

Diversity of flies (Diptera: Brachycera) in breeding farms in the Kabylia region (North-central Algeria), and identification of some myiasogenic species

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Abstract. Ourrad O, Ahmed DSA, Sadou SA, Bouzrarf K, Belqat B. 2022. Diversity of flies (Diptera: Brachycera) in breeding farms in the Kabylia region (North-central Algeria), and identification of some myiasogenic species. *Biodiversitas* 23: 2276-2284. This work provides the first checklist of the flies (Insecta: Diptera) present in breeding farms located in the south Mediterranean region of Kabylia, Algeria. A new inventory of 26 species (631 individuals) of flies belonging to 15 genera and 8 families was presented from five sites with different altitudes (245 m-1041 m) in the Kabylia region. Of them, eight species (*Calliphora vicina*, *C. vomitoria*, *Lucilia sericata*, *L. ampullacea*, *Sarcophaga africa*, *S. carnaria*, *Musca domestica*, and *Fannia canicularis*) are epidemiological, pathogenic agents of various animal and human myiasis. The fly fauna was found at varying frequencies in the five sites located at different altitudes. Besides, a negative correlation was observed between the altitude of the farms and fly distribution. The results of the PCA and FCA analysis offered better discrimination of the fly species according to the variation of the environmental parameters.

Keywords: Breeding farms, diversity, flies, Kabylia, myiasis

INTRODUCTION

Flies are among the most common insects found in all terrestrial ecosystems. They are often found in abundance in areas of human life such as; houses, markets, food centers, landfills, hospitals, including breeding farms. (Awache and Farouk 2016). They belong to the order of Diptera and sub-order Brachycera. The latter is divided by morphological criteria into two infra-orders, mainly by the shape of the ptilineal cleft and the hatching mode of the pupa. Thus, Orthorrhapha is characterized by a longitudinal dorsal cleft, whereas Cyclorrhapha is distinguished by a circular cephalic cleft (Allet 2007).

Like all Diptera, Cyclorrhapha has complete metamorphosis (egg-larva-pupa-imago). After fertilization, the females lay eggs individually or in groups, then the egg hatches and gives birth to the first larva stage. The larvae develop through successive molts, sometimes with a stop in development that can extend from several weeks to many months, called diapause or hypobiosis. The third and last larval stage undergoes a molt accompanied by a metamorphosis leading to a pupa, then a final metamorphosis giving a perfect final adult or imago (Allet 2007). The diet of the infra-order Cyclorrhapha is very diversified, includes predators, phytophagous, saprophytic, and necrophagous.

Flies belong to the most harmful insects in the world and are considered a real scourge because of their negative impact on human and animal health (Gerry 2020), notably

by their vectorial role to transmit pathogens or by their parasitic effect to generate the different myiasis. Thus, some families can transmit various pathogens, such as enteric bacteria (*Escherichia coli*, *Pseudomonas aeruginosa*, etc.), viruses (*Senecavirus A*, *Ebola virus*...etc.), helminths (*Ascaris lumbricoides*, *Taenia*, etc.), protozoa (*Entamoeba coli*, *Entamoeba histolytica*, etc.), fungi (*Candida*, *Aspergillus*, and *Penicillium*) (Adrianto et al. 2021). Besides being vectors, the larvae of some species cause zoonoses called myiasis, which inflict significant economic losses on livestock farms, especially in terms of milk production, meat quality and animal fertility. Moreover, even the human being can be affected by this parasitosis, whose clinical state differs according to the variant of the myiasis (Zumpt 1965). The most important families of the different myiasigenic species are Calliphoridae, Oestridae, Sarcophagidae, and Muscidae (Zumpt 1965; Scholl 1993).

Myiasis is a common parasitic disease in tropical and subtropical regions but is particularly rare in the northern hemisphere of the globe (Gabriel et al. 2008). This disease is known to affect both human and animal health. According to the types of host-parasite relationships, myiasis is classified as obligate and facultative. Besides, depending on the location of the parasite, myiasis is divided into wound myiasis, subcutaneous myiasis, cavity myiasis, and deep myiasis (Siwar et al. 2021).

The Sergeant brothers made the first discovery of myiasis in Algeria in 1907. Then they did research on the

same topic in 1913 and 1952 (Sergent and Sergent 1907, 1913; Sergent 1952)

Furthermore, Abed-benamara et al. (1997) recorded the first Algerian case of human myiasis. Several similar studies have also been conducted in Morocco (Asla 2012; Benbrahim 2015) and Tunisia (Anane and Ben 2010; Siwar et al. 2021).

This work constitutes the first contribution to the study of the biodiversity of flies found on breeding farms in the Kabylia region (north-central Algeria). On the first hand, it involves making an inventory of these flies and, on the other hand, identifying myiasogenic species specific to this Mediterranean region. This research was carried out by taking into consideration several environmental parameters, such as temperature, humidity, precipitation, and altitude.

