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Population Dynamics and Seasonal Development of the Egyptian Alfalfa Weevil, *Hypera brunneipennis* (Boh.), (Coleoptera: Curculionidae) in El-Farafra Oasis, New Valley Governorate, Egypt

El-Sheikh, W. E. A.
Department of Plant Protection, Faculty of Agriculture, Beni-Suef University, Egypt.
E-mail:wael78egy@yahoo.com

ABSTRACT

Egyptian Alfalfa Weevil (EAW) pose great danger in recent years of alfalfa cultivation areas in El-Farafra Oasis, New Valley governorate, a crop that has an important role in combating desertification in terms of soil stabilization and increase fertility in modern reclamation areas, the population density of damaging stages of the EAW, *Hypera brunneipennis* (Boh.) in standing Alfalfa was estimated by conducting periodic survey during two successive years. Aestivated weevils migrated from aestival shelter by the last week of November and its population attained the maximum by the third week of March. Larval stage appeared during first and second week of February 2016 and 2017 respectively and lasted until the start of May. Population size of developing adults was closely correlated with larval population. Peaks of larva and newly emerged weevils occurred on 3st and 20th March 2016 and came one and two weeks later in 2017. All weevils developed in summer were obliged to enter summer diapauses (aestivation) during mid-May the influence of prevailing high temperature and long days. The effect of weather factors viz: daily mean temperature, daily mean relative humidity and day-length on the population density of adult, abundance and summer diapauses was statistically discussed. This recent study proved that the insect had one generation in the field per year.

Keywords: Alfalfa Weevil, Plant phenology, life cycle, El- Farafra Oasis, Egypt.

INTRODUCTION

The alfalfa (*Medicage sativa* L.) is considered to be the main green forage crop in Egypt. It also contributes to soil fertility and improves soil physical characteristics (Graves *et al*. 1996; Bahy and Bakheit 2013).The Egyptian alfalfa weevil (EAW) *Hypera brunneipennis* Boh. (Coleopteran: curculionidae) was reported as one of the serious pests of berseem in Egypt (willcocks 1922). Alfalfa weevil was first reported in Virginia 1952, a key insect pest of alfalfa; it was classified as a major insect pest on the alfalfa, which is cultivated with an area of 50,000 hectares (Evans 1959) since this crop usually, receives no insecticidal treatment for fear of exposure to farm animals for the dangers resulting from it. Alfalfa is inhabited by numerous insect species some of these species are beneficial (Mohammed and Eltayeb 2003).

When studying the biodiversity of insects in alfalfa fields in the oasis of Farafra and the Bahariya Oasis (Western Desert, Egypt), Egyptian alfalfa weevil (EAW) *H. brunneipennis* were collected, threatening the fields of alfalfa cultivation in these areas. (Usama *et al*. 2014) as classified in Central Valley, California, one of the major serious lesions of the alfalfa crop, causing damage to alfalfa cultivation areas in the state (Cothran *et al.* 1972). Distribution for the alfalfa weevil, *Hypera postica* (Gyllenhal), was determined for the five major alfalfa-growing regions of New Mexico. Eastern, Egyptian, and western strains were recovered, along with a population not matching any known strain. The majority of sites examined had populations of two strains intermingled within a field. This is the first confirmation of the presence of all three strains within the same geographic region (Scott Bundy *et al.* 2005).

The geographical distribution of the alfalfa weevil in the U.S. belong to a single species with three strains (western, Egyptian, and eastern), Population density varied from one region to another and climate factors played an important role in the distribution of these strains (Hsiao 1993). When studying the effect of increased winter temperatures by 2°- degree increase, as a result, the number of larvae of the alfalfa weevil population was higher than two weeks to four weeks earlier than the Shenandoah Valley and the Southwest Virginia Region, Therefore, although the climate has a clear effect on population dynamics and is a powerful factor for the distribution of alfalfa weevil strains in alfalfa cultivation areas (Radcliffe and Flanders 1998; Kuhar *et al*. 2001). This may be because the climate usually interacts with other factors to influence ecological processes and to shape population dynamics and seasonal abundance of insects (Leirs *et al*. 1997).

