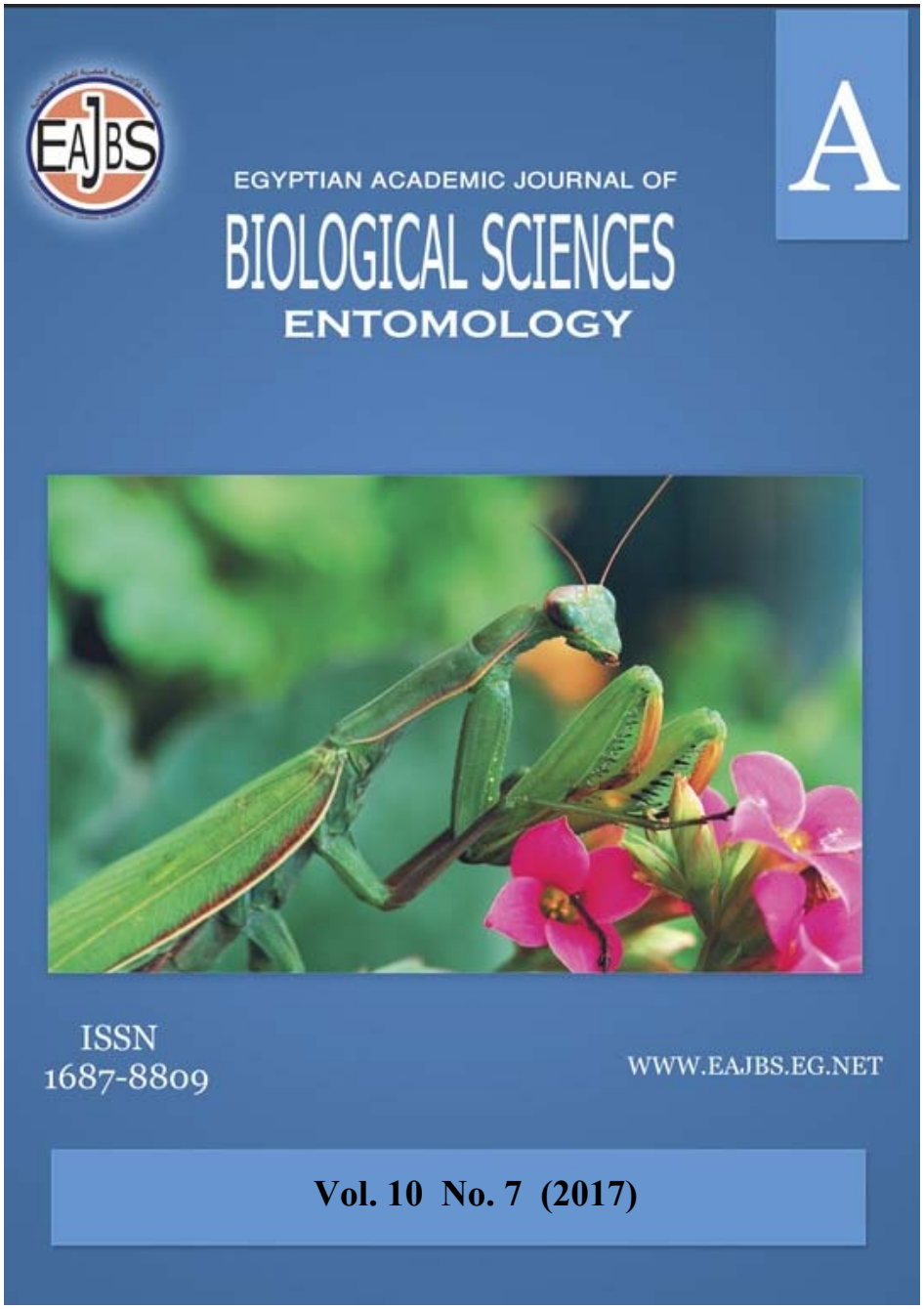

Egyptian Academic Journal of Biological Sciences is the official English language journal of the Egyptian Society for Biological Sciences, Department of Entomology, Faculty of Sciences Ain Shams University.

