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Diversity of Moths (Lepidoptera, Noctuiidae) and the Flight Curves of the Main Species in Algeria

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Abstract: This study was carried out during 2014 in different regions of the Algerian littoral; an initial list of 25 species of moths was established with illustrations of male genitalia. Catches of moths obtained from light trap data show an almost uninterrupted presence of butterflies most of the year for the majority of the listed species. The curve gives us 2 main peaks; the most important is in November with a maximum catch of 207 individuals. The second peak is recorded in December with 185 individuals. On the other hand, the minimum catch is recorded in June and September with 39 and 43 individuals, respectively. Activity of the moths is conditioned by the temperature, rainfall and the diversity of the host plants. In addition, there are the bioecological characteristics specific to the species of moths, such as the phenomenon of migration and diapause.

Key words: Algerian Littoral · Noctuidae · Capture Curve · Genitalia

INTRODUCTION

The moths are cosmopolitan species characterized by a perfect adaptation to the different biotopes; they are reported throughout Europe, Asia, America and Africa [1]. Perrier consider the Noctuidae family as a largest and widest of all the Lepidoptera families [2] which are the most widespread and widely known in the world.In Turkey, there are 5029 species in 76 families while Continental Asia has 5951 species and 11474 species in Indochina [3]. Koçak and Kemal reported the presence of 1493 species in Morocco, 1182 in Tunisia and 2155 in Algeria [4].

In addition, the Noctuidae gather 25, 000 species, where one thousand live in Europe [5]. It is of great economic importance [6] because it includes species that are characterized by extreme polyphagia and can attack all plant species, whether vegetable, floral and ornamental or even spontaneous [7].

In the 19th century, exploration to determine the biological wealth of insects in general, as well as the fauna of Lepidoptera in particular in Algeria was little known because access to the country by naturalists was difficult at that time [8]. The exploration had really begun with the arrival of colonial France, but also the British, German and other collectors. Indeed, between 1908 and 1915 in Algeria Rothschild published remarkable documents on the fauna and taxonomy of the Algerian lepidoptera, [9-13] where he proposed many species and subspecies based on his own surveys and those of many other collectors in Alger, Blida (Algiers), Oran, Sidi-Bel-Abbés, Tlemcen, HammamRighra and the other regions of Ghardaia, El Oued, Biskra, El-Kantara, Batna, Khenchela, Tebessa, AinSefra (West and South-West) etc... [14]. Like Morocco and Tunisia, the faunistic or taxonomic study in Algeria, however incomplete, has been carried out in recent years. It is worth mentioning the Germans work that carried out visits in southern Algeria, notably the Hoggar, Tassili Ajjer, etc. Where they described several species [15], that were later reported by several Algerian authors in some localities on the Algerian coast [16-18].

In Algeria, there is very little work on Noctuidae which remains subject to many other investigations, despite the most recent research of which we quote those of Dih *et al*. [19] who inventoried 10 species in the region of Algiers. On the other hand, Zouaoui focused on the population dynamics of *Spodoptera littoralis* (Lepidoptera: Noctuidae) on vegetable crops on the Algerian Sahel (Staoueli) [20].

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In the present study, we tried to carry out an inventory of moths using a light trap in the experimental station of E.N.S.A. Of El-Harrach. In addition to the inventory, we will study the flight activity of the main species caught by pheromone traps in three stations.

MATERIALSAND METHODS

Description of Sites of Study

Site of the Experimental Station of El Harrach: The experimental station of the National Institutes of Agronomic Sciences of El-Harrach (36° 43° North and 03° 08° East) is located 7kms east of Algiers. It is located at an altitude of 26m approximately and has an east exposure. It is a fallow that rests on a Clay loam soil and carries mixed crops of cereals and legumes.

Site of the Staouali Experimental Farm: The site of the experimental farm (36° 45° North and 02° 54° East) is located at the Technical Institute of Market and Industrial Cultures (ITCMI) in Staouali town located in Algiers west and is 22km far away. It rises to an altitude of 30m and rests on a clay-limono-sandy soil where several vegetable crops such as potato, tomato …etc, are installed.

