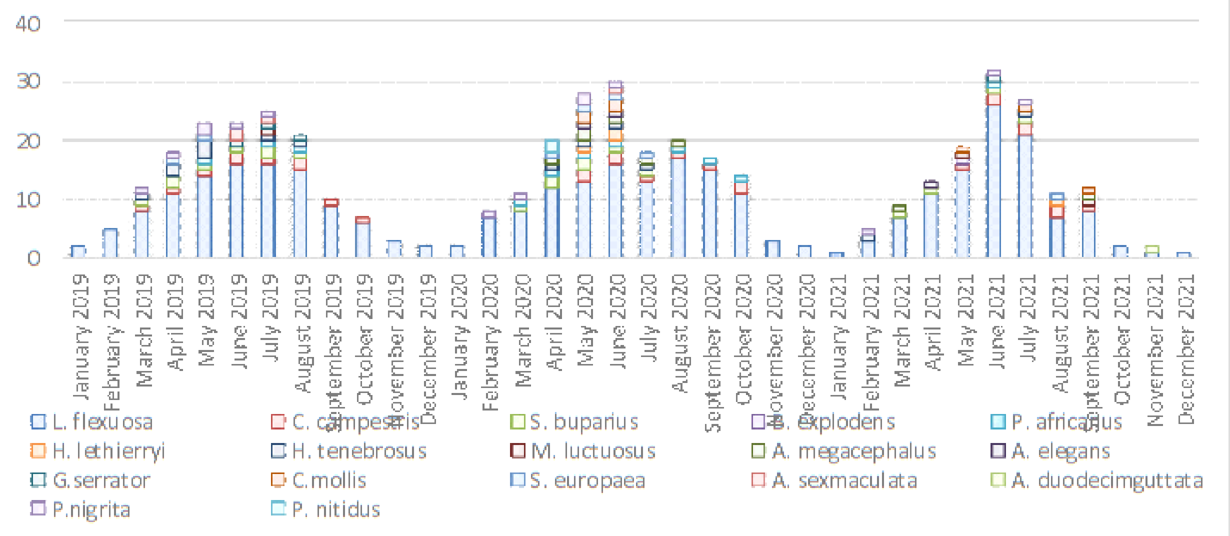

Fig. 67 - Species abundances monthly variation for the captured carabids in the non-maintained palm grove

Chapter II Results and discussion

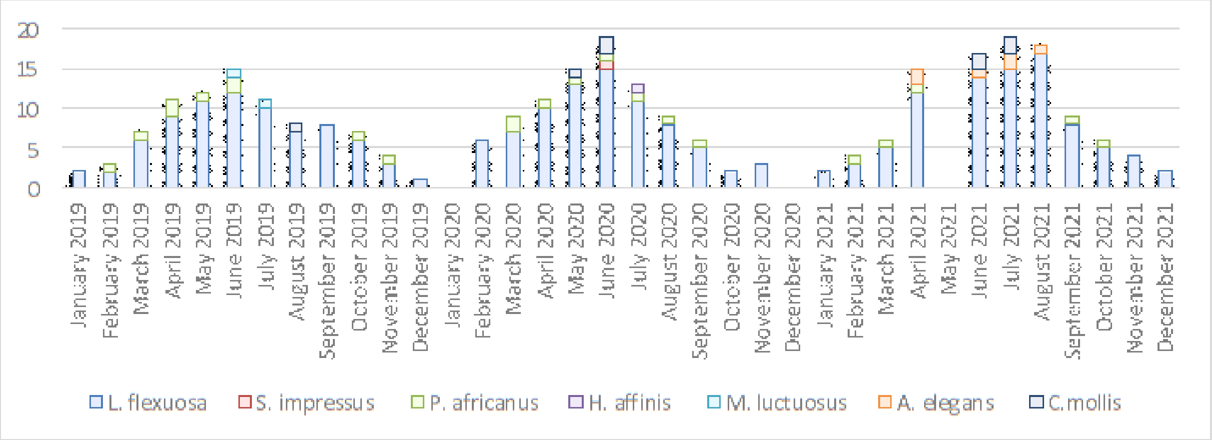

Fig. 68 - Species abundances monthly variation for the captured carabids in the wheat culture terrain

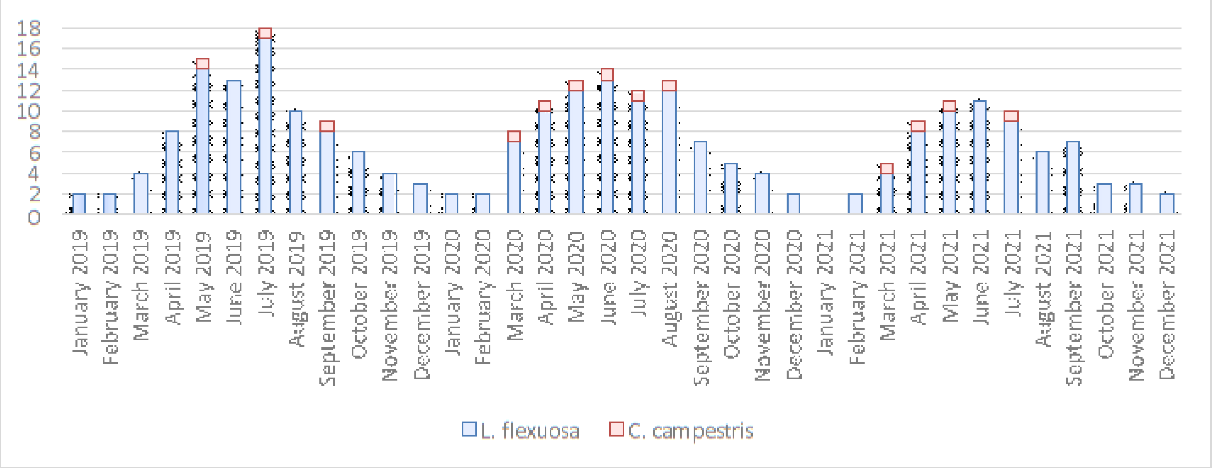

Fig. 69 - Species abundances monthly variation for the captured carabids in the alfalfa culture terrain

II.3.5.2.4. Kruskal-Wallis test

The existence of any significant difference between the numbers of individuals of Carabidae inventoried in twelve months of the year was checked using the Kruskall-wallis test. The later was chosen after applying the Kolmogorov-Smirnov normality test and finding that the normality is not significant (Tab. 15).

Tab. 9 - Kruskall-Wallis test result

K (Valeur observée)	**18,828**
K (Valeur critique)	9,488
DDL	4
p-value (unilatérale)	**0,000**
Alpha	0,05

In this case, the statistics of the Kruskall-Wallis test give a value equal to 18,828 with a probability smaller than 0.05. We therefore refuse the null hypothesis according to which there is no significant difference between the values of the numbers of Carabidae individuals inventoried in the twelve study mounths. In other words, the difference between the means of these twelve groups is statisticaly significant.

Many abiotic and biotic factors like temperature, humidity, light, predator distribution, food supply, and life cycle strategies can lead to the difference in species richness (LOVEI and SUNDERLAND 1996). For example, bare soil is often warmer and drier in spring and summer, while in winter, bare soil is more likely to freeze. For this reason, many species spend the winter under plant cover, either in crops planted in the autumn or, more frequently, in semi-natural habitats (e.g. HOLLAND & REYNOLDS 2003), only to recolonise cultivated plots in the spring.

II.3.5.2.5. - Hierarchical classification and determination of coenotic units over time

The hierarchical clustering analysis based on the Euclidean paired group (UPGMA) of ground beetles collected in the separate months of the research highlighted two discriminated groups (Figure 70): group 2 consisted of June and July (the hottest months), and group 1 included all remaining months (Figure 70). The dendrogram demonstrated that the first grouping merges the months of January and December into one category because they both were characterised with low carabids abundances (1 and 3 specimens, respectively), and then October alone forms another category that merges with the first one, and then November also forms a third category that merges with the two previous categories. The months forming this grouping (October, November, December, and January) are the coldest in the region of Ouargla. The Carabidae abundances seem to be very low at that time of the year. The second grouping merges the months of February and April into one category. The latter is added to the category formed by the month of March. The Carabidae abundances start to be more important during that period of the year (February, March, and April), and some new species start to appear (*Scarites buparius, Acupalpus elegans,* and *Pterostichus nigrita*). The months of August, September, and April form separate categories. Together, these months form group 1, while group 2 comprises just two variables. These are the months of June and July (the hottest), during which we noted an important increase in Carabidae abundance.

Coming to carabids' temporal distribution, it is concluded that abiotic factors have a more remarkable effect on the community structure than biotic factors (SOBERON 2010). A low number of specimens captured in all the agricultural envirnments (only 1747 specimens) does not allow us to find significant differences between the values of the numbers of Carabidae individuals inventoried in the twelve months. However, the temporal variation of carabids diversity seems to be controlled by climatic conditions (mainly temperature and precipitation). Indeed, the highest values of Carabidae species richness were those registered in June and July (high average temperature and low average precipitation), while the lowest values were those found in January and December (lower average temperature and higher average precipitation). According to SANDERS et al. (2007), all organisms' species richness can be determined by the temperature, as it affects their metabolic reactions. The influence of precipitation on carabids' structure is also remarkable because it provides them with a higher soil moisture and a greater plant diversity (YAN et al. 2015). The same result is given by AMRI et al. (2019), who found that spatiotemporal patterns of ground beetle diversity in a Ramsar wetland of Algeria are markedly affected by climatic factors.

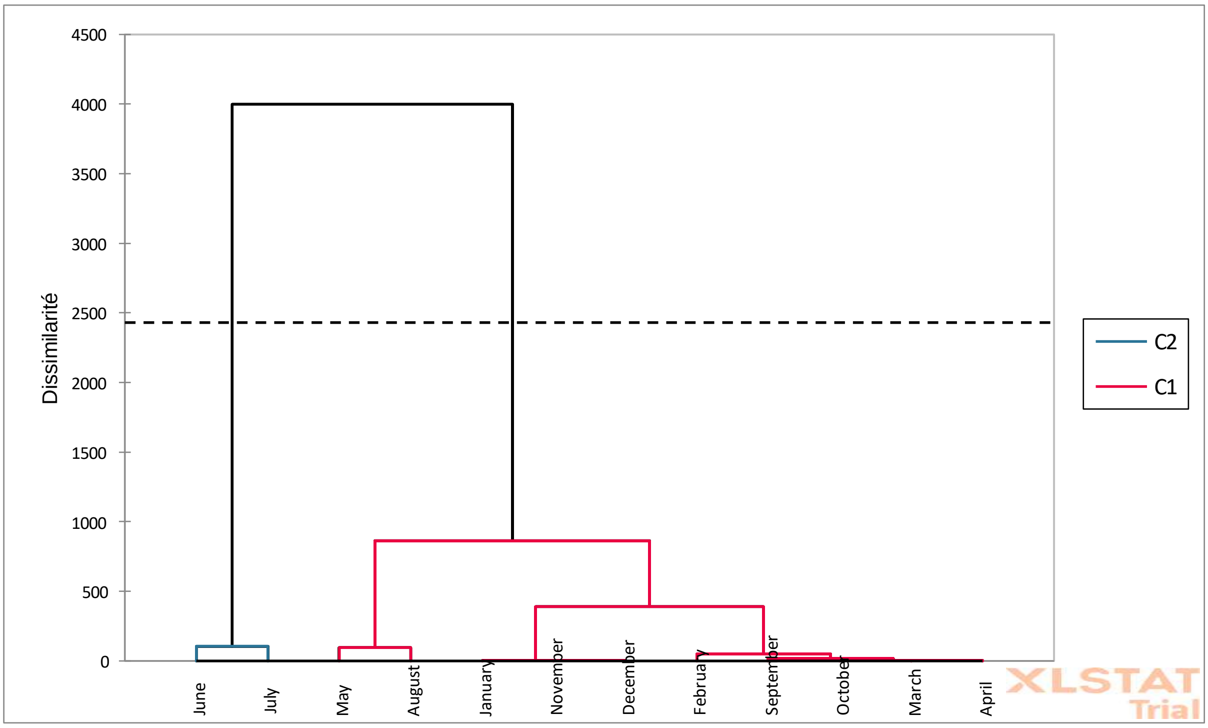

Fig. 70 - Hierarchical clustering dendrogram illustrating abundance-based similarity of ground beetle species among months in Ouargla palm groves.

