



Efficacy of aggregation nano gel pheromone traps on the catchability of *Rhynchophorus ferrugineus* (Olivier) in Egypt

A. S. Abd El-Wahab^{a*} , A. Y. Abd El-Fattah^a , W. K. M. El-Shafei^b and A. A. El-Helaly^a

^aDepartment of Economic Entomology and Pesticides, Faculty of Agriculture, Cairo University, Giza, Egypt

^bDepartment of Date Palm Pests and Diseases, Central Laboratory for Date Palm, Agricultural Research Center ARC, Giza, Egypt

*e-mail: abeer5698987@yahoo.com

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Abstract

Field experiments were carried out in the reclaimed land east of Cairo-Alexandria Desert Road, Village of Wardan, Giza Governorate, Egypt, to evaluate the impact of using nano-gels pheromone for the first time on the attraction of the RPW adults by pheromone traps compared to the control which is normal pheromone during two successive seasons in 2018 and 2019. Also, this study aimed to compare the efficacy of two types of trap, traditional trap (type 1) and dry funnel trap (type 2) in capturing of RPW adults. Results revealed that the nano gel pheromone traps attracted significantly more adults with an average of (4.26 and 3.56) adults/trap and total of (55.33 and 46.33) adults/trap compared to control with an average (2.69 and 2.46) and total of (35.00 and 32.00) adults/trap for the two seasons 2018 and 2019 respectively. Results indicated that the use of nano gel pheromone for the first time in field improved the trap catchability to RPW adults by 22.51 and 18.30% of total number of RPW adults captured throw out the two successive seasons respectively. In addition, there was no significant difference between the total numbers of RPW adults collected by the two tested type of traps over the two successive seasons. Furthermore, the sex ratio between males and females of total collected RPW adults found to be 1: 1.43 and 1: 1.94 at 2018 and 2019 respectively.

Keywords: nano-gels pheromone, *Rhynchophorus ferrugineus*, RPW trap, aggregation pheromone, traditional trap.

Eficácia das armadilhas de feromônio de nano gel de agregação na capturabilidade de *Rhynchophorus ferrugineus* (Olivier) no Egito

Resumo

Experimentos de campo foram realizados na terra recuperada a leste da estrada do deserto de Cairo-Alexandria, vila de Wardan, província de Giza, Egito, para avaliar o impacto do uso de feromônio de nano géis pela primeira vez na atração de adultos RPW por armadilhas de feromônio comparado ao controle que é o feromônio normal durante duas temporadas sucessivas em 2018 e 2019. Além disso, este estudo teve como objetivo comparar a eficácia de dois tipos de armadilha, armadilha tradicional (tipo 1) e armadilha de funil seco (tipo 2) na captura de RPW adultos. Os resultados revelaram que as armadilhas de nano gel de feromônio atraíram significativamente mais adultos, com uma média de (4,26 e 3,56) adultos/armadilha e total de (55,33 e 46,33) adultos/armadilha em comparação ao controle com uma média (2,69 e 2,46) e total de (35,00 e 32,00) adultos/armadilha para as duas temporadas 2018 e 2019, respectivamente. Os resultados indicaram que o uso de feromônio nano gel pela primeira vez em campo melhorou a capturabilidade de armadilhas para adultos com RPW em 22,51 e 18,30% do número total de adultos com RPW capturados durante as duas estações sucessivas, respectivamente. Além disso, não houve diferença significativa entre o número total de adultos RPW coletados pelos dois tipos de armadilhas testados ao longo das duas estações sucessivas. Além disso, a proporção sexual entre homens e mulheres do total de adultos coletados de RPW foi de 1: 1,43 e 1: 1,94 em 2018 e 2019, respectivamente.

Palavras-chave: nano géis feromônio, *Rhynchophorus ferrugineus*, armadilha RPW, feromônio de agregação, armadilha tradicional.

1. Introduction

The different cultivars of date palm *Phoenix dactylifera* L and ornamental palms *Phoenix canariensis* attacked by different species of insects especially red palm weevil

Rhynchophorus ferrugineus (RPW) (Olivier) (Coleoptera: Curculionidae) which has become a global palm destroyer pest (Habib et al., 2017; Milosavljevic et al., 2019).

