Effect of the Difference in Pheromone Trap Design and the Type of Pheromone Used on the Efficiency of Trapping Adults of the Red Palm Weevil, *Rhynchophorus ferrugineus* (Olivier), in Basra Governorate

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Abstract

Pheromone traps have been used successfully in the in management of red palm weevil insect in many countries, including Iraq. Therefore, this field study was undertaken to assess the effectiveness of four distinct pheromone trap designs. and four types of pheromones with different commercial brands during April and May 2024 in Safwan District, Basra Governorate, Iraq. The study's findings indicated that the design of the trap significantly influenced the efficiency of adult capture of the red palm weevil. The Pitfall trap was superior in recording the highest capture rate, which reached 9.69 insects/trap, followed by the Green Victory and Picusan traps, with capture rates of 8.72 and 7.34 insects/trap, respectively, whereas the Electrap trap recorded the lowest capture rate, which reached 7.06 insects/trap. The results also showed the importance of the type of pheromone used in attracting and capturing adults of the insect. The Rhyncho Pro Classic pheromone achieved the highest attraction rate, which reached 10.59 insects/trap, with a significant difference compared with the other pheromones. It was followed by the Green Victory and Pherosan pheromones, with attraction rates of 8.53 and 7.31 insects/trap, respectively, whereas the Rhyfer pheromone recorded the lowest attraction rate, which reached 6.38 insects/trap. The results also showed that all traps recorded higher capture rates for females, as their capture rate reached 9.20 insects/trap, with a significant difference compared with males, which recorded a rate of 7.20 insects/trap. These results indicate that trap design and pheromone type represent two important factors in improving capture efficiency, and that targeting females with pheromone traps may contribute to reducing the numerical density of the pest and supporting integrated management programs for the red palm weevil in palm orchards.

Keywords: Red palm weevil; *Rhynchophorus ferrugineus*; pheromone traps; trap design; Rhyncho Pro Classic.

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Introduction:

Date palm *(Phoenix dactylifera* L.) is a strategically important crop owing to its high nutritional value and economic importance, in addition to its role in supporting food security. It is also considered one of the oldest and most important fruit trees cultivated in the subtropical and Middle Eastern regions, as its cultivation dates back to prehistoric times [1, 2, 3]. Iraq ranks third globally in date production, with a percentage reaching 25% of global production, after the Kingdom of Saudi Arabia and the United Arab Emirates, which reflects the great importance of the Gulf countries in producing this crop [4].

The red palm weevil, Rhynchophorus ferrugineus Olivier, was recorded in the mid-1980s in some regions of the Arabian Gulf, and then this pest later spread to most date palm cultivation areas in the region [3]. In Iraq, this invasive pest was first recorded in December 2015 in the Basra Governorate, Safwan District [5, 6]. This spread is considered a serious risk, especially since date palms are the preferred host for this insect [7].

The insect *R. ferrugineus* is considered one of the most dangerous pests that infect palms worldwide, as it causes a clear reduction in productivity and leads to a decline in farmers' income in infected areas because of the high costs of pest control [4]. In the advanced stages of infestation, palm trees harbor several overlapping generations of the pest, which leads to damage to the palm trunk tissues [8]. Damage resulting from larval feeding inside the tissues may also lead to the death of infected trees [9]. Owing to the economic importance of this pest, extensive efforts have been made to develop methods for its control [10], including periodic surveys, removal of severely infected palms, and the use of chemical insecticides from different groups as preventive and curative means. Despite the effectiveness of these insecticides, their environmental effects and the possibility of pest resistance have limited their complete reliance [11]. Among the most important means used in the management of this pest is the installation of pheromone traps in palm orchards because of their role in the early detection of infestation [12].

The use of pheromone traps is considered an environmentally safe means and is also considered an important part of the integrated pest management strategies adopted globally in palm orchards [13]. These traps are used to modify insect behavior and reduce pest reproduction through mass trapping [14]. Previous studies have confirmed the efficiency of pheromone traps in monitoring and reducing the

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number of red palm weevils [15, 16, 8]. These studies also indicated the importance of visual and structural factors in improving trap efficiency, such as trap color, shape, size, design, roughness of the external sides, and the closeness of the openings to the soil surface level, in a way that facilitates insect entry into the traps [17, 18].

