

ORIGINAL ARTICLE

## Diet of two locusts *Oedipoda miniata mauritanica* and *Oedipoda caerulescens sulfurescens* (Orthoptera: Acrididae) in the coast of the Tlemcen region (Algeria)

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The Orthoptera represent a crucial link in the food chains as primary consumers. They have long been recognized as crop pests causing extensive damage and thus, arousing scientific interest around their diet. This study aims to know the diet and trophic preferences of two locust species *Oedipoda miniata mauritanica* (Lucas, 1849) and *Oedipoda caerulescens sulfurescens* (Saussure, 1884), under natural conditions. The sampling was carried out in 2016 in Ghazaouet, a coastal region of Tlemcen subject to a sub-humid climate. We examined Feces contents by comparing the epidermal fragments of plants ingested by these two locusts with a reference collection prepared from plant species existing in the sampled biotope. This method is practical for field research as it is simple, fast, and objective. The food spectrum of the two Oedipodinae reveals their clear preference for three plant species over all the plants present in the study area, and each species chooses its food according to its availability and nutritional characteristics. Moreover, *Oedipoda miniata mauritanica* shows a great affinity towards the plant species *Lavendula dentata*, with a consumption rate > 59%, on the other hand, *Oedipoda caerulescens sulfurescens* prefers the plant species *Lavendula multifida*, with a consumption rate >50%. We can, therefore, consider these two locusts as euryphagous species consuming mainly Lamiaceae.

**Keywords:** Insecta, Oedipodinae, feeding habit, Lamiaceae, North West Algeria, Ghazaouet.

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### Introduction

Food is one of the key factors for the habitat requirements of Orthoptera (Hochkirch et al., 2000). It plays a role in various biological parameters of Orthoptera populations, such as fecundity, longevity, rate of development, and fertility (Dajoz, 1982). Furthermore, the overall energy value is also an element in assessing the quality of an aliment (Louveau, Mainguet, et Gillon, 1983). That is how insects, in general, and locusts, in particular, select foods, i.e., according to their nutritional needs. This selection is caused by a highly efficient sensory capacity that starts from the orientation of the insect towards the plant to its bite, its grip until its ingestion (Bennet, 1970; Louveau, 1976). Furthermore, a locust chooses a plant depending on certain substances that stimulate or inhibit food intake. This choice is not only linked to its nutritional characteristics (Legal, 1989), i.e., it is not due to its nutritional value, nor to its abundance in the field, but instead occurs according to each locust species tolerances and requirements. Once the food is detected, bites should occur, and ingestion should be maintained. Food preferences may seem insignificant yet many species starved rather than eating unusual food plants (Isely, 1944; 1946). A better knowledge of the locust diet helps us determine whether a locust attacks the most abundant plants or the most favorite. Several works have been undertaken around the world to answer this question. By this work, we aim to: (1) define the food preference of *O. miniata mauritanica* and *O. caerulescens sulfurescens* under natural conditions in the region of Ghazouet (Tlemcen, Algeria); (2) compare the diet of these two locusts that belong to the same subfamily and genus, and see if diet changes from one Oedipodinae to another; (3) know whether or not they can make a food choice regarding the plant cover diversity, (4) and finally, find out if a locust adapts its feeding behavior according to the availability of plants in its biotope.

## Material and methods

### Study area

Our study area is located in the Ghazaouet region which is located in the North-West of Algeria, 80 km North of Tlemcen city. It is influenced by a Mediterranean climate characterized by a rainy winter and dry summer. This region is widely known for its richness in fauna and flora biodiversity.

We studied the food spectrum of the two Caelifera in a site located at 92 m altitude, with an exposure of 35°06'15.93 "N and 1°50'11.67" W, on a slope of 15% and a recovery rate of 70%.

### Orthoptera sampling methods

In order to be able to follow the Oedipodinae diet, we performed the sampling for one year, from January to December 2016, and the frequency of field trips was two hours once a month during hot and sunny hours.