According to Salem et al. (2018) the red palm weevil have spread around the world in more than 50 countries because of transportation of infested palm trees to other countries which are free of RPW infestation. In addition, sever fliers which it can fly more than 900m in 24 hrs. and during 3-5 days it can fly over 7 km (Abbas et al., 2006). The beginning of the invasion of red palm weevil in the Gulf region in mid-1980s in UAE 1985 and Kingdom of Saudi Arabia in 1987 then, in 1992 the RPW was recorded for the first time in Egypt and after that it spread to many countries (Cox, 1993). The RPW infest more than nearly 40 palm species around the world (Al-Saraj et al., 2017; Al-Dosary et al., 2016). The internal tissues were damages by the larval stages which is the serious stage as results of penetrates to the stem of palm which makes difficult to control this pest (Vacas et al., 2013). It is difficult to detect infestation in its early stages due to the absence of any symptoms of the injury as results of hidden larvae feeding (Hoddle et al., 2013; Milosavljević et al., 2019).

El-Sabea et al. (2009) reported that the annual loss of infested palm by RPW removal ranged from 1 to 5% of palm in the Middle East cost from \$5.18 to \$25.92 million, respectively.

This pest was controlled using several methods include chemical control which is mainly to control the RPW although contamination of Environment and other strategies, biological control and the pheromone traps which concenter one of the important ways to control RPW and Environment safety (El-Banna et al., 2017). A lot of efforts have been made since three decades up to date to solve this problem; one of newest solution raised is using nano pesticides (Abd El-Fattah et al., 2019). Using the aggregation pheromone traps is a promise technology to capture and kill the RPW (Faleiro et al., 2016). Currently managed of RPW under the strategy of Integrated Pest Management (IPM) by using aggregation pheromone which used in monitoring and mass trapping (Abraham et al., 1998). According to Hallett et al. (1993) the male of RPW produced the aggregation pheromone which consisted of two components (4-methyl-5- nonanol (ferrugineol) with market name Ferrolure and 4-methyl-5-nonanol+4-methyl-5-nonanone in proportion 90:10 (marketed under the name of Ferrolure+ (Mahmud et al., 2015). The trap components and design is important to achieved high capture where is the trap that contents water, lure, bait and Kairomone achieve high capture in addition the traps servicing (AL-Saraj et al., 2017). Al-Saoud and Ajlan (2013) revealed that trap color played a very important role to high capture where it the drake traps captured high number of weevil compared to other colors. Oehlschlager (1994) recommended to used 1 trap/ha in mass trapping which increasing according to activity of RPW in the field to 4-10traps/ha (Faleiro et al., 2011). Recently the pheromone trap has been developed with dry traps (Electrap™) with service less and comparative with traditional trap (AL-Saraj et al., 2017). The aim of this study to evaluate the efficiency of using nano gels pheromone for the first time in the attraction of RPW adults by Aggregation pheromone

trap and compare between two trap types, traditional trap and dry funnel trap.

2. Material and Methods

2.1. Location of experiment

The experiment was carried out at a palm farm in the reclaimed land east of Cairo-Alexandria Desert Road, Village of Wardan Coordinate in Giza Governorate for two successive seasons (Early March to the end of May each year of 2018 and 2019) to study the efficiency of aggregation pheromone that loaded in Nano gel and compare to normal pheromone under field conditions and also, compare between two trap types depending on the average and total numbers of attracted adults.

2.2. Preparation of nano gel pheromone

2.2.1. Synthesis of nano carrier (chitosan nanoparticles)

One capsule of RPW aggregation Pheromone was divided into six parts and each part was loaded onto the nano-gelas well as the control. *R. ferrugineus* aggregation pheromone containing 700 mg of the active ingredient (4-Methyl-5-Nonanol (9 parts) + 4-Methyl-5-Nonanol (one part)) (Pheromone lure was manufactured by Chim Tica international S.A. Company, Costa Rica. Trade Name PO28 Ferrolure+, 700mg lure, consists of a mixture of 4-methyl 5-nonanol and 4-methyl 5-nonanone (9:1part purity of both components >95% release rate 3-10 mg/day). Chitosan nano particles were prepared according to the ionotropic gelation process according to Hasanin et al. (2018). Blank nano particles were obtained upon the addition of a tri-polyphosphate (TPP) aqueous solution to a chitosan solution.

