Acta
Entomology and Zoology

E-ISSN: 2708-0021
P-ISSN: 2708-0013
https://www.actajournal.com
AEZ 2023; 4(1): 106-117
Received: 09-11-2022
Accepted: 15-12-2022

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Semiochemicals to control the red palm weevil *Rhynchophorus ferrugineus*

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DOI: https://doi.org/10.33545/27080013.2023.v4.i1b.102

Abstract
In the Middle East and in our country, Egypt, the Red Palm Weevil (RPW) or palm aids (*Rhynchophorus ferrugineus*, Olivier) has been a more dangerous palm pest for the past two decades. Volatile oils, also known as essential oils, are natural sources that contain a variety of chemical compounds that can attract or repel insect pests. The current study aims to use new techniques for controlling the red palm weevil by utilising essential oils as an element of semiochemicals. The laboratory study was conducted by using a two-choice olfactometer (Y), we compared palm hearts (Algumar) and certain essential oils and recorded the coefficients of attraction and repulsion separately for males and females. Our results indicated that the females' coefficient of attraction to palm hearts increased by 55%, while males were attracted to water. The coriander and basil oils also recorded high attraction rates of 61.6% for females and 51.1% for males, respectively, but the lemongrass and peppermint oils were repellent to both females and males. When mixing oils in an innovative formulation, the attraction rate was increased by 86.6% and 84.4% for both females and males, respectively. From the above, it is clear to us that mixing some volatile oils together has a strong effect by increasing the coefficient of attraction that is not present in each oil alone, increasing the oil's effectiveness. As a result, within the integrated control programmes and the country's sustainable development strategy, this method is recommended as a new method for controlling, reducing pest damage, and protecting the date crop and palm wealth.

Keywords: Semiochemicals technologies, red palm weevil, essential oils, y tube

1. Introduction

Palm aids or the Red Palm Weevil (RPW), *Rhynchophorus ferrugineus* (Olivier) (Coleoptera: Curculionidae), is a major economic insect pest with a extensive distribution in subtropical and tropical regions; it is also considered a serious insect pest of palm trees (*Phoenix dactylifera* L.) in the Middle Eastern countries, including Southern Europe, the Arabian Gulf, Egypt, North Africa, and South and South-East Asia. Its association causes damage to palms, including date, oil, sago, and coconut. More over 40 palm trees species from 23 different genera have been attacked around worldwide, (Murphy and Briscoe 1999 & Giblin-Davis 2001) [30, 23].

The most commonly used aggregation pheromones in field traps baited with are used as tools for managing and controlling this dangerous pest, Aldryhimand Al Ayedh (2015) [6]. Females of RPW were lay eggs in damaged plants or wounded, after the eggs hatching, 1st instar larvae infesting the new fresh tissue of palm tree then it was transfer to the bud region of the palm and penetrate, where they feed between 2 for 4 months that induced y kill the the heart of the crown of palm, Giblin-Davis 2001 [23].

During the last four decades, RPW electrophysiological and behavioural responses to food baits have grown significantly, and currently they have been recorded on 29 plant species, such as coconut petal, banana, pineapple, and volatiles trapped from banana trees, which elicited the highest attraction of coconut petal, pineapple, and banana., (Venugopal and Kesavan 2019) [38] & (EPPO, 2021) [18]. The chemical structure of date palm trees (*Phoenix dactylifera* L.), parts of leaflets, date stone, frond base, fruit stem, frond midrib, trunk, coir, fruit without bunches, was determined.

Volatile matter measurement values of 87.5% and 74.3% were evaluated for the samples of fruit only and leaflet, respectively. Nasser *et al.*, 2016. In many countries, strategies of integrated pest management (IPM) have been developed that contain field sanitation, agronomic practises, semiochemical technology for mass trapping and adult monitoring, biological controls, and also chemical controls of pests, Giblin-Davis *et al.*, 2014 [24] Abdel Kareim *et al.*, 2017 [1].