We sampled over an area of around 500 m<sup>2</sup> where the floral conditions are as homogeneous as possible. The individuals were captured with a sweeping net, placed separately in plastic bags, and fasted for 8/24 hours (sufficient time for them to empty their digestive tract) (Launois-Luong, 1976), which allows us to collect their Feces.

### Study method

To determine the diet of our studied species, we analyzed the composition of the Feces by comparing the fragments of the plants contained in the Feces of the captured individuals with those of a reference epidermal library prepared from the plant species collected at the various study sites. Many researchers have widely used this method (Ben Halima, 1983; Damerdji, Mekkioui, et Doumadji-Mitiche, 2000; El Ghadraoui, 2002; Picaud et al., 2003; Allal-Benfekih, 2006; Zaim, 2013).

### Biological material

We captured 120 individuals containing 60 adult females per species. We chose females over males as they have more voluminous and numerous Feces than males.

### Preparation of the epidermal reference library

To establish an epidermal reference library, we sampled and used the aerial parts of each plant (stems, leaves, and flowers) present in the study site. The epidermis was prepared according to the following protocol: The epidermis was delicately detached from the underlying tissues with fine forceps then tramped in 13% bleached water for five minutes to be thinned in order to see the structures cell walls better. After being rinsed in distilled water, they were immersed in order to dehydrate them, then mounted between slide and coverslip in Faure liquid or Canada balsam which allows better conservation, and finally, the slide was quickly heated on a heating plate to avoid air bubbles forming and removed to cool. We photographed the resulting slides; that constitute our epidermal libraries; using a microscope connected to a digital camera (Prat, 1932; Mohamed-Sahnoun, 1995; Kara, 1997).

### Feces analysis

The techniques for treating Feces were inspired by the Launois-Luong method (Launois-Luong, 1976), which consists of softening the Feces for 24 hours in water with added wetting agent (polysorbate 80) to dissociate the fragments without damaging them. By thus undergoing discoloration without apparent destruction of the epidermis. The remaining steps are identical to those used for the protocol of the epidermal reference library for plants.

### Ecological indices

To study the diet of Orthoptera, we used two ecological indices.

### The frequency of plant species in Feces

The principle consists of noting the presence or absence of the plant in the Feces; according to Butet (1985), it is expressed as follows:  $F(i) = n_i/N \times 100$

**F(i):** Relative frequency of epidermis contained in Feces, expressed as a percentage.

**n<sub>i</sub>:** The number of times the plant fragments (i) are present.

**N:** Total number of individuals examined.

### Attraction index

This method estimates the relationship between the actual consumption of a given plant species and its recovery rate in the field. To calculate the attraction index, we used the following formulas proposed by Doumandji (1992).

$$T = \frac{S}{\sum S} \times 100$$

$$IA = \frac{T}{RG}$$

**S:** Average total area of a given plant species calculated for all individuals.

**T:** Rate of consumption of a given plant species.

**IA:** Index of attraction.

**RG:** Global coverage for a given plant species.

## Results

### Floristic composition

The results clearly show a very diverse floral procession (Table 1); we identified 14 plant species distributed over nine families, three of which represent the Lamiaceae family, two representatives each of Asteraceae, Liliaceae, and Poaceae. The remaining species each belong to the remaining families.

Families	the species
Anacardiaceae	<i>Pistacia lentiscus</i>
Astéraceae	<i>Inula viscosa</i>
	<i>Scolymus sp.</i>
Borraginaceae	<i>Echium vulgare</i>
Cupressaceae	<i>Cupressus sempervirens</i>
	var. <i>horizontalis</i>
Fabaceae	<i>Trifolium angustatifolium</i>
	<i>Lavandula dentata</i>
Lamiaceae	<i>Lavandula multifida</i>
	<i>Marrubium vulgare</i>
Liliaceae	<i>Asparagus officinalis</i>
	<i>Asparagus stipularis</i>
Palmaceae	<i>Chamaerops humilis</i>
Poaceae	<i>Avena sterilis</i>
	<i>Hordeum murinum</i>

**Table 1.** Floristic inventory of the study site.

### Global plant cover

The total plant cover rate of the medium is the sum of all the plants' plant cover rates present over 500 m<sup>2</sup>. This rate helps highlight the rate of land use by dominant species and characterize the nature of the plant cover based on a scale proposed by Duranton et al. (1982).