2.2.2. Loading of pheromone onto chitosan nanoparticles:

The chitosan nanoparticles were dispersed in distilled H₂O then, the pheromone was dispersed into chitosan solution at ration 10% with stirring for 1h to get well dispersion and loading.

2.2.3. Preparation of gel

Polyethylene oxide powder was added in concentration 4% to make the previous composite in gel form for further investigation Figure 1.

2.3. Traps design

The experiment was carried out using two black types of pheromone traps siting in the ground shadow and surrounded by sand until near the holes in the sides of the trap to facilitate the entry of RPW adults to the trap through the holes for the traditional trap and through the funnel for the dry trap.

The two traps were prepared by 10-liter plastic bucket and both the body of the bucket and its cover were painted with adhesive paint. Then, the coarse sand was sprayed onto the whole bucket from outside to stick the coarse sand grains to facilitate walking of RPW adults to reach

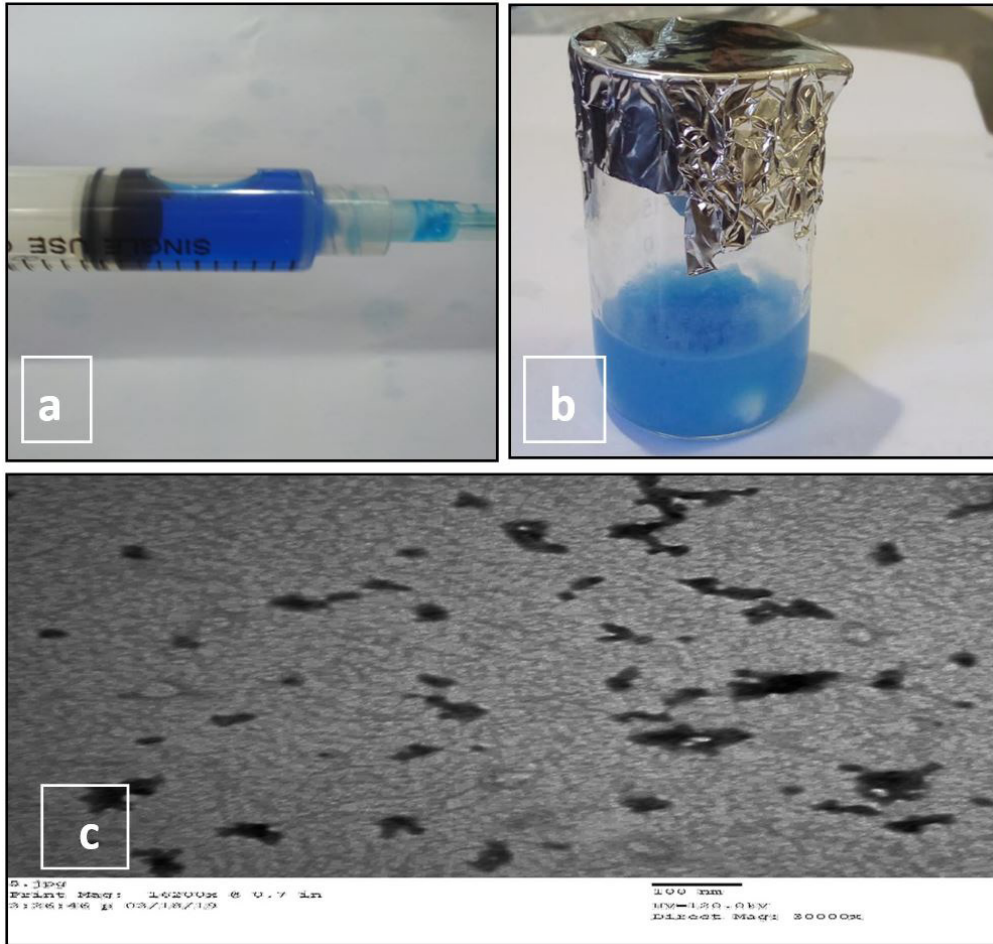


Figure 1. (a) RPW aggregation pheromone (b) Nano gels Pheromone (c) TEM image of nano gels pheromone.

the holes in trap type 1 or the funnel in the case of dry trap type 2 (Esco trap) designed by Ibn El-waleed from Esco Company. Then leave a day to dry and then paint in black because, the drake traps captured high number of weevil compared to other colors Al-Saoud and Ajlan (2013).