MATERIALS AND METHODS

Study area

The Kabylia region is a part of the Mediterranean basin and a privileged area in terms of both floristic and faunistic biodiversity. It occupies the central northern part of the Algerian territory, located between the following natural limits (Meddour 2010). The Mediterranean Sea in the north, the chain of Akfadou in the east, the chain of Djurdjura in the south, and Isser River in the west (Figure 1).

Our study was conducted at five sites in the Kabylia region, whose altitudes fluctuate between 245 m and 1041 m. The selected sites represent cattle, lamb, or goat farms, and sometimes mixed farms, which constitute one of the favorite habitats of flies. The characteristics of the different sampled zones are described in Table 1.

Flies trapping and identification

This study was carried out in two distinct and complementary phases. The first one was devoted to collecting the entomological material from the selected sites between August 2018 to August 2019, where 120 surveys were carried out in 19 farms, and the second was identifying specimens collected in the Laboratory of Ecology, Systematics, and Biodiversity Conservation (Abdelmalek Essaadi University, Tetouan, Morocco).

In the present work, our attention has been focused on the flies found on the breeding farms. For this reason, several harvesting methods were used in the field, depending on the stage of development and the group sampled. Most Cyclorrhaphes flies are known for their preference to lay their eggs on living or decaying organic matter, which will serve as a habitat and feeding substrate for their larvae. Therefore, we opted to use meat traps in our study to capture the pre-imaginal stages of these flies.

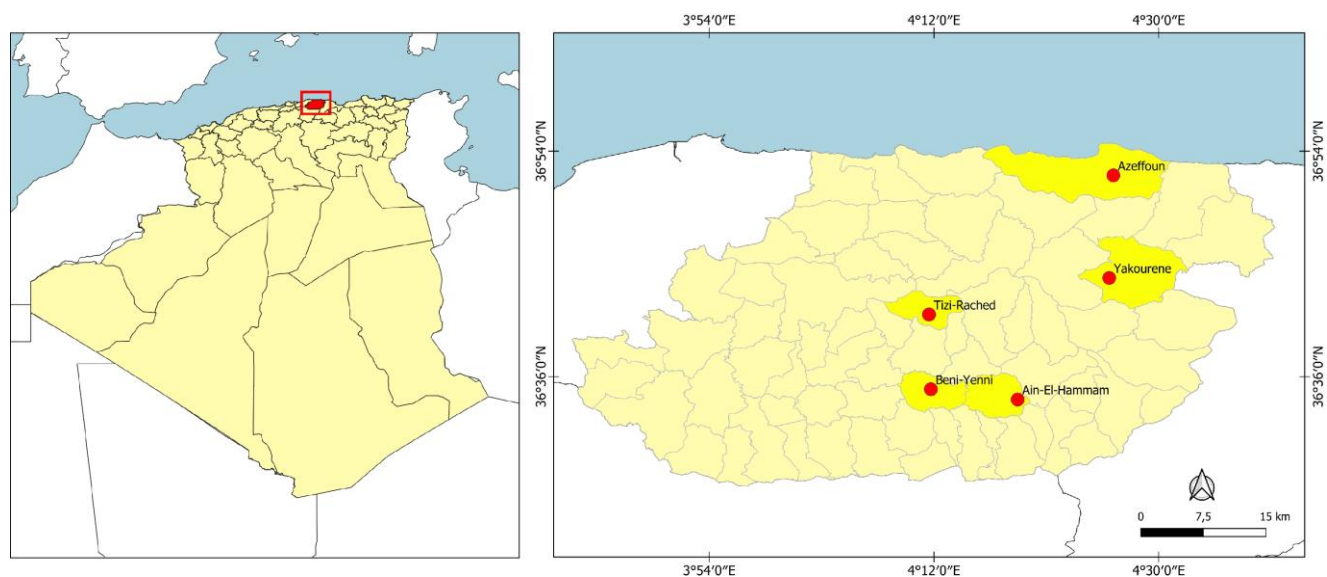


Figure 1. Map of Kabylia in Algeria and location of collecting sites (Lamine et al. 2019)

Table 1. Sampled sites with their geographical locations, elevations and types of farms

Site	Characteristics	Geographical coordinates of sites	Altitudes (m)	Type farm
Ain-El-Hammam	High Montain	36°43'11"N 4°18'42" S	1041	1 cattle farm and 3 lamb farms
Beni-Yenni	Montain	36°35'00"N 4°11'45"S	823	3 lamb farms and 2 goat farms
Yakourene	Forest	36°43'53"N 4°26'02"S	776	3 mixed lamb and goat farms
Tizi-Rached	Plane	36°40'58"N 4°11'36"S	256	3 lamb farms
Azeffoun	Coastal	36°52'04"N 4°26'22"S	245	4 lamb and goat farms

For the imaginary instars, several traps and sampling methods were used. For the imaginary stages, several traps and sampling methods were used. Firstly, food traps in the form of centrally perforated bottles containing different attractants (soapy water; water + sugar; water + cider vinegar), which are hung in and around farms. Also, adhesive traps consisting of strips soaked in castor oil or grease are hung in the stables, these are similar to conventional fly traps but are easier to use, and the specimens can be retrieved more carefully. In addition, meat traps, consisting of large bottles containing meat, are hung inside and outside stables to catch ready-to-lay females and larvae. Entomological netting is also used to catch flies as they fly. It was used to mow the vegetation around the stables, as well as the manure dumps or the inside of the stables.