Farmer field schools, one of the national RPW programmes, would manage the RPW, including quarantine protocols, trapping techniques, and the validation of recent innovative tools to improve the effectiveness of the control programme that prevents chemicals. FAO. 2019 [19].

Bioinsecticides, such as essential oils and complex mixtures of lower molecular weight that are eco-friendly for the environment and safe for humans and non-target organisms, can also be used as a sustainable alternative to biological pest control; crop protection and integrated pest management may be provided by biopesticides. Devrnja *et al*., 2022 [16]. Maximum and minimum temperatures, as well as relative humidity, were recorded, with a significant effect on attracting RPW., Soomro *et al*., 2021 [35].

In Saudi Arabia, according to the characteristics and farmers' socio-economic attributes, 156 farmers used a new technology on Farmers' adoption of RPW IPM practises. The results of the examine with differences in adoption indicated that the farmers moderately adopted the cultural practises (50.44%) but categories of legislative control (54.77%), whereas they showed a low-level of adoption regarding the prevention, chemical control and mechanical control. Alotaibi *et al*., 2022 [7].

The goal of our research is to evaluate and measure individuals' responses to new formulations containing a mixture of different types of essential oils. We also tested the attractiveness and repellency of the antennae of the *R. ferrugineus*, towards the different oils on a test tube under laboratory conditions. These new technologies, which are highly effective methods of reducing the highly damaging effects of RPW, improve the effective substance that is placed on the weevils' pheromone traps, and these alternative techniques are environmentally friendly, reducing the use of harmful insecticides.

2. Materials and Methods

a. Sample of Red Palm Weevil

In Egypt, at the Agricultural Research Centre, Giza Governorate, the samples of pupae About 50 pupae of RPW *R.* ferrugineus were collected from palm tree varieties (Zaghloul). At Dr. Samah's laboratory in the Cotton Leafworm Department of the Plant Protection Research Institute, the experimental design was obtained by obtaining the hearts of palm (Algoumar) from date palm varieties (Zaghloul), which were set up at 25 °C and 60% RH, as shown in Fig. 1. The tissues were quickly kept in the freezer. Thirty weevils, "15 males and 15 females," of the RPW were placed separately on plastic cups after emergence; They were sexed into males and females and individually held in (3 x 2 cm) plastic cup containers with cotton pieces saturated with distilled water only and a small amount of sugarcane that were fed until used on our experimental. (Fig. 1c, d).

Fig 1: a) Sample of essential oil. B) Pupal of RWP from infested palm. C) Separate females and males of weevil. d) Sugarcane feed. E) Laboratory experimental by y tube

b. Sample of essential oils

In National Research Center, Dokki, Giza, the steam distillation for three hours using a Clevenger-type apparatus at Medicinal and Aromatic Plants Department, essential oils were obtained from 100 gram of seed Coriander: (*Coriandrum sativum* L.), leaves Basil:(*Ocimum basilicum*), seed Cumin:(*Cuminum cyminum* L.) and Clove:(*Eugenia caryophylla* Thunbseed), flower (*Camomile Matricariaaurea* L.), leaves lemongrass: (*Cymbopog oncitratus* L.), Thyme or Kafur (*Cinnamomum camphora* L.), Thyme (*Thymus vulgaris*), Cinnamon (*Cinnamomum verum*), *Geranium* (*Pelargonium graveolens*).

c. Innovative techniques of Two-choice olfactometer

According to Ibrahim *et al.* (2018) [27], Laboratory experiments at the Plant Protection Research Institute, Dokki, Giza,50 µl of each tested oil was placed in a micropipette (20-200 µl), and 50 1 of each tested oil was impregnated on filter paper. Finally, filter paper was put in the center of the Y tube glass arm, control arm contained distilled water on filter paper, manual air into the right and left of the y tube arms flow by pump about 60 - 80 ml/min, as shown in Fig. 2. The adult weevils, whether female or male, that entered each arm of the tube were counted and recorded, as were the times of their attractiveness.