II.4. - Role of some carabid species in aphid's biocontrol

This part of our study has as objective the testing of the role of some carabid species in aphid's biocontrol. The content will be presented under two parts, In the first part we will record the flight activity of aphids and six of their carabid predators in five different agricultural envirments of the region of Ouargla. Specifically, we compared species richness, temporal distribution and abundance of aphids and carabids in the five sites from February to May 2019 (the choice of that period was based on the results of our arthropodological inventory carried out between September 2019 and August 2020. We also determined the synchrony between the flight activity of aphids and their carabid predators. The carabid species heve been selected owing to their abundance and their ability in consuming aphids (WINDER et al. 2001). In the second part, we will try to test the efficacity of the same carabid species to aphid's biocontrol as field studies generally reported that carabids have the potential to suppress pest populations, yet did not demonstrate that these beetles were directly responsible for significant decreases in pest density.

qII.4.1. - Composition and spatiotemporal variations of the aphidofauna inventoried in the study sites

The composition and the spatiotemporal variations of the inventoried aphidofauna, is presented in discussed in the following section.

II.4.1.1. - Total number of aphid species found at the study sites

The list of aphid species found at the five sites in the Ouargla region is presented in Table 10.

Tab. 10 - List of aphid species found in the Ouargla region

Sub-family	Trib	Gener	Species
Aphidinae	Aphidini	*Aphis*	*Aphis craccivora* Koch, 1854
			Aphis fabae Scopoli, 1763
			Aphis gossypii Glover, 1877
	Macrosiphini	*Myzus*	*Myzus percicae* (Sulzer, 1776)

This study revealed the presence of four aphid species. Table 10 shows a strong dominance of the Aphidini tribe with three species of the genus *Aphis* and one species belonging to the

Macrosiphini tribe of the genus *Myzus*. These species are already known to be polyphagous and cosmopolitan.

According to HULLÉ et al (1999), *A. craccivora* can be found on a large number of plants belonging to different botanical families: Asteraceae, Cucurbitaceae, Fabaceae, Solanaceae, with a preference for Fabaceae such as broad beans and alfalfa.

Similarly, *A. fabae* is a species that alternates between its primary host, usually European spindle (*Evonymus europeus*), and its secondary hosts, herbaceous plants belonging to numerous botanical families such as Fabaceae, Chenopodiaceae, Asteraceae, Brassicaceae, and various flower crops and ornamental plants (HULLÉ et al, 1999).

According to the same author, *Aphis grossypii* attacks a large number of crops, including potatoes, tobacco, and legumes, but has a preference for cucurbits (melons, cucumbers, …), Malvaceae (cotton), and Rutaceae (*Citrus*).

Myzus persicae, in turn, alternates between primary hosts of the genus *Prunus* and secondary herbaceous hosts (HULLÉ et al, 1999). BOUSSAD & DOUMANDJI (2004) report that, among the insects collected on a bean crop, the Aphididae family is the most representative with a total of 73 specimens.

Working in Biskra (Algeria) region, LAAMARI & HEBBAL (2006) identified 16 aphid species in a field of *A. faba*. In 2014, BENOUFELLA-KITOUS et al. (2014) reported the presence of 27 species of aphids in a bean field in the region of Draâ Ben Khedda (Tizi-Ouzou, Algeria) inclusive of 125 specimens belonging to 25 species in 2008 and 143 specimens attributed to 19 species in 2013. In chickpea and lentil crops situated in Tala Amara (Tizi-Ouzou, Algeria), BENOUFELLA-KITOUS & MEDJBOUD-BENSAAD (2016) have identified 55 aphid species. The work of LOPES et al. (2012) in Belgium recorded the presence of 37 aphid species in a pea field. SINGH et al. (2016) in a study on biodiversity of aphids infesting legumes in India, reported the presence of 73 species that could infest these crops. In 2019, BENOUFELLA-KITOUS et al. (2019) studied the aphid diversity of four food legumes (broad bean, chickpea, pea and lentil) in the region of Tizi-Ouzou. The results obtained by these authors showed the existence of 43 species of aphids.

The relatively low Aphid species richness characterizing the investigated sites can be justified on the one hand by the climatic conditions that are less favourable to aphid flight than those of the northern regions of Algeria, and on the other hand by the abundance and diversity of cultivated host plants and weeds likely to attract aphids which is relatively lower in our regions than in the Northern ones. HANSKI & CAMBEFORT (1991) assert that the richness of a stand depends on the level of available trophic resources and climatic conditions of the investigated biotopes. Indeed, the increase in plant diversity leads to an increase in the diversity of phytophagous plants (BARBAULT, 1981).

II.4.1.2. - Total abundances of the inventoried aphid species

During the four months of trapping, 9833 aphids belonging to 4 taxa were captured (Table 10). The most abundant species was: *Aphis craccivora* that made up around 64.2 % of the total number of individuals caught. *A. fabae* species made up around 24.1 %, then came *A. gossypii* and *M. percicae* that presented 3.16 % and 8.2 % of the total individuals caught respectively (Fig. 71). *Aphis craccivora* and *A. fabae* were the most abundant because they are highly adaptable to different climatic conditions. Indeed, the high abundance of Aphis craccivora seems to be due to its belonging to the category of anholocyclic species, allowing it to maintain itself throughout the year in the form of parthenogenetic individuals (HULLÉ et al, 1999). The abundance of *Aphis fabae* may be due to this species' ability to have two different types of cycle: either holocyclic, alternating between primary hosts and secondary herbaceous hosts, or anholocyclic on secondary hosts when the climate allows it to survive through parthenogenesis (HULLÉ et al, 1989).

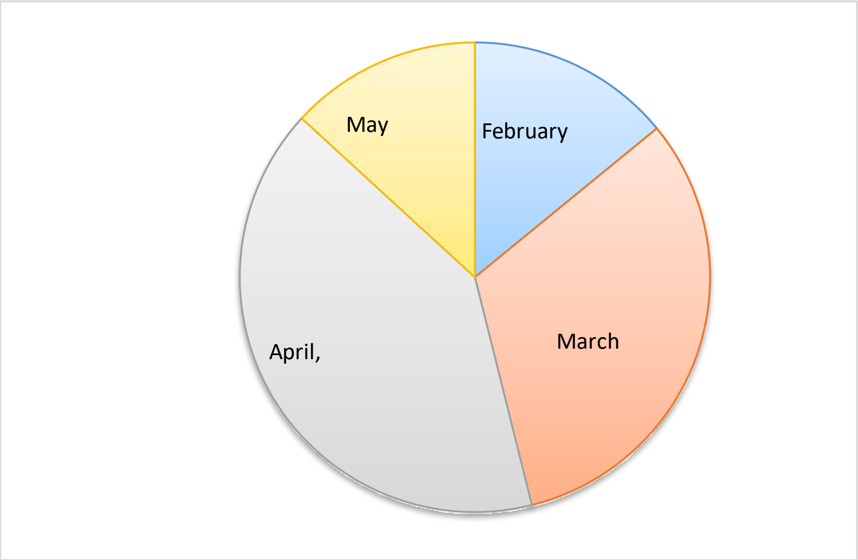

Fig. 71 - Total abundances of the inventoried aphid species

II.4.1.3. - Spatial variation in aphid diversity and abundance in the Ouargla region

The aphids sampling results are shown in Fig. 72 and Fig. 73.

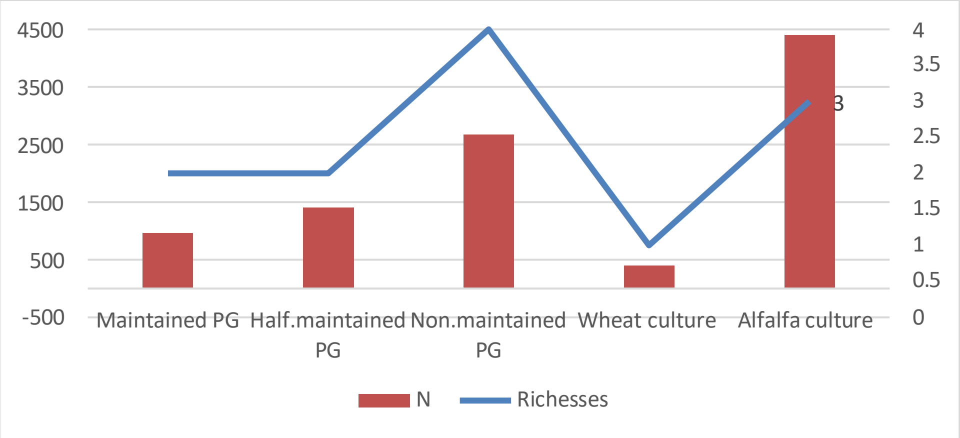

Fig. 72 - Spatial variation in total aphid diversity and abundance in the Ouargla region

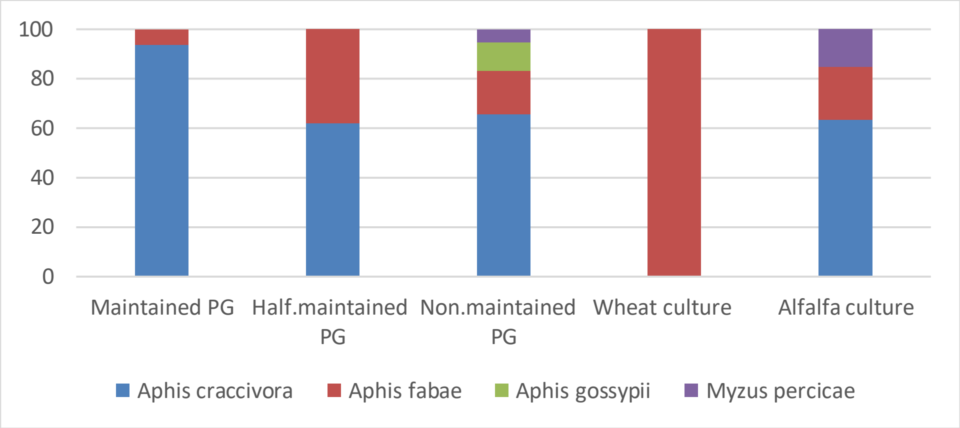

Fig. 73 – Spatial variation in species relative abundance of the inventoried aphids

According to the results shown in Figures 72 and 73, the total number of aphids was highest in the alfalfa crop, followed by the unmaintained palm grove and the semi-maintained palm grove with 2,670 and 1,400 specimens, respectively. These two environments are best represented (Fig. 72). In the maintained palm grove, more than 90% of the abundance was represented by *Aphis craccivora*, while less than 10% was represented by *Aphis fabae*. The same species appeared in the semi-maintained palm grove, with more than 60% *for Aphis craccivora* (Fig. 73). The unmaintained palm grove contained four species dominated by *Aphis craccivora* (more than 60%) and *Aphis fabae* (more than 10%). In the wheat crop, we reported the presence of a single aphid species (*Aphis fabae*), while three species dominated by *Aphis craccivora* (more than 60%) were recorded at the last site(Fig. 73).

BENOUFELLA-KITOUS et al. (2019) reported that the species *A. fabae* is most prevalent in fava bean crops. KHELOUL and MEDJBOUD-BENSAAD (2014) highlight the establishment of *A. fabae* on *Rumex* sp, *Vicia sicula*; *Sonchus* sp., and *Melilotus officinalis*. The work of LAAMARI et al. (2010) reports that this aphid has been found on around fifteen plant species. The black bean aphid has been found by BEN HALIMA-KAMEL and BENHAMMOUDA (1993) on eggplant, cucumber, and melon. According to HULLE et al. (1999), *A. fabae*'s primary host is charcoal, and its secondary hosts are Fabaceae, Brassicaceae, Solanaceae, Asteraceae, and various floral and ornamental crops. *A. craccivora* was trapped by BENOUFELLA-KITOUS and MEDJDOUB-BENSAAD (2016) with a frequency of 17.79% in a chickpea plot. LAAMARI and HEBBAL (2006) note the predominance of *A. craccivora* in a fava bean plot with a frequency of 21.3%. LAAMARI et al. (2010) mention the presence of this species with a percentage of 6%. JACKY and BOUCHERY (1982) report that the black alfalfa aphid overwinters on the alfalfa root collar and that in the warm season it contaminates alfalfa, clover, beans, peas, and other legumes.