The alfalfa weevil, *H. postica* was collected from the northern and southern regions of Nebraska and the activity of insects and larvae was greater in the south due to the appropriate temperature and plant age. (Stilwell 2010). Atmospheric factors and spatial diversity have an important role in the density of alfalfa weevil, *H. postica* and associated natural enemies in dryland fields. (Rand 2013), in the winter, the alfalfa weevil was collected in small numbers, and the total number of insects and larvae increased in the spring and the population was low was clearly at the onset of summer (Fred and Sharron 1990; Thomas *et al*. 2000). As Temperatures rise in the north and south of Nebraska, expected to see alfalfa weevil larvae the alfalfa attacking the Leaf and buds of the crop, and it is possible to observe the presence of larvae and insects during day (Robert *et al*. 2016). The alfalfa weevil, *H. postica* can be predicted by measuring plant height, and there is a direct correlation between the age of alfalfa plant and the number of alfalfa weevil (Leslie and Robert 1977).

In recent years, the number of Egyptian alfalfa weevil (EAW) *H. brunneipennis*, has increased in the fields of alfalfa in Egypt, especially the New Valley Governorate, and has become a serious scourge for vegetable growth and due to the lack of ecological studies available in Egypt for this insect especially the Modern areas of agricultural reclamation (desert), therefore, the present work was initiated to study the population density of larva and adult stages as being damaging stages, time of occurance, seasonal development and population fluctuation as influenced, by certain environmental factors. Such study will permit estimation of numbers of numbers of larvae and adults when damage may occur.

MATERIALS AND METHODS

Study Area: The study was conducted in the Oasis of El- Farafra, a small oasis in the desert of Western Egypt with the capital of El- Farafra Palace, which is administratively followed by the province of New Valley Governorate which is located in the southwestern part of the Egyptian Western Desert, and shares the international borders with Libya to the west and Sudan to the south. It represents two-thirds of the Egyptian land area, equivalent to 44% of the total area. The New Valley Governorate has three administrative zones, called El-Farafra, El-Dakhla and El-Kharga Oases, and is considered a major depression in the form of a zigzag series, such Oases extend in an un-straight line parallel to the Nile valley and far from the west direction by about 200 to 300 Km^2. (Ahmed 1974; Ekaterina *et al.* 2016).

El-Farafra Oasis is located at latitude and longitude (26°49′23.3″N 27°46′33.3″E) 130 meters above sea level and 320 Km^2 north-west of the El-Dakhla Oasis, 170 Km^2 south of the EL- Bahariya Oasis and about 627 Km^2 Cairo. This area is characterized by hot, dry climate in summer and warm in the winter, temperatures reach the highest rate in June 50 degrees' Celsius temperatures ranging from April to September between 25 - 35 °C, and the lowest period and starting from October until March temperatures range from - 2 to 23 °C. Rain is almost non-existent throughout the year does not exceed 2 mm / year, while the relative humidity is not less than 30 % during the year wind speed between 6-10 m / s. (Neveen *et al.* 2015).

In El-Farafra Oasis, Agriculture is concentrated during the winter because of a strong summer causing water deficit the agricultural production and system of irrigation are depending on fossil (limited-renewed) ground water. Accordingly, agricultural extensions of some crops (as rice) with high water supplement were more or less limited and replaced by other economic crops with moderate water supplement such as alfalfa, maize, sunflower, peanut, wheat, faba bean, cotton …etc. In order to decrease environmental toxicity from one side and to increase exportation value of our agricultural products from the second, decision makers in the Egyptian Ministry of Agriculture banned all conventional insecticides from use in New Valley governorate and considered it as clean and isolated area. Accordingly, no insecticidal treatments could be applied to face the dangerous attack of agricultural pests.

Sampling: Estimation of population density of larva and adult was carried in the El-Farafra Oasis, New valley governorate, during two successive Alfalfa growing seasons 2015 and 2016. For each year, an area of 1 acre of alfalfa crop was identified and samples were taken every week at four times a month during the presence of the insect in the field. Received the usual agricultural treatments, but with no chemical control application. Seasonal counts of larva and adult in the field were conducted using the sweeping net method. Samples were taken at 11a.m using the two diagonals of the experimental area at weekly intervals. In this method, 100 full-length double net strokes were practiced. At every sampling date, the catch was anaesthetized, spread on white sheet paper and the number of the weevil larva and adult was counted and recorded. The surrounding adjacent habitats of these alfalfa plantations were represented mainly by both cultivated winter crops (as wheat, faba bean, Peas…) and some wild shrubs such as giant reed; *Arundo donax* and salt- cedar; *Tamarix aphylla* in addition to the above surrounding vegetations.

Meteorological data: Records on daily mean temperature, (°C), daily mean relative humidity (%) and day-length (hr.) from November to the next June of each season were obtained from the meteorological station monthly sheets at New Valley governorate.