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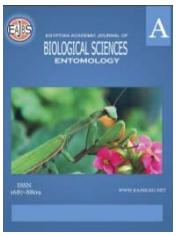
www.eajbs.eg.net

Egypt. Acad. J. Biolog. Sci., 10(7): 253–262 (2017)

Egyptian Academic Journal of Biological Sciences
A. Entomology

ISSN 1687- 8809
www.eajbs.eg.net



Efficiency of Food Baits, Synthetic Attractants and Trap Type on *Rhynchophorus ferrugineus* (Olivier) Trapping in Palm Plantations- Ismailia, Egypt- by Aggregation Pheromone Traps

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ARTICLE INFO
Article History
Received: 14/10/2017
Accepted: 14/11/2017

Keywords:
Rhynchophorus ferrugineus, pheromone traps, kairmone.

ABSTRACT

Pheromone trapping of the red palm weevil *Rhynchophorus ferrugineus* (Olivier) is considered an environmentally safe tool in the IPM adopted strategy worldwide in date palm plantations. Field trials were conducted in Kasassin District, Ismailia Governorate -Egypt, to enhance the RPW pheromone-trapping efficiency. The current study was carried out during two successive years from April 22nd, 2015 to October 10th, 2016. Results indicated that captured weevils were significantly affected by trap types where PICUSAN® trap gave the highest captured number during the experiment period which lasted for 12 weeks, *i.e.* 119 adult weevils, followed by the bucket trap new that registered 90 weevils. Moreover, the combined effect of sugarcane honey, pheromone, ethyl acetate and pesticides gave more attractiveness than the other 4 tested combinations, *i.e.* 110 adult weevils were captured by this bait during the 12 weeks of the experiment, while the other four combinations captured 81, 44, 26 and 20 weevils. The least registered weevil's number was in sugarcane honey and pesticides. This might due to the combined effect of such treatments. The efficacy of synthetic kairmone with different combination on the attraction of weevils was also investigated. The best combination was water, aggregation pheromone, palm tissue and molasses 15% in water with mixture (EtAc: EtOH, 1:3). This combination collected about 311 adults during the 12 weeks period of the experiment. The mixture (EtAc: EtOH, 1:3) was able to boost pheromone and was almost as effective as the use of the complete bait. Ethyl acetate alone does not improve the attraction power for aggregation pheromone. In addition, sex ratio was calculated and it was found that male: female ratio was 1:1.9.

INTRODUCTION

The red palm weevil (RPW) *Rhynchophorus ferrugineus* (Olivier) (Coleoptera: Curculionidae) is a palm borer native to South Asia, which has spread mainly due to the movement of infested planting material to the Middle East, Africa and the Mediterranean during the last two decades. Globally, the pest has a wide geographical distribution in diverse agro-climates and an extensive host range in

Oceania, Asia, Africa and Europe, Robin *et al*. (2013). The RPW is reported to attack over 40 palm species belonging to 23 different genera worldwide. Although it was first reported as a pest of coconut (*Cocos nucifera*) in South Asia, it has become the major pest of date palm. RPW was reported in Egypt in the early 1990s (Cox, 1993) and has since spread to all of the major date-palm oases in the country, mainly through transportation of infested palm trees. The larval and adult stages of this insect feed within tunnels inside the trunk of palms and this behavior frequently damage the infested trees. In infested plantations, yield registered a drop from 4.2 to 0.3 metric ton/ Feddan (Gush, 1997).

Aggregation pheromone traps, is the main element in the control program of the red palm weevil in most of its distribution sites in the world. The food-baited pheromone-trapping system is considered as an environmentally friendly approach compared to the use of insecticides, which is often relied upon for the control of RPW. Several variables are important for successful *R. ferrugineus* trapping and retention; trap design, lure efficiency and longevity, type of food bait, trap density, placement of traps, replacement of food baits and efficacy and repellence of insecticides used in pheromone traps (Abdallah and Al-Khatri, 2005 and Al-Saoud *et al.,* 2010, Faleiro, 2004 and Al-Saoud, 2008). On the other hand, Abbas (2005) used the aggregation pheromone traps to investigate the population density of *R. ferrugineus* infesting date palm. In Egypt, Zayed, (2008) evaluated the efficiency of some food baits compared to chemical attractants for management of red palm weevil by pheromone/food-based trap system throughout the year, and determined the best efficient food bait during the subsequent annual season. The related species is highly polyphagous with a number of known hosts exceeding more than ten different palm species (Murphy and Briscoe, 1999).