According to HULLE et al. (1999), *M. persicae*'s primary host is the peach tree and other Rosaceae of the genus *Prunus*, and its secondary host is nearly 50 botanical species, including Solanaceae, Asteraceae, Brassicaceae, Apiaceae, and Cucurbitaceae. According to LOPES et al. (2012), *M. persicae* is very prevalent in potato crops, accounting for 70% of aphids identified on this crop. This species was captured by SEKKAT (2015) on peach, pepper, potato, tomato, and several weed species. According to this author, *M. persicae* is one of the most feared and most frequently harmful aphid species to crops, requiring specific phytosanitary interventions. This aphid is known to be a vector for more than 100 plant viruses (BLACKMAN and EASTOP, 2000).

II.4.1.4. - Temporal distribution of the aphids captured in the study sites

The temporal variation in aphids abundances seems to be the same at all the study sites. At the start of sampling, all aphid spicies populations was present in low densities of around at a temperature of 25°C measured on February (Fig. 74 to Fig. 78). After that, the number of aphids started to be haigher on March till getting its maximum ever at a temperature of 28°C. Then, this increase stopped and gradually decreased on April at a temperature of 38°C. Finally, this number stabilized in May until the end of sampling despite temperature fluctuations.

The reduction in populations may be the result of a combination of factors, including a decrease in the nutritional quality of the sap and an increase in temperatures. According to VAN-EMDEN (1972), high temperatures combined with low relative humidity cause aphids to lose water, reducing their activity and nutrition under the effect of water stress.In addition, ROBERT (2013) points out that a natural decline in populations is the result of reduced overall production, known as a self-regulating mechanism caused by overpopulation of wingless individuals, which leads to the formation of winged individuals and a reduction in female fertility.

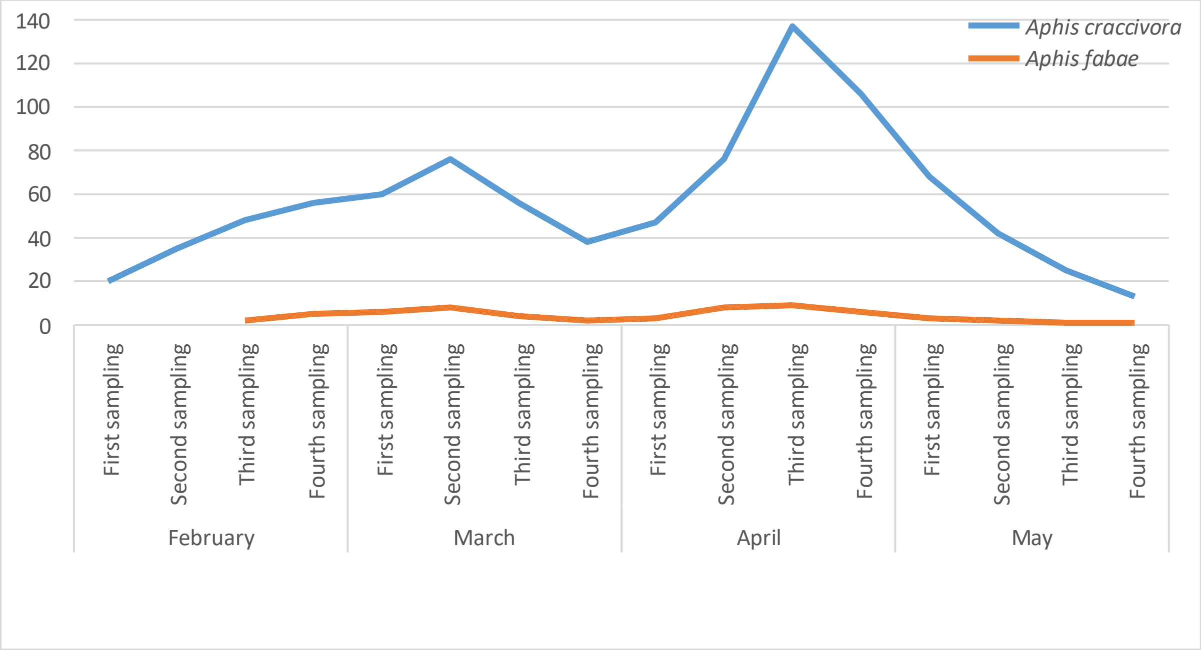

Fig. 74 - Temporal distribution of the aphids' abundances in the maintained palm grove

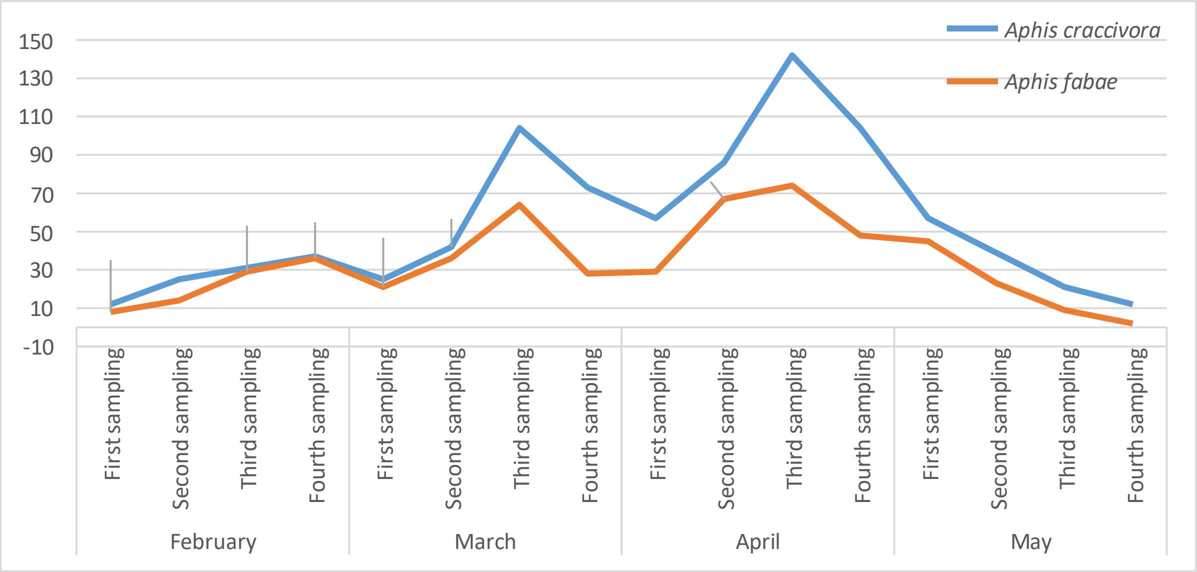

Fig. 75 - Temporal distribution of the aphids' abundances in the half-maintained palm grove

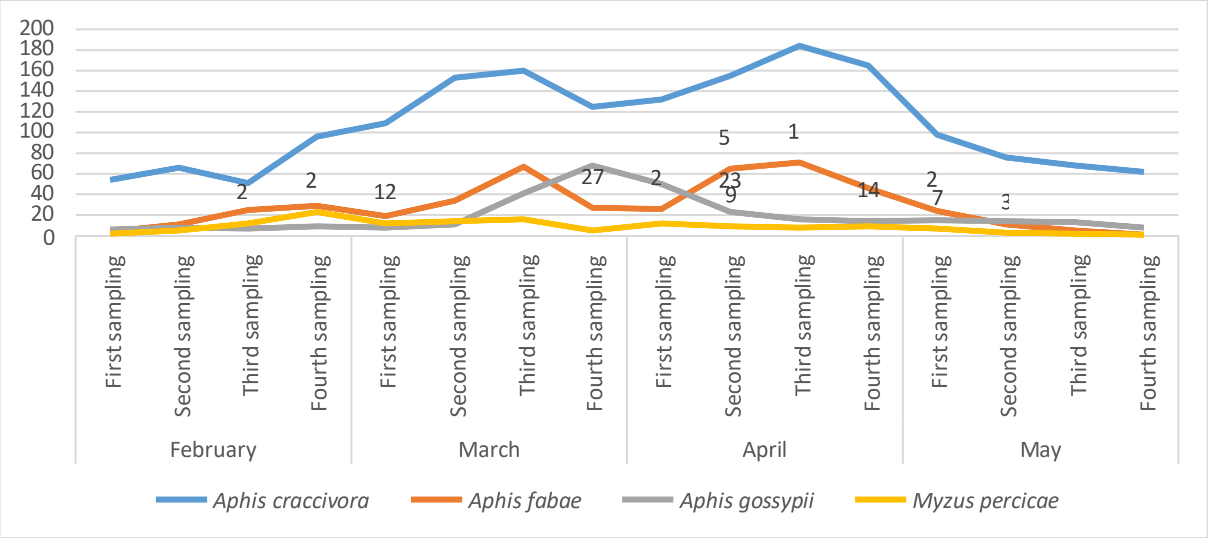

Fig. 76 - Temporal distribution of the aphids' abundances in the non-maintained palm grove

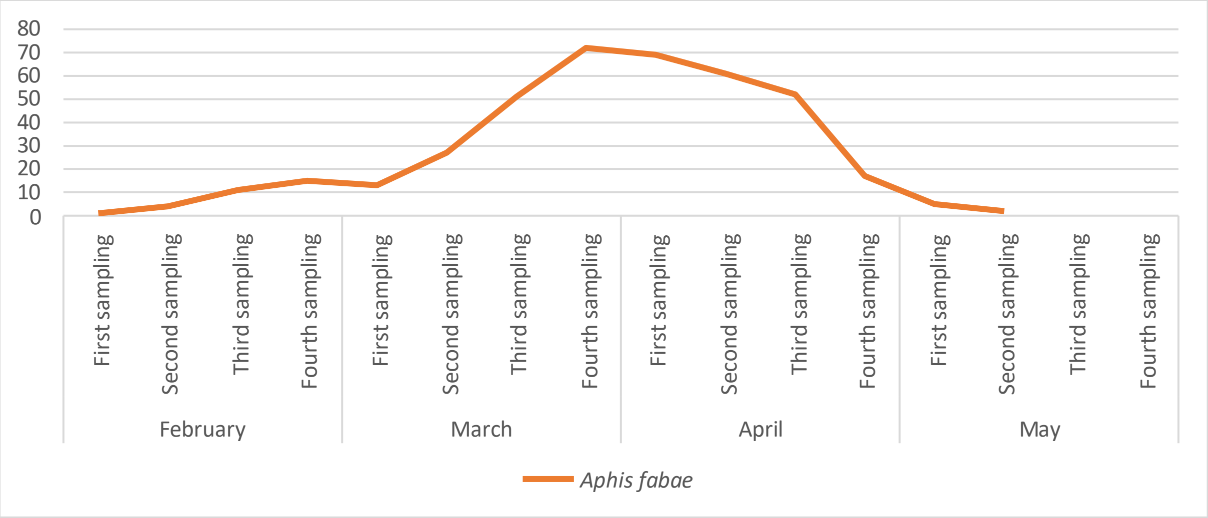

Fig. 77 - Temporal distribution of the aphids' abundances in the wheat culture

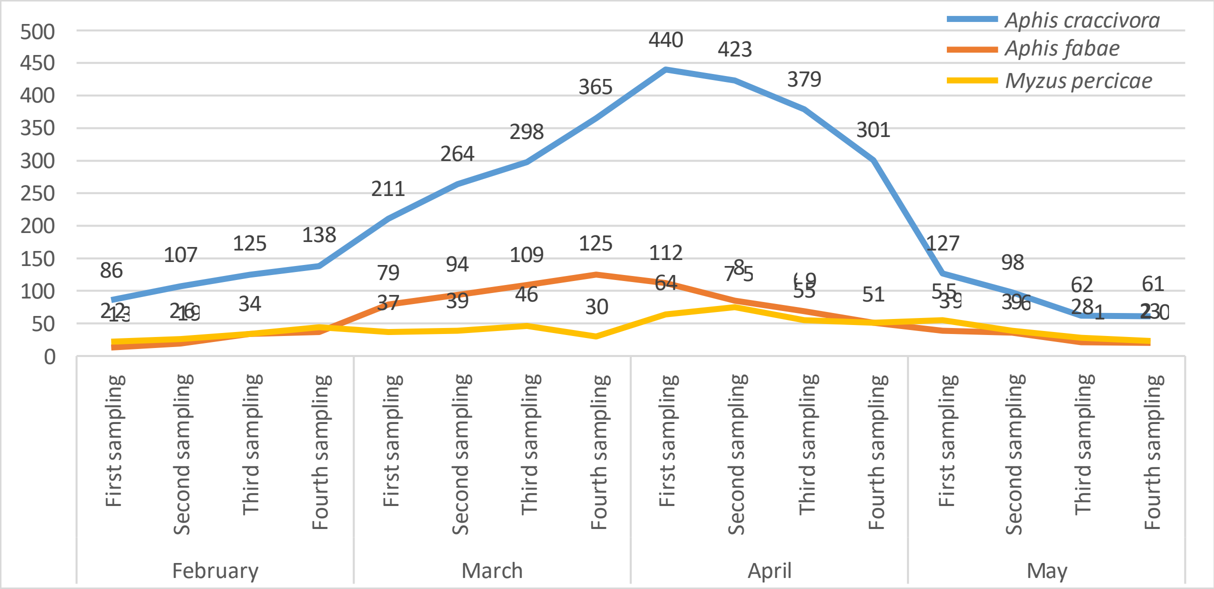

Fig. 78 - Temporal distribution of the aphids' abundances in the alfalfa culture

II.4.2. - Coincidence in the temporal activities of aphids and carabids

The coincidence between the carabid species and the aphid species temporal variation is presented in the figure 84. It appears that the populations of these two groups of insects increase at similar periods of the year (Fig. 79). Most carabids populations begin getting increased earlier than those of aphids. Furthermore, the temporal variation in the population's rythms of *Pterostichus nigrita*, *Calosoma algiricum* and *Harpalus affinis* are the closest to that of *Aphis craccivora*, while that of *Cymindis lineola*, *Calathus mollis*, and *Carabus faminii* are the closest to *Aphis fabae*.

