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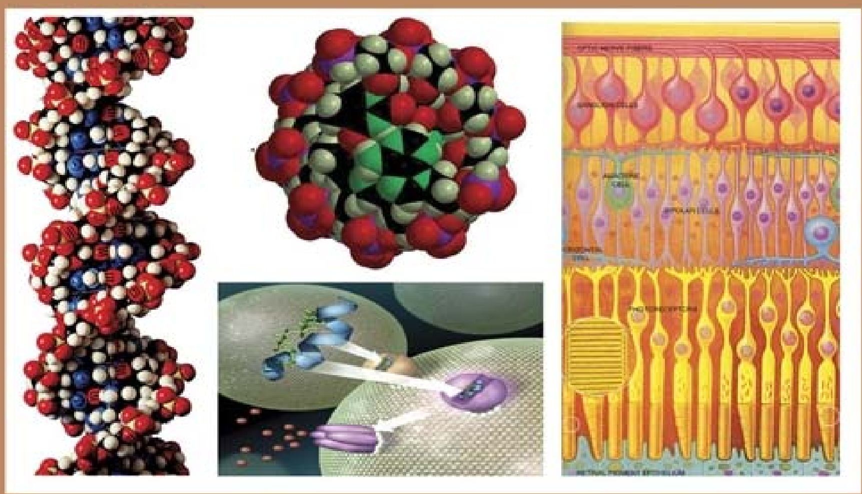

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Efficacy of aggregation pheromone in trapping red palm weevil (*Rhynchophorus ferrugineus* Olivier) infested Date palms in Damietta, Egypt.

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ABSTRACT

The study was applied on date palm plantations of Ezbet Al-Gabaila, Kafr Al-Battikh, Damietta, Egypt to determine RPW population fluctuation, correlation with environmental factors (temperature & relative humidity) and sex ratio during the experimental period from March 2013 to February 2014. Results indicated that the total number of captured weevils was 2184 weevil. Based on chi square test, there was a highly significant difference in numbers of captured weevils from month to another. The highest number of weevils was 698 weevils, captured in March but the lowest catch was 49 weevils recorded in December. Two major population peaks were noticed: the first peak reached its maximum in March; the second peak started in September, reached its maximum in October. Also significant difference was found between males and females as sex ratio was about 1 male: 2.6 females; this proved the ability of the tested pheromones to capture more females than males weevils in the traps which makes trapping a potential tool for managing this economic insect. There was a linear relation between the numbers of captured RPWs and both temperature and humidity, respectively. These relations was a high significant positive relation found between number of captured RPWs using pheromone traps and field temperature conditions, while a high significant negative relation was found with field relative humidity. Results concluded that the pheromone traps have a great effect in capturing adults of RPWs.

INTRODUCTION

Date palm, *Phoenix dactylifera L.* (Arecaceae) is one of the oldest and most important fruit trees cultivated in the Middle East and North Africa including Egypt (Sawaya, 2000). One of the major threats to *Phoenix dactylifera* all over the world is the red palm weevil (RPW), *Rhynchophorus ferrugineus* (Olivier), (Coleoptera: Curculionidae) (Dembilio *et al.*, 2009). RPW has been identified as a category-1 pest of date palm in the Middle-East by FAO (Faleiro, 2006).

RPW was detected in the Gulf area in mid-1980s(Abozuhairah *et al.,* 1996) then it was able to cross the Red Sea as it was found in Egypt (Ismaelyia and Sharkyia governorates) in 1992 (Cox, 1993).