Site of Boudouaou - El Bahri: The site of Boudouaou - El Bahri (36° 43° N and 03° 24° E) is located to the east of the Mitidja in the locality of Boudouaou to about 35kms of Algiers. It is the western boundary of the Boumerdes region. It rises to an altitude of 24 m. The site specializes in vegetable crops under cover.

Pheromone Traps: The pheromone trap consists of a sticky bottom that needs to be changed after saturation and a durable waterproof material roof. It carries in its middle a hook to suspend this one to 1m 20 of the ground. The capsule containing the pheromone is located between the roof and the sticky bottom. It must be renewed every four weeks. Pheromone traps have been installed in three stations, namely the experimental station of the National Institutes of Agronomic Sciences (ENSA) in El-Harrach, at the center, according to the cardinal directions, the Technical Institute of Cultivation and Market gardening (ITCMI), Staouali at the west and Boudouaou - El Bahri in the east. This type of trap allowed us to track and capture the males whose counting occurs every ten days between September 2014 and November 2015

Light Trap: The trap used is a luminous type, it was manufactured by us. It features an attractive system consisting of ultraviolet lamps (60 LEDs) which surround a 40cm board stick, hung on an iron support and contained in a plastic container in which cotton is soaked with ethyl acetate to kill trapped insects. It is known that the model of the trap as well as the physical qualities of the light radiation, intervene directly on the quality and the quantity of the crops. We note that only one light trap was installed in the experimental station of the National Institutes of Agronomic Sciences in El Harrach between September 2014 and November 2015. The samples are taken every decade and the harvest is done in plastic pellets bearing the date and place of collection.

Mounting Butterflies: Beforehand, the sorting of the captured insects is carried out on sheets of white paper where the place and dates of catches are mentioned. The butterflies on which it exerts a small pressure, are put in a slot of a wooden stall. The midworm is then picking the middle of the thorax with an entomological pin and the wings are spread perpendicularly to the body and on which two strips of transparent paper are placed to flatten them and prevent them from deforming during drying. It is reported that the wings of moths are provided with scales which are liable to be detached at the slightest touch. After drying, it is obviously necessary to remove the strips of transparent paper and specify the scientific name as well as the date of harvest and the locality of the sample

Preparation Mount Between Slide and Slip of Genitalia: The abdominal end of the moth is cut with scissors and placed in a 10 ml beaker containing potassium (KOH) on a heat source to dissolve the fat of the genital structures. The latter is cleaned by distilled water (H_2O) baths before being immersed for a few minutes in alcohol at 90°C. for dehydration. Assembly between blade and slide is done by placing the genitalia in a drop of liquid Faure or balsam of Canada which is heated slightly to eliminate the air.

Identification of Species: Moths are identified on the basis of their morphological characteristics and genital structures, under a binocular lens, in the Department of Agricultural and Forestry Zoology at the National Institutes of Agronomic Sciences (ENSA) El-Harrach. Indeed, it is recognized that individuals of the same species have similar genitalia whereas the latter are specific for each species and are different for species belonging to another genus (Fig. 1).

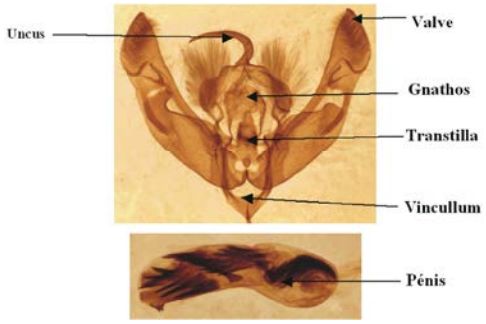


Fig. 1: Génitalia of *Hoplodrinaambigua*

Ecological Indices

Ecological Indices of Composition

Total Wealth (S): Total wealth is the total number of species present in a given biotope or station.

Relative Abundance or Centesimal Frequency (%)

$$F\% = \frac{ni}{N} X100$$

F:Relative abundance of stand species
ni:Number of individuals of species i taken into consideration
N:Number of individuals of all species combined.