Trap types:

a) Type1(traditional)

This trap containing aggregation pheromone, kairomone, and 500 g of sugar cane (renewed every month) and 5 liters of water (renewed every 15 days) illustrated in Figures 2 and 3. This trap has 4 holes 3×7 cm around the trap body and 3 other holes on its cover (Abuagla and Al-Deeb, 2012; Al Saoud and Ajlan, 2013; Al Saoud et al., 2016; Gilal et al., 2017).

b) Type 2(dry funnel)

This trap containing only the aggregation pheromone and kairomone (without food bait or water) and it has one hole in the cover (3.5×18 cm) with a funnel installed on the cover of the trap. This funnel equipped with a set of thorns that allow the insects to enter and does not allow it to

exit where it is considered a simulator of a trap Electrap™ illustrated in Figures 2 and 3.

2.4. Field experiment

Twelve traps were used 6 form traditional traps (3 traps contain nano gel pheromone and 3 of the control) and 6 traps representing the trap types (3 traps from type 1 and 3 traps from type 2). These traps were placed in shadow and at equal distances of 50 meters between the trap and the other (Al-Saoud et al., 2010, 2016; Hashim et al., 2013).

2.5. Statistical analysis

Data were analyzed using Proc., ANOVA in SAS (SAS Institute, 2006).

3. Results and Discussion

3.1. Impact of nano gel pheromone on the attraction of the RPW adults by pheromone trap during two successive seasons in 2018 and 2019

Data presented in Table 1 and illustrated in Figures 4 and 5 showed impact of using nano gel pheromone for the first time on the attraction of the RPW adults by



Figure 2. Specification and measurements of the two trap types used in the experiments: (a) Type 1 (traditional trap) (b) Type 2 (dry funnel trap).