The results of the plant cover rates evaluated in the study site (Table 2) show that *L. dentata* is the most representative species with a recovery rate of 32.25%, followed by *P. lentiscus* (12.23%) and *I. viscosa* (10.35%). The remaining species exhibit a relatively low cover rate.

Station	RG%
<i>Lavandula dentata</i>	32.25
<i>Pistacia lentiscus</i>	12.23
<i>Inula viscosa</i>	10.35
<i>Lavandula multifida</i>	7.72
<i>Marrubium vulgare</i>	6.01
<i>Asparagus officinalis</i>	3.36
<i>Hordeum murinum</i>	3.06
<i>Scolymus sp.</i>	1.72
<i>Echium vulgare</i>	1.63
<i>Trifolium angustatifolium</i>	1.52
<i>Chamaerops humilis</i>	1.42
<i>Asparagus stipularis</i>	1.21
<i>Avena sterilis</i>	0.83
<i>Cupressus sempervirens var. horizontalis</i>	0.12

**Table 2.** Overall coverage of the study area.

### Locust diet

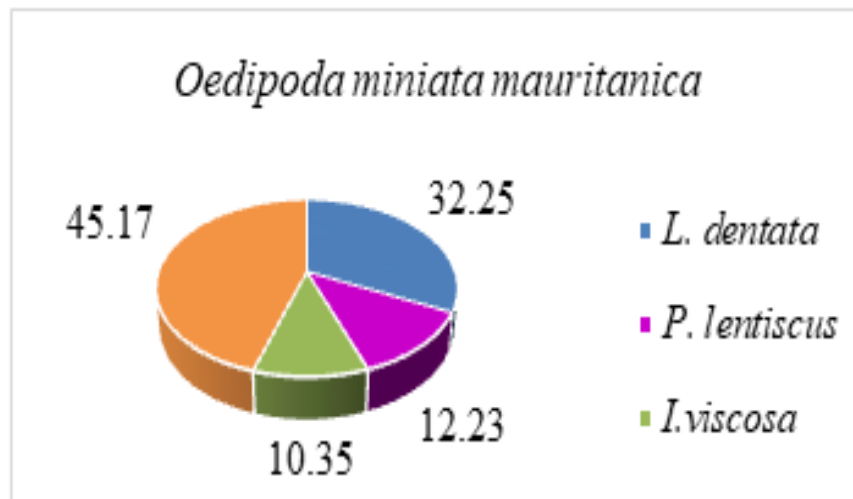
To study these two species' diets, we performed a comparative analysis between the floristic composition of the plant cover of the study site and the floristic composition of the Feces of the individuals that were captured in the same biotope. We calculated the ecological indices that include the plant species frequency in the Feces and the attraction index.