The male aggregation pheromone of the red palm weevil was initially identified in the early 1990s. This pheromone consists of a combination of two chemical compounds: ferruginous (4-methyl-5-nonanol) and ferrugineone (4-methyl-5-nonanone), which are released by males to attract individuals of both sexes. Ferruginous is considered the most effective component for attracting insects under field conditions, especially when a suitable food source is present [19]. Subsequently, this pheromone was produced commercially and used in the development of pheromone traps [20]. The efficiency of attracting adult insects also increases when kairomones, such as ethyl acetate, which is one of the volatile compounds associated with the plant host, are added. Therefore, trapping systems for this pest have depended on using a source of natural host odor to enhance pheromone attractiveness and achieve more sustainable management of the pest [21].

Some studies have shown that the use of one trap for every four dunams led to an 80% reduction in infestation and a 58% increase in productivity within one year [22]. The combined effect of both the pheromone and the kairomone, especially ethyl acetate, with food materials such as sugarcane molasses and insecticides, also achieved higher effectiveness in attracting insects, as the traps recorded the highest number of adults, which reached 110 insects [13].

Traditional bucket traps have been used to trap red palm weevil adults and were among the first traps adopted when the pest was discovered and spread. However, different trap designs have become commercially available, which requires conducting more studies to determine their efficiency in attracting and killing pests compared to traditional traps. Therefore, this study aimed to evaluate the efficiency of four different designs of pheromone traps and four types of pheromones, with the aim of supporting and developing integrated management programs for the red palm weevil in the Basra Governorate.

Materials and Methods

Evaluation of the Efficiency of Trap Design and Pheromone Type in Capturing Adults of the Red Palm Weevil

ISSN 2072-3857

The efficiency of traps in trapping red palm weevil insects was evaluated by collecting trapped adult insects monthly from each pheromone trap and counting their numbers. The sex of the trapped insects was also determined based on the morphological characteristics of the rostrum, as the males are characterized by the presence of bristles on the upper front part of the rostrum, while the females lack these bristles, and this characteristic is considered a clear taxonomic characteristic for distinguishing between the two sexes.

Experimental Site

The study was conducted during April and May 2024, which represents the peak activity period of the red palm weevil insect, in the Safwan district located southwest of Basra Governorate. The palm orchards in the study area are irrigated by drip irrigation systems that depend on groundwater extracted from artesian wells.

Four areas were selected from palm orchards with tree ages ranging between 10 and 20 years. The experiment was conducted using a completely randomized design. Twelve traps were installed in each area, with three replicates for each type of pheromone, resulting in a total number of traps was forty-eight pheromone traps. An appropriate distance of 100 m was maintained between traps. The traps were placed in shaded sites under palm trees, away from direct sunlight. They were also fixed on moist soil to ensure a sustained and homogeneous release of the chemical bait into the surrounding environment [23, 24].

Trap Design and Components

Four pheromone traps with different designs belonging to several manufacturing companies were used in this study. All traps were made of plastic and designed to monitor the number of adult red palm weevils and follow their activity by attracting them into the trap and killing them. The traps included the following:

The Dry Pheromone Trap Electrap

This trap is characterized by an external pyramidal design that is open from the top, which facilitates the entry of insects. The smooth internal surface also helps prevent escape after entry. There are bristles at the entrance that push the insect and return it to the trap. A transparent plastic cover was placed above the pyramid opening to protect the aggregation pheromone from rain. The black color of the trap helps raise the temperature inside, which leads to the death of adult insects due to dehydration. The pheromone material is fixed inside a glass chamber that allows its spread in the air within a radius of 25 m,

ISSN 2072-3857

stimulating the antennae of males and females and directing them toward the trap. This trap was produced by Future Innovation Right Solution Technology (FIRST), Abu Dhabi, United Arab Emirates, and was obtained from the Plant Protection Department.

Picusan Trap

The Picusan trap has a black pyramidal design. Its length was 26 cm, and the diameter of its base was 43 cm. It comprises three components: a cylindrical base measuring 25 cm in diameter and 6 cm in height, a black pyramid with a rough surface characterized by grooves spaced 1 mm apart, and an upper green cover designed to protect the pheromone from precipitation. The cover left an opening of 4 cm between the upper part of the pyramid and its top. The cover also contains a basket fixed in the internal half of the trap, which is used to place the aggregation pheromone. This trap was manufactured by the Spanish firm Sospalm and acquired from Ard Unifert Agricultural Co..