Frequency of Occurrence or Constancy: The frequency of occurrence represents the ratio of the number of occurrences of a given species to the total number of records N [21]. It is calculated by the following formula:

$$C\% = \frac{Pi\ x\ 100}{N}$$

C%: frequency of occurrence
Pi: number of surveys containing the species under study;
N: total number of surveys carried out;

Depending on the frequency of occurrence, the following categories are distinguished.
F.O< 5%: Species is rare
5% <F.O <25%: species is accidental
25%<F.O <50%: species is incidental
50%<F.O <75%: species is regular
75%<F.O <100%: species is constant.
F.O = 100%: species is omnipresent. The frequencies of occurrence of the stand or species are grouped into classes, which are determined according to the following Sturge rule:

N = 1 + (3,3 log n)

N: Number of classes
n: number of species present

Structural Ecological Indices: The diversity indices depend on the specific richness of the stand and its structure and make it possible to evaluate the biodiversity of the stand.

Shannon-Weaver Diversity Index: The diversity index of Shannon-Weaver is considered the best way to translate diversity. This index is calculated using the following formula:

$$H' = -\sum_{I=1}^{s}\left(\frac{Ni}{N}\right) X \log 2\left(\frac{Ni}{N}\right)$$

Ni: number of individuals of a given species, i ranging from 1 to S (total number of species).
N: total number of individuals.

Piélou Fairness Index: Equitability is a second fundamental dimension of diversity: it is the distribution of the number of individuals per species. It is the ratio between the maximum diversity (Hmax), it is expressed as follows:

$$E = \frac{H'}{H\max}$$

E: Equitability Index
H ': Shannon-Weaver Diversity Index
H'max: Maximum diversity, it is obtained by the following formula H'max = log 2(s)
S: Is the number of species forming the stand.

Fairness makes it possible to compare the structures of insect stands.

Simpson Diversity Index: The Simpson index measures the probability that two individuals randomly selected

Belong to the same species:

$$Ds = \sum \frac{Ni(Ni-1)}{N(N-1)}$$

Ds = Simpson's diversity index
Ni = number of individuals of a species or family;
N = total number of individuals in sampling

The diversity index of Simpson varies from 0 to 1. If Ds tends to 0, diversity is low and if Ds tends to 1, diversity is strong.

RESULTS AND DISCUSSION

Inventory and Relative Abundance of Moths: The species inventoried by the light trap in the experimental station of the National Institutes of Agronomic Sciences, El Harrach, listed in the following Table (1).

The results of catches of moths during the year 2014 using light trap in the ENSA station made it possible to identify 25 species (Table 1). The relative abundance of species is variable, where four classes are present. The first group consists of the species *Spodoptera littoralis,* with 167 individuals, representing 12.83% of the total population followed by *Lacanobia oleracea* (93 individuals), *Discestra trifolii* (86 individuals), *Autographa gamma* (80 individuals) and *Helicoverpa armigera* (79 individuals) with rates varying between 6.14% and 7.14%. The second category is composed of medium species with a relative abundance ranging from 3.38% to 4.76%. This is the case of *Hoplodrina ambigua* (44 individuals), *Tyta luctuosa* (47 individuals), *Agrotis segetum* (47 individuals), *Spodoptera exigua* (49 individuals), *Mythimna (Aletia) albipuncta* (53 individuals), *Chrysodeixis chalcites*, *Agrotis ipsilon* (56 individuals), *Agrotis puta* (62 individuals) and *Cerastis faceta* (63 individuals). Finally, the last class contains the weakly represented species with a relative abundance of less than 2.92% and a number of individuals not exceeding 38 (Fig. 2).

Frequency of Occurrence and Constancy: The values of the frequency of occurrence and the constants of the species caught by light trap during the period from January to December 2014 are presented in Table 2.

The constancy classes of the captured species are determined in relation to the occurrence frequencies. According to the Sturge rule, there are 11 of them. The interval for each class is 100%: 12, is almost 8, 92%. If 0 <FO% <8, 92% the species is described as rare. In the case where 8, 92% <F.O %< 17, 84%, the species is frequent. When 17.84% <F.O %< 26, 76% the species taken into consideration is accidental. If 26, 76% <F.O %< 35, 38% the species is accidental. When 35, 68% <F.O%<44, 60% the species is very accessory. If 44, 60% <F.O %< 53, 52% the species belongs to the class not very regular. In case 53, 52% <F.O %< 62, 44% the species is regular. If 62, 44% <F.O %<71, 36% the species is very regular. When 71, 36% <F.O%<80, 28% the species is constant. When 80, 28% <F.O%<89, 20% the species belongs to the very constant class. For 89, 20% <F.O% <100% the species are ubiquitous.

