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Study of the Population Dynamics of the Olive Fly, *Bactrocera oleae* Rossi. (Diptera, Tephritidae) in the Region of Essaouira

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Abstract

The *Bactrocera oleae* Rossi fly is the most important olive pest. It is of major economic importance in the olive production area of Essaouira, where weather conditions are optimal for the conduct of the various stages of its life cycle. The lack of phytosanitary treatments worsens this situation. The development of the larval stages and different generations are related to the phenological stages of the olive and are controlled by changes in habitat conditions. Trapping of adult males by Deltas traps baited with sex pheromone, at the four study sites, has identified some characteristics of the evolution of the adult populations' flight dynamics. Our main results show a decreasing gradient of early emergences of different stages from the coast to the continental areas as well as the absence of the summer generation at the inner station. Soil analysis in the two stations showed that the hypogenous pupae wintering in the soil survive until June. Knowledge of the factors involved in the bio-ecology of the olive fly and the phenology of the host allows the elaboration of monitoring/warning calendars, and phytosanitary measures in order to establish an IPM program adapted to the requirements of olive orchards in the region.

Keywords

***Bactrocera oleae*, Dynamics, Generation, Coastline, Morocco**

1. Introduction

As in all olive-growing regions of the world, the Moroccan olive growing region of Essaouira is attacked by the olive fly *Bactrocera oleae* (Rossi) (Diptera: Tephritidae), the main olive pest in regions the Mediterranean and the Middle East [1]. The geographical distribution of the fly is extended with the culture of its host where it is

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introduced beyond the Mediterranean, its region of origin. This is a pest of a great economic importance in the area of distribution of the cultivated olive tree [2]. The larvae Oligophagous feed on fruit pulp of both wild and domestic forms of the genus Olea [1] and cause significant losses in the pulp reducing the production and affecting the quality of olives and oil [3]. The damage caused by this pest results in production losses that can exceed 80% by the combined effects pulps destruction, fruit drop and increasing oil acidity especially if the olive harvest is late [4]. In untreated orchards the fly can infest over 90% of olive fruit [5] [6]. The life cycle is strictly linked to the phenology of the olive tree. This pest has several generations per year whose number is variable in space and time. The development of the populations of each stage and the number of generations depend on climatic factors (temperature and humidity) and harvest dates [7]. Several generations occur throughout the summer and fall [8] [9]. The Olive producing region in Essaouira is the only one along the Moroccan coastal. The climatic conditions of coastal areas are generally favourable to the development of the pest, which explains the high population densities observed in the orchards of the area compared to the population of the plains and valleys within the country.

This study aims to follow the population dynamics in each stage of the development cycle of the olive pest *Bactrocera oleae* (Rossi) during its annual development cycle. This is in order to elaborate an integrated pest management program, based on the monitoring of adult flights, and the evolution of pre-imaginal stages in olives during production periods and in the soil during the white phase.

2. Materials and Methods

2.1. Study Area

The study sites are chosen based on their situation from the ocean and along a gradient of increasing continental characteristics from the coast to the inner areas. We surveyed four stations (Ida ougard S1(31.437X, −9.714Y), Had dra, S2 (31.566X, −9.536Y), Korimate S3 (31.766X, −9.537Y) and Akrmoud S4 (31.448X, −9.278Y), distant from the coast 8 km, 17 km, 7 km and 49 km, respectively (linear distance) (**Figure 1**). The climate of the region ranges from arid to semi-arid, characterized by erratic rainfall. The average rainfall in 38 years (1971-2008) is of the order of 330 mm/year, a maximum of 633 mm was recorded during the campaign (1995/1996).

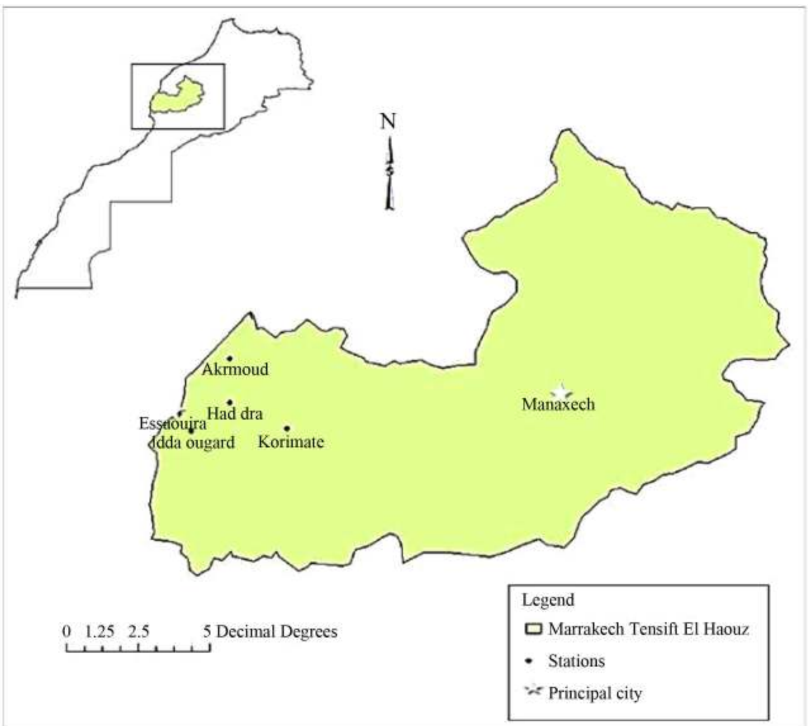


Figure 1. Location of the 4 study sites (S1: Idda ougard, S2: Had dra, S3: Korimate, S4: Akrmoud).