The RPW is a concealed tissue borer (Faleiro and Satarkar, 2003). Larvae are the most destructive stage; it penetrates deep into the stem (Faleiro, 2004), feeds on surrounding soft succulent tissues, causing total loss of the palms (Faleiro, 2006).All developmental stages remain inside the palm trees (Alhudaib, 2006), because of this cryptic habitat it is very difficult to detect RPWs in the early stages of infestation (Al-Saoud, 2010a) and also difficult to apply chemical insecticides for controlling the insect (Faleiro, 2006). Consequently, the recent strategy for management of RPW has focused on integrated pest management programs (IPM) including the use of aggregation pheromone traps (Al-Saoud *et al*., 2010).Abd-Allah and Al-Khatri (2005) found that the combined effect of pheromone, kairomone and food bait (date fruits) trapped the maximum number of weevils, especially females. Pheromone trapping of RPW is an environmentally friendly tool in the IPM strategy currently adopted worldwide for RPW control. This system does not create resistances, easy to handle, long lasting, reduces populations, allows population monitoring, help to reduce the pesticide use and helps the efficacy of other control methods by optimizing the application of insecticides (Kaakeh, 2000). Pheromone technology has been widely used to manage RPW in commercial date plantations, e.g., the United Arab Emirates (Abbas *et al*., 2006) and Saudi Arabia (Faleiro *et al.,* 2010). The purpose of this study is to determine the seasonal variations of abundance of adults RPW and the effectiveness of pheromone traps for monitoring and controlling populations and effect of temperature and relative humidity on weevils' activity in Al-Gabaila, Kafr Al-Battikh, Damietta, Egypt.

MATERIALS AND METHODS

Study sites

The study was conducted in Ezbet Al Gabaila, Kafr Al Battikh at Damietta governorate, Egypt, which located at 31°24'28" N latitude 31°38'40" E longitude. Six sites were chosen to be the field of study; each site had at least from 50 to 100 date palm trees with (5-15) m in height and approximately (10-30) years old. A total of 6 traps (A, B, C, D, E, F) were installed for a trapping period from March 2013 till February 2014.

Pheromone traps

Traps were fabricated using about 8 L plastic white bucket with three holes, 5 cm diameter, in the bucket's lid and five lateral rectangular windows (3×8 cm) just below the lid around the side walls. The outer surface of the bucket was covered by dark rough cloth (sackcloth) to help the weevils climbing it and enter, also the dark color had been recommended because it is generally more effective in catching RPWs in the field (Al-Saoud, 2012). The upper surface of the lid had a small handle to ease opening the trap. The used pheromone is called "Ferrugineol" or (Ferrolure+®) which is a synthetic pheromone lures of *R. ferrugineus* male aggregation pheromone mixture (a mixture of 4 - methyl –5 - nanol and 4 – methyl – 5 - nanone (9:1)) imported from Chem Tica Internacional SA, Costa Rica, in the shape of 400 mg pack which was hung on the inner side of the bucket lid with a piece of wire. Kairomone is considered as Ethyl acetate with 98% purity. It was placed in 20 ml dark-brown bottle, with 1 mm hole in its lid, hanged to the inner surface of the trap's lid. It must be noted that the trap was insecticide free pheromone traps. The trap was provided with food substrate consisting of about 350 gm. of dates, a teaspoonful of yeast and 3-4 L of water. The trap was buried in the soil up to the lateral holes. Six traps were used, one in each site. The traps were separated by at least 100 m.

Traps were inspected twice a week, during the experimental period, to replace the food substrate (dates) and add water and the kairomone bottle was refilled as needed. The pheromone pack was replaced by a new one almost monthly during hot season and every 2 months during cold season.

Seasonal abundance

Captured weevils were collected from each trap twice a week and transferred to the laboratory where they counted and sexed. Sum of numbers of caught weevils was gathered monthly for each trap and cumulatively throughout the experimental period. Monthly variations of the red palm weevil abundance were recorded during the experimental period.

Determination of sex ratio

Trapped adults were identified as males or females and sex ratio was determined.

Statistical analysis

The number of males, females and total weevils recorded monthly per each trap. Data obtained were statistically analyzed using SPSS version (20). A χ^2 analysis was used to compare between numbers of weevils from month to another during the experimental period. The sex ratio of captured adults was evaluated by χ^2 as well.

RESULTS AND DISCUSSION

Seasonal abundance of RPW

The monthly variations in numbers of captured RPWs in all six sites (A, B, C, D, E, F) during the experimental period from March 2013 to February 2014 illustrated in Fig (1). The total number of captured RPWs in all sites during the study period was 2184 weevils. Based on chi square test there were highly significant differences in the population fluctuation of captured RPWs from month to another (χ^2 = 1867.67; P < 0.001). The number of catch was 698, 264, 198, 153, 57, 58, 162, 202, 140, 49, 73 and 130 weevils for March, April, May, June, July, August, September, October, November, December (2013), January, and February (2014) respectively.