The present work was undertaken to study the effect of trap design on weevils' capture, relative efficiency of different food type on weevils' attraction and to develop synthetic Kairmone with different combinations.

MATERIALS AND METHODS

Study Site and Period:

The study was carried out in El Kassasin District Ismailia Governorate, Egypt. The area of the study site was 12 Feddans. The study was carried out during two successive seasons from July, 2015 to October, 2016.

The Study Experiments:

Several experiments were carried out to investigate the effects of trap design, food type and developing synthetic kairmone with different combinations on RPW population.

Effect of Trap Type on Weevils' Numbers:

The effect of trap type on weevils' captures was studied using the following trap designs as shown in figure (1):

Design 1: A nine liters bucket trap made of plastic, just under its top, the bucket walls were perforated forming two rectangular like windows with dimensions of 2.5 and 15 cm.

Design 2: A nine liters bucket trap made of plastic with a funnel of 8 cm in diameter fixed inside the bucket. The bucket wall was perforated with 4 identical holes at equal distances; each has the same diameter, *i.e.* 2.5 cm.

Design 3: A PICUSAN® trap containing 1 insect container (bowl), 1 pyramidal body of the trap, 1 green top, 1 lure container and 4 bridles (to join with the bowl and pyramidal body). The bowl was fixed to the pyramidal body of the trap with the

bridles. The same step was repeated on the opposite side and the green cover was joined at the upper part of the pyramidal body, then, the pheromone container was fixed on the center.

Design 4: A nine liter bucket trap made of plastic, walls were perforated with 4 identical holes at equal distances, each has the same diameter, *i.e.* 2.5 cm and at 15 cm from the bottom of the bucket

The experiment was conducted during the period of May 20nd to end of August, 2015 used five replicate . The four above mentioned tested trap types were placed in a row keeping an approximate distance of 25 meters between each trap type. Five rows were used as replicates and the distance between rows was 50 meters. Kairmone (Ethyl acetate), pheromone capsules and liquid soap were replaced every week. Fluctuations in weevils' population were determined by the numbers of captured adult weevils at weekly intervals based on aggregation pheromone traps.

Fig.1: Traps of Different Designs used for capturing *R. ferrugineus*

Relative Efficiency of Different Food Types:

This experiment was carried out during the year 2016 (May 20nd - August 14th) to determine the relative efficiency of food baits in traps, with or without aggregation pheromone and ethyl acetate. The trap used was of the type PICUSAN® where five replicates were made with the following combinations:

1-Sugarcane honey 10% +pheromone +ethyl acetate + pesticides (bait 1)
2- Sugarcane honey 10% +pheromone + pesticides (bait 2)
3- Sugarcane honey 10% + pesticides (bait 3)
4- Pheromone +ethyl acetate+ water +pesticides (bait 4)
5- Ethyl acetate+ water + pesticides (bait 5)

Developing Synthetic Kairmone with Different Combinations:

This experiment was carried out in 2016; from August 1st till May 10th (12 weeks) to evaluate the relative efficiency of different baits in traps with aggregation

pheromone. The pheromone traps of the type PICUSAN® were distributed at distances of about 50 meters from each other and apart from palm trees with 50 meters distance at least between the tested sets/ pairs. Four traps were used per treatment and the following combinations were made:

1-Water+aggregation pheromone (combination 1)

2- Water +aggregation pheromone +palm tissue +molasses x 1 bottle] (combination 2)

3- Water +aggregation pheromone + [(EtAc + EtOH, 1:3) x 1 bottle] (combination 3)

4- Water +aggregation pheromone +palm tissue +molasses (combination 4)

5- Water +aggregation pheromone + [(EtAc) x 1 bottle] (combination 5)

Adult weevils captured in traps were removed and counted weekly. In addition, sex ratio in relation to the different kairmones, fluctuations of weevil adults and the total number of RPW caught in each trap were also studied.

Statistical analysis:

The data were subjected to ANOVA and the means were compared by carrying out the Least Significant Difference test 5%, (S.A.S Institute, 1985). In addition, the SPSS program- version 18- was also used.