The maximum rainfall period runs between November and February. The remaining months form a xeric period that lasts about seven months. However, the proximity of the Atlantic Ocean relatively compensates the water deficit of the atmosphere. Oceanic influences are less influent from the coast to the interior which leads to changes in climatic conditions. The continental features result in a temperature increase and a decrease in humidity.

The recorded data at the meteorological stations in the region and those of the field samples, show that the maximum temperatures in the coastal area are relatively low (34˚C to 38.5˚C) measured respectively during the months of July and August in the stations (S1 and S4), compared to the temperatures recorded in the continental region represented by the station S3 (36˚C to 43˚C) during the same period of Olive campaigns. In all habitats surveyed maxima are higher in July and August. The average moisture content is relatively low (30% to 68%) in the continental station (S3) against 40% to 70% in the intermediate station S2, while in coastal stations S1 and S4 the rate was over 90%. The sandy soil is rich in elements with sandy limestone substrates in the south at the S1 and S3 resorts and sandy clay soils in the northern part S2 and S4. The soils of the various stations are relatively basic with pH between 7.3 and 7.8, the organic matter content between 1% and 1.5%. The structure is more or less loose in the coastal resorts S1 and S4 in internal prismatic stations S2 and S3.

2.2. Levy, Direct Analysis and Dissection of Olive Samples

The study of the dynamics of the various life stages of *Bactrocera oleae* is carried out in the four stations selected by three methods:

- The male trapping method
- Monitoring the development of different larval stages by the analysis of olives collected and dissected
- The study of the densities of pupae at hypogenous stage performed on soil samples collected at foot tree in both stations (S1 and S2).

During olive campaigns 2009-2010 and 2010-2011, we conducted olive sampling in 4 surveyed orchards. In each orchard, the collection of olives is carried out on 5 trees distanced at least 70 meters. Six olives by cardinal direction (North, East, South, and West) are levied on every tree, in the outer ring, 24 olives per tree. Olives of each sample were analysed directly with the naked eye, to count the number of bites and exit holes, then dissected in the laboratory and observed under a dissecting microscope to identify the stage of development and count galleries.

2.3. Trapping Adult Males Fly: Study of Flight Dynamics

To study the characteristics and changes in pest population, the relative abundance and the impact on the host, and to determine the effects of latitude, degree of continentality and exposure on the flight dynamics of adult males of *Bactrocera oleae*. We carried out mass trapping based on the technique of sexual confusion. DELTA traps yellow colored fitted sheets are glued baited with synthetic pheromone of the female fly *Bactrocera oleae* in polyethylene capsules. Adult males attracted by the pheromone, are trapped in the sticky plaque trap [10] [11]. The plates are glued every week and renewed when congested or after four weeks. The capsules are also changed once every four weeks. The trapping survey is conducted in four stations (S1, S2, S3 and S4). In each station, three traps, a distance of about 70 m, are installed. The trap is suspended from a branch at the height of 1.5 m to 2 m from the ground, more or less within the canopy, in the orientation quadrant South-west, ecotope preferred by flies for oviposition. The counting is made on a weekly basis.

2.4. Sampling of Hypogenous Pupae in the Soil

In S1 and S2 stations, soil samples were taken during the period of transition between the phase of activity and the white phase of the fly cycle. The choice of the sampling period is based on studies by [12] [13] in Al Haouz region. For this study the sampling was conducted over the period spanning from November to June for two successive campaigns 2009-2010 and 2010-2011. In each station, forty soil samples of 40 cm^2 are levied on the first 10 cm of depth from the surface. Soil samples were taken at 5 trees per station according to the four cardinal directions, two concentric rings, and four samples in the inner ring, under the cover of the canopy of the tree, and four samples in the outer ring outside covered the shaft. Sieving soil samples used to list existing pupae, empty, dead and living. Specimens are preserved in 70% alcohol solutions.

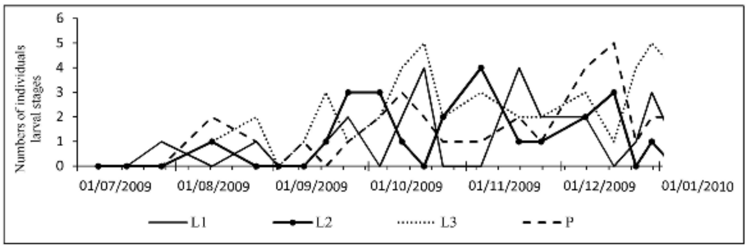
2.5. Statistics Analysis

To compare the results obtained at the various stations we conducted a series of correlations. Data entry and analysis were conducted using the Statistical Package for the Social Sciences (SPSS, Version 10.0). The differences between the variables studied were determined through comparison of means established by the one-factor analysis of variance (ANOVA) and the general linear model for multivariate analysis. Thus, multiple *a posteriori* comparison tests were performed to determine homogeneous groups using the Tukey's test.