### *Oedipoda miniata mauritanica*

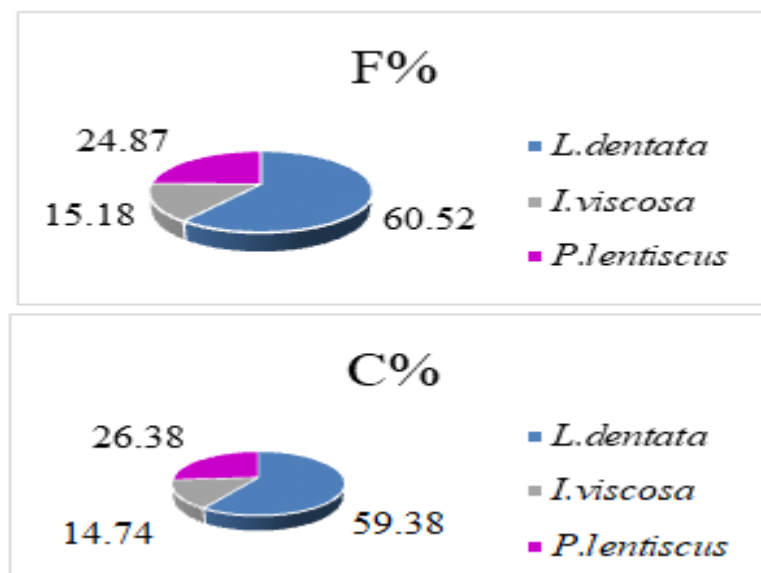
By combining the global plant cover of the species consumed by *O. miniata mauritanica*, with their attraction indices and their consumption rates, we notice that the fringed lavender (*L. dentata*) is the most consumed species, but *P. lentiscus* is the most appealing species to this locust (IA=2.15), even if this latter's global plant cover remains significantly lower than that of lavender.

At the study site, the diet of *O. miniata mauritanica* is composed of three plant species *L. dentata*, *L. viscosa* and *P.lentiscus*. These species present a global plant cover rate of, respectively, 32.25%, 12.23% and 10.35% (Fig. 1).

The consumption rate remains closely linked to the relative frequency of plant fragments found in the feces of *O. miniata mauritanica* (Fig. 2); we record the highest consumption rate and relative frequency value for *L. dentata* (T%=59.38%; F=60.52%), followed by *P. lentiscus* has (T%=26.38%; F%=24.87%), and eventually, *I. viscosa* which possesses the lowest values (T%= 14.74%, F%15.18%) (Fig. 3-6).



**Fig. 1.** Global recovery of species consumed and not consumed by *O. miniata mauritanica*.



**Fig. 2.** Relative frequencies and consumption rate of species found in Feces of *O. miniata mauritanica*.

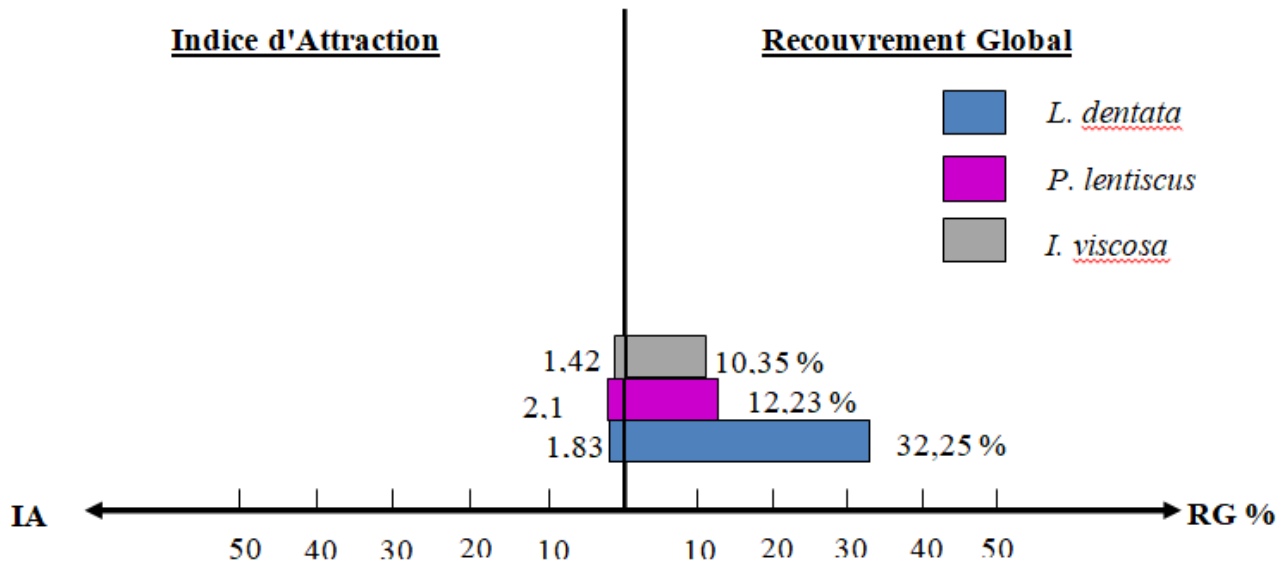


Fig. 3. Comparison between the attraction indices of species consumed by *O. miniata mauritanica* and their overall recovery rate.