All traps were emptied and changed every three days. The captured specimens were stored in tubes filled with ethanol at 70%, labeled, and kept in the laboratory until identification. Specimens were observed under a stereomicroscope OPTIKA at 10x20 magnification after being previously dried and pinned. Species identification was carried out based on morphological characteristics using the literature (Oosterbroek 2006; Hackston 2017). The larvae captured belong to the Calliphoridae family, which were identified at the third stage. These were prepared and described according to the protocol described by Szpila (2010).

Data analysis

Ecological indices

The analysis of the faunal composition of the fly population can reflect some characteristics of the areas surveyed, particularly the ecological factors influencing them. Several indices were used to study the flies' population, collected from the different sites of the study area. The species richness (S) represents the total number of fly taxa collected at each site. Relative abundance (RA%) is expressed as the percent of the number of individuals of each taxon to the total number of individuals of all fly species collected in the area (Kumara et al. 2012).

$$C\% = n * 100 / N$$

n : number of individuals of each species ;
N : Total number of all individuals

Frequency occurrence of each study site is calculated as the ratio of the number of records containing the study species (Pi) to the total number of records carried out (N), expressed as a percentage (Kumara et al. 2012). Then, using Sturge's law for the occurrence index, six classes of constancy were obtained. When $C \leq 16\%$ species are considered rare, as infrequent when $16\% < C \leq 32\%$; as accessory when $32\% < C \leq 48\%$; as regular when $48\% < C \leq 64\%$; species are qualified as constant when $64\% < C \leq 80\%$, and frequent or ubiquitous when $C \geq 80\%$ (Benoufella and Medjdoub 2016).

$$C\% = pi * 100 / N$$

pi : records containing the study species;
N : total number of records

Shannon's diversity index (H') is the amount of information provided by a sample on the structures of the stand from which it is derived and on the way in which individuals are distributed among the different species (Haghi et al. 2021). It is calculated as follows:

$$H' = -\sum Pi \text{Log}_2 Pi$$

Where $Pi = ni/N$

H': species diversity,
ni: number of species,
N: total stand size.

A high value of this index corresponds to a species-rich stand with a balanced distribution of abundance. Conversely, a low value of the distribution corresponds either to a stand characterized by a low number of species for a high number of individuals or to a stand in which there is a dominant species. In order to estimate the distribution of fly populations in the sites studied, the Equitability (E) was calculated (Motevalli et al. 2021). This is the relationship between specific diversity (H') and maximum diversity (Hmax) and is expressed by the following formula:

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

With $H'_{max} = \text{Log}_2 S$

S: species richness and was estimated by the total number of each species per site (Spellerberg and fedor 2003).

Statistical analysis

The Kabylia region is subject to a Mediterranean climate, so the distribution of fauna, especially fly fauna, is mainly related to the climate, notably to temperature and humidity. In order to demonstrate the influence of environmental conditions on fly distribution in the study region, the annual averages of each parameter in each site were calculated using climatic data obtained from the National Office of Meteorology of Algeria.

The Spearman correlation coefficient was applied on the parameters to demonstrate the impact of altitude on species diversity. Principal components analysis (PCA) was performed to establish the correlation between climatic variables, altitude and species diversity in the study sites.

Factor Correspondence Analysis (FCA) is an extension of principal component analysis. It allows the information contained in the contingency table formed by the two categorical variables to be synthesized and visualized. FCA is used to demonstrate the relationship between the altitudinal gradient and the distribution of species in the study area.

RESULTS AND DISCUSSION

During the whole sampling period covering the five study sites. Many of the specimens recorded were identified to species level, others were difficult to identify for lack of identification keys or deterioration of the

specimen, so we were forced to limit ourselves to generic level.

Specific Richness

In the present study, a total of 668 specimens were collected. The flies were divided into twenty-six species belonging to fifteen genera and eight families. Among these families, the Muscidae is the most diverse one, represented by nine species and six genera (*Musca*, *Hydrotaea*, *Thricops*, *Azelia*, *Coenosia*, and *Eginia*). The second most important family is the Calliphoridae, represented by seven species grouped in two genera (*Calliphora* and *Lucilia*). The other families were recorded with less diversity in the sample sites. The large diversity of Muscidae was probably related to the good adaptation of houseflies to the habitat of livestock farms. A similar inventory was carried out by Dawaye et al. (2021) on synanthropic flies, conducted in Central Africa, which showed that most of the species inventoried in the study area were cosmopolitan and had very wide geographical ranges.