Aphid colonies grow until, after exponential growth, they reach peaks of high abundance. They are exploited by a sequence of natural enemies that remains relatively constant from year to year (STEWART et al., 1991; DIXON, 2000). The management of energy allocation between the search for suitable patches and reproduction is particularly crucial for the reproductive success of females (FERRER, 2008). The presence and absence of competitors are factors to be taken into account when characterizing the quality of a patch. Inter- and intraspecific competition is an important factor influencing the natural behavior of insects in general. When Carabidae exploit food that is limited in time or quantity, there is a risk that if this resource becomes scarce, the number of consumers will increase. Added to this is intra-guild predation (MARTINI, 2010). In order to minimize the risk of intra-guild predation, different aphidivorous species may have co-evolved to share egg-laying in time and space (CODERRE et al., 1987). Cannibalism is often described as an adaptation to food shortages and allows communities to survive even in times of food scarcity (MARTINI, 2010).

The rate of cannibalism is thought to be modulated by the amount of food resources available, but also by the density of predators present (AGARWALA & DIXON, 1992). Consequently, the resource must be present for a sufficiently long period of time to allow sharing between several successive predators. At least one best numerical response is expected.

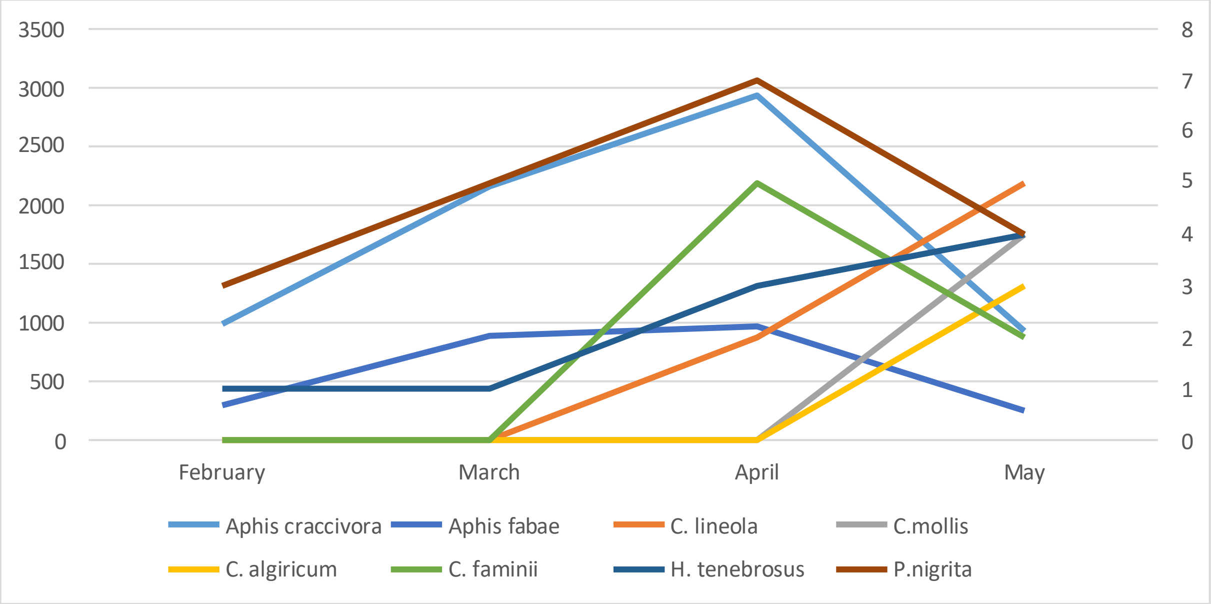

Fig. 79 - Coincidance of carabid and aphid species populations temporal variations

II.4.3. - Predation impact of carabids at different population densities on aphids development

The idea of using carabids in biological control is not new, but its practices in field are very sparce. Traying to know how can carabids control aphids development, we have carried out our experiences of biocontrol using six species of Carabidae and two species of Aphids (A. *craccivora* and *A. fabae*). Aphids have been chosen owing to their abundance and frequency of their individuals. In fact, the results that has been already presented concerning aphids inventory in our study sites show that *A. fabae* was the most wed spread while *A. craccivora* was the most abundandant. However, the choice of carabids was much more based on their historical proved efficacity against pest than on their abundances. We can cite for example the proved efficacity of *Poecilus cupreus against aphids; of Pterostichus* and *Poecilus* against *D. antiqua* pupae in corn fields; *Carabus* adults against *L. decemlineata* larvae, a pest of cultivated potato; *Calosoma sycophanta* against the gypsy moth *Lymantria dispar* (Lymantriidae) FRANCISCO J. (2021).

We have carried out our experiences on alfalfa plants combining each three carabid species to one Aphis species. These combinations were based on the already described temporal variation of aphids and carabids populations. Concequently, we have tested the efficacity of each of *Pterostichus nigrita*, *Calosoma algiricum* and *Harpalus affinis* to control *Aphis craccivora* populations, and each of *Cymindis lineola*, *Calathus mollis*, and *Carabus faminii* to control the populations of *Aphis fabae*.

II.4.3.1. - Aphids population growth in control pots

In order to compare the aphid population growth in the different control cages an adjustment with a linear model was achieved. On X axis are presented the cumulative sum of daily mean temperatures and on Y axis, the aphid numbers are presented· The sum of the daily mean temperatures is used to balance the variability between days and to allow comparison between controls.

The results show that the number of aphids and the cumulative temperature are closely related in all the pots. The population of *Aphis* keep increasing proportionly with cumulative temperature increses, and then they get stabilized with the increasing temperatures. Aphids are an abundant resource for carabids, but relatively limited in time. However, a gradient can be observed: aphids are more ephemeral. Aphids are also plurivoltine and can therefore have up to 20 generations per year. These predators can have between 10 and 12 generations per year depending on climatic conditions (FRAVAL, 2006). On average, it takes about ten days at 20°C to complete a generation, sexual generations appear in autumn, and parthenogenetic generations in spring and summer (BOUHOURA, 1987). Spring aphids multiply for a few generations by parthenogenesis when the temperature is above 18°C on the peach tree. The speed of aphid development and their fertility depend on temperature (GHELAMALLAH, 2016). A female aphid needs an average of 120°C. Temperature can also influence the number of winged insects produced and their ability to fly, and promotes their mobility (GHELAMALLAH, 2016).

II.4.3.2. - Aphids population growth in presence of carabids

The tests of efficacity of the six chosen carabid species in decresing the two chosen *Aphis* species are presented and discussed in the following.

II.4.3.2.1. - Tests on *Aphis craccivora*

Here we will present the results of test of control of *Aphis craccivora* with three carabid species: *Harpalus affinis, Pterostichus nigrita and Calosoma algiricum.*

II.4.3.2.1.1. - *Aphis craccivora* growth in presence of *Harpalus affinis*

As shown in figure 85, the development of aphid population in presence of carabids is very different from that in control pots.

This carabid beetle seems to be able to slow down severely the aphid population growth. The greatest density of beetles gives the greatest reduction in aphid number and with 3 individuals per pot the aphid population growth is controlled. Predator population densities seem to be one of the determinant factors which establish predation effectiveness.

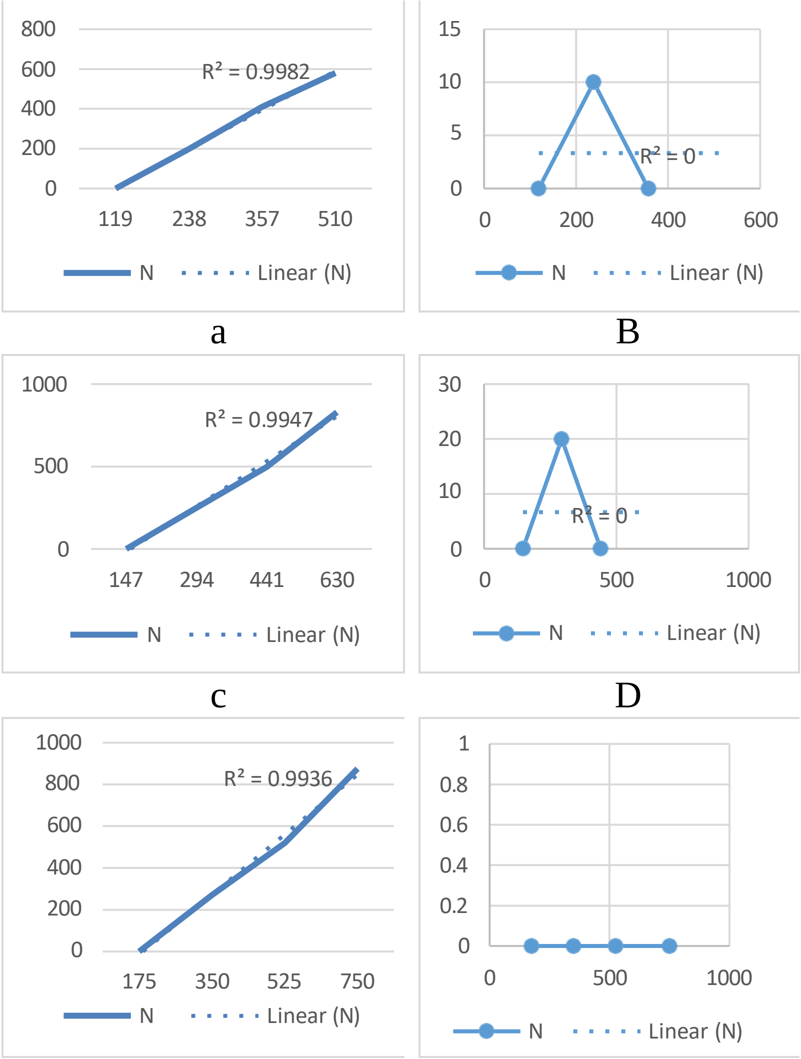

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Fig. 80 - *A. craccivora* population growth in presence of *Harpalus tenebrosus* ((a,c,e): without predator, (b): with 1, (d): 2, (f): 3 A. fabae in March April May 2023 ; N: number of aphids; r²: correlation coefficient

II.4.3.2.1.2. - *Aphis craccivora* population growth in presence of *Pterostichus nigrita*

In the presence of a medium population density of *Pterostichus nigrita*, the aphid numbers at the end of the experiment were lower than in the controls. Paradoxically, aphid populations in the presence of greatest number of predators have a higher growth rate than in the controls (Fig. 81). According to GALKA & KAJAK (1971) a predation of adults and older larvae of aphids induces an increase in population numbers as a compensating effect observed when a part of the population is removed. So, in our case a decrease in the aphid numbers, corresponding to a predation higher than 10% is observed only at medium predator densities.