RESULTS AND DISCUSSION

Effect of Trap Type on Weevils' Numbers:

Results showed that there was a significant difference between the attracted weevils in the different trap types as shown in Table (1). Total captured numbers of *R. ferrugineus* adults during the experiment period registered 90, 25, 119 and 30 in traps type 1, 2, 3 and 4, respectively. Results indicated that types 1 and 3 were highly significant for weevil's attraction when compared to the other two types. Yet, PICUSAN® trap showed the highest attraction capacity, *i.e.* 119 weevils, (Figure2). The results obtained were agreed with (Rajapakse *et al.*1998) who found that the open plastic bucket (5 L) baited with ferrugineol- pentanol, hanging on coconut palm stem at 1.5 m captured significantly more weevils than the funnel and metal traps he used. Moreover, Martinez *et al*., (2008) found that the wind funnel (dimensions of 2.40 x 1.14 x 0.71 m) significantly enhanced the entrance percentage to the trap up to 60% against 10% only for a trap without funnel.

Table (1): Numbers of Attracted Weevils to the Different Trap Design

Date	design 1	design 2	design 3	design 4
Week1	11	2	17	8
Week2	12	3	14	4
Week3	9	5	19	0
Week4	10	2	13	6
Week5	15	2	8	2
Week6	10	4	9	2
Week7	14	1	12	1
Week8	3	3	7	3
Week9	4	1	9	3
Week10	2	2	11	2
Total	90	25	119	30
Mean	18 [a]	5[b]	23.8[a]	6[b]

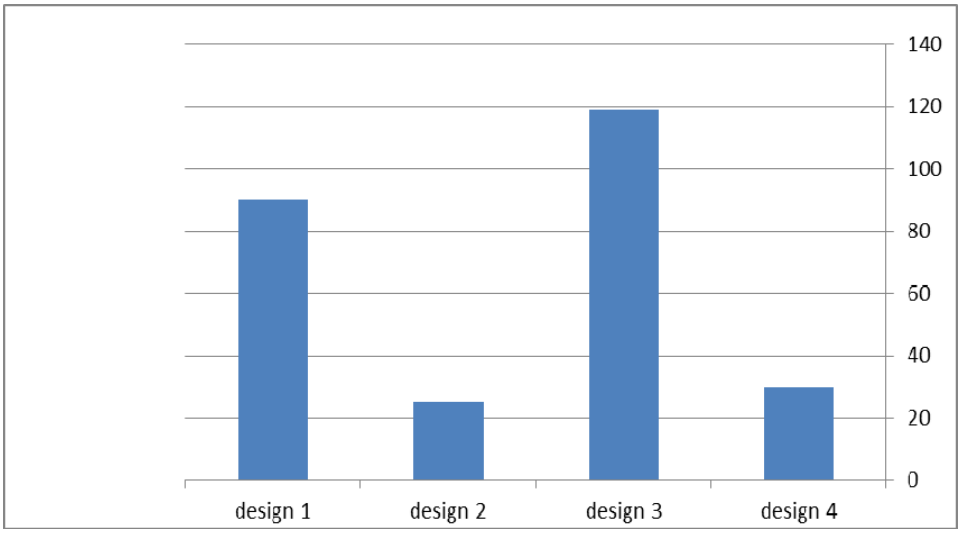

Fig (2) : Average numbers of weevils in the traps types

Relative Efficiency of Different Food Types:

Data presented in table (2) shows that captured adults in baited traps with different treatments were 110, 81, 44,26 and 20 weevils with the 5 baits respectively, *i.e.* sugarcane honey 10%, pheromone, ethyl acetate and pesticides; sugarcane honey 10%, pheromone and pesticides; pheromone, ethyl acetate and pesticides; ethyl acetate, pesticides and water and finally, sugarcane honey 10% and pesticides.. Trapping adults of *R. ferrugineus* with food-baited traps to monitor activity of the pest, or mass trapping of adults in the field has been recommended since 1975 as a component of the weevil's IPM program in coconut plantations in India (Abraham and Kurian, 1975). Food baits added to palm weevil and other Rhynchophorus species pheromone traps played an important role in orienting the attracted weevils into the trap (Hallett *et al.,* 1999). The synergy that occurs between the pheromone lure and the food bait is vital in enhancing trapping efficiency of food-baited *R. ferrugineus* pheromone traps. Weak bait–lure synergy resulted in the attracted weevils orienting themselves towards nearby palm trees instead of towards the trap.