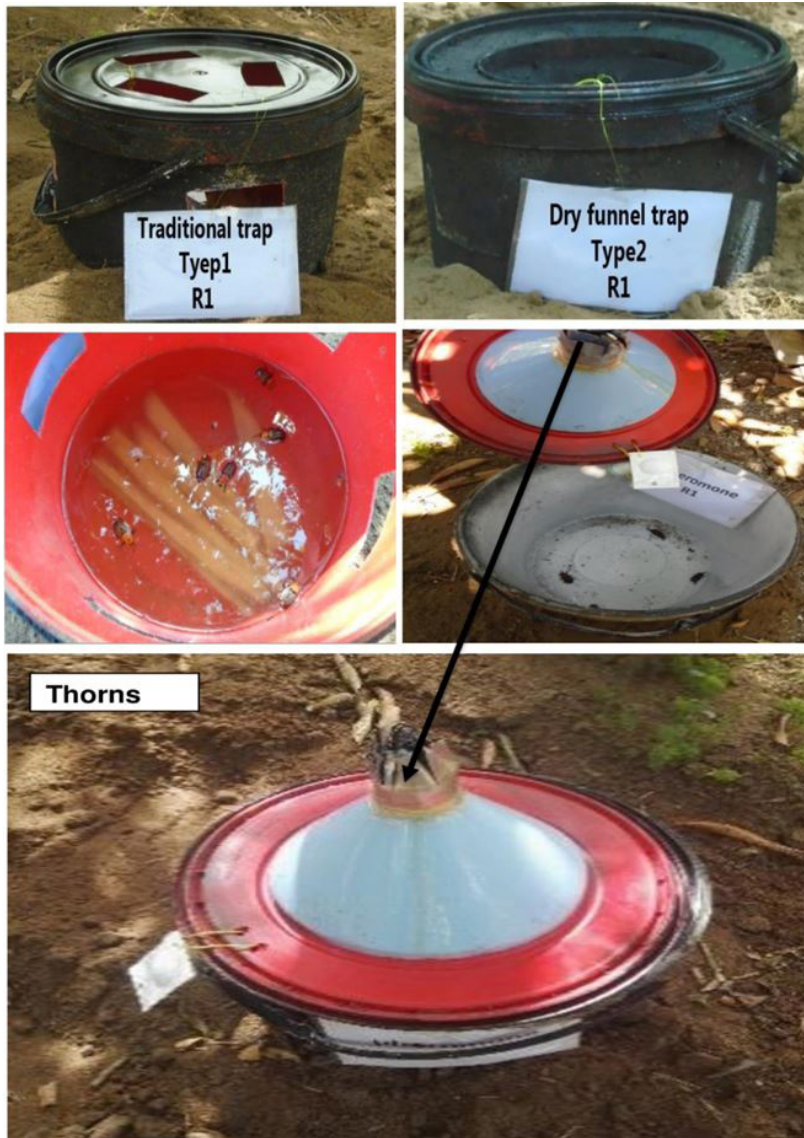


Figure 3. The two types of traps used in the experiment in the field.

Table 1. Number of RPW adults captured by Nano Gel Pheromone trap during 2018 and 2019 compared to control.

Weeks	Seasons							
	2018				2019			
	Control pheromone (Mean ± SD)		Nano Gel Pheromone (Mean ± SD)		Control pheromone (Mean ± SD)		Nano Gel Pheromone (Mean ± SD)	
week1	4.00	± 1.73	3.33	± 2.31	3.67	± 2.52	3.67	± 1.00
week2	6.33	± 2.31	5.00	± 3.61	5.67	± 0.58	4.67	± 1.53
week3	2.00	± 1.00	5.33	± 4.04	2.67	± 1.15	4.67	± 1.00
week4	5.00	± 1.73	6.33	± 1.15	5.33	± 2.52	6.67	± 1.00
week5	2.00	± 2.00	5.00	± 1.00	3.00	± 2.00	3.33	± 1.15
week6	2.33	± 2.52	5.33	± 2.52	1.33	± 0.58	5.00	± 1.53
week7	2.00	± 1.00	5.33	± 1.53	1.00	± 1.00	3.67	± 0.58
week8	2.67	± 1.53	3.67	± 0.58	3.33	± 0.58	4.00	± 0.58
week9	1.67	± 1.53	4.00	± 2.65	0.67	± 0.58	3.33	± 0.58
week10	2.00	± 1.00	5.00	± 2.65	2.00	± 2.65	2.67	± 1.00
week11	2.33	± 1.53	4.00	± 1.73	1.00	± 1.00	2.33	± 0.58
week12	2.00	± 1.00	2.33	± 1.53	2.00	± 1.00	2.00	± 1.73
week13	0.67	± 0.58	0.67	± 1.15	0.33	± 0.58	0.33	± 0.58
Total	35.00		55.33		32.00		46.33	
Mean	2.692^b		4.256^a		2.461^b		3.564^a	
L.S.D.			0.989				1.0415	

^a=significant difference highly exist; ^b=significant difference exist; L. S. D. least significant difference; S.D. = significant difference.

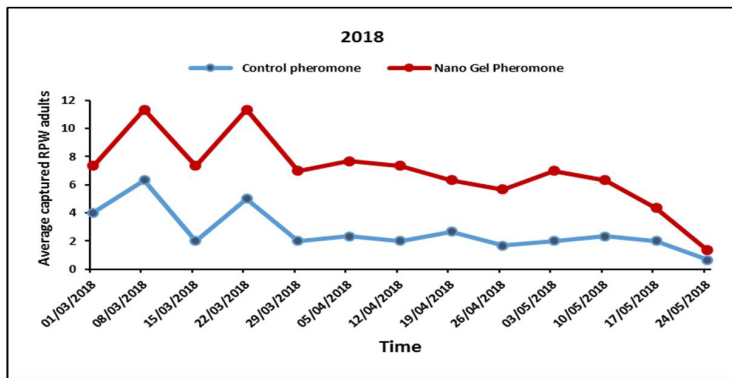


Figure 4. Number of RPW adults captured by Nano Gel Pheromone trap during 2018 compared to control.