3. Results

3.1. Study of the Population Dynamics of the Larval Stages of the Fly *Bactrocera oleae* after Dissection of Harvested Olives

The curves of changes in the numbers identified at station 1 (S1: Iddaougard) Station 2 (S2: Had dra) the station3 (S3: Korimate) and station 4 (S4: Akrmoude) have almost the same shape (**Figure 2**). They show fluctua-



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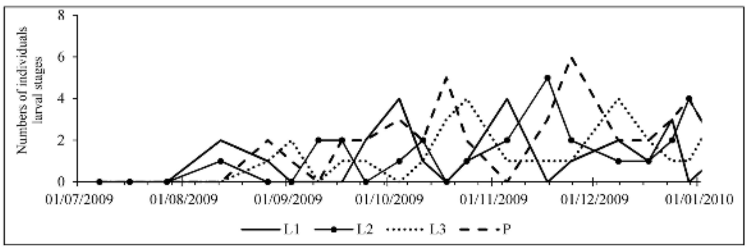

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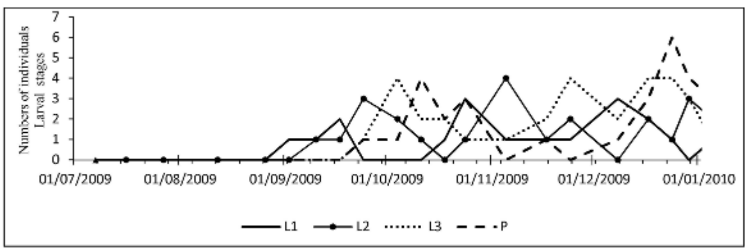

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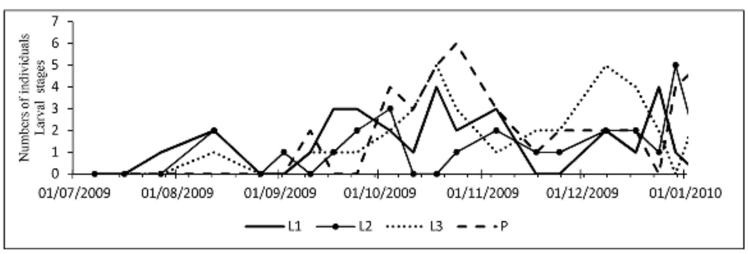


(d)

Figure 2. Number of individuals of each larval stage identified in the olive fruit samples, collected from the studied stations after dissection during the olive campaign 2009/2010. (a): station 1 (Idda ougard), (b): station 2 (Had dra), (c): station 3 (Korimate), (d): station 4 (Akrmoud). L1, L2, L3: larval stages, P: pupae. For the three larval stages (L2, L3 and P), the differences trough months were highly significant ($p < 0.001$).

tions with peaks offset in time between the different stages and between the different stations according to the continentality gradient. For all stages of development and studied in each station, there are three major peaks that span the period from the beginning of September to late December-early January. During and after the olive harvest, that is early in the coast regions, (October). The numbers remain important, as this is spread over time either at the same region or in the same orchard.

According to statistical analysis (ANOVA), there was a highly significant difference trough months ($p < 0.001$) for the three last larval stages (L2, L3 and P) for all studied campaigns.

In the stations S1, S2 and S4, the density of individuals of each larval stage is observed in the period between July and January. While for the station S3 first larval stages appear later in late August and early September. Thus, in the two coastal stations S1 and S4, an increase in numbers was recorded at the beginning of July for the larvae of the L1 stage during the second decade of the same month there is the emergence and increasing the number L2 larvae. The third-stage larvae L3 are detected with L2 larvae to the beginning of the third decade of the month. Their number increases with the decrease in the number of L2 larvae. Towards the end of July all larval stages are registered in the two stations and the number of pupae reached its maximum. Towards the end of the first decade of this month there is a loss of larval stages L2 and L3. A decrease in pupae population occurs after. In general the abundance of individuals in various stages remains low during the summer, from late July to mid-August, almost all larvae belonging to L1 and L2 stages inventoried in these stations are dead. At the station S2, situated on the edge of the coastline, the onset of larval stages follows the same sequence but slightly shifted in time compared to previous stations. L1 larvae are recorded only in the second week of July, a week after L2 while the L3 stage is detected in late July and early August. While for the station S3, L1 larvae are hatched towards the end of August and beginning of September, hence the absence of the summer generation at this station. During autumn in all stations, the densities of the various stages increased significantly compared with those recorded in summer.

According to the correlation results based on the results matrix concerning individuals in various stages in the 4 stations, we recorded a strong significant correlation ($p < 0.05$) between the stations S1 and S4, with $r = 0.85$ and $r = 0.78$ for 2009-2010 and 2010-2011, respectively. Indeed, the correlation noted between shore stations was more significant compared to that recorded between the station S3 and the other stations. The low correlation was recorded between the two stations S1 and S3 (**Table 1**).