***Oedipoda caeruleascens sulfurescens***

*O. caeruleascens sulfurescens* obviously ingest three plant species. They belong to Lamiaceae and Anacardiaceae families. We also notice that the consumption rate remains closely related to the relative frequency of plant fragments found in the Feces of *O. caeruleascens sulfurescens*.

We notice that *Lavandula multifida* is the most frequent species in the Feces, therefore, the most consumed (F%=49.85%), followed by *L. dentata* (F%=45.57%), and subsequently by *P. lentiscus*, which seems to be the less ingested and the less attractive species at the same time (F%=of 4.61%; IA=0.38). Although the plant cover rate of *L. multifida* is the lowest (7.92%), it attracts more *O. caeruleascens sulfurescens* because the attraction index is the highest amongst the three species (IA=6.57).

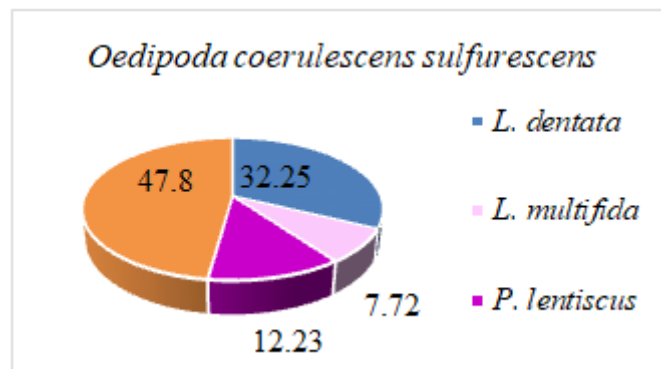


Fig. 4. Global recovery of species consumed and not consumed by *O. caeruleascens sulfurescens*.