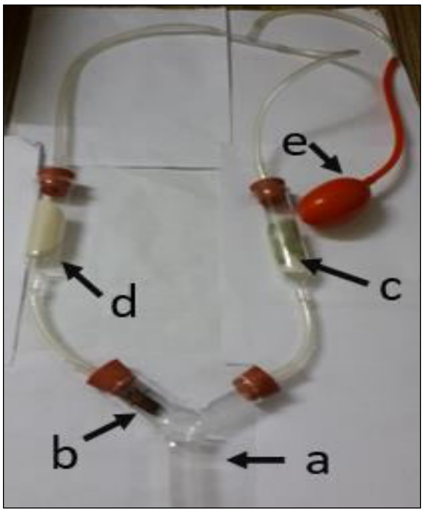

Fig 2: Two-choice olfactometer (design by Dr. Samah S. Ibrahim), a) Y tube right arm. b) Y tube left arm. C) Filter paper with 50 µl of each tested oil. d) Filter paper as a control "distilled water". e) The manual air flow was used 60–80 ml/min by pump

d. Y-tube assay

Our present experiment used eleven individual different oils (" essential oils"), each containing 50 µl, we used eight treatments, which are listed in Table 1.

Table 1: Y tube olfactometer choice between different semiochemicals.

Treatments	Right arm of Y tube	Left arm of Y tube
T_1	Palm heart Algumar	Control" Distilled water"
T_2	Palm heart Algumar	(Basil)
T_3	(Coriander)	(Cumin)
T_4	(Basil)	(lemon grass)
T_5	*Camomile*	Mint
T_6	Mixture of five oil "Basil, Coriander, Cumin, Camomile and *Mentha*).	Control" Distilled water"
T_7	Mixture of six oil Thyme, Cinnamon, Kafur, Clove, Geranium, Marjoram	Control" Distilled water"

e. Equation of calculations

We used two measures to determine attractiveness in the olfactometer. Equations of % positive response (100*T/N), and % total response (100*(T + C)/N), Where: (T): number of adult of RPW entering the test chamber, (C): number of adult of RPW entering control (blank) chamber, (M): total number of adult of RPW in the olfactometer. Gregg *et al.*, 2010 [22] and Del Socorro *et al.*, 2010 [13].

According Sharaby and Al-Dosary 2014 [34], Intensity of reaction (IR), Number of insects (C) moving to the control and Number of insects (S) attracted to the right arm of y tube olfactometer.

IR = 100 x S - C /S + C

2.1 Repellent response: < 1%; Very weakly attractive: 1-10%; Weekly attractive: 11-20%; Attractive: 21-40% and highly attractive > 40%.

2.2 Statistical analysis

One – way ANOVA were used a statistical analysis of variance ANOVA, Least Significant Difference (LSD) at 5% level of probability (LSD 0.05). (SAS Institute, 1996).

3. Results

3.1 Intensity of the reaction (IR) of RPW *R. ferrugineus*.

In general, the results in Table 2 explain that, the total number of female RPW *R. ferrugineus* weevils, positive responses, and the intensity of the reaction to all treatments on the Y tube showed that the total number of adult weevils used on our experiment was 45, and approximately 25 adult female RPW were attracted to the palm heart ("Algumar") with a highly intense reaction (+11.1%). On the other hand, the Algumar, were repellent to males with (-51.1), in contrast to the filter paper saturated with water on the control, which attracted more males with a high number of weevils entering the tube containing water (34), with a positive response rate of 75%, as shown in Table 2. Our results also indicated that the same results on the second treatment, T2, indicated that the kairomones emitted from Algumar attracted a high number of males (25), with a 55% positive response, while basil oil attracted more females (51.1%) than males were attracted to Algumar (55%). This means that we can put the oil and a small amount of Algumar on the traps to increase the efficiency of pheromone traps. Females and males' greater attraction to palm hearts (Algumar) may be due to the high percentage of kairomones in the palm, which may be an important role that attract males and females. *R. ferrugineus*.