Statistical analysis: Relationships were examined by simple of multiple linear regression analysis between numbers and all sequential combination of the weekly meteorological data. Each life stage in both the years of study was analysed with two ways ANOVA. Megastat, version 10.0 (Orris 2005) was used for all statistical analysis.

RESULTS AND DISCUSSION

Results

***Population density of injurious stages:**

Data depicted in fig. 1 and 2, indicate that the *H. brunneipennis* two periods of activity during each of the years 2016 and 2017.The first period of activity extended from the end of November to the third week of February representing the reactivated weevils (over summer weevils). The second period represented the adults of the only one developed generation which extended from the first week of March until the mid of May. The seasonal abundance and occurrence of larva and adult stages through the two successive seasons 2015/2016 and 2016/2017 showed that the aestivated weevils resumed activity and migrated to Alfalfa fields on the last week of November 2015 and a week later in 2016.The number of reactivated weevils gradually increased and the peaks occurred on the end of January 2016 (55 weevils) and on the first week of February 2017 (40 weevils), after which the population of adults sharply dropped to reach the minimum on the third week of February 2016 and a week later in 2017. The total number of collected-reactivated weevils amounted 307 and 222 weevils in 2016 and 2017, respectively. Larval stage appeared during first and second week of February 2016 and 2017 respectively. Larval peaks occurred on the first week of March 2016 and on 15th March 2017. However, the larval population in 2016 was higher (513 larvae) than 2017 (424 larvae).

During 2016 the highest number of larvae (80 larvae) occurred on 3th March, while this figure was 72 larvae and existed on the 2th week of March 2017. Larval population showed a sharp decrement on the end of April 2016 and after 7 days in 2017. In other words, larval stage lasted about 11 and 12 weeks in 2016 and 2017, respectively. Newly emerged weevils appeared at the first and mid-March of both two years 2016 and 2017. The number was low at these dates after whichnit gradually increased to reach its maximum activity at the third week of March 2016 and beginning of April 2017. Adult population showed a gradual decrease and the number of sampled weevils became very low at the mid of May. Present data indicated that only one peak was found of both larva and newly emerged weevil populations in the field. Results showed that this insect species had only one generation every year. Weekly number of adults was comparatively higher in 2016 than in 2017.

***Seasonal development of the Egyptian alfalfa weevil:**

Aestivated weevils resumed activity by the onset of winter season when the air temperature decreased to become about 22 °C and 13 % relative humidity.

Reactivated females started oviposition from 5th January to 3rd March, 2016, and extended to 13th March 2017 as shown in fig.3.

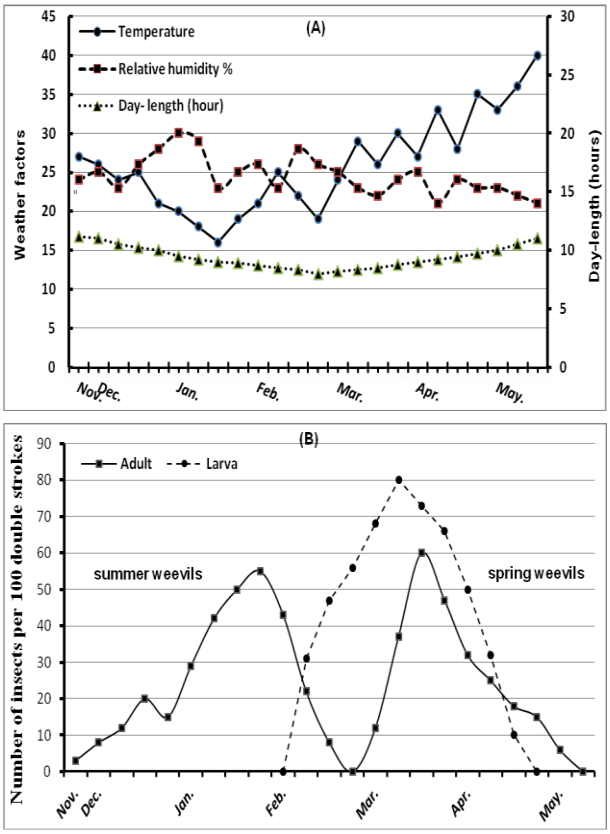

Fig. 1. A. weekly means of temperature, relative humidity and day-length at El-Farafra Oasis, New Valley governorate.B. weekly fluctuation of larva and adult populations of the EAW, *H. brunneipennis* in seasons 2015/2016.