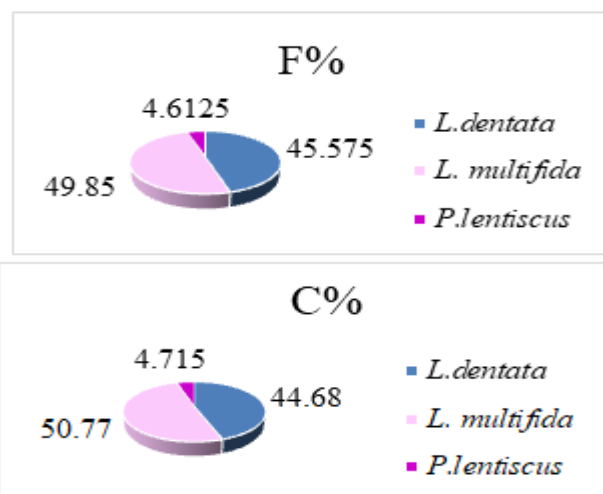
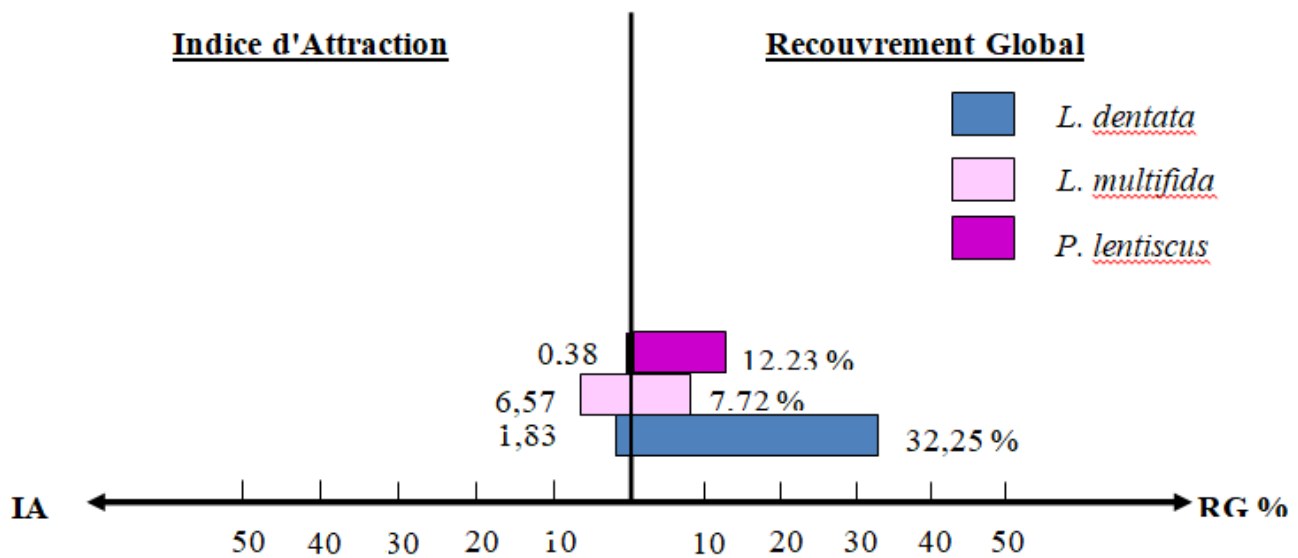


Fig. 5. Relative frequencies and consumption rate of species found in Feces of *O. caeruleascens sulfurescens*.



**Fig. 6.** Comparison between the attraction indices of species consumed by *O. caerulescens sulfurescens* and their overall recovery rate.

## Discussion

In this work, we studied the diet as well as the trophic spectrum of *O. miniata mauritanica* and *O. caerulescens sulphurescens* in the Ghazaouet region (Tlemcen, Algeria). Thus, we established a comparative analysis of the floristic composition of the plant cover of the biotope and the floristic composition of the Feces of individuals captured in that same biotope. Thus, it was determined that these two locusts consume mainly Lamiaceae species and show a great polyphagia consuming at least three plant species. Indeed, monophagous Orthoptera tend to be rare (Picaud et al., 2003). However, the different plant species present in the study site are not all part of the trophic spectrum of these locusts, for they show several degrees of selectivity in their diet.

Regarding the frequency of plant species in the Feces of the two species, we noticed that each one exhibits a food preference characterized by choice of the ingested plants. This preference for one or more plants could be related to the plant's accessibility or the nutritional needs during the year. According to Dajoz (1985), the choice of the plant is not due to its nutritional value nor its abundance in the field, but it seems that it may instead be linked to other stimuli influencing the feeding behavior of the locust (Otte et Joern, 1977; Launois-Luong, 1976). However, this trophic behavior cannot be fully understood if it is isolated from other activities, such as long-distance trips or daily trips within site, because the food spectrum is available to the locust changes. Wind tunnel experiments with Acrididae-from *Schistocerca* genus-have shown the possibility of olfactory attraction over long distances (Dadd, 1963).

In addition, each phytophagous insect holds a complex system of chemical messages which trigger, regulate, and coordinate some of its feeding behavior sequences (Pesson, 1980). Their proliferation accords better with the hypothesis of trophic resources amelioration than with that of climatic factors' direct impact in a given location.

Many acidians bit unsuitable food plants before rejecting them (Clark, 1947; Pfadt, 1949; Johnston and Buxton, 1949; Williams, 1954). This act also demonstrates the importance of taste stimuli in food discrimination. Nevertheless, there are cases where repulsive odors are encountered during orientation and before biting (Williams, 1954); food acceptability is probably determined primarily at this stage.