The analysis in Table 2 shows that five species of moths have a frequency of occurrence greater than 91.67%. They are considered to be omnipresent: *Spodoptera littoralis, Acontia lucida*, *Agrotis segetum*, *Cerastis faceta* and *Discestra trifolii*. The second category consists of species with constant occurrence frequencies (75% -83, 33%). It is composed of:*Lacanobia oleracea, Mythimna (Aletia) albipuncta, Tyta luctuosa, Autographa* gamma and *Acontia lucida*. Nine species have a frequency of occurrence value ranging from 75.00% to 66.6% and are classified as regular. This is the case of *Agroti sputa*, *Chrysodeixis chalcites, Helicoverpa armigera, Hoplodrina ambigua, Lithophane leautieri, Noctua pronuba*, *Mythimna (Pseudaletia) unipuncta*, *Spodoptera exigua* and *Xestia c-nigrum*. The species *Archanara algae*, *Xylocampa areola*, *Eutelia adulatrix* have a frequency of occurrence between 33.33 and 41.67 and are grouped within the ancillary class. Finally, we find the accidental species which have frequencies of occurrence equal to 25% are *Dysgonia algira*, *Noctua comes* and *Xestia xanthographa*.

This table gives the value of the Shannon index (3.07) which is high, which shows that the medium described is very diversified in species. This is confirmed by Simpson's index of diversity, which tends towards 1 and shows that diversity is strong. As for the Piélou regularity index, it shows good equitability in the study environment because the value obtained is all high and close to 1.

Temporal Fluctuation of Moths Captured by Light Trap: Catches of moths by light traps are virtually uninterrupted over most of the year. Figure 3 shows two peaks, one in January (285) and the other in December (185). However, the population remains high in February (207). On the other hand, catches plummeted in June and September, but were appreciable during the other months of the year. High summer temperatures and grubbing of vegetable crops in the region induce very average catches by delaying the emergence of moths during the summer period (July to September), which is characterized by excessive drought [21]. Similarly, temperature and diet have a great effect not only on mating and larval development, but also on diapause and the ability to fly insects [22-28]. It is assumed that a temperature of 22°C induced An intense activity of the moths and allows them a good development [29].

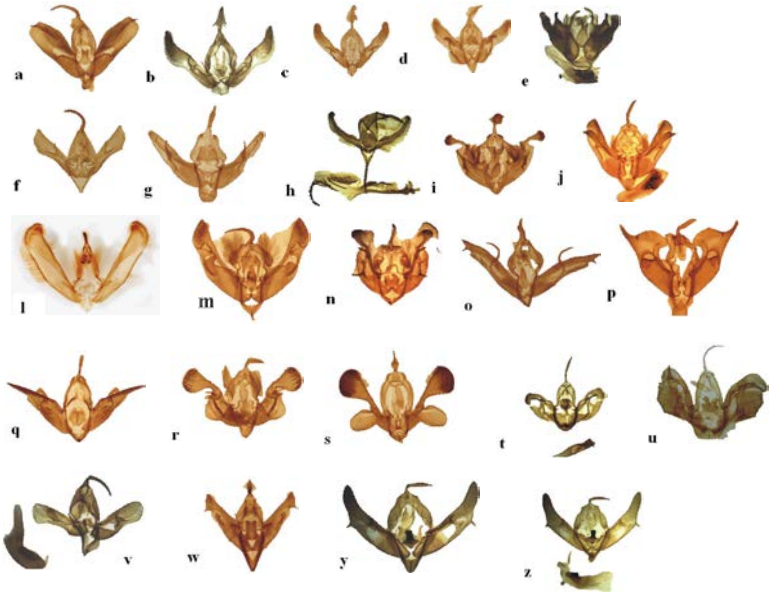
Table 1: Inventory and relative abundance of moths inventoried by the light trap in the experimental station of El Harrach