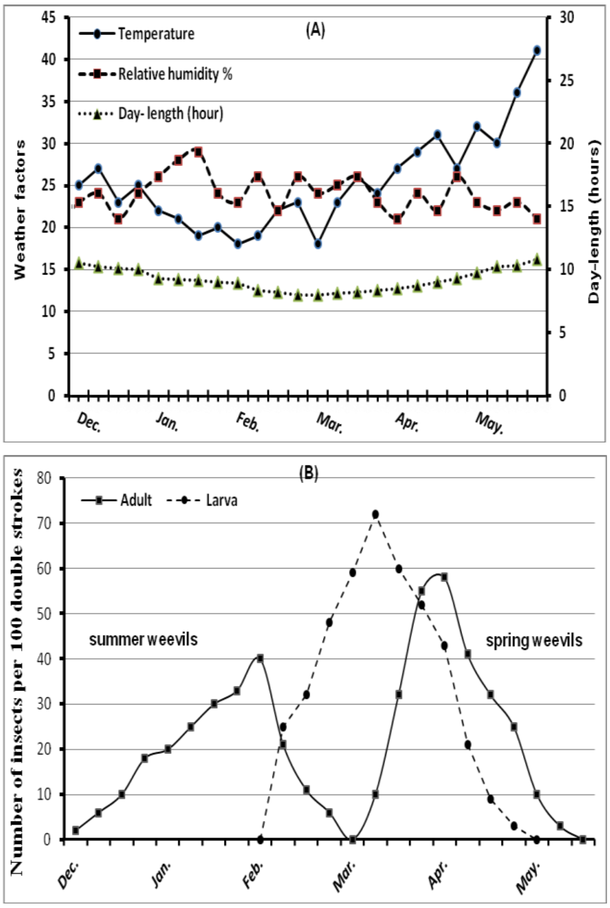

Fig. 2. A. weekly means of temperature, relative humidity and day-length at El-Farafra Oasis, New Valley governorate.B. weekly fluctuation of larva and adult populations of the EAW, *H. brunneipennis* in seasons 2016/2017.

SEASON:	2015/2016											
MONTHS	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.
Reactivated Weevils	♦	♦♦♦♦	♦♦♦♦	♦♦♦								
Egg			●●●●	●●●●	●							
Larva				▪▪▪▪	▪▪▪▪	▪▪▪						
Pupa				★★	★★★★	★						
Spring Weevils					♦♦♦♦	♦♦♦♦	♦♦					
Summer diapause							🌢🌢	🌢🌢🌢🌢	🌢🌢🌢🌢	🌢🌢🌢🌢	🌢🌢🌢🌢	🌢🌢🌢🌢
SEASON:	2016/2017											
Reactivated Weevils		♦♦♦♦	♦♦♦♦	♦♦♦♦								
Egg			●●	●●●●	●●							
Larva				▪▪▪	▪▪▪▪	▪▪▪▪	▪					
Pupa				★	★★★★	★★						
Spring Weevils					♦♦♦	♦♦♦♦	♦♦♦					
Summer diapause							🌢	🌢🌢🌢🌢	🌢🌢🌢🌢	🌢🌢🌢🌢	🌢🌢🌢🌢	🌢🌢🌢🌢

Fig. 3. Phenology and seasonal development of the EAW, *H. brunneipennis* during two successive seasons 2015/2016 and 2016/2017 in El-Farafra Oasis, New Valley Governorate.

First larva appeared on 2nd February 2016 and after 10 days in 2017.

Larval stage completed its development after 68-78 days in 2016 and 74-85 days in 2017. Pupal stage took place on 20 February and lasted until 5 April 2016 and after a week in 2017. An average of 50 and 60 days were demanded for the development of pupal stage in 2016 and 2017, respectively. The developmental period of immature stages was 100 and 110 days in 2016 and 2017.

The newly emerged weevils appeared in the field on 3th March 2016 and 10 days' latter in 2017. The feeding period of the adult stage lasted 70 days in 2016 and 63 days in 2017. During 2016, adults finished their feeding maturity and went into summer diapause (aestivation) on the second week of May, while the aestivation phenomenon occurred at the end of May in 2017. Based on the previous data, it could be stated that the EAW had only one generation throughout the period extending from December to the end of next June and the adult goes into aestivation from the beginning of July till mid of November.