Dadd (1963) mentioned that there is no doubt that taste responses are involved in accepting (or rejecting) what is bitten and sustaining feeding afterward. Further, hungry insects often bite with no other stimulus than contact with a substrate; indeed, they can attack unlikely materials (e.g., metals, glass, wax, and wood) (Dadd, 1960), and it is quite conceivable that phytophagous insects, especially those that feed at the edge of the leaves, require only contact with a suitable surface to initiate feeding.

We noticed that *O. miniata mauritanica* shows a high affinity towards the plant species *L. dentata*, while *O. caerulescens sulfurescens* manifests a high one towards *L. multifida*. These results seem to agree with those of Mesli (2007), who reported that aromatic and medicinal plants form a significant part of the locust diet, as locusts are attracted to fragrant plants. This latter author also confirmed that a locust could be qualified as euryphagous or a stenophagous depending on the vegetation richness in the environment. We also observed that plant species with low grassy cover, such as *L. multifida*, have a high attraction index and are sometimes overexploited by these locusts. In fact, out of the 14 plant species present in the entire sampled area, the two Oedipodinae species consume each of only three plant species, which translates an exploitation rate of the trophic niche only up to 21.42% for both species. Thus, we can deduce that they have the same trophic range in this region.

According to Chapman (1982), the majority of phytophagous insects have more than 50% of oligophagous or monophagous species, i.e., feeding on a single plant family, on the other hand, in Orthoptera and in particular in locusts, 60% of the species are polyphagous, and 25% are described as graminivorous. Picaud et al. (2003) mentioned that specialist Orthoptera species are scarce and that the graminivorous species choose their food according to the high sugar concentrations contained in the grasses. Therefore, they have many food options when foraging. Indeed, Danoun (2016) studied the trophic spectrum of these two

Oedipodinae in the mountains of Tlemcen (Ahfir region) and the highlands of the region of Tlemcen (Sebdou region) and observed that *O. miniata mauritanica* has a slightly more comprehensive trophic range than *O. caerulescens sulfurescens* and that despite their belonging to the same subfamily. The same author mentioned that these two species show polyphagia and eat mainly fatty (*F. poaceae*), thus, joining Essakhi (2015) findings in the Morocco region. Isely (1944) indicates that graminivorous species have mandibles more adapted to the grinding of hard materials than those of forbivorous or mixed feeders and linked this morphological distinction to the fact that grasses are generally more challenging than the leafy parts of herbaceous plants.

According to Picaud et al. (2003), for grasshoppers, food appears to be selected on a nutritional basis, likely to contain the high sugar content of grasses. This trophic preference towards grasses was explained by Allal-Benfekih (2006) by the fact that grasses contain fewer molecules of secondary metabolism than dicotyledons. Several studies have demonstrated that metabolites including alkaloids of the pyrrolizidines (Ben Halima, 1983), quinolizidines (Picaud et al., 2003), glucosides (Mainguet et Louveaux, 2000) or tannins (Boppré et Fischer, 1994) group are generally locust repellants.

## Conclusion

Our study reveals that a locust feeding behavior depends as much on its tolerances and requirements as on the abundance and quality of the vegetation cover. Thus, the amplitude of feeding variation depends ultimately on the conditions prevailing in the environment, i.e., climatic and edaphic factors can indirectly influence it, and that by modifying the characteristics of the host plants, knowing that an insect can only feed if the plant has physical and chemical properties that suit its nutritional needs (Daget et Godron, 1984; Dajoz, 1985).

Besides, locusts seek food with low water content in humid environments, whereas they prefer water-rich food in dry ones (Millot, 1937), so plants consumption, and thus, food choice can be induced by the environment. Therefore, the feeding behavior of these insects through these aspects of food-seeking, detection, and ingestion, then constitutes an essential part of the insect/plant relationship.

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