3.2. Evolution in Numbers of Pre-Imaginal Stages during the Olive Campaign 2010-2011

During the campaign (2010/2011), the abundance of individuals of different stages of development of the fly is significantly important to the levels of all stations compared to the previous year (**Figure 3**). The station S3 "Korimate" showed a slight increase in the number of early stage during the summer period relative to the preceding olive campaign draws that already identifies larvae and pupae around the first week of August. Increasing numbers of larval stages showed a delay of about two weeks at the station S3, from the station S2, and three weeks from the two stations over the coast S1 and S4.

4. Flight Dynamics of Adult Males

The averages numbers of males captured in three traps each station for each sample is shown in **Figures 4(a)-(b)**.

4.1. Evolution of Male Catches during the Olive Campaign 2009/2010

The activity of adult males in the four stations is spread throughout the year (**Figure 4(a)**), but numbers becomes important at the beginning of September, the number of males captured per trap, significantly increasing in four stations with time lags between stations by location from coastal position. The emergence and flights increase first in the more coastal stations (station S1 and S4) then most continental stations, station S2 and S3 station. In the stations (S1, S2, S4) the dynamics of adult flights shows four peaks during the period from the beginning of September until the end of January. The numbers recorded at stations over the coast are higher than those recorded in internal stations during the first autumn emergence; while the station S3 shows the workforce as important during the fourth phase of emergence.

Table 1. Correlations established between the results obtained in various stations by counting specimens in larval stages of the fly during the olive companions 2009-2010 and 2010-2011.

Compared Stations	Coefficients of correlation	
	2009/2010	**2010/2011**
S1-S2	0.55	0.45
S1-S3	0.38	0.12
S1-S4	0.85	0.78
S2-S3	0.72	0.53
S2-S4	0.64	0.39
S3-S4	0.34	0.36

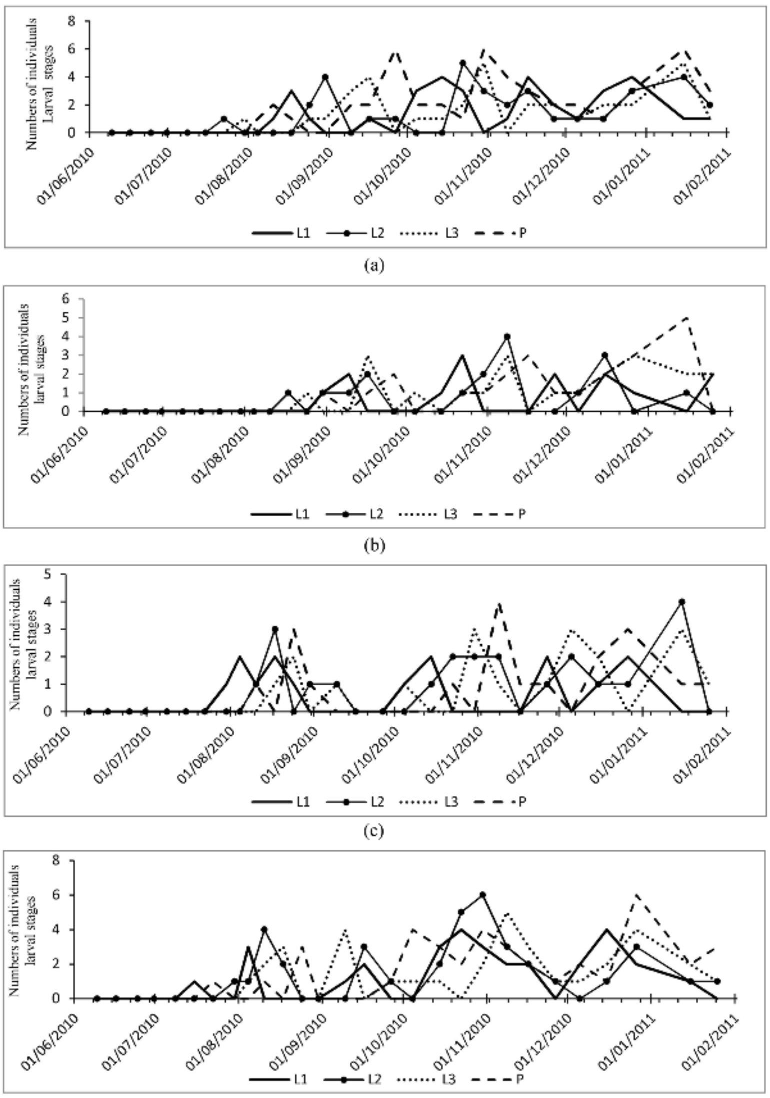


Figure 3. Number of individuals of each larval stage identified in the olive fruit samples, collected from the studied stations after dissection during the olive campaign 2010/2011. (a): station 1 (Iddaougard), (b): station 2 (Had dra), (c): station 3 (Korimate), (d): station 4 (Akrmoud). L1, L2, L3: larval stages, P: pupae. For the three last larval stages (L2, L3 and P), the differences trough months were highly significant ($p < 0.001$).