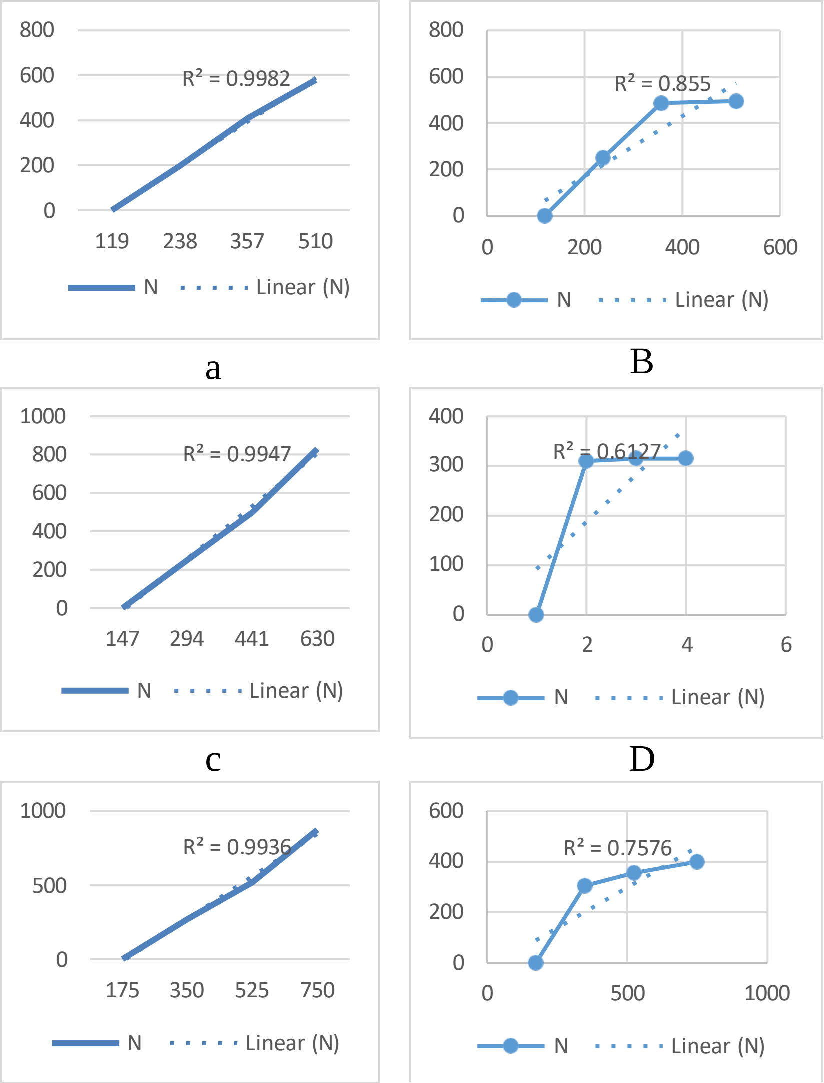

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Fig. 81 - *A. craccivora* population growth in presence of *Pterostichus nigrira* ((a,c,e): without predator, (b): with 1, (d): 2, (f): 3 *A. fabae* in March, April and May 2023 respectively; N: number of aphids; r²: correlation coefficient

II.4.3.2.1.3. - *Aphis Craccivora* growing in presence of *Calosoma algiricum*

An important slow down of aphid population growth is observed for the lowest population density of *Calosoma algiricum* aphid numbers at the end of the experiment are reduced but not their growth rates (Fig. 82).

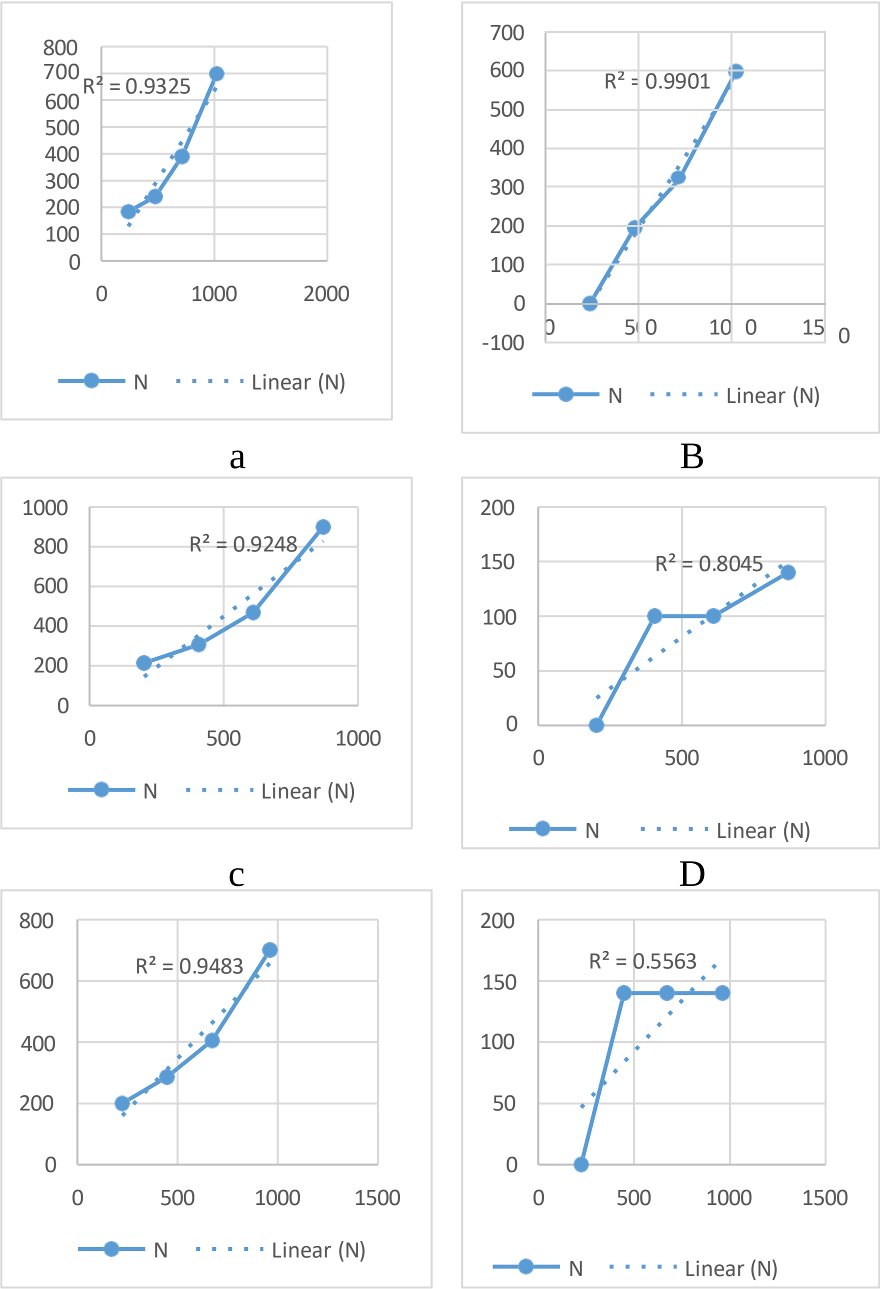

Fig. 82– *Aphis craccivora* population growth in presence of *Calosoma algiricum* ((a,c,e): without predator, (b): with 1, (d): 2, (e): 3 *A. fabae* in June 2023 May and June 2024 respectively; N: number of aphids; r²: correlation coefficient

II.4.3.2.2. - Tests on *Aphis fabae*

Here we will present the results of test of control of *Aphis fabae* with three carabid species: *Cymindis lineola*, *Calathus mollis and Carabus faminii.*

II.4.3.2.2.1. - *Aphis fabae* growth in presence of *Cymindis lineola*

In all pots, a markable efficacity of *Cymindis lineola* has been recorded. Even with hight densities *Cymindis lineola* was still able to brake the exponential growth of the pest (Fig. 83).

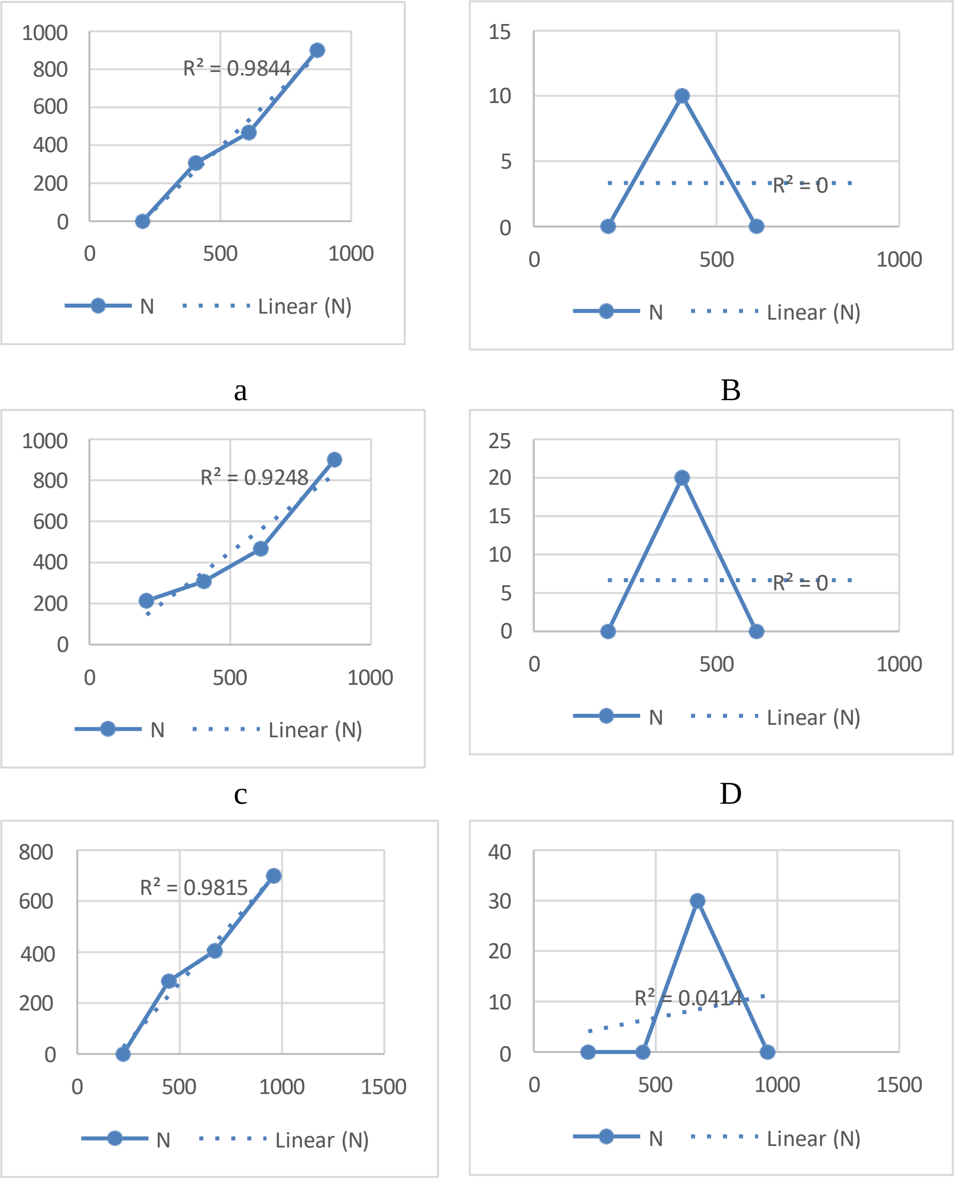

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Fig. 83 – *A. fabae* population growth in presence of *Cymindis lineola* ((a,c,e): without predator, (b): with 1, (d): 2, (f): 3 *A. fabae* in May 2023 and May 2024 respectively; N: number of aphids; r²: correlation coefficient

II.4.3.2.2.2. - *Aphis fabae* growth in presence of *Calathus mollis*

An important slow down of aphid population growth is observed, especially for intermediate population densities (Fig. 84).