The Small Bucket Trap Green Victory

This trap is characterized by a shape resembling a Bucket Trap and consists of two parts. The lower part resembles a white container and can be opened to clean the dead insects and closed again. The upper part is black and contains a half-inverted funnel that prevents insects from escaping. At the top of the trap, there is an opening on which a cover is fixed using plastic screws. A plastic basket containing the pheromone was placed in the middle of the cover. The traps were buried in the ground. Its external surface is rough, which helps the insect climb and enter, whereas its internal surface is smooth, which obstructs the exit of insects after they enter. This trap was produced by Green Victory Pvt. Ltd., India, and was obtained from Al-Maha Company in the State of Kuwait.

Pitfall Trap

The Pitfall trap consisted of two parts. The lower part is a yellow container, whereas the upper part is black and in the form of an inverted container. Together, the two parts form a middle gap that allows insects to enter the trap. Inside the trap, there was a wheel on which a polyethylene bottle containing the attractant was fixed. After making a hole in the ground at a depth of 10 cm, the yellow lower part was fixed inside the hole, and the black upper part was fixed above it. This trap was produced by the M2i Group (Melchior Material and Life Science France), belonging to Syngenta Crop Protection AG, France, and was obtained from Al-Jabali Agricultural Company in the Hashemite Kingdom of Jordan.

Type of Pheromone Used in Each Trap

ISSN 2072-3857

Four different types of male aggregation pheromones specific to the red palm weevil, manufactured by several companies, were used in this study. The pheromone was replaced monthly to ensure the continuation of its attractive effectiveness during the experimental period. The pheromones included the following:

1. The male aggregation pheromone Rhyfer

This pheromone contains ferrugineol as the active ingredient at a dose of 700 mg. It was used alone without adding ethyl acetate. It was produced by the German company Tripheron and obtained from the Plant Protection Department in Baghdad.

2. The aggregation pheromone Pherosan

The active ingredient of this pheromone is the male aggregation pheromone, ferrugineol. It was used with the kairomone, ethyl acetate. It was produced by the Spanish company Sospalm and obtained from the Lebanese company Ard Unifert.

3. The aggregation pheromone Green Victory

This pheromone contains ferrugineol as the active ingredient at a dose of 700 mg. This was used with the addition of the kairomone ethyl acetate. It was produced by Green Victory Pvt. Ltd. in India and obtained from Al-Maha Agricultural Company in the State of Kuwait.

4. The aggregation pheromone Rhyncho Pro Classic

The active ingredient of this pheromone consists of a mixture that includes the insect aggregation pheromone ferrugineol, kairomone ethyl acetate, and ethanol. This mixture simulates the odor of fermented palms. The compound is in liquid form inside a 40 ml bottle supplied with a ceramic wick that helps the active material to spread homogeneously. This product is registered under the trademark M2i. It was produced by Syngenta Crop Protection AG, France, and obtained from Al-Jabali Agricultural Company in the Hashemite Kingdom of Jordan.

Statistical Analysis

The data were analyzed using a randomized complete block design (RCBD). Mean comparisons were performed using the least significant difference (L.S.D.) test at a 5% significance level. Additionally, SPSS statistical software was used to analyze the results and identify significant differences among treatment means.

Results and Discussion

Evaluation of the Efficiency of Trap Design and Pheromone Type in Trapping Adults of the Red Palm Weevil

ISSN 2072-3857

The statistical analysis results presented in Table 1 revealed significant differences among the study factors, including trap design, pheromone type, and sex of the adult insect. The Pitfall trap was superior in attracting adults of the red palm weevil, as it recorded the highest rate, reaching 9.69 insects/trap. The capture rates of the Green Victory and Picusan traps were 8.72 and 7.34 insects/trap, respectively. The Electrap trap recorded the lowest rate of adult capture, reaching 7.06 insects per trap.