Table 2: Females and males of *Rhynchophorus ferrugineus* on y tube olfactometer choice

Treatments	y tube olfactometer	Numbers of female ♀ RPW entering the test arm of y tube	♀Positive response %	IR % ♀ RPW	Number of males ♂ RPW entering the test arm of y tube	♂Positive response %	IR % ♂ RPW
T_1	R" Algumar"	25	55	+11.1	11	24	-51.1
	L" Distilled water"	20	44	- 11.1	34	75	+ 51.1
T_2	R " Algumar"	22	48.8	-11.1	25	55	+11.1
	L "Basil"	23	51.1	+11.1	20	44	-11.1
T_3	R " Coriander"	30	66.6	+33.3	22	48.8	-2.2
	L " Cumin "	15	33.3	-33.3	23	51.1	+2.2
T_4	R " Basil"	25	53.3	+11.1	27	60	+20
	L " lemon grass"	20	44.4	-11.1	18	40	- 20
T_5	R " Mint"	20	40	-11.1	26	57	+15.5
	L " Camomile"	25	55	+11.1	16	42	-15.5
T_6	R " Mixture 1 "	22	48.8	-24.4	27	60	+31.1
	L " Distilled water "	23	51.1	+24.4	18	28.8	-31.1
T_7	R " Mixture 1"	6	13.3	-73.3	7	15.5	- 68.8
	L " Mixture 2"	39	86.6	+73.3	38	84.4	+68.8

R: Right arm of y tube, L: Left arm of y tube

The intensity of reaction to the mixture of five oils was only 24.4% for females, whereas the mixture of two oils was highly attractive for females. As shown in Table 1, there is a significant difference between all treatments and the attractiveness and duration of the emission of oil receptors on the antenna of the female RPW. Furthermore, the intensity of reaction for the first mixture T6 was 73.3%, but only 24.4 percent for the second mixture T7. All treatments received a positive response, and mixture 2 received an 86.6% very high attractiveness (Table 1). Table 2, on the other hand, revealed that the 2nd mixture attracted a high number of males, as well as having the highest mean of time with 13.58 compared to all treatments, and the intensity of the IR was recorded at a high of 68.8% when comparing the 1st mixture and the 2nd mixture.

According to Table 2, the treatment (T5) that compares Camomile and menthol attracted the highest percentages: 55% for females and 16% for males. Camomile oil contains various chemicals such as Bisabolol oxide A (70.83), Bisabolol oxide B (6.39), Trans-á-Farnesene (5.87), and Bisabolone Oxide (5.59), as shown in Table 2. When mixing oils in T6 (Basil, Coriander, Cumin, Camomile, and *Mentha*) and T7 (Thyme, Cinnamon, Clove, Kafur, Rose-Scented Geranium, and Marjoram) in an innovative manner, the attraction rate was 86.6% for mix 1 and 84.4% for mix 2, both for females and males.

3.2 Response of adult RPW to essential oils

Results illustrated in Table (3) explain that, the mean number of females and males showed highly significant differences between the right arm "Algumar" (0.56±0.075) and left arm "distilled water" (0.42±0.074) of the y tube. In treatment (T3), there were significant differences between females attracted to coriander and cumin oils, as well as between males and females attracted to coriander. Also, there were highly significant differences between males and females attracted to cumin oil, while there was no significant difference when both adult weevils of RPW choice consumed cumin oil. The Baisl and lemongrass oils had no effect on the attracted responses of both adult weevils (males and females) in T4.

Table 3: The average number of females and males of *Rhynchophorus ferrugineus* attracted to specific essential oils.