Species of moths	annexe	Ni	AR
Acontia lucida(Hufnagel, 1766)	a	38	2, 92
Agrotis ipsilon (Hufnagel, 1766)	b	56	4, 30
Agrotis puta (Hübner, 1803)	c	62	4, 76
Agrotis segetum (Denis & Schiffermüller, 1775)	d	47	3, 61
Archanara algae (Esper, 1789)	e	30	2, 30
Autographa gamma (Linnaeus, 1758)	f	80	6, 14
Cerastis faceta (Treitschke 1835)	g	63	4, 84
Chrysodeixis chalcites (Esper, 1789)	h	53	4, 07
Discestra trifolii (Hufnagel, 1766	i	86	6, 61
Dysgonia algira (Linnaeus, 1767)	j	17	1, 31
Eutelia adulatrix (Hübner, 1803)		37	2, 84
Helicoverpa armigera (Hübner, 1808)	l	79	6, 07
Hoplodrina ambigua (Denis &Schiffermüller, 1775)	m	44	3, 38
Lacanobia oleracea (Linnaeus, 1758)	n	93	7, 14
Lithophane leautieri (Boisduval, 1928)	o	30	2, 30
Noctua pronuba (Linnaeus, 1758)	p	37	2, 84
Noctua comes(Hubner 1809)	q	28	2, 15
Mythimna (Aletia) albipuncta (Denis &Schiffermüller, 1775)	r	53	4, 07
Mythimna (Pseudaletia) unipuncta (Haworth, 1809)	s	32	2, 46
Spodoptera exigua (Hübner, 1803)	t	49	3, 76
Spodoptera littoralis (Boisduval, 1833)	u	167	12, 83
Tyta luctuosa (Denis et Schiffermuller, 1775)	v	47	3, 61
Xylocampa areola (Esper, 1789)	w	20	1, 54
Xestia c- nigrum (Linnaeus, 1758)	y	37	2, 84
Xestia xanthographa (Denis &Schiffermüller, 1775)	z	17	1, 31
Total		1302	100

Ni: Number of individuals AR: Relative abundance.

Annexe:

Genitalia of the listed species of moths:



From the beginning of March, we witness a gradual decline in the population of the moths due to the disappearance or the rarity of some species, as in the case of *Archanara algae*, *Chrysodeixis chalcites, Eutelia adulatrix, Helicoverpa armigera, Hoplodrina ambigua, Lithophane leautieri, Noctua pronuba, Mythimna (Pseudaletia) unipuncta* and *Spodoptera exigua*. Due to the combined action of temperature, rainfall and rarity of host plants. Some species such as *Acontia lucida*, *Agrotis segetum* and *Spodoptera exigua* resume their activity during the months of July and August, which explains the increase in catches during these months.