The results also showed a clear significant variation among the four types of pheromones in their efficiency in attracting adult insects. The Rhyncho Pro Classic pheromone achieved the highest attraction rate, reaching 10.59 insects per trap, surpassing the other pheromones used. This was followed by the Green Victory and Pherosan pheromones, with attraction rates of 8.53 and 7.31 insects per trap, respectively. In contrast, the Rhyfer pheromone had the lowest attraction rate, at 6.38 insects per trap.

Regarding the effect of insect sex, the results showed that the pheromone traps attracted females at a higher rate than males, as the capture rate of females reached 9.20 insects/trap, with a significant difference compared with males, which had a capture rate of 7.20 insects/trap. This may indicate the efficiency of aggregation pheromones, especially when combined with kairomones or volatile materials similar to the odor of the plant host, in attracting females to a greater degree, which is important in integrated pest management programs, because reducing female numbers contributes to reducing the reproductive capacity of the insect within date palm orchards.

As for the three-way interaction between trap design, pheromone type, and insect sex, the treatment of pitfall traps with Rhyncho Pro Classic pheromone recorded the highest attraction rate for both females and males, reaching 13.50 and 11.25 insects/trap, respectively. This indicates that the design set up highly efficient sprays when employed with a pheromone, including a combination of aggregation pheromone, kairomone, and ethanol, to simulate odor on fermented palm, which enhances its attractivity to adult insects. Conversely, the attraction of females and males to the Picusan trap + Rhyfer pheromone was minimum (5.75 and 4.25 insects/trap, respectively).

In general, these results suggest that the efficacy of pheromone traps is not simply a function of the pheromone type but is also dependent on trap design and structural parameters, including the geometry of the entrance opening, spacing between the trap surface and soil surface, roughness of external surfaces, and ability to retain insects after they enter. The combination of kairomone and

ISSN 2072-3857

ethanol could also be directly linked to the improved performance of Rhyncho Pro Classic because attractive chemical signals are closer to the odors that plants emit during fermentation or damaged palm tissues. Accordingly, traps with a pitfall design, especially when used with compound pheromones, can be adopted as an effective tool for monitoring and reducing the number of adult red palm weevils in integrated pest management programs in Basra Governorate.

Table 1: Evaluation of the efficiency of trap design and pheromone type in capturing both sexes of adults of the red palm weevil**.**

Mean of sex	Mean of trap design	Pheromone type				Sex	Trap design
		Rhyncho Pro Classic	Green Victory	Pherosan	Rhyfer		
Males	7.06	7.75	6.50	5.50	4.50	Males	Electrap
7.20		9.75	8.50	7.50	6.50	Females	
	7.34	9.25	5.75	5.00	4.25	Males	Picusan
		11.75	9.25	7.75	5.75	Females	
Females	8.72	10.00	8.25	6.25	6.75	Males	Green Victory
9.20		11.50	10.25	9.25	7.50	Females	
	9.69	11.25	9.25	7.75	7.25	Males	Pitfall trap
		13.50	10.50	9.50	8.50	Females	
	8.20	10.59	8.531	7.31	6.38	Mean of pheromone type	

L.S.D.	**Source of variation**	**L.S.D.**	**Source of**

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value		value	variation
0.41	Sex × pheromone type	0.21	Sex
0.59	Trap design × pheromone type	0.29	Trap type
0.83	Sex × trap design ×	0.29	Pheromone
		0.41	Sex × trap

Effect of the Interaction Between Trap Design and Pheromone Type on the Efficiency of Capturing Adults of the Red Palm Weevil

The results shown in Figure 1 show the presence of significant variation in the effect of the interaction between trap design and the type of pheromone used on the efficiency of capturing adult red palm weevils. The Pitfall trap supplied with Rhyncho Pro Classic pheromone achieved the highest capture rate, reaching 12.38 insects/trap, indicating the efficiency of this design when combined with a compound pheromone-containing attractant that simulates the odor of the fermented plant host. In contrast, the Picusan trap supplied with Rhyfer pheromone recorded the lowest attraction rate for adults, reaching 5.00 insects/trap. This variation reflects that capture efficiency is not only related to trap design or pheromone type individually, but is also affected by the degree of compatibility between the physical design of the trap and the nature of the attractant material used.