***Effect of some weather factors on the population density of adults:**

The population density of the EAW adults and weather factors in the tested area were statistically analyzed in order to get an idea about the effect of the tested weather factors on the population fluctuation of the insect. Table 1 and 2 present the simple correlation and regression values of this statistical analysis.

A- Effect of daily mean temperature:

The activity period of the EAW adults could be divided into two distinct periods: the first period extends from December to February and was represented by the reactivated weevils while the second period extending from mid of March to the end of June and was represented by the newly emerged weevils of the spring generation. Results of statistical analysis of simple correlation showed a positive correlation (r = + 0.277& + 0.312) between the daily mean temperature and adult density during the first period of activity in both 2016 and 2017, while this relation was negative (r = - 0.546 & - 0.432) in the second period of the same previously mentioned years. The precise effect of daily mean temperature was determined through the mathematical calculation of the partial regression values. Accordingly, data in hand indicated that the increasing of temperature by 1°C.from the daily mean temperature would increase or decrease the mean number of reactivated weevils by 6.2 and 4.4 weevils in 2015/2016 and 2016/2017, respectively. On the other hand, a change of temperature by one °C of daily mean temperature during the second period of insect activity would produce a reverse change (P. reg. = + 5.312 & + 3.201) in the weekly number of adults by 5.3 weevils in 2016 and 3.2 weevils in 2017 when the other weevils' factors remain constant.

B- Effect of relative humidity:

The relation between relative humidity and the insect population density showed a positive (r = + 0.251 & + 0.301) correlation during the first period of activity during the two tested years (2016, 2017). This relation was negative (r= - 0.192) in 2016 while a fairly positive relation was obtained in 2017 during the second period of activity.

C- Effect of day- length:

The statistical analysis of our data revealed that the population fluctuation of the EAW adult in the field is quite correlated with the seasonal changes of day-length. The simple correlation coefficient value (r) showed a significant positive relation between day-length and adult population during the first period of activity in 2015 and 2016. Thus the increase or decrease of the day-length by one hour would increase or increase the number of reactivated weevils by 7.6 and 8.4 weevils in 2015 and 2016, respectively. On the other hand, day-length showed a negative effect on the insect population density during the second period of activity in both 2016 and 2017. Thus a change in day-length by one-hour decease or increase may induce a reverse change in the adult population by 14.5 and 15.3 adults in 2016 and 2017, respectively (Tables: 1 and 2).

Table 1. Simple correlation and partial regression of weather factors and percentage of variance explained on the population activity of Egyptian Alfalfa Weevil at El-Farafra Oasis.

Tested year	Weather Factors	Simple correlation and partial regression values		Analysis of variance values		
		r	P.reg.	F.	P	E.V.%
2015-2016 Reactivated Weevils	Daily mean Temperature	+ 0.312	- 6.254	1.312	0.001	73.78
	Daily mean Relative humidity	+ 0.301	+ 1.053			
	Day length mean	+ 0.635	+ 7.650			
New generation 2016	Daily mean Temperature	- 0.546	+ 5.312	1.860	0.001	82.86
	Daily mean Relative humidity	- 0.192	- 2.671			
	Day length mean	- 0.321	- 14.522			

Table 2. Simple correlation and partial regression of weather factors and percentage of variance explained on the population activity of Egyptian Alfalfa Weevil at El-Farafra Oasis.

Tested year	Weather Factors	Simple correlation and partial regression values		Analysis of variance values		
		r	P.reg.	F.	P	E.V.%
2016-2017 Reactivated Weevils	Daily mean Temperature	+ 0.277	- 4.403	2.264	0.001	68.81
	Daily mean Relative humidity	+ 0.251	+ .982			
	Day length mean	+ 0.534	+ 8.451			
New generation 2017	Daily mean Temperature	- 0.432	+ 3.201	1.490	0.001	71.25
	Daily mean Relative humidity	- 0.320	- 1.328			
	Day length mean	- 0.403	- 15.302			

D- The combined effect of the weather factors:

The combined effect of the tested climatic factors was highly significant (p > 0.01) during both evaluated seasons. The amount of variability in insect population (expressed as % variance explained) that could be accounted for by the three climatic factors is shown in (Tables, 1and 2), It is clearly that the amounts of explained variance by the three tested factors were so great and of high significant in both seasons (P > 0.01), these values amounted 73.78 %, 82.86 % in the first year and 68.81 %, 71.25 % in the second one, indicating that the tested climatic factors had great effects and play a great role in regulating the population dynamics of this species. These results indicate that there are other environmental factors which were not involved in the present study might play a great role in the variability of the population density of EAW adults during the activity season.