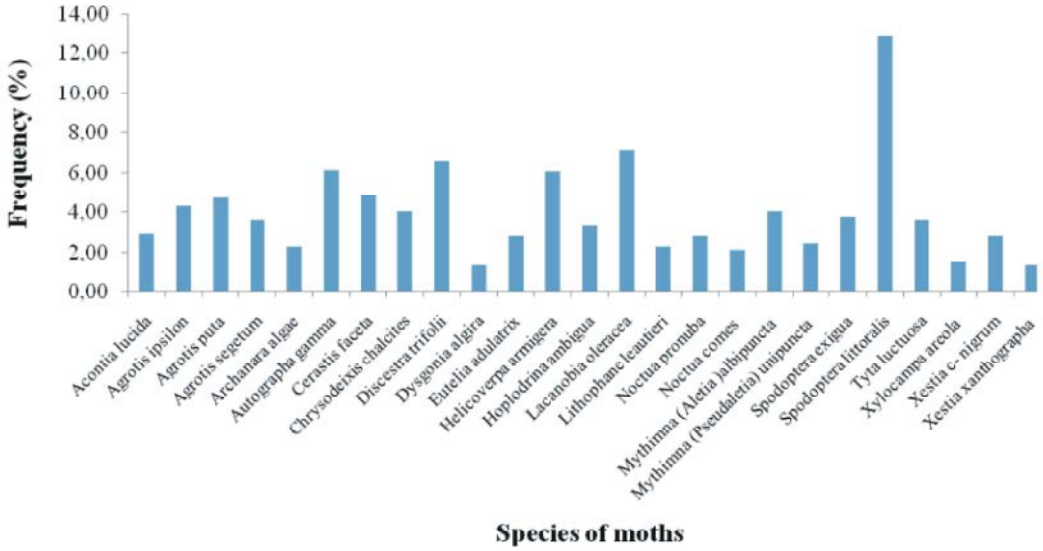


Fig. 2: The important moth species captured by light trap in 2014 in Algeria

Table 2: Frequency of occurrence and consistency of the species of moths recorded in Algeria

N°	Species of moths	Ni	F O	Frequency
1	*Acontia lucida*	9	75, 00	Constant
2	*Agrotis ipsilon*	11	91, 67	Omnipresent
3	*Agrotis puta*	7	58, 33	Regular
4	*Agrotis segetum*	11	91, 67	Omnipresent
5	*Archanara algae*	4	33, 33	Accessories
6	*Autographa gamma*	9	75, 00	Constant
7	*Cerastis faceta*	11	91, 67	Omnipresent
8	*Chrysodeixis chalcites*	6	50, 00	Not very regular
9	*Discestra trifolii*	11	91, 67	Omnipresent
10	*Dysgonia algira*	5	25, 00	Accidental
11	*Eutelia adulatrix*	5	41, 67	Veryaccessories
12	*Helicoverpa armigera*	7	58, 33	Regular
13	*Hoplodrina ambigua*	7	58, 33	Regular
14	*Lacanobia oleracea*	10	83, 33	Very Constant
15	*Lithophane leautieri*	6	50, 00	Not very regular
16	*Noctua pronuba*	6	50, 00	Not very regular
17	*Noctua comes*	6	25.00	Accidental
18	*Mythimna (Aletia) albipuncta*	10	83, 33	Very Constant
19	*Mythimna (Pseudaletia) unipuncta*	7	58, 33	Regular
20	*Spodoptera exigua*	8	66, 67	Very regular
21	*Spodoptera littoralis*	12	100, 00	Omnipresent
22	*Tyta luctuosa*	10	83, 33	Very Constant
23	*Xylocampa areola*	10	33.33	Accessories
24	*Xestia c- nigrum*	8	66, 67	Very regular
25	*Xestia xanthographa*	8	25.00	Accidental

Ni: Number of surveys containing the species i .F O: Frequency of Occurrence

Table 3: Structural Ecological Indices

Indices	Values
Specific wealth	25
Simpson	0, 95
Shannon	3, 07
Equitability	0, 95

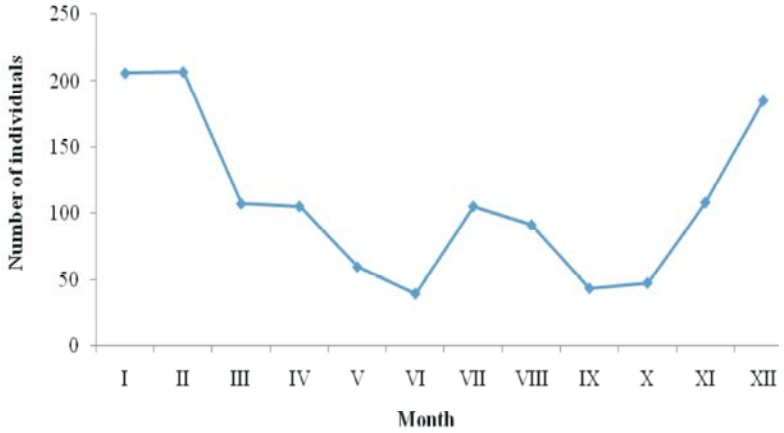


Fig. 3: Spatio-temporal evolution of the global population of mothscaptured by light trap in Algeria in 2014

Table 4: Flight activity of the main species of moths caught using pheromone traps at three stations