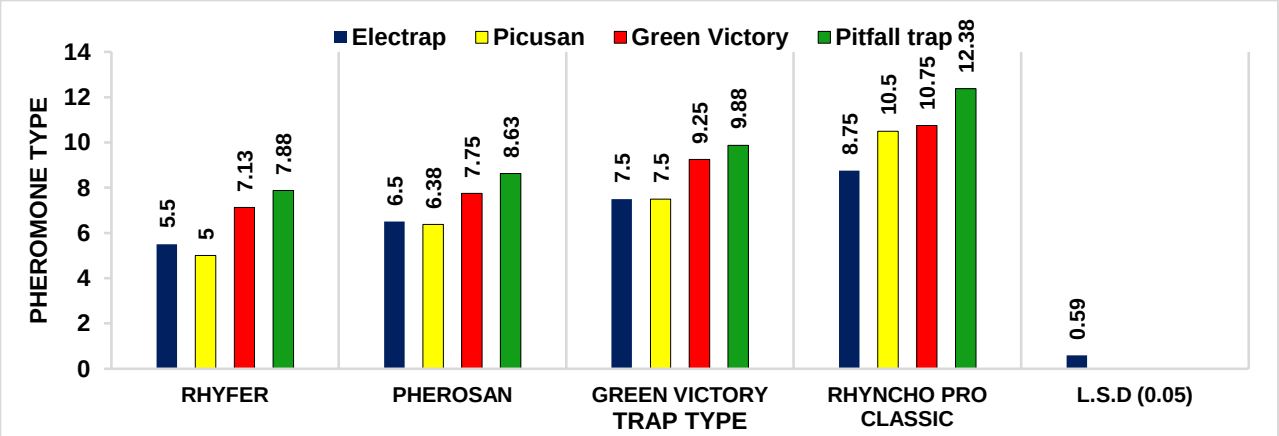

Figure 1: Effect of the interaction between trap design and pheromone type on the efficiency of capturing adults of the red palm weevil.

Effect of the Interaction between Trap Design and Sex of Adults of the Red Palm Weevil

The results shown in Figure 2 indicate that the interaction between trap design and insect sex affected the capture rates of adult red palm weevils. The

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Pitfall trap recorded the highest attraction rate for both females and males, reaching 10.50 and 8.88 insects/trap, respectively, without clear significant differences between them. This indicates that this design was more suitable for attracting both sexes than the other designs. Meanwhile, the Electrap trap recorded the lowest attraction rate for females and males, reaching 8.06 and 6.06 insects/trap, respectively. The decrease in the efficiency of this design may be due to the nature of the insect entry mechanism or to the difference in the position of the opening and the characteristics of the external surface compared to the other traps.

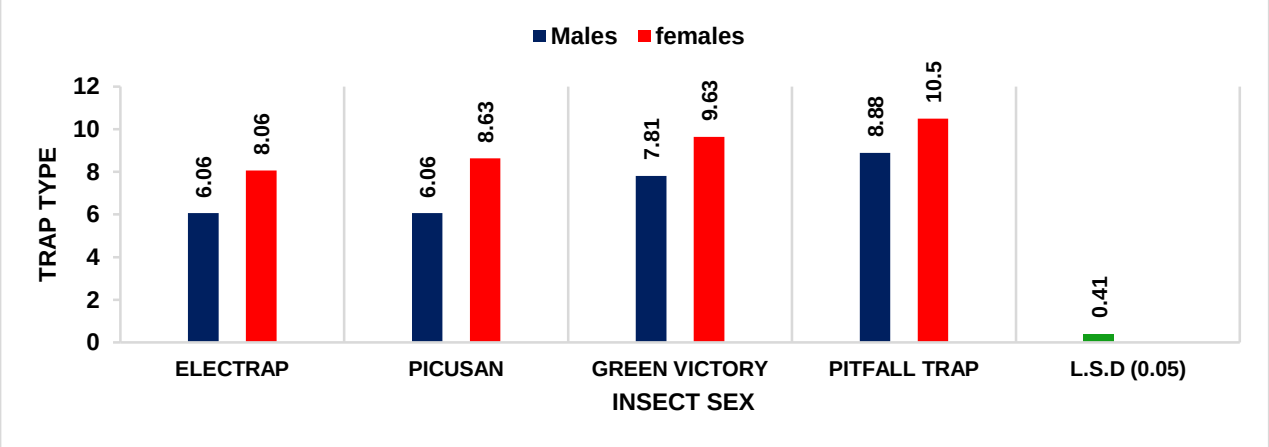

Figure 2: Effect of the interaction between trap design and adult sex on the efficiency of capturing adults of the red palm weevil