The specific richness of the sites studied is illustrated in Figure 2. The results obtained show that the site of Tizi-Rached (TR: located at 256m) is the richest in terms of species, with 17 taxa recorded. The coastal region of Azeffoun (Azf: located at 240m) also showed a significant richness in flies, which included 16 different species. The great richness recorded in these regions is probably due to the warm temperature specific to these localities. The Yakouren site, located in a forested area, is marked by a medium diversity (11 taxa). Moreover, the sites located in the mountains of Beni Yenni (823m) and Ain-El-Hammam (1041m) were characterized by a low species richness of ten and nine taxa, respectively. In addition, it can be seen that the values of species richness were influenced by altitude. Indeed, the Spearman test, applied to the collected data, showed a negative correlation ($r: -0.900$, $P: 0.05$) between altitude and fly diversity in the study area. Thus, the low diversity recorded at high altitudes is probably due to the low temperatures specific to these zones. Cold temperatures are known to limit the development of flies.

The inventory revealed myiasogenic species known in the world; these species represent 31% of the population studied. The presence of these species can lead to alterations in animal breeding and can cause serious socio-economic losses in milk production, meat quality and animal fertility.

Relative abundance and occurrence frequency

The faunal list of flies collected from the five study sites is presented in Table 2, including the abundance rate of each taxon and its consistency class. Of the 26 taxa recorded, four species: *Calliphora vicina*, *Musca autumnalis*, *Musca* sp., and *Thricops* sp. were found in all five sampling sites with a wide range of abundances between the different locations. *Calliphora vicina* was the most abundant species in the study area, followed by Yak (26.39%), TR (24.24%), Azf (21.77%), AEH (10.53%), and BY (8.45%). These variations in abundance show that altitude negatively affects the density of this species in the

study area. *Musca autumnalis* and *Musca* sp. were present with an average abundance ranging from 24.21% to 6.12% and from 19.01% to 3.03% in the different sites, respectively. In addition, *Thricops* sp. was characterized by a low abundance, ranging from 7.04% to 2.04%. These observations could demonstrate that all four taxa can be qualified as cosmopolitan species. Similar results were found by Ansari et al. (2019) in the south of Iran.

The coefficient of occurrence of each species was calculated in the different locations, revealing six classes of constancy in the study area. The results obtained showed a heterogeneous distribution of the fly population from one site to another. Besides, nine taxa (*Eginia* sp., *Coenosia* sp., *Fannia canicularis*, *Fannia* sp., *Steleoneura* sp., *Parochtiphila* sp., *Sarcophaga* sp., *Melanostoma scalare*, and *Sphaerophoria scripta*) were identified as rare species in the region. This occurrence is probably due to the poor adaptation of these species to breeding farms' environments. Most of these species are phytophagous or floricolous species. The latter has been investigated in the northeast of Algeria (Djellab 2012).

Figure 3 has sorted the different recorded species concerning the altitude of the sites. According to the obtained data, it can be noticed that some species were specific to certain areas. Therefore, the low altitude (TR and AZ) is characterized by the presence of 9 species influenced by the environmental conditions of the areas. This altitude with a warm climate is characterized by the presence of nine species, which are *Eginia* sp., *Coenosia* sp., *Lucilia caesar*, *Sarcophaga carnaria*, *Sarcophaga* sp., *Melanostoma scalare*, *Sphaerophoria scripta*, *Steleoneura* sp., and *Parochtiphila* sp. Similar results were found in a region characterized by a warm temperature (Dawaye et al. 2021). On the other hand, only two species *Hydrotaea borussica* and *Drosophila* sp. were found in the high altitude sites (AEH and BY), characterized by colder weather. Research by Kimura (2004) has reported the presence of these taxa in a temperate climate.

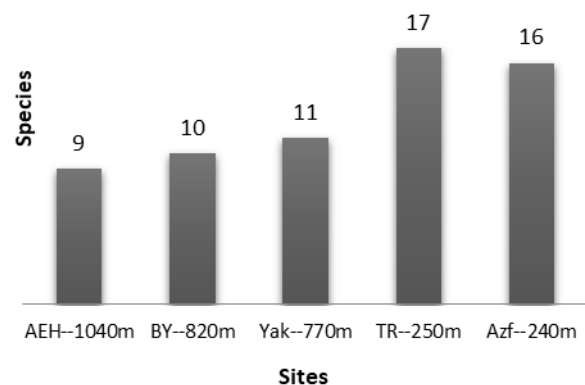


Figure 2. The specific richness of the flies inventoried in the sampling sites in the Kabylia region

The Shannon-Weaver index calculated for the five studied sites was shown in Table 3. The values of this parameter fluctuated between 2.1 and 2.52 bits in the different locations. The maximum values of the Shannon index were recorded in the sites of Tizi-Rached (TR) and Azeffoun (Azf), which are located at low altitudes. The obtained results revealed that the conditions of this environment are adequate for the spread and diversity of fly species. The values of the Pielou equitability index fluctuate between 0.5 and 0.78. The ratios obtained by dividing the diversity index (H') by the maximum index (H'_{max}) are close to 1. This clearly means that the different species can cohabit together, and this habitat is favorable to their development. Similar results were found on the distribution of medical flies in Egypt (Hammad et al. 2019).