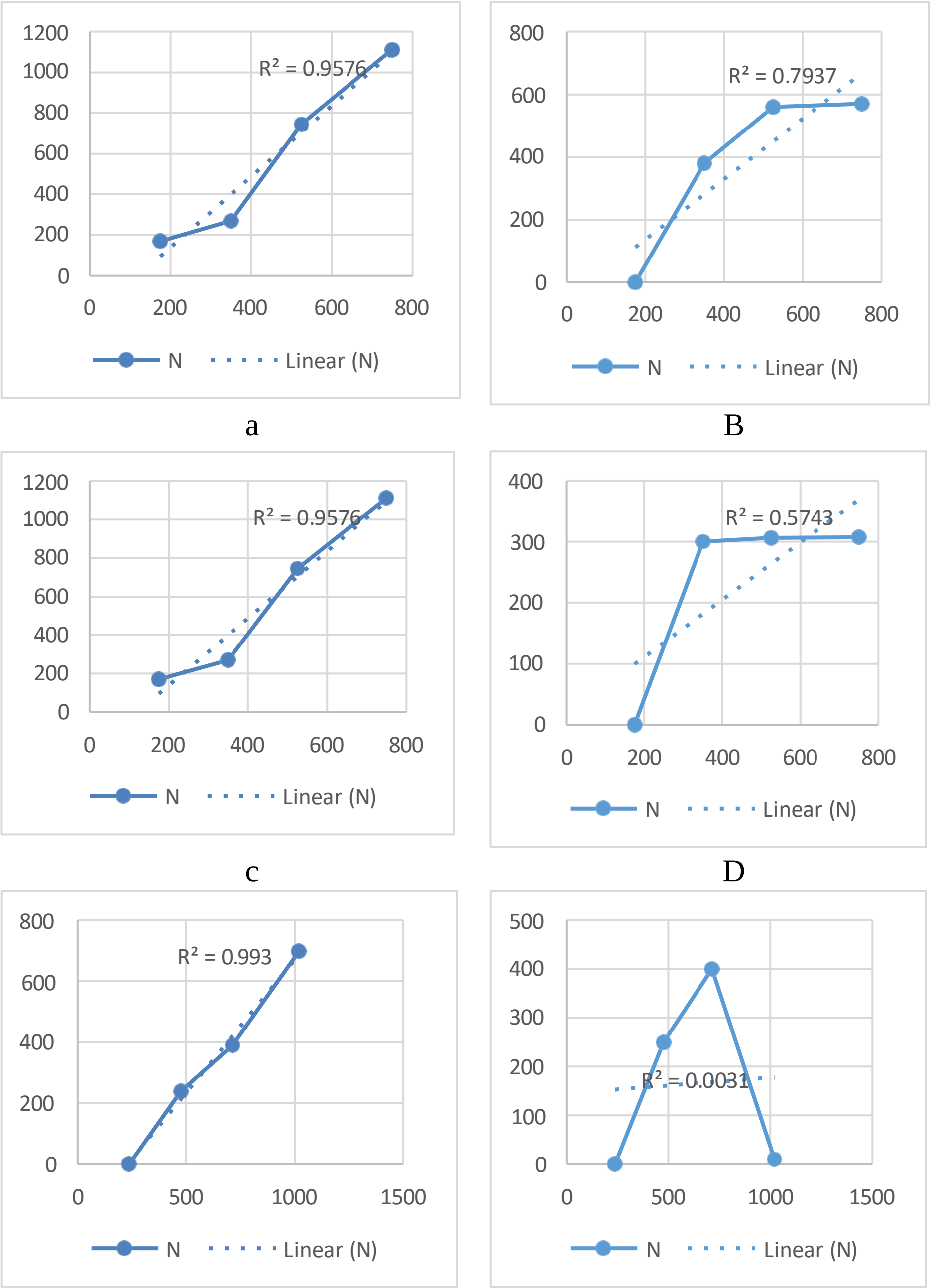

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Fig. 84 – *A. fabae* population growth in presence of *Calathus mollis* ((a,c,e): without predator, (b): with 1, (d): 2, (f): 3 *A. fabae* in May and Juin 2024; N: number of aphids; r²: correlation coefficient

II.4.3.2.2.3. - *Aphis fabae* growth in pr &esence of *Carabus faminii*

For the lowest population density of *Carabus faminii* aphid numbers at the end of the experiment are reduced but not their growth rates (Fig. 85).

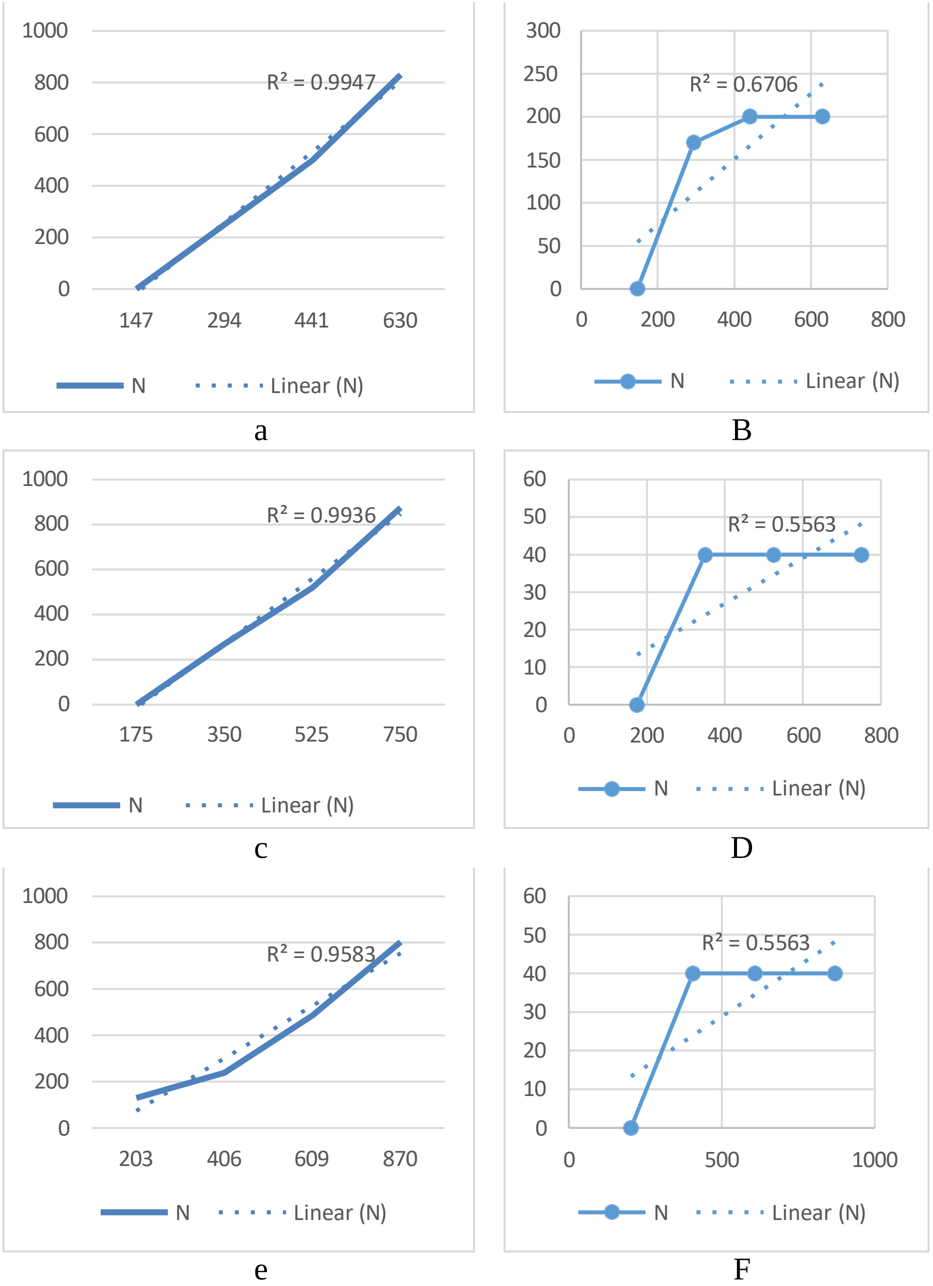

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Fig. 85 – *Aphis fabae* population growth in presence of *Carabus faminii* ((a,c,e): without predator, (b): with 1, (d): 2, (f): 3 A. fabae in April 2019, May 2023 and May 2024 respectively; N: number of aphids; r²: correlation coefficient

II.4.3.3. -Discussion of results obtained from biocontrol tests

The investigations were made with six carabid species common in our agricultural envirments: *Harpalus affinis* (small sized beetle) *Pterostichus nigrita* (medium sized beetle) and *Calosoma algiricum* (big sized beetle) to control *Aphis craccivora* populations, and each of *Cymindis lineola* (small sized beetle), *Calathus mollis* (medium sized beetle), and *Carabus faminii* (big sized beetle) to control the populations of *Aphis fabae*.

We have noticed that in the presence of small sized carabids the aphid population growth was strongly reduced and its expanential phase was broken. At high population density, carabids controlled entirely the aphid population growth. These beetles seem to be the most efficient in the control of aphids populations. Medium sized beetles are also effective predators when used with intermediat densities. However, big sized carabids seem to be the less efficient in biocontrolling aphids. So, the population density of the predators is one of the factors determining the predation efficiency. This density is proportinly related to the size. In fact, species of the genus Carabus rarely reach densities of one individual per square meter, while smaller species are more common, with average densities of around 10 individuals per square meter (THIELE, 1977).

Semi-controled experiments are simple techniques for studying prey- predator relationships in similar conditiond to the natural ones. With this method the real impact of a predator at defined population densities on the development of single prey can be easily investigated (HODEK et al. 1972). With this method, we demonstrated that a non specific predator acting alone could have a very important impact on aphid population dynamics.

Intraspocific competition probably plays a important role in determining field densities as well as predation abilities. This factor must be taken into account for biological control.

As they are numerous, diversified, and able to limit the growth of a pest population even at field densities, carabId beetles and other non specific predators appear to be able to maintain the aphid populations on the general equilibrium position defined by STERN et al. (1959), under favorable conditions· Their ability in aphid regulation, their persistence in the crops during periods of low pest densities (SUNDERLAND, 1970) and thus during periods of pest emigration and increase are important factors in preventing outbreaks.

Generally, indigenous predators and non specific predators have been forgotten in integrated pest management. There are a few reasons for this. The first is that general predators are always present, even when a pest outbreak occurs, so they are not considered to be able to prevent outbreaks. But, according to STERN et al. (1976), the agroecosystems may lack a minor key or feature to adversely affect a pest or favorably modify the environment to increase the effectiveness of natural enemies. In fact, these predators act in permanently reducing the population of a few potential pests, (REICHERT & LOCKLEY 1984) and so maintaining their numbers below an economic threshold. When predator populations are reduced, by climatic factors or agricultural practices, pest outbreaks occur or phenomena like pest substitutions or pest resurgences (METCALF, 1980). The second reason is that their ecology, population structures and dynamics and species interactions are not well known yet. The third reason is that the prey-predator relationships between non specific predators and a single prey are difficult to study.

CONCLUSION

Conclusion

This work had three main objectives, the first one was the inventory of the coleopterofauna that characterizes some agricultural envirnments of the region of Ourgla. The second objective was about some bioecological traits, the bioecology and the spatiotemporal variations of a coleopteran predator family, the Carabidae. Finally the role of some carabids in aphids biocontrol.

The characterization of the microhabitats in which the Coleoptera species are distributed showed that the soils present a textural similarity (sandy-loam), the pH values vary between 8.5 and 8.75 and the soil moisture and the organic matter levels are low.

The plant species inventoried at the study sitesbelong to 11 botanical families, of which Poaceae is the most diverse (15.38% to 33.33%), followed by Amaranthaceae (16.67% to 26.67%), Asteraceae (11.76% to 25%) and Fabaceae (5.88% to 15.38%). In addition, all the study sites are classified as densely vegetated environments.

The arthropods that colonize the study sites had their maximum values of total richness, Sm index and number of individuals in the non-maintained palm grove, then the values started to decrease progressively in the other sites until the area planted with alfalfa, where they do not exceed 44 species. Sampling enabled us to count 4 classes of arthropods. The class Insecta was always the most represented, Collembola came second (1.53% to 9.82%), then the classes Arachnida (2.05% to 7.46%) and Malacostraca (0.2%) which were the least represented. The inventory resulted in the capture of 16 orders. The order Hymenoptera clearly dominated the other orders. Heteroptera and Coleoptera are also well represented.

On the other hand, the total coleopteran abundances and richnesses were totally different from a site to another. The maximum was recorded in the non maintained palm grove with 6853 specimens belonging to 65 species, followed by the maintained and the half-maintained palm groves with 4369 and 3684 specimens belonging to 52 and 51 species respectively. The velues of abundance were largely different in the remaining sites (wheat and alfalfa cultures) with 539 and 525 specimens belonging to 27 and 23 species respectively.

Among the families, Carabidae was the most diversified with 28 species (presenting 38.46 % of the total number of species). Tenebrionidae came in second with 20 species (30.77 %), followed by Coccinellidae and Scarabeidae with 12 species each (23.08 % each), then curculionidae with 10 species (15.38 % each). In terms of abundance, the Cybocephalidae family predominated and accounted for more than a half of the Coleoptera inventoried. The Coccinellidae family ranked second, followed by the Carabidae and Tenebrionidae families.