Fig. (1) shows that the monthly variations in *R. ferrugineus* abundance by pheromone traps increased gradually, reached its peak in March, 2013. A Second smaller population peak was found from September 2013 reached its maximum in October 2013.

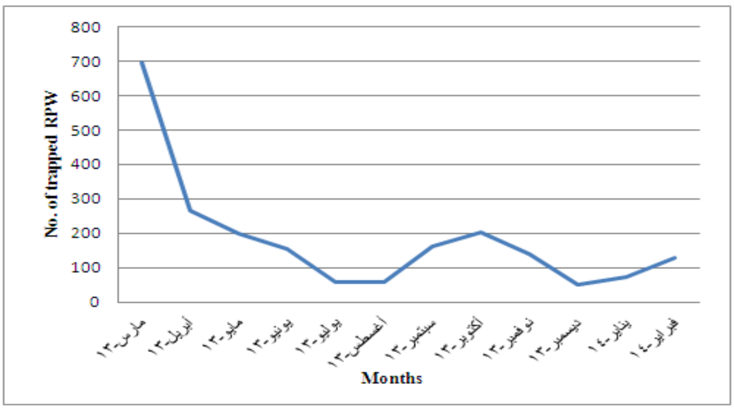

Fig. 1: The monthly variations of captured RPWs using pheromone traps in all study sites.

The highest catch was found during March, 2013 with 698 captured weevils, while the lowest was in December, 2013 with 49 captured weevils. The data of seasonal variations of RPWs abundance in all sites confirmed that weevil captures tended to be higher during spring and the early warm autumn. On the other hand trap captures were generally lower during hot summer and cold winter so, spring and autumn were the most suitable seasons for RPW activity.

The average number of adult weevils caught per trap/month differed between sites during the period of study (Fig. 2). The highest number of trapped weevils/month was recorded in B (42.33 weevil/month) and F (42 weevil/month) whereas the lowest number of weevil/trap/month was E (20.25 weevil/month).

The obtained results are in agreement with the findings of Abdallah and AlKhatri, (2003), who observed that RPW adults emerging continually throughout the year. On the other hand El Sebaey (2003) in Egypt indicated that *R. ferrugineus* had two main active seasons annually. The first adult brood was observed in April and the second one was in November. Furthermore, Al-Saoud, (2007) showed that the adult RPW were present throughout the year, and the number of females was higher than the number of males.

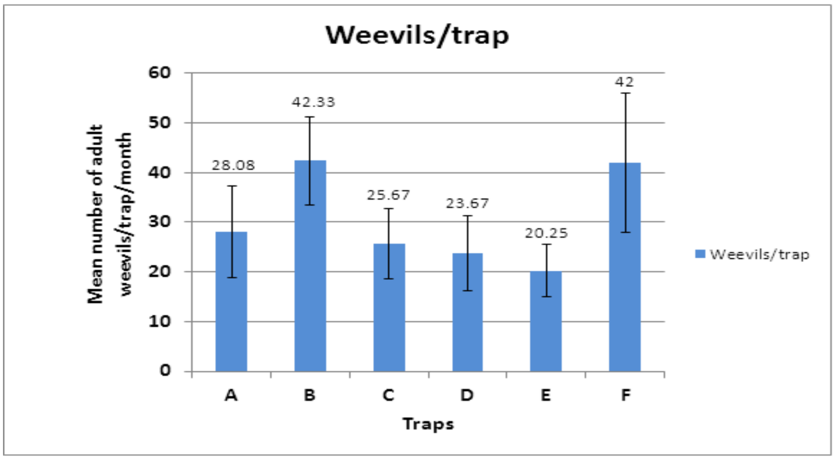

Fig. 2: The mean number of captured adults RPWs per trap/month during the study period.