Effect of the Interaction Between Pheromone Type and Sex of Adults of the Red Palm Weevil

The results presented in Figure 3 demonstrate that the two-way interaction between pheromone type and insect sex did not show significant differences. However, the capture rates differed among the pheromones used. The Rhyncho Pro Classic pheromone recorded the highest attraction rate for both females and males, reaching 11.63 and 9.56 insects per trap, respectively. This shows the superiority of this pheromone in attracting adults of the insect from both sexes, which may be related to its composition, which includes the aggregation pheromone with the kairomone and ethanol, which increases the efficiency of chemical attraction.

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In contrast, the Rhyfer pheromone recorded the lowest attraction rate for males and females, reaching 5.69 and 7.06 insects/trap, respectively. These results indicate that the addition of kairomones or volatile materials similar to the odor of the plant host may contribute to improving the efficiency of the pheromone in attracting adult insects.

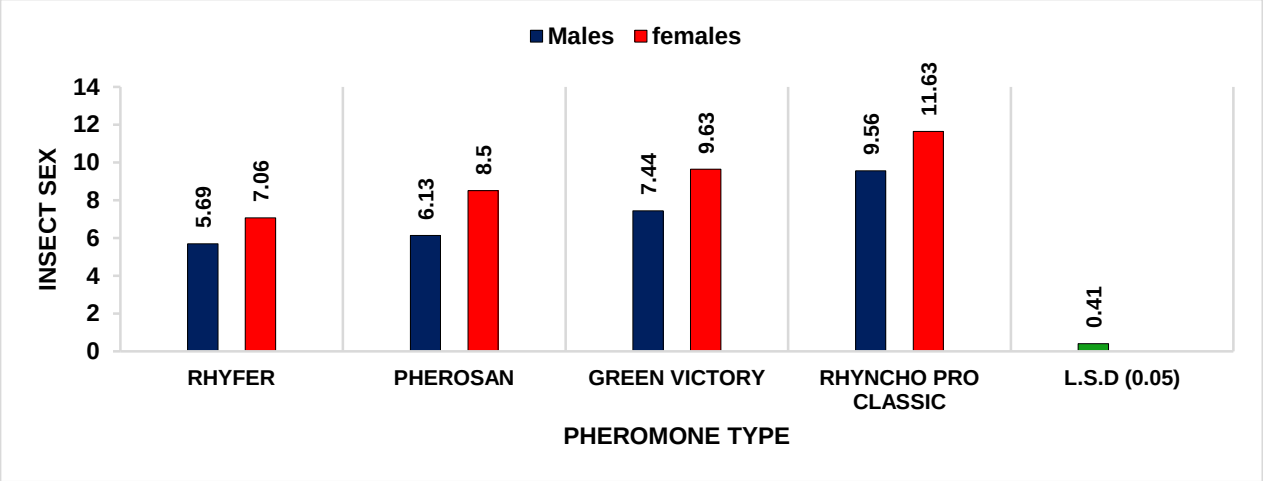

Figure 3: Effect of the interaction between trap design and adult sex on the efficiency of capturing adults of the red palm weevil

Discussion

Early detection of red palm weevil infestation is considered one of the fundamental pillars for the success of control programs, and pheromone traps are considered one of the most effective means of monitoring the pest and reducing its numerical density. The results of the current study demonstrated that the two traps, pitfall traps and Green Victory traps, recorded the highest capture rates of adult red palm weevils. This may be attributed to the nature of the trap design and the position of the pheromone inside it, as the pheromone is suspended in the upper internal part, which makes it more exposed to air movement and helps spread its odor over a wider distance. As for the pyramidal traps, placing the pheromone at the base of the trap may be a reason for obstructing the spread of the odor, which reduces its attractiveness to the adults of the insect. The difference in the area of the trap openings may also be one of the factors affecting the variation in the release of volatile materials from the pheromone or attractant material.