In the palm groves (the maintained, the half-maintained and the non-maintained palm groves) *Cybocephalus seminulum* was the most dominant species among all the coleopteran species inventoried, *Pharoscimnus numidicus* and *Pharoscimnus ovoideus* came second, then came *Lophyra flexuosa, Coccinella algerica* and *Adonia variegate*. In alfalfa culture, we found that *Lophyra flaxuosa* was the most anundant followed by *Ouelma melanopus, Adonia variegata, Anthicus antherinus, Coccinella algerica, Brachycerus barbarus* and *Pheropsophus africanus.*

Thus, we determined 7 diets, 56 predatory species, 31 phytophagous species, 24 omnivorous species, 2 carnivous and 2 polleniphagous species, one xyllophagous and one saprophyt species The catches were 89% (14196 specimens) dominated with predatory species (in all five sites), then came omnivorous and phytophagous species with 7% and 3% respectively. The remaining categories were weekly presented.

Of the 117 Coleopteran species inventoried in the study sites, 28 species were carabids among which 4 species are classified by Algerian law as endemic species (*Carabus faminii, Cicindela campestris*, *Anthia sexmaculata* and *Graphipterus serrator*).

The Carabidae species belong to thirteen sub-families of unequal importance. Among the subfamilies, Harpalinae was the most diversified with 5 species. Lebiinae came in second with 4 species followed by Scaritinae and Carabinae with three species each, then Cicindelinae, Brachininae, Antiinae, and Pterostichinae with two species each. In terms of abundance, the Cicindelinae sub-family predominated and accounted for more than three-quarters of the Carabidae inventoried (85.43 % of the fauna collected). The Harpalinae subfamily ranked second with 3.78 %, than the Lebiinae and Scaritinae with only 2.56 % and 2.45 % respectively.

The faunal composition analyzed on the basis of the importance of genera has also shown different proportions (Fig 41). *Harpalus* and *Scarites* were the most diverse, with three species each (23.1 %) followed by *Calosoma*, *Brachinus* and *Anthia* with two species each (15.4 %). In terms of abundance, *Lophyra* and *Cicindela* were the most dominant, with the highest number of individuals, followed by *Scarites* and *Harpalus*.

This community is clearly dominated by the category of medium-sized species, followed by small and large species respectively. In addition, predators clearly dominated the total fauna collected, followed by polyphagous species and generalist predators. In terms of species richness, dominance is shared between generalist predators and polyphagous species. Also,

In terms of abundance, xerophytes dominated. However, in terms of diversity, the species inventoried in the study area were dominated by hygrophilous species, accounting for 43%. Also, almost all of the species identified in the region of Ouargla were macropters (96%).

In terms of abundance, diurnal species appeared to be the most represented, while in termes of diversity nocturnl species dominted.

The Carabidae inventoried were classified according to their bioecological distribution into 8 bioecological appunrtenance bazed categories. The Carabidae community was dominated by Eurasian and Saharo-Arabian species with 63% of the total, followed by species that are Eurasin, Saharo-Arabian and North American and those that are Eurasian, Saharo-African and African with 7% each.

Coming to carabids spatial distribution, the first four sites were more diverse (between 8 and 16 species) than the last one (only 2 species). The Shannon-Weaver index H' in the five sites varied between a minimum of 0.98 bits (site 5) and a maximum of 1.25 bits (site 4), while the values of H'max varied between 3 bits and 3.49 bits. The very similar values of the equitability index at almost all sampling levels (0.25 and 0.42) testified to a high degree of irregularity in the Carabidae population. The Sempson index results, which tend remarkably towards 0, were better able to show the great dominance of one or more species over the others. In particular, *Lophyra flexuosa* and *Cicindela campestris* were represented by a markably high number of individuals, while the other species were poorly represented.

Hill's values, which were very close and tend towards 0 in the sites 1, 2 and 3, confirm a higher level of diversity in terms of species richness than in terms of number of individuals. The sites 4 and 5 showed higher values of the Hill index (Fig. 54), indicating less diversity with a remarkable dominance of a single species (*Lophyra flexuosa* in our case).

The number of individuals recorded in the five sites of the study area differed from one site to another. It was the highest in site 1, with 30% of the total stand, followed by sote 2 with 24%. The sites 3 and 4 showed comparable abundances with 13.12 and 10% of the total, respectively. The site 5 remained the least abundant, with only 176 individuals (10%).

Among the sub-families, Cicindelinae was the only one inventoried at site 5 and the most abandoned at the other sites in the study region. The Harpalinae sub-family was ranked second at sites 1, 3 and 4, whereas it was ranked third after the Lebiinae at site 2.

The difference between the means of these five groups is statisticaly significant. The highest similarity was observed between the first and the third palm groves, while the lowest similarity value was 16% between the wheat culture site and the half-maintained palm grove.

The IndVal analysis revealed the presence of only one characteristic species of the the region of Ouargla in all the study sites. That was *Lophyra flexuosa* a xerophylous, macropterous, insectivorous, diurnal, long leged species generally found on sandy soils covered with sparse vegetation.

Bazing on the estimation of the sampling effort curve, an additional sampling effort seemed to be needed to approach completeness of the inventory and reach a plateau in the curve.

On the other hand, the species richness of the Carabidae community had significant variations in composition during the study period. Spring and summer were the richest seasons in the entire region.

The hierarchical clustering analysis based on the Euclidean paired group (UPGMA) of ground beetles collected in the separate months of the research highlighted two discriminated groups group 2 consisted of June and July (the hottest months), and group 1 included all remaining months.

Furthermore, aiming to study the role of carabids in controlling aphids' populations, aphids were inventoried, their spatiotemporal variation was stadied then the coincidence between them and six species of Carabidae were established. Finaly the efficacity of the chosen six carabid species was testified.

Concernind aphids inventory, 9833 aphids belonging to 4 taxa were captured. The most abundant species was: *Aphis craccivora*. *A. fabae* came second then *A. gossypii* and *M. percicae***.** At the begining of sampling, all aphid spicies populations was present in low densities at a temperature of 25°C measured on February. After that, the number of aphids started to be haigher on March till getting its maximum ever at a temperature of 28°C. Then, this increase stopped and gradually decreased on April at a temperature of 38°C. Finally, this number stabilized in May until the end of sampling despite temperature fluctuations.

All the curves of temporal variation of aphids populations were proportionaly gowing with those of the six chosen carabid species, but the of *Harpalus affinis* (small sized beetle) *Pterostichus nigrita* (medium sized beetle) and *Calosoma algiricum* (big sized beetle) were the closest to the curve of *Aphis craccivora* populations, and each of *Cymindis lineola* (small sized beetle), *Calathus mollis* (medium sized beetle), and *Carabus faminii* (big sized beetle) were the closest to *Aphis fabae* population curve.

Based on carabids and aphids abundances and the coincidence between their populations, the efficacity of each three carabid species was tested to control the aphid species to which the curves of spatiotemporal variation was the closest.

The results obtained on the control pots have shown that the number of aphids and the cumulative temperature are closely related in all the pots. However, the results obtained from the other pots indicated that the population density of the predators is one of the factors determining the predation efficiency. This density is proportionaly related to the size, while efficacity increased from the big sized species to the small sized ones.

The difficulties we encountered in this part of our work (capturing and identifying Carabidae) appear to be the same as those encountered by other Algerian authors and are responsible for the relatively small number of species reported in Algeria : (1) The relatively low number of studies that focus only on carabids, which leads to insufficient information about them. The objectives of most studies varied, some sampling not only carabids but also the total number of natural enemies, or even the entire entomofauna; (2) the use of different sampling methods, including sweep nets, beating, and pitfall traps; which needs a big effort and a long time (3) the difficulty in identifying ground beetle species, with few keys available, and (4) the lack of specialists in the taxonomy of Carabidae, which means that Algerian ground beetles are not well described taxonomically.

As for perspectives, we can suggest that studies of Carabidae could play an impor tant role in ecosystems' studies to characterise habitats and determine the environmental integrity. Furthermore, palm groves, thanks to their dense vegetation cover and the microclimate they offer, seem to be favourite sites for insect communities, including carabids. However, the ecological challenge is very important there and the biodiversity can be more significant and well preserved if these areas are protected or at least sustainable in relation to their exploitation. On the other hand, we have to make more efforts to better study the diversity and spatiotemporal distribution of ground beetles in similar ecosystems.

That will allow us to identify and locate endemic, rare, or endangered species for conservation.

Our results have implications for the conservation of Carabidae diversity in Saharan regions and also highlight the importance of them maintaining the variation in plant cover, which constitute distribution models in these micro-environments of refuge.

Our Saharan regions lose large quantities of water through farming and high levels ofevapotranspiration. This state of affairs will inevitably lead to a change in its animal and plant composition and will result in a reduction in its biological richness in general and of Coleoptera in particular and specifically of Carabidae. Maintaining this richness requires appropriate and sustainable management.

Good governance, effective institutions at local level and strong protection measures are crucial factors in preventing the degradation of these lands.

We hope that this research will encourage the strengthening of protection measures in Saharan regions, a priority area for biodiversity conservation.

In the future, pest management, particularly aphid control, should take carabids into consideration. Studies must be led to an investigation of the efficiency of these methods and must continue to assess the role of general predators in preventing outbreaks, in relationship to agriculture development and environment protection.

Carabids are currently being promoted as beneficial insects for both pest reduction and weed seed suppression. Therefore, to get a better understanding of the biocontrol contribution of carabids we need to include their ecological, foraging and feeding behavior because it is affected by their interaction network.

Although a list of qualitative parameters is studied in this work, further investigation of this aspect is required. Quantitative parameters and the spatiotemporal variation of these parameters are the most significant points to be addressed.

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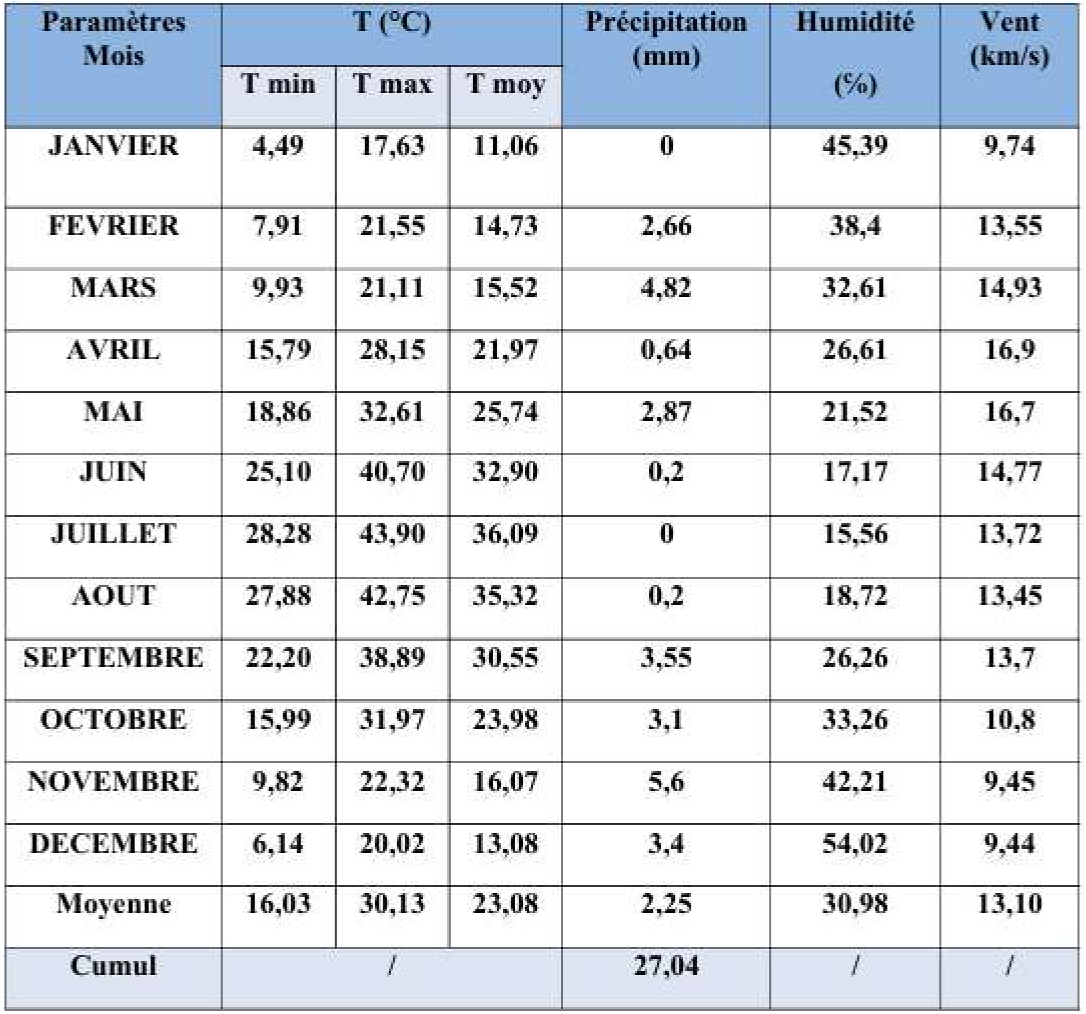
Appendixes