Table (2): Number of Adults Captured to Different Kiromone

Date	Bait (1)	Bait (2)	Bait (3)	Bait (4)	Bait (5)
Week1	10	9	8	1	3
Week2	8	5	4	0	2
Week3	14	11	5	3	1
Week4	9	8	7	5	3
Week5	13	12	4	1	2
Week6	9	4	3	5	4
Week7	5	6	6	3	2
Week8	9	2	2	3	1
Week9	12	5	1	0	0
Week10	7	7	0	0	1
Week11	9	5	2	3	1
Week12	5	7	2	2	0
Total	**110**	**81**	**44**	**26**	**20**
Mean	**22^{a}**	**20.2^{b}**	**8.8^{c}**	**5.2^{d}**	**4^{d}**

Bait (1): sugarcane honey +pheromone + ethyl acetate + pesticides
Bait (2): sugarcane honey +pheromone + pesticides
Bait (3): pheromone + ethyl acetate + pesticides
Bait (4): ethyl acetate + pesticides+ water
Bait (5): sugarcane honey + pesticides

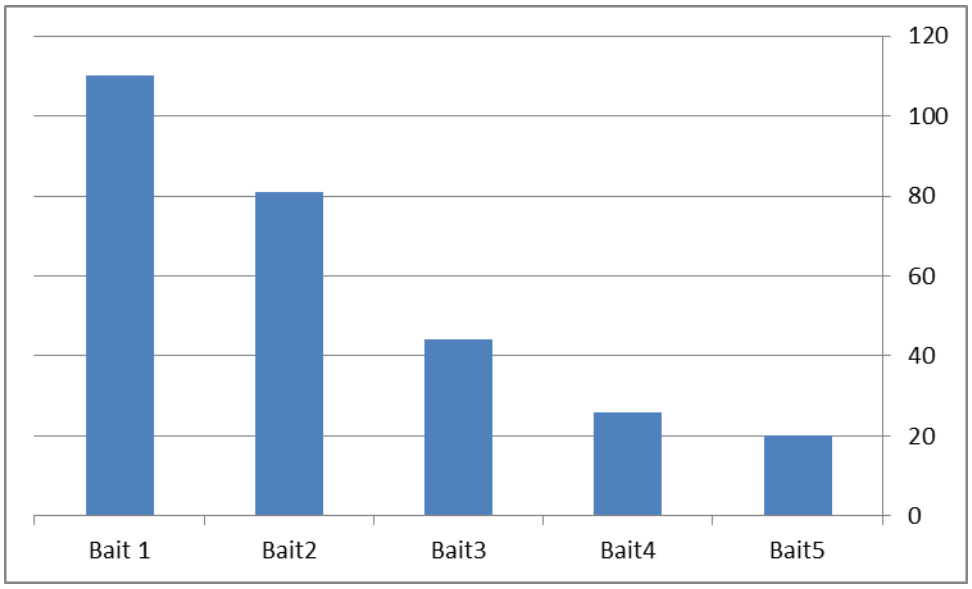

Fig. (3): Total Number of Captured Weevils per bait

The obtained results showed that the combined effect of sugarcane honey 10%, pheromone, ethyl acetate and pesticides gave more attractiveness than other treatments which might due to the effect of combined treatments. Ethyl acetate as one of the component of the synergistic kairmone (El Sebay, 2003) has been used in order to improve the attraction (Jaffe *et al.*, 1993). However, ethyl acetate without natural additional bait could not increase trap captures as compared to the pheromone in some trials in Spain (Alfaro *et al.*, 2011). Therefore, it was necessary to find new synthetic kairmones that improve *R. ferrugineus* attraction.

Developing Synthetic Kairmone with different combinations:

The results of the study revealed two promising compounds, *i.e.* combination (2) and (4). Data was recorded during 12 weeks,. Results presented in table (3) and (4) clarifies that the bait that gave the highest captured insects was combination (2) which consisted of water, aggregation pheromone, palm tissues and molasses 15% in water and (EtAc + EtOH) x 1 bottle. This bait collected 311 adults, followed by combination (4) that collected 277 adult weevils. The combination number (3) consisted of water, aggregation pheromone and (EtAc + EtOH) x 1 bottle. Whereas, the least bait in capturing adults consisted of water and the aggregation pheromone only, (127 adults were captured). Thus, it will be interested to use these two combinations, *i.e.* 2 and 4, in mass trapping and/or monitoring of *R. ferrugineus* in palm trees as one of the stone corners of IPM.