After the adults of the insect sense the odor of the pheromone, they fly toward the pitfall traps, land, and crawl on their edge. When they try to determine the source of the pheromone, they slide easily into the trap because of

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a state of motor confusion. The smooth internal surface prevents them from escaping, especially in pitfall traps such as the Pitfall trap and Green Victory. For pyramidal traps such as Electrap and Picusan, the insect needs a longer flight and searching response toward the pheromone source, and it may land on the top of the pyramid or on the trap cover, which gives it a greater opportunity to fly away instead of entering the trap. This result agrees with that indicated in [25].

A previous study [26] found the superiority of the yellow pitfall trap in capturing insects, as it recorded 1763 insects with a sex ratio of 3.15:1 in favor of females, compared with the yellow pyramidal trap with a green cover, which recorded 1376 insects with a sex ratio of 1:3.40 for females to males. In contrast, one study [18] did not find significant differences among the large bucket trap, small 2 L pitfall trap, and dry Electrap trap. This also indicated the superiority of the Rhyncho Pro Classic pheromone over the M2I New, Rhyncho plus (EZ), and ISCA pheromones. A study [27] mentioned that three different trap designs, namely Picusan, inverted funnel, and gallon, attracted close numbers of insects, as the total number reached 1685 insects, including 486 males and 1199 females. The interaction between the kairomone ethyl acetate and the aggregation pheromone led to an increase in insect capture by 34.4%, as the capture rate reached 1.27 males and 3.03 females/trap, compared with traps supplied with pheromone only, which recorded 0.88 males and 2.31 females/trap.

A study [28] indicated that the conventional bucket trap captured the highest number of red palm weevils, reaching 64.83 insects/trap, followed by the dry Electrap trap, with a number reaching 54.16 insects/trap. The Electrap trap also captured 45.50 insects/trap when the mirror was covered, whereas the Picusan trap recorded 33.00 insects/trap. The conventional bucket trap system without food bait and with water only recorded 20.83 insects/trap, whereas the conventional system supplied with retention only, and without food bait or water, recorded 15.00 insects/trap. The high attractiveness of the dry Electrap trap was attributed to the presence of pheromones and kairomones, especially ethyl acetate.

A study [29] explained that the dry Electrap trap system supplied with pheromone and ethyl acetate, and without food bait or water, achieved capture efficiency equivalent to the conventional bucket trap system free from food bait and water. This result does not necessarily mean that the attractiveness of the Electrap system is

due to the chamber supplied with mirrors added by the manufacturer at the bottom of the trap. According to the manufacturer, the attractiveness of this system depends on the production of infrared radiation as a result of the presence of reflective mirrors at the bottom of the trap containing diffusers of pheromone and ethyl acetate. These radiations act as mediators between the bait and the olfactory receptors in the red palm weevil to generate an attractive response [30].

A study [31] showed the effectiveness of the dry Electrap trap with and without mirrors inside the chamber, when compared with standard and modified bucket traps in attracting Rhynchophorus palmarum. This indicated that the presence of mirrors inside the Electrap trap was not a decisive factor in attracting adult pests and that the efficiency of this trap may be mainly due to the ring of bristles present inside the conical entry point, which prevents the insects from escaping after entering. It was also mentioned that its effectiveness does not differ greatly from the effectiveness of bucket traps, and that the use of the aggregation pheromone led to a reduction in insect numbers by more than 95% compared with the period before its use.

The Picusan trap is characterized by its pyramidal shape and ability to retain more than 90% of the adult red palm weevils that enter it. The differences in the efficiency of the trap types in capturing the pest may be due to differences in the physical characteristics of the trap designs [32]. The Picusan trap contains one funnel-shaped entrance that allows insects to enter, and the funnel design reduces the possibility of insects escaping from the trap after they enter it [17].

The superiority of the aggregation pheromone Rhyncho Pro Classic in the current study may be attributed to its kairomone mixture, especially ethyl acetate and ethanol, which enhances the effectiveness of the pheromone in attracting adult insects. A study [10] showed the efficiency of traps supplied with a mixture of the aggregation pheromone ferrugineol, the kairomone ethyl acetate, palm tissues, and water, as they recorded the highest capture rate, reaching 145 insects, compared to dry traps. Another study [15] also confirmed that pheromone traps supplied with the commercial aggregation pheromone ferrugineol, the kairomone ethyl acetate, and a fermented mixture of dates and sugarcane molasses contributed to reducing the numbers of red palm weevils, and the infestation of palm trees was absent afterward. The sex

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ratio of trapped insects was biased towards females by approximately 2.5:1.