Environmental parameters

The environmental variables (Temperature, Humidity and Rainfall), altitude and specific richness of each site are described in Table 4.

Principal Components Analysis

An analysis of the principal components shows that the two first factor axes explain the majority of the information (Figure 4). In the Dim1x Dim2 factorial plane, the two axes

took into consideration to describe the correlations between the variables related to the spatial structures. They account for 98.93% of the total information, with 92.17% for axis 1 and 6.97% for axis 2, respectively. The PCA carried out for the five sampling sites shows the followed altitudinal gradient. The AEH and BY sites are classified in high altitudes with low temperatures and high precipitation. The Yak site is classified in medium-altitude, low temperature, and medium humidity; the TR and Azf sites are classified in low altitude, high temperature, and high humidity. The distribution of species in the region fluctuates according to altitude, temperature, and humidity (Table 2).

The score plot separated the different sampling areas according to the environmental conditions specific to each of them. The loading plot demonstrated the relationship between the different variables. According to Dim1, species richness (S) is positively correlated with the variables Humidity (H) and Temperature (T), which can be explained by the direct influence of these two factors on the diversity and distribution of species. In addition, according to Dim1, species richness (S) is negatively correlated with the two variables Altitude (Alt) and Precipitation (P), which shows the negative influence that these two factors have on the distribution and diversity of species, as long as altitude and precipitation increase, the diversity of species decreases.

Table 2. Relative abundance (%) and occurrence classes of fly species, found in the different sampling sites

Family	Taxa	AEH	BY	Yak	TR	Azf
Muscidae	<i>Musca domestica</i> Linnaeus, 1758	13.68% (R)	7.04% (A)	-	-	8.16% (A)
	<i>Musca autumnalis</i> De Geer, 1776	24.21% (F)	12.68% (C)	9.72% (R)	7.58% (A)	6.12% (I)
	<i>Musca osiris</i> Wiedemann, 1830	-	4.23% (I)	-	-	4.08% (I)
	<i>Hydrotaea borussica</i> Stein, 1899	-	9.15% (I)	-	-	-
	<i>Musca</i> sp.	9.47% (I)	19.01% (C)	12.5% (C)	3.03% (r)	12.93% (R)
	<i>Azelia</i> sp.	5.27% (r)	-	4.16% (r)	2.27% (r)	-
	<i>Thricops</i> sp.	6.32% (I)	7.04% (I)	3.47% (r)	4.55% (r)	2.04% (r)
	<i>Eginia</i> sp.	-	-	-	3.03% (r)	-
	<i>Coenosia</i> sp.	-	-	-	2.27% (r)	-
Calliphoridae	<i>Calliphora vicina</i> Robineau-Desvoidy, 1830	10.53% (A)	8.45% (R)	26.39% (F)	24.24% (F)	21.77% (F)
	<i>Calliphora vomitoria</i> (Linnaeus, 1758)	9.47% (A)	-	6.25% (I)	-	4.08% (r)
	<i>Calliphora loewi</i> Enderlein, 1903	-	4.23% (I)	7.64% (A)	6.06% (I)	6.12% (A)
	<i>Lucilia sericata</i> (Meigen, 1826)	12.63% (R)	-	15.97% (C)	9.09% (A)	11.57% (R)
	<i>Lucilia ampullacea</i> Villeneuve, 1922	-	-	4.17% (I)	12.12% (R)	4.08% (I)
	<i>Lucilia silvarum</i> Meigen, 1826	8.42% (I)	-	3.47% (r)	7.58% (A)	3.41% (r)
	<i>Lucilia caesar</i> Linnaeus, 1758	-	-	-	1.52% (r)	-
Sarcophagidae	<i>Sarcophaga africa</i> (Wiedemann, 1824)	-	4.93% (I)	6.25% (I)	6.06% (A)	-
	<i>Sarcophaga carnaria</i> (Linnaeus, 1758)	-	-	-	-	5.44% (I)
	<i>Sarcophaga</i> sp.	-	-	-	-	1.36% (r)
Fanniidae	<i>Fannia canicularis</i> (Linnaeus, 1761)	-	-	-	3.03% (r)	2.04% (r)
	<i>Fannia</i> sp.	-	-	-	-	4.08% (r)
Syrphidae	<i>Melanostoma scalare</i> (Fabricius, 1794)	-	-	-	3.97% (r)	-
	<i>Sphaerophoria scripta</i> (Linnaeus, 1758)	-	-	-	2.27% (r)	-
Tachinidae	<i>Steleoneura</i> sp.	-	-	-	-	2.72% (r)
Drosophilidae	<i>Drosophila</i> sp.	-	23.24% (R)	-	-	-
Chamemyiidae	<i>Parochtiphila</i> sp.	-	-	-	1.52% (r)	-