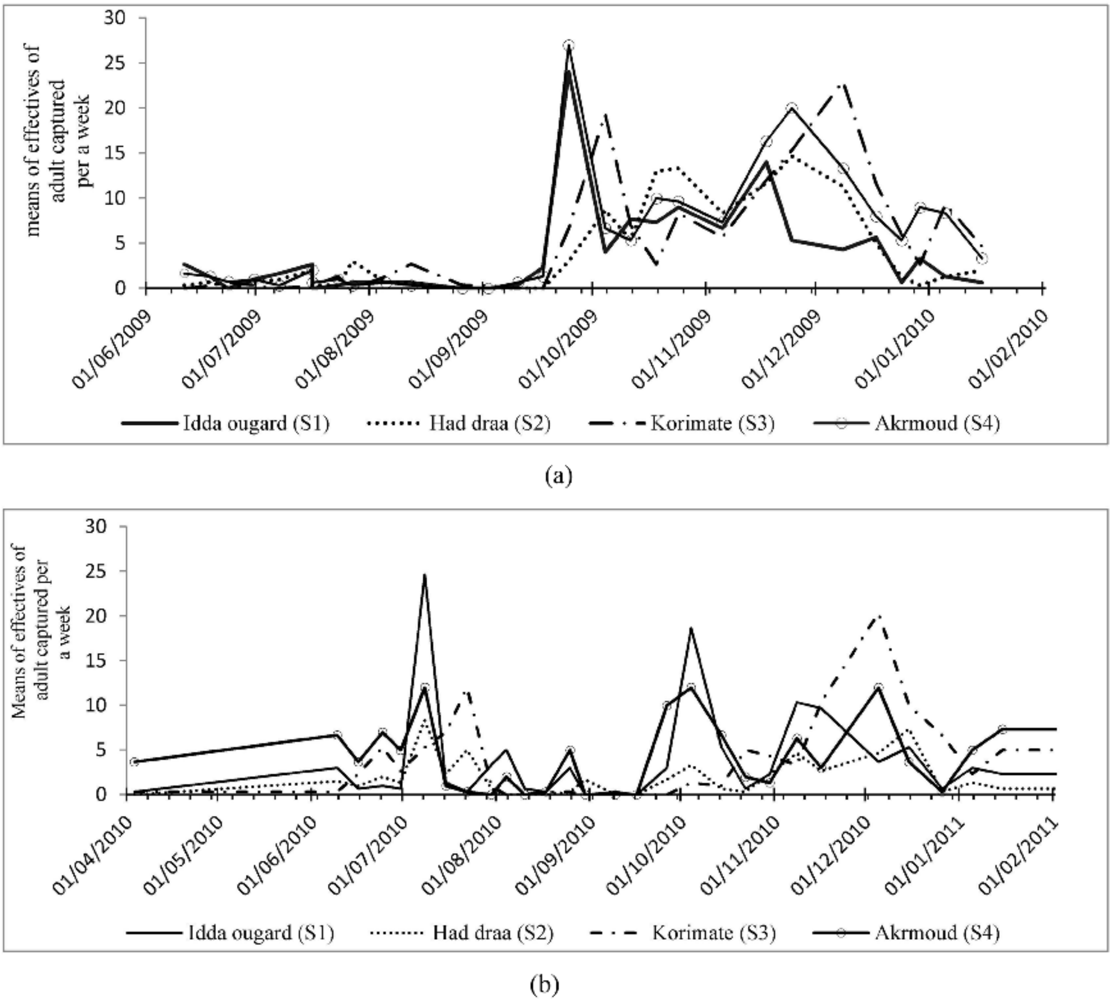


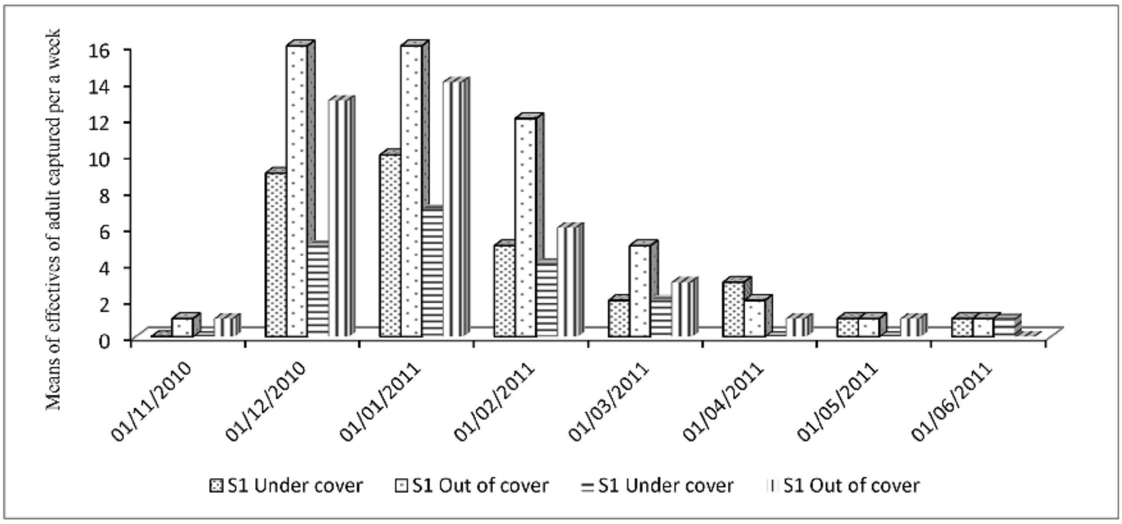
Figure 4. Evolution in average of specimen number of male flies captured per week in each station during the olive campaign 2009-2010 (a) and 2010-2011 (b). Male flies captured vary significantly ($p < 0.005$) in S2 and 3 compared to the others stations.