Species	ENSA El Harrach	ITCMI Staoueli	Boudouaou El - Bahri
Agrotis segetum	49	6	97
Agrotis ipsilon	55	56	127
Autographa gamma	168	116	408
Helicoverpa armigera	91	101	143
Spodoptera littoralis	143	126	187
Spodoptera exigua	25	5	356

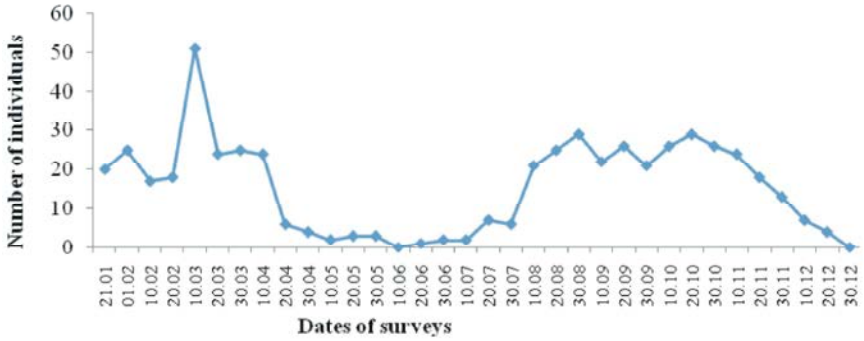


Fig. 4: Spatio-temporal evolution of the global population of moths harvested in the station of E.N.S.A. El - Harrach in 2014

With the exception of the species *Lithophane leautieria* all other moths complete their larval and nymphal cycle which explains the progressive increase of the adult population from the beginning of November marking the end of a generation.

The evolution of the moths is conditioned by two main factors; On the one hand, climatic conditions, in particular temperatures and rainfall and on the other hand the presence or absence of food, are certainly added to the bioecological characteristics peculiar to the species [30].

Station of Staoueli: The analysis of the shape of the flight curve in Fig. 4 gives us two main periods of flight of the moths. The first is from the end of July to the end of December, marking two main catch peaks of 29 individuals each, the first being noted towards the end of July and the second towards the second dekad of October. From mid-January onwards, flights have resumed after a short period of quiescence due to unfavorable climatic conditions. This period extends into early April and records a peak catch of 51 individuals in the first dekad of March. A sharp fall in flights is observed from 20 April. This is in fact the beginning of the laying period and the larval phase which lasts almost three months from the end of April to the end of July. This period coincides with the development of vegetable crops in the region.

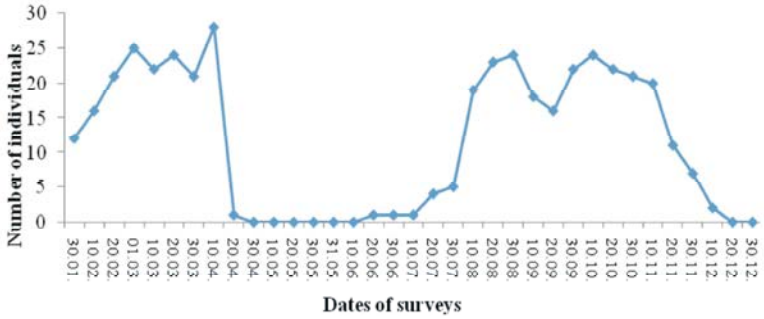


Fig. 5: Spatio-temporal evolution of the global population of moths harvested in the station of the I.T.C.M.I of Staouali in 2014

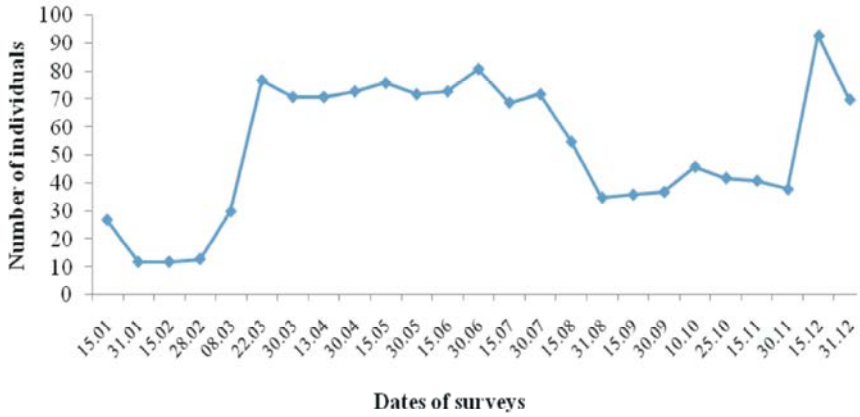


Fig. 6: Spatio-temporal evolution of the global population of moths harvested in the resort of Boudouaou El Bahri in 2014