Note: F: Frequent; C: Constant; R: Regular; A: Accessory; I: Infrequent; r: Rare

Table 3. Shannon-Weaver diversity and equitability index

Site	AEH	BY	Yak	TR	Azf
H' (bits)	2.1	2.13	2.17	2.52	2.50
H'max(bits)	2.71	3.01	3.31	5.12	4.82
E'	0.78	0.71	0.66	0.5	0.52

Table 4. Environmental parameters of the sampling sites in the Kabylia region, Algeria

Region	Altitude (m)	Temperature (°C)	Rainfall (mm)	Humidity (%)	Specific richness
Azf	240	22.22	869.06	79	16
TR	256	20.11	1020.88	52	17
Yak	770	18.17	1165.16	60	11
BY	823	16.4	1196.02	34	10
AEH	1041	15.34	1288.13	21	9

*BY: Beni Yenni; AEH: Ain-El-Hammam; TR: Tizi-Rached; Yak: Yakourene; Azf: Azeffoun

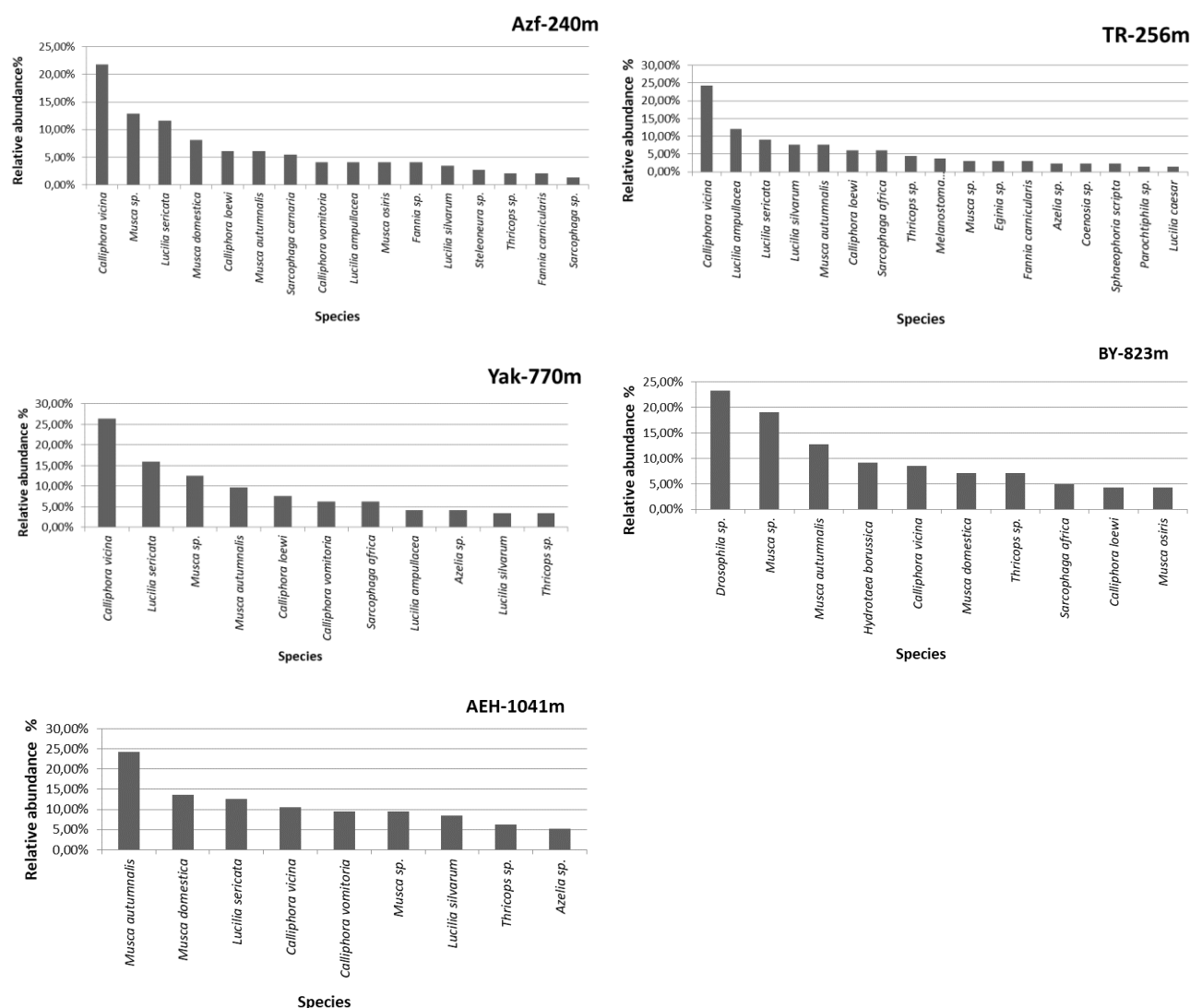


Figure 3. The relative abundance of flies inventoried in each studied site. Shannon-Weaver diversity index and Pielou equitability index