4.2. Male Catches Evolution during Olive Campaign 2010/2011

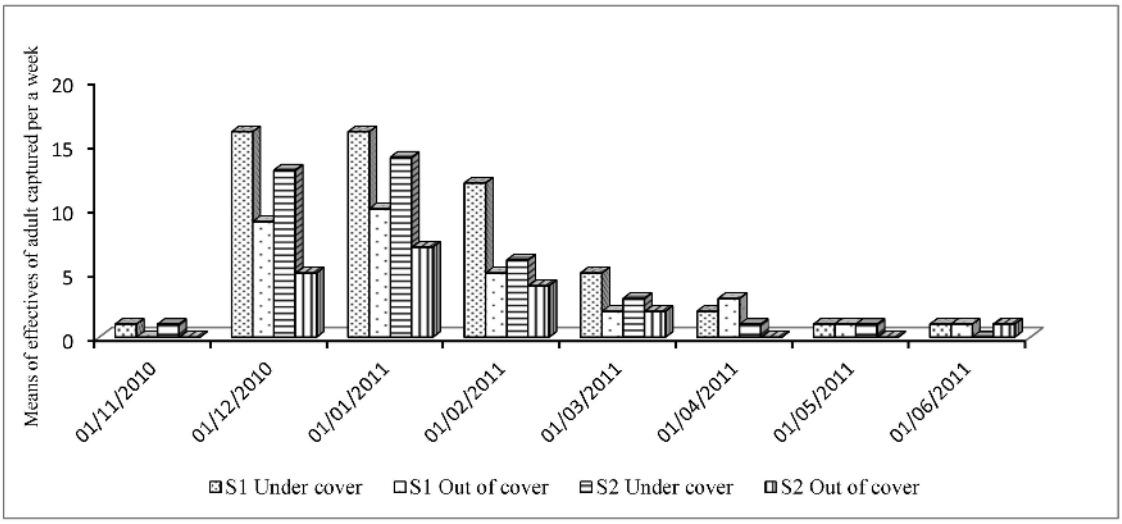
The number of males captured during the month of March is low and slightly unchanged (**Figure 4(b)**). It is relatively more important in the Akrmoud station (S4) than in the other stations. The decrease at the end of June, followed in July by an increase in the number of captured flies, especially at the Ida Ougard station (S1) where this number reaches a remarkable value at the start of the month. From mid-July numbers are near zero until mid-September. Then the variation curves in the four stations show three main peaks, with shifts in time and amplitude differences between stations: in the nearby coastal resorts (S1 and S4) and the station Had Dra (S2) and finally the innermost station Korimate (S3). The numbers caught at the Akrmoud station (S4) are low because the production of olives is very low during the olive campaign despite the mild summer and moderate temperatures. Generally, the number of male flies captured fluctuates significantly ($p < 0.005$) in S2 and 3 compared to the others stations.

5. Sampling Results of Hypogenous Pupae Populations

The number of pupae varies significantly ($p < 0.05$) among the two stations and between covers types mainly at period stretched from December to March. As shown in **Figure 5**, the pupae in the soil are present since the end of November: the number is increasing gradually to the maximum during the month of January. It gradually de-



(a)



(b)

Figure 5. Evolution of the average number of pupae sampled at stations 1 and 2 during the white phase of the cycle of the olive tree in campaign 2009-2010 (a) and the campaign 2010-2011 (b). (S1 & S2 stations). The number of pupae varies significantly ($p < 0.05$) among the two stations and between covers types mainly at period stretched from December to March.

creases until April in all samples. The numbers are rapidly weak and cancel out the situation outside cover of the station S2 towards the end of the month.

The number of pupae collected from the floor of the station S1 is always important, it is much higher than that obtained in the station S2. On the other hand the numbers of live pupae identified at ground level under cover of the canopy is still higher than that recorded outside cover. At the station S2 these numbers are often very low. In the S1 station pupae in the soil exist until the beginning of June, especially under the canopy area. The number of pupae in the soil of the two stations was important during the campaign 2009/2010.

6. Discussion

In stations near the coast S1, S2 and S4, the succession of larval stages forms a summer generation that lasts between late June and late August of the surveyed year. However, in the S3 station inwards away from the influences of the ocean, the pre-imaginal stages were not observed until early September, and the summer generation is not registered. [14] reported that weather conditions significantly affect the course of the growing season of the olive and consequently the bio-ecology of the pest *Bactrocera oleae*. Indeed, climate conditions change between the different study sites, especially as it approaches the coast. The high relative humidity and temperatures softened even in summer (near the coast), cause an early start of the phenological stages of the olive tree and the appearance of attractive and receiving olives for oviposition to the succession of larval stages. Summer conditions that are limiting factors will arrive at the end of August.