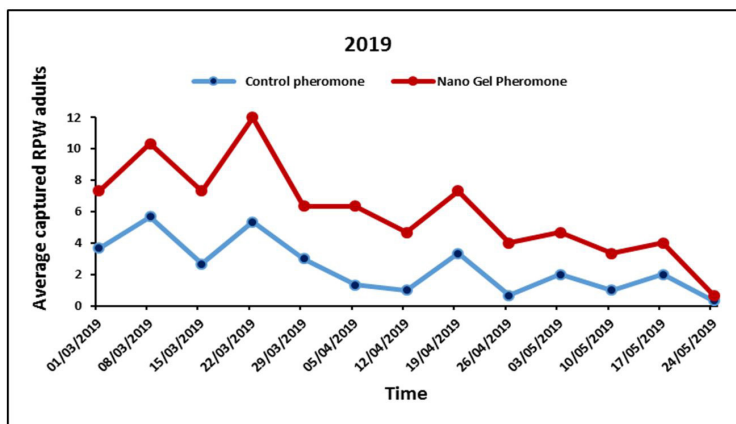


Figure 5. Number of RPW adults captured by Nano Gel Pheromone trap during 2019 compared to control.

pheromone trap compared to the control which is normal pheromone during two successive seasons in 2018 and 2019. Data indicated that the trap contained nano gel pheromone attracted significantly more adults with an average of (4.26 and 3.56) adults/trap and total of (55.33 and 46.33) adults/trap compared to control with an average of (2.69 and 2.46) and total of (35.00 and 3.200) adults/trap for the two seasons 2018 and 2019 respectively. These results revealed that, using nano gel pheromone for the first time in this field improved the trap catchability to RPW adults by 22.51 and 18.30% of total number of RPW captured adults for the two seasons 2018 and 2019 respectively. Our results are in agreement with those of Bhagat et al. (2013) who reported that in particular the involvement of the nano-gelled pheromone when they achieved d effective management of *Bactrocera dorsalis*,, a widespread harmful

pest for a number of fruits. El-bendary et al. (2016) studied in the Egypt the toxicity of nano-zinc oxide and nano-aluminum oxide against rice weevil, *Sitophilus oryzae* under laboratory conditions, and the results showed that nano-aluminum oxide was more effective than nano-zinc oxide and malathion. El-Helaly et al. (2016) evaluated the effect of silica-nano particles in comparison with silica and diazinon in control *Spodoptera littoralis* (Bosid.) under laboratory and semi- field condition, the results showed that nano- silica caused more toxic than the other treatments.

3.2. Comparison between two types of trap and its influence on captured adults of RPW during 2018 and 2019

Data presented in Table 2 and illustrated in Figure 6 showed the comparison between two types of aggregation pheromone trap type 1 which is the traditional

Table 2. Comparison between two types of trap and its influence on captured adults of RPW during 2018 and 2019.

Weeks	Seasons							
	2018				2019			
	Type 1 traditional trap (Mean ± SD)		Type 2 dry funnel trap (Mean ± SD)		Type 1 traditional trap (Mean ± SD)		Type 2 dry funnel trap (Mean ± SD)	
week1	7.33	± 3.51	10.67	± 5.51	7.33	± 1.15	8.33	± 2.52
week2	11.33	± 5.51	11.67	± 3.06	10.33	± 3.06	8.33	± 2.08
week3	7.33	± 3.51	3.67	± 2.08	7.33	± 2.08	4.33	± 0.58
week4	11.33	± 2.52	12.33	± 2.08	12.00	± 4.58	12.33	± 4.04
week5	7.00	± 2.65	5.33	± 0.58	6.33	± 0.58	4.33	± 1.53
week6	7.67	± 4.04	6.33	± 1.15	6.33	± 4.04	4.00	± 1.00
week7	7.33	± 2.31	13.33	± 2.08	4.67	± 2.89	14.00	± 4.00
week8	6.33	± 2.08	4.33	± 3.21	7.33	± 2.08	4.67	± 2.52
week9	5.67	± 1.53	6.33	± 4.51	4.00	± 2.00	5.33	± 3.51
week10	7.00	± 3.46	6.33	± 1.15	4.67	± 2.31	4.33	± 1.15
week11	6.33	± 3.06	2.67	± 1.15	3.33	± 2.08	1.00	± 1.00
week12	4.33	± 2.08	2.00	± 1.00	4.00	± 1.00	2.00	± 2.65
week13	1.33	± 0.58	3.67	± 3.21	0.67	± 0.58	1.00	± 1.00
Total	90.33		88.67		78.33		74.00	
Mean	6.948^a		6.820^a		6.025^a		5.794^a	
L.S.D.		1.811				1.782		

^a=significant difference highly exist; L. S. D. least significant difference; S.D. = significant difference.