The factorial correspondence analysis carried out on the different taxa identified at the five study sites (Figure 5) showed that the greatest contributions were determined on the two first factor axes (F1×F2 plane), making it possible to explain 49.8% and 24.5% of the cloud inertia respectively, making a total of 74.3%. Three groupings appear clearly in the F1×F2 plane. These groupings mainly concern the different types of distribution of the flies captured. The first one corresponds to the omnipresent species in the five study stations, the second one groups the species captured only at Tizi-Rached at low altitude and the third one corresponds to the species recorded at Beni Yenni at high altitude.

The factorial correspondence analysis shows that the spatial organization of the flies counted in the breeding farms of the five sites in the study region is directly related to the ecology of the species.

There are ubiquitous species distributed throughout the five sites: *Calliphora vicina*, *C. vomitoria*, *C. loewi*, *Musca domestica*, *M. autumnalis*, *M. osiris*, *Thricops* sp., *Azelia* sp., and the alticolous species in few stations: *Lucilia ampullacea*, *Sarcophaga africa*, *Fannia canicularis*, *Coenosia* sp., *Parochthiphila* sp. in Tizi-Rached and *Hydrotaea borussica*, *Drosophila* sp. in Beni Yenni.

Identification of myiasogenic species

The fly larvae identified in the livestock farms are listed below (Table 5). They were collected by meat traps or by direct extraction from the animals (sheep and goats) in the different sampling sites. All the larvae caught in the meat traps belong to a single species, *Calliphora vicina*. This species was also the most frequent species found as an imago stage in the study sites (Table 3).

Moreover, only three species were collected from the wounds and mucous membranes of the animals, namely *Phormia regina*, *Protophormia terraenovae*, and *Lucilia sericata*. The latter was the only species found in the imago stage in the breeding farms. The absence of adults of the other species is probably due to the infestations received

when the animals were released. In addition, all the identified larvae belonged to the Calliphoridae family, which is known to be necrophagous species.

Table 5. List of larvae found in the study area

Type of sampling	Species
Meat traps	<i>Calliphora vicina</i>
	<i>Phormia regina</i>
Direct sampling	<i>Protophormia terraenovae</i>
	<i>Lucilia sericata</i>

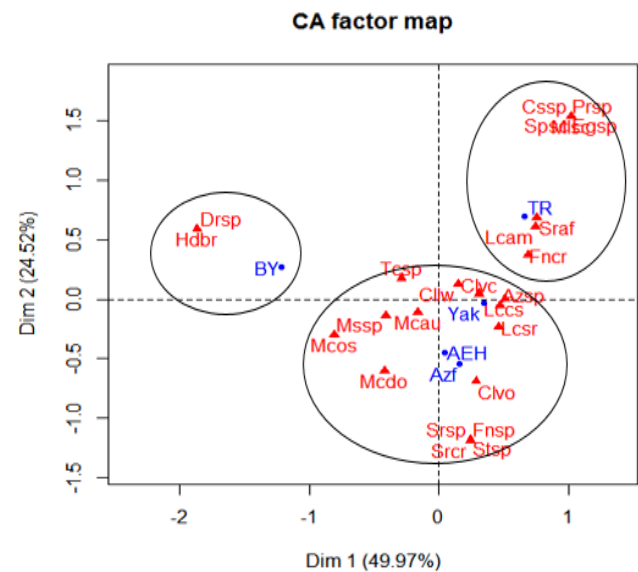


Figure 5. FCA of the distribution of taxa recorded in the Kabylia region of Djurdjura. *Azf: Azeffoun; AEH: Ain-El-Hammam; Yak: Yakourene; TR: Tizi-Rached; BY: Beni-Yenni