The same results were obtained by Hallett *et al.* (1993) who stated that emission of the pheromone alone from a trap does not attract many weevils as compared to a red palm weevil pheromone trap with a fermenting food source. On the other hand, natural palm baits have poor attractant power by themselves but strongly synergize the effect of the aggregation pheromone (Hallett *et al.* 1999). The addition of water to traps baited with palm tissues was found to be essential, with catches increasing more than threefold compared with dry traps (Vacas *et al.*, 2013). Several authors found that ethyl acetate also appeared to have an important role in the effectiveness of traps and increase the attraction of red palm weevils when used along with pheromone and food bait (Abdallah *et al.*, 2008; Guarin *et al.*, 2011).

Table (3): Mean Number of Weevils Attracted to Different Kairmone combinations

Week NO.	combination(1)			Combination(2)			combination (3)			combination (4)			Combination (5)		
	F	M	T	F	M	T	F	M	T	F	M	T	F	M	T
Week1	3	1	4	17	5	22	12	2	14	14	8	22	5	3	8
Week2	10	4	14	14	11	25	17	2	14	18	5	23	3	2	5
Week3	12	8	20	18	5	23	13	8	21	11	9	20	13	5	18
Week4	13	6	19	35	11	46	23	11	24	19	5	24	10	6	16
Week5	11	5	16	17	9	26	13	10	23	10	7	17	9	5	14
Week6	6	3	9	15	9	24	14	8	22	7	5	12	4	4	8
Week7	11	3	14	14	11	25	11	4	15	9	7	16	7	3	10
Week8	4	2	6	18	10	28	23	3	16	11	5	16	3	1	4
Week9	7	2	9	14	5	19	11	5	16	14	11	25	5	3	8
Week10	10	5	15	20	8	28	14	4	18	19	16	31	12	4	16
Week11	13	5	18	21	5	26	13	4	17	23	14	38	5	4	9
Week12	11	4	15	18	4	22	18	5	23	14	9	33	8	3	11
Total	11	48	159	221	93	311	176	66	223	169	97	277	84	43	127

Combination (1): Water+ aggregation pheromone, Combination (2): Water+ aggregation pheromone +palm tissue+ molasses 15% in water
Combination (3): Water+ aggregation pheromone+ (EtAc+ EtOH) x1 bottle], Combination (4): 4- Water +aggregation pheromone +palm tissue +molasses x 1 bottle] (combination 4) (5): Water + aggregation pheromone + [(EtAc) x 1 bottle]

Table (4): Mean number and SD of RPW in each of the 5 tested traps

Kairmone trap no.	Mean	Std. Deviation
1	31..80	±3.93
2	62.2	±7.29
3	44..7	±7.16
4	55.90	±9.59
5	25.40	±4.92

The SPSS statistical analysis program was used also to detect the fluctuation of the RPW during the 12 weeks of the experiment in the 5 previously mentioned traps. Table (5) shows that the highest number of weevils was registered in the 4th week of data collection, while the least registered number of weevils was during the first week

Fig (4) : *R. ferrugineus* Adults Attracted to Different Kiromones

Sex Ratio *of R. ferrugineus* Captured in Aggregation Pheromone Traps:

Results shown in table (3) revealed that the total numbers of attracted weevils were 820 during the 12 weeks of the experiment. Males' captures registered 353 while females' captures reached 662, with a sex ratio of 1: 1.9. Similar results were reported by Al-Saoud (2015), where he indicated that the sex ratio between males and females was 1:2.1. The highest female and male captures occurred in combination (3) followed by (4) as shown in figure (5).