Sex ratio:

Sex differences in trap catch were noticed. Both sexes were attracted to traps, but the number of female captured in the traps was higher than male weevils (Table 1). According Table (1) the total number of captured RPWs in all six sites during the study period was 2184 weevils, 613 of them were males and 1571 were females, with a sex ratio 1 male: 2.3 - 2.6 females. Based on chi square test, there was a highly significant difference between the numbers of males and females as female weevils responded to the pheromone more than males ($\chi2$ = 420.222; $P < 0.001$).

Female density was higher than male density and it constituted 71.9% of the total population captured in the study field. In addition, Faleiro (2005) also found that the weevil captures were female dominated and for every male weevil trapped two female Weevils were captured.

The results are in confirmation with the study of Poorjavad (2009), female weevils responded to the aggregation pheromones more than males. Present study suggests that females may have a higher sensitivity to the aggregation pheromone than males. This is due to the fact that the red palm weevil females have more basioconic sensillae on antenna than males (Avand-faghih, 2004). The basioconic sensillae in the weevil, *R. palmarum*, are known to be sensitive to the aggregation pheromone (Said *et al*., 2003). In other studies, (Al-Saoud, 2007; Al-Saoud, 2009b) reported a sex ratio ranging from 1:1.33 to1:2.28, male: female.

Table 1: Total trap catches of males and females and sex ratio during the study period.

Site	Male	Female	Total	χ^2	Sig.	Sex ratio (male/female)
A	90	247	**337**	**73.14**	**0.000**	**2.7**
B	141	367	**508**	**100.54**	**0.000**	**2.6**
C	85	223	**308**	**60.05**	**0.000**	**2.6**
D	85	199	**284**	**45.76**	**0.000**	**2.3**
E	68	175	**243**	**47.12**	**0.000**	**2.6**
F	143	361	**504**	**94.29**	**0.000**	**2.5**
Total	613	1571	**2184**	**420.222**	**0.000**	**2.6**

Effect of temperature and relative humidity on weevils' activity:

Environmental parameters influence the distribution, abundance and activity of organisms such as insects. During the experimental period from March (2013) to February (2014), the average temperature and humidity were calculated for each month as shown in Table (2). An analysis was done to find the relation between the monthly numbers of captured RPWs and the variations in both average temperature and humidity, respectively. The results showed that both of these two environmental parameters (temperature and humidity) seem to affect the activity of RPWs.

Table 2: The monthly variations in numbers of captured RPWs with the corresponding weather factors.

Months	No. of RPWs	Mean Temperature c°	Mean R. humidity%
March-2013	698	28.58	41.15
April-2013	264	29.11	41.71
May-2013	198	32.52	50.57
June-2013	153	33.72	55.83
July-2013	57	34.32	64.75
August-2013	58	35.75	60.39
September-2013	162	32.37	55.87
October-2013	202	28.29	58.80
November-2013	140	26.67	60.93
December-2013	49	18.96	47.33
January-2014	73	19.93	57.71
February-2014	130	21.82	56.37

According to Pearson Correlation analysis there was a linear relation between the numbers of captured RPWs and both temperature and humidity, respectively. Data in Table (2) showed that there was a high significant positive relation that found between number of captures RPWs using pheromone traps and field temperature conditions ($r= 0.18$, $p= 0.001$),as r is the correlation coefficient, which meant increasing the activity of RPWs with the increasing of temperature (Fig. 3), while a high significant negative relation was observed between number of captures RPWs using pheromone traps and field humidity($r= -0.22$, $p= 0.001$) which meant increasing the activity of RPWs with the decreasing of humidity (Fig. 4).

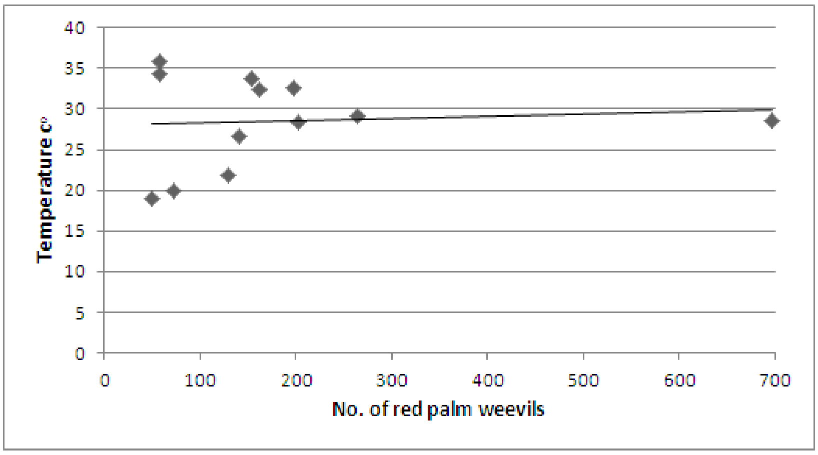

Fig. 3: The positive correlation between the number of captured RPWs and temperature.