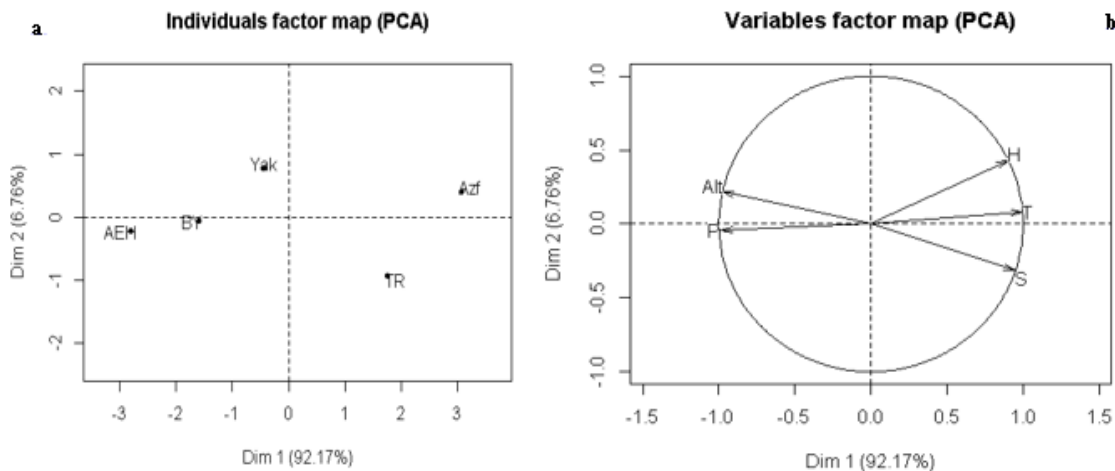


Figure 4. PCA of the environmental parameters of the Kabylia Djurdjura region. *a/scoreplot: BY: Beni Yenni; AEM: Ain-El-Hammam; TR: Tizi-Rached; Yak: Yakourene; Azf: Azeffoun / b/loading plot: Alt: Altitude; P: Rainfall; H: Humidity; T: Temperature; S: Specific richness

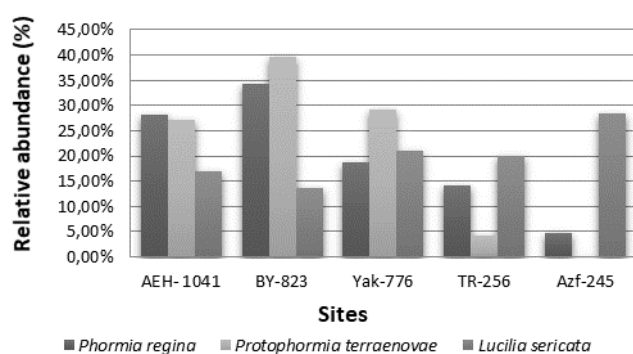


Figure 6. Relative abundance of myiasogenic species in the study sites

The relative abundance values of these myiasogenic species were represented in the following graph (Figure 6). The larvae collected directly from the infested animals are ectoparasites. They are agents of a zoonosis that affects animals and sometimes humans; this zoonosis is called Myiasis. These species are known for their pathogenic role on vertebrate lives by causing several infestations (Francesconi and Lupi 2012). Our results agree with those found by other authors (Abdel-Hafeez et al. 2015).

The data illustrated in Figure 6 shows that the two species, *Phormia regina* and *Protophormia terraenovae*, have similar variations in different locations. These species were highly abundant in Beni Yenni site, with abundance values of 34.37 and 39.58%, respectively. However, the presence of *P. regina* and *P. terraenovae* species were low (4.69%), even absent (0.00%) in Azefoun, respectively. The density of these species decreases with the diminution of the altitude of the farms. Thus, a positive correlation between altitude and these species was revealed by Spearman test ($r: 0.900$ and $r: 0.700$; $P: 0.05$, respectively).

However, the myiasogenic species, *Lucilia sericata*, showed different behavior in the study area. Indeed, an important presence of larvae was recorded in the low altitude (Azf: 28.42%), against low abundance recorded in Beni Yenni farms (13.68%). A negative correlation was observed ($r: -0.800$; $P: 0.05$) between altitude variation and larvae abundance.

In addition, the fly fauna captured in the breeding farms of the south Mediterranean region of Kabylia, showed that eight species have an epidemiological interest. These species are *Calliphora vicina*, *C. vomitoria*, *Lucilia sericata*, *L. ampullacea*, *Sarcophaga africa*, *S. carnaria*, *Musca domestica*, and *Fannia canicularis*. They are the origin of different animal Myiasis that can be effectively transmitted to humans. Several authors have confirmed the pathogenicity of these fly species (Leclercq 1990; Asla 2012; Jacquiet et al. 2016). According to Bouree and Resende (2001), the genus *Drosophila* was among the flies responsible for myiasis.

In conclusion, the present work, conducted in the south Mediterranean region of Kabylia, opens the possibility of research on the myiasogenic species in Algeria. The results

obtained showed an exceptional fly species diversity of in terms of fauna, ecology, and epidemiology. In general, the variations in abundance of imagos and larvae showed a negative relation with the altitude of sampling sites. This knowledge will make it possible to gain a more detailed insight into the diversity of flies in Algeria and to establish a faunal list of the species present on livestock farms. Furthermore, this study will make it possible to develop improved strategies for controlling and combating myiasogenic species. It will also provide a better understanding of these flies' epidemiological behavior and pathogenic role on animals and humans.

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