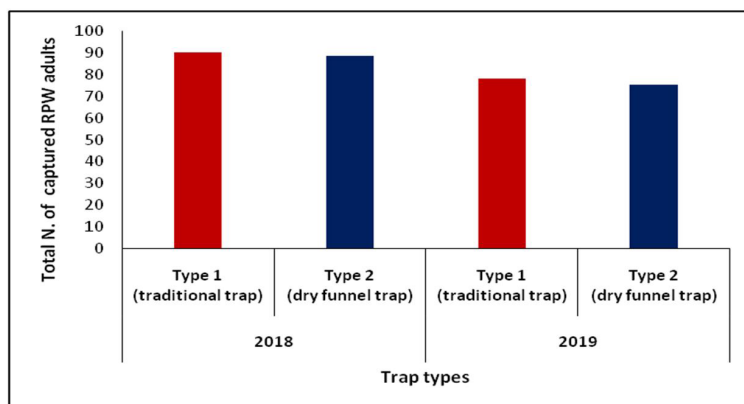


Figure 6. Comparison between two types of trap and its influence on captured adults of RPW during 2018 and 2019.

trap bucket Figures 1 and 2 and the second one type 2 is funnel trap bucket Figures 1 and 2. Data indicated that there was no significant difference between the total numbers of RPW adults by two types of traps over the two seasons of study. It is clear that although there is no significant difference between the number of insects collected by the dry funnel trap and the traditional trap, the funnel trap is very suitable for places and farms that suffer from the lack of manpower. Otherwise, the traditional trap without renewing water every 2 weeks has turned into an insect attraction only to infect neighboring palms. While the dry trap does not need maintenance only add pheromone and keramone and renewed every 3 months as it is low cost compared to the cost of the Electrap™, which is very similar to funnel trap. These results were similar with those of El-Banna et al. (2017) mentioned that after comparing the efficacy of four trap design, they found that there was no significant difference between the total numbers of RPW adults by the trap design 2 (which was similar to our traditional trap type1) and trap design 4 (which was similar to our funnel trap type 2). Although there is no significant difference between the number of RPW collected by Electrap™ and the normal trap but Electrap™ need less effort and appropriate to the area that increased in the number of traps as a results activity of RPW (Al-Saraj et al., 2017).

3.3. Sex ratio of *R. ferrugineus* adults attracted to aggregation pheromone traps in 2018 and 2019

Obtained data in Figure 7 illustrated that the sex ratio of captured adults using aggregation pheromone traps. The numbers of attracted females were higher than males in experiment duration (3 month) two tested years (2018 and 2019). The sex ratios of male to female were 1: 1.43 and 1: 1.94 at 2018 and 2019 respectively. The results obtained are similar with those recorded by

Al-Saoud (2007) who stated that the adults of RPW were presented throughout the year, and the number of females was higher than the number of males. In Spain Sansano et al. (2008) found that during one year, the average number of trapped female was 2.5 times higher than the male's one. El-Sebay et al. (2010) observed that number of RPW female attracted to aggregation pheromone traps was considerable high than males during two successive years (2008 and 2009).

El-Shafei (2011) indicated that significantly more females were caught by 1.43 times than males during the whole year of 2009, and the results also indicated that significantly more females were caught by 1.76 times than males during the whole year of 2010. Zahra (2014) found that the numbers of females attracted to aggregation pheromone traps were generally twice as that of males. The sex ratios of male to female were 33.4: 66.6 during the tested year 2012-2013.