Tab 1. – Climatical data for the region of Ouargla between 2013 and 2022 (www.infoclimat net www.tutiempo.net)



Paramètres Mois	T (°C)			Précipitation (mm)	Humidité (%)	Vent (km/s)
	T min	T max	T moy			
JANVIER	4,49	17,63	11,06	0	45,39	9,74
FEVRIER	7,91	21,55	14,73	2,66	38,4	13,55
MARS	9,93	21,11	15,52	4,82	32,61	14,93
AVRIL	15,79	28,15	21,97	0,64	26,61	16,9
MAI	18,86	32,61	25,74	2,87	21,52	16,7
JUIN	25,10	40,70	32,90	0,2	17,17	14,77
JUILLET	28,28	43,90	36,09	0	15,56	13,72
AOUT	27,88	42,75	35,32	0,2	18,72	13,45
SEPTEMBRE	22,20	38,89	30,55	3,55	26,26	13,7
OCTOBRE	15,99	31,97	23,98	3,1	33,26	10,8
NOVEMBRE	9,82	22,32	16,07	5,6	42,21	9,45
DECEMBRE	6,14	20,02	13,08	3,4	54,02	9,44
Moyenne	16,03	30,13	23,08	2,25	30,98	13,10
Cumul	/			27,04	/	/

Tab. 3 - Lists, abundances and relative abundances of the coleopteran families and species trapped in Ouargla between September 2019 and August 2022, all with their diet categories

Diet categories	Families	Species	RA (%)	RA (%)	RA (%)	RA (%)	RA (%)
Predatory species	Carabidae	*Lophyra flexuosa* (Fabricius, 1758)	4,86	6,7	5,26	34,1	47
		Cicindela campestris (Linnaeus, 1758)	0,57	0,6	0,4	0	2,48
		Carabus faminii Dejean, 1826	0,14	0,05	0	0	0
		Calosoma algiricum Géhin, 1885	0,18	0,03	0	0	0
		Calosoma maderae (Fabricius, 1775)	0,02	0	0	0	0
		Scarites buparius (Förster, 1771)	0,48	0,3	0,28	0	0
		Scarites impressus Fabricius, 1801	0	0,22	0	0,14	0
		Scarites cyclops Crotch, 1871	0	0,03	0	0	0
		Apotomus rufithorax Pecchioli, 1837	0	0,05	0	0	0
		Brachinus explodens Duftschmid, 1812	0	0	0,01	0	0
		Pheropsophus africanus (Dejean, 1825)	0,18	0	0,16	3,06	0

		Drypta distincta (P. Rossi, 1792)	0	0,11	0	0	0
		Harpalus lethierryi Reiche, 1860	0	0,33	0,06	0	0
		Harpalus affinis (Schrank, 1781)	0	0,08	0	0,14	0
		Harpalus tenebrosus Dejean, 1829	0	0	0,21	0	0
		Microlestes luctuosus (Holdhaus *in* Apfelbeck, 1904)	0,02	0	0,04	0,28	0
		Acinopus megacephalus (P. Rossi, 1794)	0,34	0,6	0,12	0	0
		Acupalpus elegans (Dejean, 1829)	0,44	0,62	0,04	0,83	0
		Syntomus fuscomaculatus (Motschulsky, 1844)	0,02	0	0	0	0
		Cymindis lineola L. Dufour, 1820	0	0,49	0	0	0
		Graphipterus serrator (Forskål, 1775)	0	0	0,06	0	0
		Calathus mollis (Marsham, 1802)	0	0	0,1	1,11	0
		Bembidion tetracolum Say, 1823	0,16	0	0	0	0
		Siagona europaea Dejean, 1826	0,11	0	0,1	0	0
		Anthia sexmaculata (Fabricius, 1787)	0	0,03	0,06	0	0
		Anthia duodecimguttata Bonelli, 1813	0	0	0,01	0	0

		Pterostichus nigrita (Paykull, 1790)	0,28	0	0,21	0	0
		Poecilus nitidus (Dejean, 1828)	0	0,11	0,03	0	0
	Dytiscidae	*Dytiscus* sp.	0	0	0	2,09	0,76
	Coccinellidae	*Coccinella algerica* Kovár, 1977	2,91	2,74	3,09	3,34	3,24
		Adonia variegata (Goeze, 1777)	1,47	2,17	1,57	4,17	10,5
		Exochomus melanocephalus (Brandt, 1833)	0,18	0,3	0,25	1,95	2,48
		Pharoscymnus numidicus (Pic, 1900)	10,7	13,2	12,6	0	0
		Pharoscymnus ovoideus Sicard, 1929	5,44	9,15	6,17	0	0
		Epilachna chrysomelina (Fabricius)	0	0	0,43	0	0
		Hippodamia tredecimpunctata	0,07	0,19	0,13	0,28	0
		Exochomus nigipennis	0,14	0,19	0,28	0	0
		Scymnus subvillosus	0,09	0,16	0,22	0	0
		Coccinella novemnotata	0,07	0,14	0,1	0	0,57
		Coccinella undecimpunctata	0,07	0,19	0,16	0	0
		Stethorus punctillum	0,94	1,95	1,08	0	0,38
	Histeridae	*Hister* sp.	0	0,41	0	0	0
		Gnathoncus rotundatus (Kugelann, 1792)	0	0	0,03	0	0
		Saprinus semipunctatus Fabricius	0	0	0	0	1,33
	Staphylinidae	*Xantholinus* sp.	0	0,08	0	0	0
		Ocypus olens (O.F.Müller, 1764)	0	0,11	0	0	0
		Staphyla sp.	0,05	0	0	0	0
		Silpha obscura Linnaeus, 1758	0	0,22	0	0	0
		Bledius sp.	0	0,33	0	0	0

		Bledius unicornis (Germar, 1825)	0,09	0	0	0	0
		Cetonia sp.	0	0	0,04	0	0
	Cantharidae	*Rhagonycha lignosa* (Müller, 1764)	0	0	0,01	0	0
		Cantharis pellucida Fabricius, 1792	0	0	0,04	0	0
		Cantharis rustica Fallén, 1807	0,07	0	0	0	0
	Cybocephalidae	*Cybocephalus seminulum* Baudi di Selve, 1870	65,7	55,4	51,7	2,23	0,76
	Nitidulidae	*Carpophilus* sp.	0,02	0	0	0	0
Omnivorous species	Anthicidae	*Anthicus instabilis* Schmidt, 1842	0,92	0	0	0,56	0,38
		Anthicus quadriguttatus Haldeman, 1843	0,96	0,43	0,33	2,5	5,33
		Anthicus antherinus (Linnaeus, 1760)	0,16	0,03	0	4,17	6,1
		Anthicus floralis (Linnaeus, 1758)	0	0	0	0	8
	Tenebrionidae	*Blaps lethifera* Marsham, 1802	0	0	0,01	0	0
		Blaps lethifera Marsham, 1802	0,07	0	0,01	0	0
		Gnaptor spinimanus (Pallas, 1781)	0	0	0,07	0	0
		Asida sp.	0	0	1,2	0	0
		Akis lusitanica Solier, 1836	0	0	0	0	1,9
		Pimelia angulata Fabricius, 1775	0,05	0,05	5,72	0	0,19
		Pimelia bipunctata Fabricius, 1781	0,41	0	0	0	0
		Pimelia payraudi Latreille, 1829	0	0	0,09	0	0
		Pimelia grandis (Klug, 1830)	0	0	0,12	0	0

		Pimelia costata Waltl, 1835	0	0	0,01	0	0
		Pimelia angulata Fabricius, 1775	0	0	0	0,14	0
		Pimelia interstitialis Solier, 1836	0	0	0,12	0,14	0
		Stenocara sp.	0	0	0,01	0	0
		Mesostena puncticollis Solier, 1835	0	0	0	2,5	0
		Mesostena angustata (Fabricius, 1775)	0	0	0	0,7	0,76
		Opatrum sp.	0	0	0,04	0	0
		Scleron armatum (Waltl, 1835)	0,07	0	0	0	0
		Erodius emondi Solier, 1834	0	0	0,33	0	0
		Tribolium castaneum (Herbst, 1797)	0	0	0,61	0	0
		Zophosis (Septentriophosis) plana (Fabricius, 1775)	0	0	3,18	0	0
Phytophagous species	Elateridae	*Adrastus* sp.	0	0	0,01	0	0
		Agriotes lineatus (Linnaeus, 1767)	0,05	0	0	0	0
	Curculionidae	*Xyloborus* sp.	0	0	0,39	0	0
		Baris algirica J.Desbrochers, 1892	0	0	0,01	0	0
		Rhytideres (Rhytideres) plicatus (Olivier, 1790)	0,05	0	0	0	0,19
		Pachytychius haematocephalus Rye, 1873	0	0,03	0	0	0
		Trachyphloeus spinimanus Germar, 1823	0	0	0,01	0	0
		Sitona callosus Gyllenhal, 1834	0	0	0	0,42	0,57
		Larinus sp.	0,07	0	0	0	0

		Leucosomus sp.	0	0,03	0	0	0
		Lixus angustatus (J.C.Fabricius, 1775)	0	0,03	0,01	0	0
		Lixus algirus J.C.Fabricius, 1802	0,02	0,05	0,04	1,39	0
	Scarabeidae	*Scarabaeus sacer* Linnaeus, 1758	0	0	0,43	0	0
		Thorectes rugatulus Jekel, 1865	0	0,05	0	0	0
		Tropinota hirta (Poda, 1761)	0	0,11	0,03	0	0
		Tropinota squalida (Scopoli, 1763)	0,14	0	0,06	0	0
		Tropinota turanica Reitter, 1889	0,05	0	0	0	0
		Pentodon algerinum (Herbst, 1789)	0,07	0	0,03	0	0
		Geotrogus deserticola (Blanch.)	0,02	0	0	0	0
		Rhizotrogus pallidipennis Blanchard, 1851	0	0,08	0	0	0
		*Oxythyrea (Oxythyrea) pantherina (*Gory & Percheron, 1833)	0	0,19	0	0	0
		Oxythyrea funesta (Poda, 1761)	0	0	0	0,97	3,62
		Hoplia sp.	0,11	0,11	0,27	0,56	0,57
		Aphodius obliteratus Sturm, 1823	0	0	0	0,7	0
	Buprestidae	*Julodis* sp.	0,11	0	0,09	0	0
	Chrysomelidae	*Oulema melanopus* (Linnaeus, 1761)	0	0	0	25	0
	Apionidae	*Apion* sp.	0	0	0	0	0,38
	Brachyceridae	*Brachycerus algirus* (J.C.Fabricius, 1787)	0	0,08	0	0	0
		Brachycerus barbarus (C.Linnaeus, 1758)	0	0	0	5,01	0

		Brachycerus undatus Fabricius, 1798	0	0,19	0	0	0
	Sylvanidae	*Oryzaephilus surinamensis* (Linnaeus, 1758)	0,23	0	0	0	0
Carnovorous species	Dermestidae	*Dermestida* sp.	0,34	0,79	0,19	0	0
		Attagenus sp.	0	0,08	0	0	0
Polleniphagous species	Meloidae	*Mylabris variabilis* (Pallas, 1781)	0	0,03	0	0	0
		Mylabris quadripunctata (Linnaeus, 1767)	0	0	0,03	0	0
Xyllophagous species	Cerambycidae	*Prionus pectinicornis* Kocher & Reymond, 1954	0	0,05	0	0	0
Saprophagous species	Ptinidae	*Ptinus* sp.	0,25	0,3	1,33	1,53	2,48