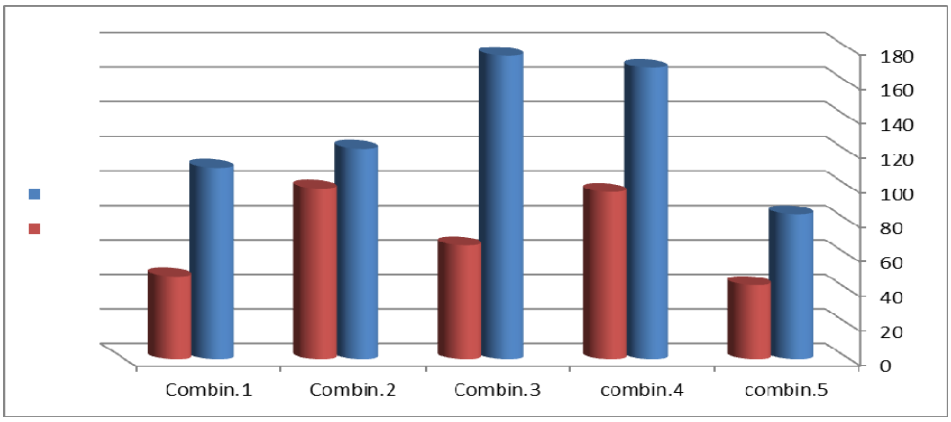

Fig. (5): Numbers of *R. ferrugineus* males and females in different Kiromone traps

CONCLUSION

Monitoring the activity of RPW is essential for keeping a close watch on the establishment and subsequent build-up of the pest. Early detection, on the other hand, is crucial to avoid death of palms and is the key to the success of any IPM strategy adopted to combat this pest. Using of PICUSAN® trap with a bait of sugarcane honey, pheromone, ethyl acetate and pesticides or Water, aggregation pheromone, palm tissue and molasses 15% in water or Water +aggregation pheromone +palm tissue +molasses x 1 bottle are recommended for mass trapping and monitoring of the red palm weevil.

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ARABIC SUMMARY

كفاءة الطعوم الغذائية والجاذبات المخلقة ونوع المصيدة في جذب سوسة النخيل حمراء في زراعات النخيل- الاسماعيلية- مصر- باستخدام مصائد الفرمونات التجمعية

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٢- معهد بحوث وقاية النبات- مركز البحوث الزراعية- مصر

٣- المعمل المركزي للزراعة العضوية- مركز البحوث الزراعية- مصر

يعتبر استخدام المصائد الفرمونية في جذب سوسة النخيل الحمراء من الوسائل الأمنة بيئيا والتي تستخدم حاليا في استراتيجية الإدارة المتكاملة للآفات في زراعات النخيل علي مستوي العالم. اجريت عدة تجارب حقلية فى مركز القصاصين، محافظة اسماعيلية- مصر- لتحسين كفاءة استخدام المصائد الفرمونية في جذب سوسة النخيل الحمراء. وقد تم تنفيذ التجارب خلال سنتين متتاليتين (22 أبريل 2015 وحتي ١٠ اكتوبر ٢٠١٦). واشارت النتائج إلي ان نوع المصيدة قد أثر تأثيراً معنويا علي عدد الحشرات المنجذبة. حيث جذبت المصيدة الأسبانية اكبر عدد من الحشرات (119 سوسة)، يلي ذلك المصيدة الجردل جديدة والتي سجلت 90 سوسة. هذا وقد اعطي التأثير المشترك لكل من عسل قصب السكر والفرمون وخلات الإيثيل والمبيدات قوة جذب اكبر عن باقي الطعوم الأربعة المستخدمة حيث سجلت المصيدة 78 حشرة خلال التجربة، في حين سجلت مصايد الطعوم الاربعة الاخري. وانجذب اقل عدد من الحشرات في خليط قصب السكر والمبيدات. الأمر الذي قد يرجع إلي التأثير المشترك لتلك المعاملات. كما تم دراسة تأثير الكيرمون المخلق بتركيبات مختلفة علي انجذاب سوسة النخيل وكان افضلها في جذب الحشرات الماء والفرمون التجميعي وأنسجة النخيل والمولاس 15% في الماء، والكيرمون المخلق حيث جمعت هذه المعاملة 311 حشرة خلال 12 اسابيع من التجربة. وقد استطاع المخلوط المكون بنسبة 1 خلات الإيثيل إلي 3 إيثانول ان يعزز من تأثير الفورمون قريبا. في حين لم تستطيع خلات الإيثيل وحدها ان تحسن من قوة الجذب الخاصة بفرمون التجميع. وتم ايضا حساب النسبة الجنسية فاكانت 1 ذكور إلي 1.9 إناث