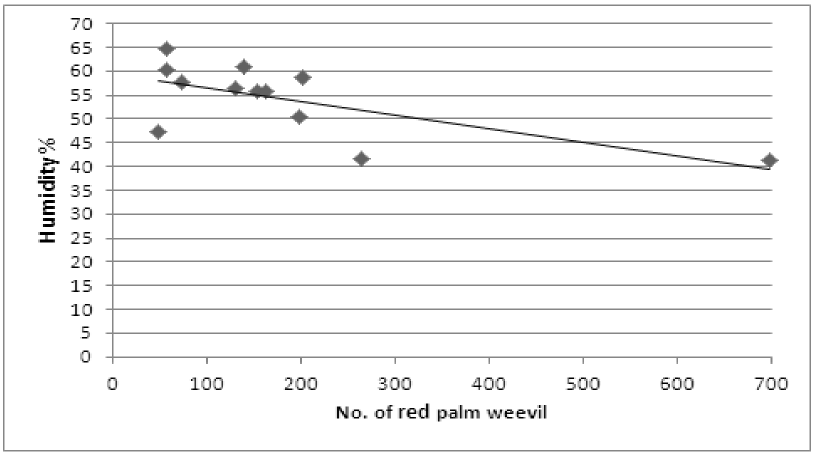

Fig. 4: The negative correlation between the number of captured RPWs and R. humidity.

Data in Table (3) showed the effect of weather factors (mean daily temperature & RH) on the population abundance of RPW during study period. The simple correlation coefficient (r) value indicated significant positive correlation between average temperature and adults population abundance of the RPW during the tested year of study from Marsh 2013 until February 2014, while the means of daily relative humidity had significant negative effect on the population abundance of the RPW adults during the study period.

Table 3: The correlation between the number of captured RPWs and temperature, R. humidity.

Parameters	**N**	**r**	**P-value**
Temperature	366	0.18	**0.001**
R. humidity	366	-0.22	**0.001**

N : refers to number of days during this study (entire year).
r : refers to the Pearson correlation coefficient.

A multiple regression analysis, which is a statistical tool for understanding the relationship between two or more variables was done to predict the numbers of captured RPWs(dependent / explained variable) depending on values of both temperature and humidity (independent /explanatory variables) that are thought to be associated with changes in the numbers of collected RPWs.

Multiple regression equation (model), which is used to predict the value of the dependent variable by looking at how the independent variables are behaving, takes the following form:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \varepsilon$$

Where ***Y:*** represents the dependent variable (numbers of captured RPWs).

X_1 and X_2 represent the explanatory variables (temperature and R. humidity, respectively).

β_0 is the intercept of the straight line.

while $\beta 1$ and $\beta 2$ (Beta, the coefficient of X_1 and X_2, respectively)

ε represents the error in predicting the value of ***Y***

According to Table (4), the values of multiple regression coefficients were obtained, "Intercept" refers to the constant term **β_0** in the regression equation which equals **(6.93)**, while **β_1** equals **(-0.14)** and **β_2** equals **(0.224).**

According to these coefficients and the basic form of the multiple regression equation:

($Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \varepsilon$) which is previously illustrated, we could predict the number of captured RPWs and its abundance depending on the information of both temperature and humidity using the following equation:

$$\textbf{No. of captured RPWS} = 6.93 - 0.14\textbf{Temerature} + 0.224\textbf{Moisture} + \varepsilon$$