Discussion

Seasonal abundance and population chanege of the different stages of an insect throughout a definite period usually reflect the concept of the insect life cycle and its seasonal development. Weekly estimation of larva and adult stages of the EAW in clover fields in Egypt during two successive years proved that this species had one larval peak and two peaks for adult stage during its activity season. These results also indicate that the insect had only one generation in the field per year. This fact was supported by the presence of one larval peak and one peak of newly emerged weevils. Similarly, only one generation could develop when field collected egg were, hatched and further developed into the different stages in outdoor cages. These results confirm the finding of Fred and Sharron 1990; Thomas *et al.* 2000. However, Naguib and khattab (1980) stated that the EAW had two or three generations annually from December to mid of May. It seems that their results were not plausible since their data depended only on the peak numbers of the adult population.

Furthermore, the period extending from December to mid-May cannot cover the developing time to two or three generations particularly if we considered that this species demands 269, 52, 48, days for the pre-ovipposition, ovipposition periods and development of immature stages (Robert *et al.* 2016).

The considerable variation in the number of larvae and adults through the seasons of this study reveals that the EAW could respond to the environmental factors. There is a high degree of association between weather factors and adult density. The non-correspondence between the population density of reactivated weevils and temperature increase may indicate that the difference between maximum and minimum temperature would be important as stimulus, rather than relying on average temperature, which probably does not get high enough during the fall. The existence of a positive correlation between day length and relative humidity on one hand and reactivated weevil population on the other hand, may suggest that these variables play a great role in bringing the adults to a proper stage of readiness for leaving aestival shelters through fall. These explanations agree with the data obtained by (Radcliffe and Flanders 1998; Kuhar *et al*. 2001) with the same species. Based on the values of correlation and multiple regression analysis, it seems that temperature and day length are the most effective factors. Daily temperature ranging between 20°c and 25°c and day-length of less than 12 hr. accelerated the development of immature stages and increased the number of newly emerged weevils (Leirs *et al.* 1997).

However, the exposing of these adults to high temperature and long days more than 13 hr. as prevailed in nature from the beginning of May to the end of June May, obligate the weevils to enter summer diapauses (aestivation). The role of day length and high temperature in the induction of summer diapauses in EAW adult was experimentally studied by Rand 2013.

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ديناميكية التعداد والنمو الموسمي لسوسة ورق البرسيم المصرية *Hypera brunneipennis* (Boh.) (Coleoptera: Curculionidae) في واحة الفرافرة ، محافظة الوادي الجديد - مصر

وائل الظاهر عبدالحفيظ الشيخ
قسم وقاية النبات ، كلية الزراعة ، جامعة بني سويف - مصر.

تشكل سوسة ورق البرسيم المصرية خطرا كبيرا في السنوات الأخيرة لمناطق زراعة البرسيم بواحة الفرافرة محافظة الوادي الجديدة ، وهو محصول له دور مهم في مكافحة التصحر من حيث استقرار التربة وزيادة خصوبتها في مناطق الاستصلاح الحديثة. ولقد أجريت هذة الدراسة في حقل برسيم حجازي مساحتة واحد فدان خلال عامين متتاليين (2016/15-2017/16) ، حيث هاجرت EAW سوسة ورق البرسيم المصرية (سوس الصيف) بعد قضاء فترة بيات صيفي الي حقول البرسيم في الأسبوع الأخير من شهر نوفمبر والاسبوع الاول من شهر ديسمبر خلال موسمي الدراسة. ظهرت اليرقات خلال الأسبوع الأول والثاني من فبراير 2016 و 2017 على التوالي واستمرت حتى بداية مايو ، وسجل اعلي تعداد من اليرقات والسوس الحديث (سوس الربيع) في 3 و 20 مارس 2016 ، وجاءت بعد أسبوعين في عام 2017، ونتيجة ارتفاع درجات الحرارة وطول فترة النهار تبدأ الحشرات الكاملة في الدخول في البيات الصيفي خلال منتصف شهر مايو من كل عام. العوامل الجوية : تم مناقشتها احصائيا مثل متوسط درجة الحرارة ، متوسط الرطوبة النسبية ، طول اليوم علي كثافة التعداد للحشرات. واثبتت الدراسة الحالية لاول مرة ان لهذة الحشرة جيل واحد في السنة بمناطق الاستصلاح الحديث بواحة الفرافرة محافظة الوادي الجديد.