3.4. Factorial analysis for the significance of different studied factors.

Data in Table 3 and Figure 7 showed the effect of three factors (years, trap types, nano gel pheromone) on the number of RPW adults captured by aggregation pheromone trap for two seasons in 2018 and 2019. Analyzed and compared data revealed that there was no significant difference between the numbers of RPW adults captured by aggregation pheromone trap in the two seasons of study or in the two tested trap types. While there was significant difference between the recorded numbers of captured RPW adults by trap contained nano gel pheromone compared to the control trap contained normal aggregation pheromone for the two seasons of study 2018 and 2019. The same trend was noticed in collected RPW adults number of male and female.

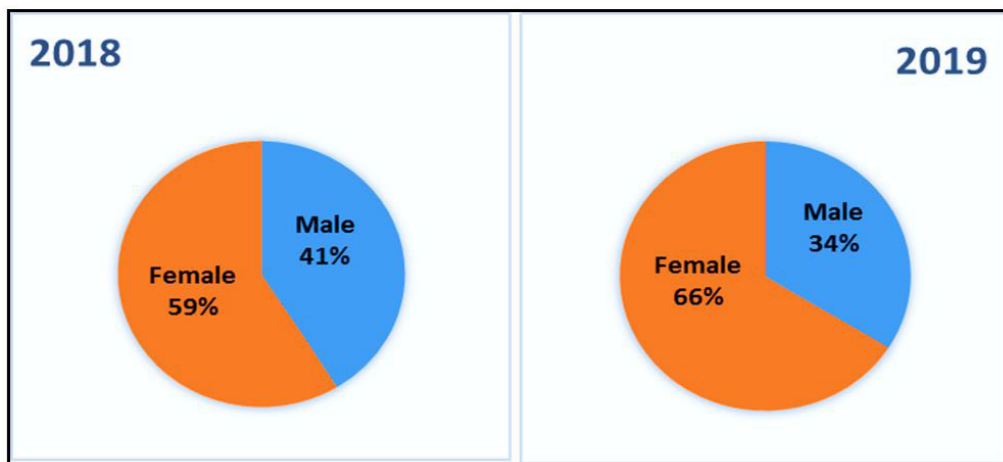


Figure 7. Sex ratio (males: females) of *R. ferrugineus* obtained from aggregation pheromone traps at Wardan village, in 2018 and 2019.

Table 3. Factorial analysis for the significance of different studied factors on the number of RPW adults captured by aggregation pheromone trap during the two tested seasons 2018 and 2019.

Factor	Level	N	Mean ± SD	
Year	2018	156	3.44 ± 2.19	a*
	2019	156	2.96 ± 2.40	a
	F. value		1.75	
	P. value		0.189	
	L.S.D.		0.733	
Trap types	T1 Traditional	156	3.24 ± 1.93	a
	T2 Dry funnel	156	3.15 ± 2.01	a
	F. value		0.09	
	P. value		0.769	
	L.S.D.		0.429	
TRT	control	156	2.575 ± 1.86	b**
	Nano gel pheromone.	156	3.910 ± 2.06	a
	F. value		5.73	
	P. value		0.0173	
	L.S.D.		0.4291	
SEX	Female	156	1.99 ± 0.35	a
	Male	156	1.21 ± 0.30	b
	F. value		22.27	
	P. value		0.0003	
	L.S.D.		0.350	

*a=significant difference highly exist; **b=significant difference exist; F Value = Mean square; P Value = indicates probability; L.S.D = least significant difference.

4. Conclusion

The use of RPW aggregation pheromone traps, both in early detection of the infestation or in the control as a mass trapping of RPW adults is one of the most important means of RPW integrated pest management. There is a need to develop and improve its efficiency therefore, this paper evaluated the effect of the use of red palm aggregate pheromone for the first time in the form of nano gel pheromone on the efficiency of the trap catchability of red palm weevils adults and compare between two trap types, traditional trap and dry funnel trap. Using of nano gel pheromone in RPW aggregation pheromone traps is recommended either for early detection of the infestation by RPW or in mass trapping because it improved the trap catchability by about 20%. In addition. Although, there was no significant difference between dry funnel trap and the traditional trap, but it reduces the effort and costs of maintaining needed regularly to traditional trap especially in the farms with low number of labor.

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