As for the moths, all the plants are good, especially the tender ones, their devastation only concern the wild grasses and then once they are suppressed by the cultural ways the caterpillars migrate then to the cultivated plants [31]. If one takes the example of *Spodoptera littoralis* which attacks a large number of host plants among them the cultivated plants (lettuce, potato, tomato, cabbage, cauliflower, vine) [32].

Station of E.N.S.A. El - Harrach: The same observation is observed in the station of E.N.S.A to know the presence of two main periods of flight between cut by a phase of laying and larval. The first flight period begins in early March and ends in the first dekad of April. During this period two main peaks are recorded, one recorded at the beginning of March with 25 individuals and the other on April 10 with 28 individuals. A sudden drop in adult populations was observed around the second dekad of April, marking the beginning of the egg laying and the larval phase of the moths. This period lasts more than three months and ends towards the beginning of July. The first adults of the moths are observed towards the end of July marking the beginning of the second flight period which will last until the second dekad of the month Of December. Two flight peaks of 24 individuals are observed first as the first one is noted towards the end of August and the second towards the beginning of October. Finally, a fall in adult populations is observed on 20 September, probably due to climatic conditions and lack of food, which is an important ecological factor. Depending on its quality and abundance, it will intervene by modifying fertility, longevity, rate of development and mortality of animals [33] (Fig. 5).

Boudouaou El Bahri Station: The observation of the flight curve of the adults of the moths in the Boudouaou El Bahri station shows that, unlike the other stations, the activity of the adults of the seven moths is observed throughout the springtime period. Indeed, a peak of 81 individuals was recorded towards the end of June. From the end of July a sharp drop in catches is observed to reach a minimum of 35 individuals towards the end of August. The level of catches stabilizes between 35 and 46 individuals in autumn. In our opinion this phase coincides with that of eggs and larvae for the species *Agrotis segetum, Spodoptera exigua, Agrotis ipsilon* and *Chrysodeixis chalcites.* On the other hand, the other species in this case: *Spodoptera littoralis* and

Autographa gamma mark an uninterrupted presence with overlapping generations in the station. Flight activity will resume gradually for all species except *Chrysodeixis chalcites* in winters with a peak of 93 individuals recorded around December 15th. The sharp decline in adult activity in January and February is due either to poor climatic conditions for some species or the larval stage for others. It should also be noted that the station is specialized in plasticulture, tomato crops, strawberry, eggplant and zucchini are the main crops practiced in the station which explains the peculiarity of the activity of the moths compared to the others Operations (Fig. 6).

Cayrol in 1972 [1] speaks about 4 to 7 generations in the year in North Africa for *Spodoptera littoralis*, it also mentions that this species is harmful in Marrakech; In summer the attacks are observed in June, while in Algeria this species is absent during this period. In September October, the species disappears from Marrakech and appears in Algeria, in Winter and in spring, the species reappears in the south of the Maghreb.

As for the species *Agrotis ipsilon*, it chooses the wet passages during the summer period causing significant damage to its distribution area. According to Cayrol [1] in spring this species is widespread in northern Africa, Egypt and in Sudan, in early summer, butterflies reach southern Europe.

CONCLUSION

At the end of this work, an initial list of 25 species of moths was established. The moths were captured using light traps placed across different regions of Algeria. Monitoring of the flight activity of the global moth population during 2014 shows that the majority of moths complete their cycle towards the beginning of October with a flight period extending until the end of February. Cardé reports that many insect species migrate during winter to low-latitude polar habitats where they can breed during the summer [34]. In order to increase the influence of food and climate on the activity of moths, we have followed in three different stations the activity of the main species of moths using pheromone traps. The results show that the quality of the food and the climate play an important role in the activity of the moths.

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