A previous study [13] also showed that the combined effect of pheromone, ethyl acetate, sugarcane honey, and insecticides achieved the highest number of captured insects, reaching 110 adults. The male aggregation pheromone, a combination of palm tissues and 15% molasses in water with a suitable ratio of ethyl acetate and ethanol (1 3), also attracted the highest number of captured insects, reaching 311 insects, with a male-to-female ratio of 1:1.9. Another study [33] showed that traps containing pieces of sugarcane treated with insecticides together with the pheromone rhynchophorol were more effective in attracting both sexes of the insect than traps supplied with the pheromone alone or with sugarcane treated with insecticides only.

A study [34] indicated the importance of secondary components in pheromones by evaluating the effectiveness of three different types of aggregation pheromones, namely Dynalure ferruginol, Rhyncolure rhynchophorol, and Metalure, which consist of 89% ferruginol and 11% 2-methyl-4-heptanol, in attracting adults of two species of palm weevils. The study found that the two pheromones Dynalure and Rhyncolure were highly effective in attracting both insect species, and that the proportion of females was higher in traps containing Rhyncolure and Metalure.

Conversely, a study [35] reported no significant differences in the weekly numbers of insects captured when using three commercial pheromone baits, namely Ferrolure, Rhyfer, and Rhyncap, as the total capture rate for each pheromone reached 8.93, 7.07, and 5.93 insects, respectively, despite the difference in their dispensing devices.

The efficiency of attracting adult female red palm weevils to pheromone traps may be explained by their increased seasonal activity in the field compared to that of males. Although mating of adults often occurs inside the trunk of the infected palm tree, females then seek a more suitable host for laying eggs. Their high sensitivity to aggregation pheromones may also be related to their possession of a greater number of basiconic sensilla on their antennae than that of males, which increases the possibility of their attraction to the traps and falling into them. This result agrees with the results of previous studies [36, 37, 38, 20, 39].

A previous study [9] indicated that the number of adult females attracted to pheromone traps was 2.26 times higher than the number of adult males. Another study [40] also recorded the

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superiority of the number of captured females compared with males throughout the year and during two seasons, as the number increased gradually at the beginning of the season and reached its peak in May. The percentage of males was 35.11% and that of females was 64.89%. Similarly, a study [41] recorded a bias in the sex ratio in pheromone traps in favor of captured females of the red palm weevil in all treatments, as their numbers exceeded twice the number of males. This indicates the ability of the aggregation pheromone, Ferrolure, to capture a larger number of females, which contributes to reducing the egg-laying process, and consequently reducing the pest density and reducing its damage to palm trees.

Accordingly, the use of pheromone traps in a certain area does not necessarily lead to the capture of all individuals of the red palm weevil but rather contributes to attracting and capturing a part of the pest population. To increase the efficiency of attraction and capture, especially for females, an integrated trapping system must be adopted, including the selection of the best bait components, such as pheromones, kairomones, food, and water, in addition to paying attention to trap design, trap density, and trap distribution within orchards. This agrees with the findings of [42, 43].

Conclusion

This study demonstrates that both trap design and pheromone type significantly influence the efficiency of capturing adult red palm weevils (*Rhynchophorus ferrugineus*) in date palm orchards in Basra Governorate, Iraq. The Pitfall trap proved to be superior among the four designs tested, achieving the highest capture rate (9.69 insects/trap), whereas the Rhyncho Pro Classic pheromone outperformed all other pheromone types, recording the greatest attraction rate (10.59 insects/trap). The combination of pitfall traps with Rhyncho Pro Classic pheromone yielded the highest capture rates for both sexes. Notably, all traps captured significantly more females than males, suggesting that pheromone trapping effectively targets the reproductive population. These findings highlight the importance of optimizing trap design and selecting compound pheromones containing kairomones and ethanol, which mimic fermented palm odors, to substantially enhance pest monitoring and mass trapping programs. The results provide practical guidance for improving integrated pest

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management strategies against the red palm weevil in Iraqi date palm orchards and similar environments in the future.

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