In the station S3 orchards are late flowering and maturing, so that the availability of receiving olives susceptible to oviposition coincides with summer including climate conditions corresponding to high temperatures and low humidity significantly affecting the development of stages. Stage development changes often manifest in reduced adult activity, inhibition of oviposition, the eggs hatch and development of vulnerable larvae (L1 and L2 stages) [15]. These results are consistent with results of previous studies undertaken in various oil-producing regions of the world that have shown high mortality of eggs and larvae of the fly when the weather is hot and dry [6]. The absence or low abundance of the populations of pre-imaginal stages and adult flies during the summer has been demonstrated by the results of work in some areas in Morocco, at the Sais [16] and Al Haouz Marrakech [17] and in other parts of the world: in Tunisia [18], Algeria [19], in the island of Crete in Greece [20], California [4] [9] and Italy [21]. Reproductive diapause may be extended by summer conditions, hot and dry, even when receptive olives are available [22]. This explains the remarkable declines in population densities of various preimaginal stages to distinguish summer and autumn peaks in the different areas of olive production [13] [14] [17] [18] [20] [23] Understanding these phenological differences may have important implications for the strategies proposed for phytosanitary control of various stages of the fly.

In coastal stations, the reproductive cycle of the olive tree is anticipated, olives fruit set begin from June and those that come in maturation phase become receptive in stations S1 and S4, hence the beginning of the infestation in July. The optimal climatic conditions for the proliferation of the fly explain the high level of infestation in these two stations. Generally, fly populations in coastal areas are naturally more important than in inland areas [24] [25].

According to our results, the numbers in various stages increased between early July and early August and reached their maximum in late July-early August and were cancelled in mid-August. Most individuals identified in olives thereafter died. The cessation of reproductive activity in summer lasts one to two decades in these stations in the orchards of Al Haouz region of Marrakesh, diapause period may exceed the August [13], according to distribution of climatic factors during the olive companion. Thermal thresholds (10˚C and 38˚C - 40˚C) [4] and humidity limiting survival stages of the cycle of the fly, which this pest is rarely recorded in the region. During the 2008-2009 Campaign, the harvest was cancelled. Fruit left on the trees ensured the availability of food and support for oviposition, this can be explained, at least in part, by the abundance of individuals of the first generation of the fly during the olive crop 2009/2010.

During the year 2010-2011, we recorded in coastal stations S1 and S4 a wave of abnormal and early flowering, which began in mid-January followed by a fruit that gave rise to mature fruit in late spring and early summer in June and July. The weather conditions were favourable during this campaign. That period was characterized by significant rainfall with mild temperatures and relatively high humidity. These conditions yielded a significant and exceptional production and therefore the harvest lasted longer. Nevertheless, olives in station S3 were abandoned without being harvested because of lack of labour force and means.

In autumn, we noted the succession of three maxima in the numbers with overlapping curves of their evolution. This reveals the coexistence of the different stages of development belonging to succeeding generations. Indeed, overlapping generations was highlighted in the study population. Furthermore, we found a remarkable decrease of density in the different larval stages of the fly Bactroacera oleae in subsequent generations to harvest. In fact, we recorded the sale of the product to the fields in the coastal stations which justifies the use of aggressive and often inappropriate treatments during the early harvest. Thus, we found that much of the production was left on the trees. Consequently, we suggest that the harvest is involved in the control of populations of the fly by the date of its implementation and how it is conducted. The two parts of the station S1 have opposite exhibitions, including the exposed south, sheltered from oceanic influences (humid winds from the north). This fact may explain the observed decrease of the rate of infestation by the fly and frequency of diseases like peacock eye compared to those observed in the exposed north, where the influences of the North humid winds are important.

The results of the correlations between the different stations (**Table 1**) show a variation in the size of populations and conduct of the various stages in the continentality gradient from the coast (S1 and S4) to the interior of the continent with S3 as the intermediate station S2 located almost on the transition line.

The pace of variation curves do not change according to the campaign. However, the onset of larval stages was slightly early during 2010/2011, whose olive production in the region has reached an exceptional level. The density of larval stages decreased during the second half of the fall season after harvest, as early as September in the stations S1 and S4 in early October in S2 and later, around the beginning of November and December in the station S3.

The movement of flies from early harvested orchards to the late harvest ones is probably responsible for the intense infestation of these [13] [20] [26]. This may explain the increase in adult populations at the station S3 in late fall. The phenological stages of the olive tree are anticipated towards the coast. In fact, the gradient of precocity seems to follow the continentality gradient from the coast to the interior, such that the temperature gradually increases and the moisture inversely decreases.

Several previous studies of the olive tree in various ranges worldwide, showed a relatively large infestation of olives by the larvae of *B. oleaea* in wetter areas, *i.e.*, areas of high altitudes, irrigated orchards and coastal areas [13] [27] [28] In coastal areas, it is shown that the adults are active throughout the year, such as eggs and larvae can be detected in fruits left on the ground or which have fallen and left on the trees [29].