Table 4: Multiple regression coefficients

variables	**Unstandardized Coefficients**		**Standardized Coefficients**	***t*-stat.*****	**P-value**
	ß*	**Std. Error****	**ß***		
Intercept (Constant)	**6.93**	**2.574**		**2.692**	**0.007**
Temperature (X_1)	**-0.14**	**0.033**	**-0.213**	**-4.224**	**0.000**
R. humidity (X_2)	**0.224**	**0.065**	**0.175**	**3.475**	**0.001**

This results is in harmony with the findings of Faleiro (2005) who found that Maximum temperature and rainfall had a significant impact on the weevil activity in India while, the maximum temperature was positively correlated ($r = 0.51$) with weevil captures, rainfall was negatively correlated ($r = -0.61$) with the weevil catch. In this respect. Also, Huang *et al.*, (2008) in China indicated that the climatic conditions had an obvious influence on the trapping effect of pheromone for RPW. The trapping population was significantly reduced in the conditions of rain and low temperature. In addition, Abdallah and Al-Khatri, (2003), reported that there is an effect of the climatic conditions of maximum and minimum temperature and the Relative Humidity on the population fluctuation of RPW.

Pheromone trapping of red palm weevil an ecologically safe and environmentally friendly tool in the IPM strategy currently adopted worldwide for red palm weevil management in date palm plantations and one that can be implemented on large scale either by the state or by farmers on a collective basis.

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ARABIC SUMMARY

فعالية فيرمون التجميع فى اصطياد سوسة النخيل الحمراء *Rhynchophorus ferrugineus* التى تصيب نخيل البلح بدمياط ـ مصر.

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٣- قسم علم الحيوان ـ كلية العلوم ـ جامعة المنصورة – مصر.
٤- قسم علم الحيوان ـ كلية العلوم ـ جامعة دمياط ـ مصر

تمت الدراسة على زراعات نخيل البلح بعزبة الجبايلة -كفر البطيخ ـ بمحافظة دمياط ـ مصر لتحديد تأرجح جماعة سوسة النخيل الحمراء على مدار عام من مارس ٢٠١٣ حتى فبراير ٢٠١٤ وعلاقة هذا التأرجح مع بعض العوامل البيئية وهى درجة الحرارة والرطوبة النسبية فى الحقل كذلك تحديد النسبة الجنسية للحشرات المجمعة خلال فترة الدراسة.

أشارت النتائج الى تواجد الحشرة على مدار العام ، وقد وصل تعداد الحشرات المجمعة خلال الدراسة ٢١٨٤ حشرة بالغة من خلال ست مصائد مزودة بفيرمون التجميع تم تثبيتها بمنطقة الدراسة على مدار العام. وبتحديد علاقة تعداد الحشرات المجمعة على مدار شهور العام ، ظهر لتعداد الحشرة قمتان احداهما كبيرة وصلت ٦٩٨ حشرة فى شهر مارس ٢٠١٣ والاخرى بدأت فى سبتمبر ٢٠١٣ (١٦٢ حشرة) وأوكتوبر ٢٠١٣ (٢٠٢ حشرة). وكان أقل تعداد للحشرة فى شهر ديسمبر ٢٠١٣ (٤٩ حشرة). وبالتحليل الاحصائى ظهر فارق معنوى للنسبة الجنسية للحشرات المجمعة حيث زاد عدد الاناث عن ضعف عدد الذكور ووصلت النسبة الى ١ : ٢.٧ . مما يعطى أهمية كبيرة للمصائد الفيرمونية كأداة فعالة فى ادارة هذه الآفة.

كما سجلت النتائج والتحليل الاحصائى وجود علاقة خطية بين غزارة الحشرات المجمعة وكل من درجة الحرارة والرطوبة النسبية فى الحقل ، وقد كانت العلاقة ذات تأثير موجب بين غزارة الحشرات المجمعة ودرجة الحرارة بينما كانت ذات تأثير سالب مع الرطوبة النسبية.

بهذه النتائج يتضح مدى انتشار وكثافة هذه الآفة الخطيرة بمحافظة دمياط ، كما تظهر أهمية استخدام مصائد الفيرمون التجميعى والعمل على تحسينها كوسيلة فعالة آمنة صديقة للبيئة فى ادارة هذه الحشرة الاقتصادية.