Flight dynamics of adult males revealed fluctuations workforce whose temporal distribution was heterogeneous. In the stations S1, S2 and S4, we recorded substantial catches of adult males to early April, which the catches were becoming more significant in the month of June and July. However, the actual captured S3 station level were low during this period, which can be explained by the conditions of low humidity (30% - 40%) and high temperature (36˚C - 39˚C) and mainly to the unavailability of the receptive olives. Similar results have been reported in different areas of the extension area of the olive [14]. Fluctuations in numbers of stages at the station S4 were not regular because this station is directly subject to oceanic influences and characterized by a constantly damp climate. Thus, production during the 2010-2011 campaign was low compared to the previous season in this station (S4), resulting in a significant decrease in density of captured adults was noted.

During the period that lies between early September and late January, the average workforce of captured adults showed very high values marking the succession of generations. The number of generations of the fly, which highlights the results obtained in the different stages of development, seems to suggest four generations in the stations S1, S2 and S4, which is a summer and three autumn. However, in the S3 station, we noted the absence of the summer generation, however fictitious winter generation can be considered. The generations of the fall phase proved overlapping, that made the longevity of various stages of development of the fly is variable and controlled by the conditions of the biotope.

Studies conducted in different localities reported that the cycle of olive fly shows a variation of the number of generation according to the spatial variations of the following weather conditions: the latitude, altitude, longitude, near the ocean and temporal variations of olive crop to another [30] [31].

Regarding the evolution of the density of pupae in the ground, we found live pupae since the end of November until March half in both stations S1 and S2. These pupae were not detected in the off-covered soils station S2 because the soil is permanently overhauled by ploughing, while in the station S1, the number decreased gradually in the off-covered soils. However, in soils of the station S1, they remain present until June because these soils are loose, well drained and always maintained at appropriate amplitudes relative humidity. However, in Marrakech region (semi-arid to arid climate), the pupae are no longer found in the soil after the month of March [12] [13]. The number of identified pupae reached its maximum value during the months of December and January, during which the L3 larvae leave infested olives that are still on the trees and which has been falling on the floor. The abundance of pupae is clearly important at the station in the station S1 S2, throughout the period of their existence.

The physicochemical characteristics of the soil texture, permeability, the ability of water and maintaining the moisture retention influence longevity and the probability of survival of larvae and pupae from pupation. Rainwater can cause mortality larvae and young pupae by immersion [32]. Old pupae can survive immersion in up to four days. For cons, the mortality of young pupae increases rapidly after a six-hour stay in the water.

The floor of the station S1 is sandy limestone furniture that has significant coarse component. Its permeability is significantly higher than the floor of the station S2 which is of clayey nature with a very fine granular texture. After the rain, the ground station S2 develops a relatively compact crust making penetration difficult pupae and living conditions unbearable pupae. And this results lead to their death by asphyxiation. The largest share of the surviving pupae enter inability to hatching. In the station S2, the off-covered area is continually plowed and planted by the underlying culture. The reversal of the ground and putting into pupae found, exposed to the action of abiotic surface conditions (climatic factors) and biotic factors such as predators, bacteria and fungi [33]-[35]. The optimum climatic conditions allow the survival of pupae for long. Since the lower thermal threshold pupal survival is around 10˚C in the laboratory and between 8˚C and 9.5˚C in the environment [36], these conditions are seldom stored in the Olive coastal region of Essaouira. This may explain the persistence of the pupae in the soil of the two stations and their existence until June. Thus, previous studies have shown that the temperature alternating 7˚C and 11˚C for one or two months causes a mortality of pupae that can reach 100% relative humidity of 60% [37]. This alternation is not reported in the weather data in the region.

Monitoring the activity of adult fly through the catch followed by installation of pheromone traps or food can detect theft and avoid big surprise outbreak of the fly and large infestations. The determination of the control elements of bio-ecology of *Bactrocera oleae* fly and population dynamics of the various stages of its development cycle can help to consider a good strategy against the fly in the study area. The fight against the pest requires 2 - 3 treatments per year depending on the degree of infestation and the climatic conditions. During harvest, it is highly recommended to replace the techniques of shaking down which causes injury fruit and causes biochemical alterations making the oil unstable with increasing acidity. The decision of the harvest date should consider the maturity index of the olives and the state of adult dynamics of the fly to avoid over-infestation by last autumn generations. According to the literature, phytosanitary intervention attempts are poor and insecticide applications are recorded but are random and not based on knowledge of the pest and its development cycle [38]. Also, the fragmented state of the orchards, the small size of the properties, the existence of the olive trees receiving no agricultural intervention scattered throughout the area, and the ignorance of the owners of olive groves in the management of olive cultivation hamper unfortunately, all individual and collective effort of pest fight.

7. Conclusions

The dynamics of the various larval stages of the fly at the whole study area shows time lags that occur from shore stations to the innermost stations. The summer period is characterized by a low density of larval stages disappearing during the month of August. This dynamic is usually dependent on weather conditions and the availability of receptive fruit controlled by continentality. Flight dynamics showed that the life cycle of the fly has at least four generations whose stages are overlapping over the summer and autumn periods. The offsets between stations are synchronous with the shifts in the evolution of the phenological stages of the olive, and accompanied by a movement of adult flies from early orchards and their concentration in the late ones. The presence of the pupae in the soil was detected at the end of November while persisting until the end of May-early June.

Plant protection in the region must be generalized and conducted by the regional agricultural services through their contributions in raising awareness, funding and intervening for monitoring the use of treatments. Compliance with orchard protection is compulsory.

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