Treatments	Essential oils	female ♀ RPW	female ♂ RPW	F	LSD
T1	R" Algumar"	0.56±0.075 b	0.77±0.064 a	9.52	0.1951
	L" Distilled water"	0.42±0.074 bc	0.23±0.064 c		
T2	R " Algumar"	0.51±0.075 a	0.58±0.074 a	0.41	0.2096
	L "Basil"	0.53±0.075 a	0.42±0.074 a		
T3	R " Coriander"	0.68±0.07 a	0.48±0.075 ab	4.58	0.2026
	L " Cumin "	0.31±0.07 b	0.53±0.075 a		
T4	R " Basil"	0.56±0.075 a	0.63±0.073 a	1.58	0.2076
	L " lemon grass"	0.44±0.075 a	0.37±0.073 a		
T5	R " Mint"	0.42±0.07 a	0.56±0.075 a	1.27	0.2081
	L " Camomile"	0.56±0.075 a	0.44±0.075 a		
T6	R " Mixture 1 "	0.51±0.075 a	0.60±0.073 a	1.21	0.2082
	L " Distilled water "	0.49±0.075 a	0.40±0.073 a		
T7	R " Mixture 1"	0.13±0.051 b	0.15±0.054 b	68.47	0.1429
	L " Mixture 2"	0.88±0.047a	0.86±0.051 a		

R: Right arm of y tube, L: Left arm of y tube. letters in each column are significantly different (P, 0.05).

In current study, as shown by the results in Table 3, when tested plant oils such as mint and chamomile elicited varying degrees of response in both males and females, no significant difference was found between the same oil and the two oils at the same treatment. There are no significant differences in the oil mixture that occurred on treatment T7, so there is no effect on the attractiveness of males and females of RPW; however, when mixture number 2 with (T7) was used, there were highly significant differences in attractive females and males between mix 1 and mix 2. As a result, mix 2 is more appealing than mix 1.

3.3 Time-related behavioral response to adult *R. ferrugineus*

Table 4 shows that the time of exposure is an important measurement to compare with all other oils used in other studies. Statistically, we compare the females and males of RPW on each treatment. After 7.28 min from the time the female of RPW moved to the arm of the tube containing Algumar, it was considered to have made a choice between the smell of Algumar and water ("no smell"); on the other hand, males were recorded as having a low time for being attracted to water with 2.87 min. It can be clearly seen that Algumar attracted females on low tide, while the water attracted males on low tide. Because of the movement of the adult weevil after the release of the tested oil compound, the times of response differed from one adult weevil to the next and also between replicates; the weevil moves the antenna to the right and left arms of the Y tube, the mean number of times between all treatments recorded a significant difference.

Accordingly, there is a significant difference between water and basil oil for both females and males. Females were more attracted to sweet basil than males were to cumin, and there were no differences between males and females for cumin or sweet basil. When females take longer to enter the arm of the tube, the same result occurs. Feather papers contain more lemongrass than basil. There are no differences in the attracted times of chamomile and mint, as showed in Table 4.

Data in Table 4 investigated that, males were attracted to water first, followed by mix 1, while the mix 1 was repellent to RPW males. Females preferred water that had a low time, and when mixed oil was used, whether mix 1 or mix 2, the time of female attraction was highly significant when compared to mixture 2. Finally, the response to treatment T8 between mixtures 1 and 2 revealed more differences in males and females, while there were no differences in males and females who tested mixture 2.

As a result, the mixture contains two more RPW attracted females and males. To summarize, when we combine certain oils, we may induce the formation of a new compound that increases the efficacy of the mixture; as a result, the mixture may have a repellence or attractive effect. Furthermore, we recommend mixture 1 as a new formulation as a palm weevil repellent, while the 2nd mixture contains Algumar, which also increases the number of males attracted, as shown in Table 1. and placed it on traps that will be used to increase the catch of red palm weevil (RPW), *R. ferrugineus*, as a new method to control these danger insect pest.

Table 4: Time responses of females and males of *Rhynchophorus ferrugineus* RPW after choose of y tube.

Treatments		Attracted Time"min." female ♀ RPW	Attracted Time"min." male ♂ RPW	F	LSD
T_1	R" Algumar"	7.28±1.23 b	12.28±1.57 a	7.64	3.83
	L" Distilled water"	8.26±1.66 b	2.87±0.86 c		
T_2	R " Algumar"	9.03±1.79 ab	9.43±1.60 ab	2.14	4.72
	L "Basil"	12.29±2.03 a	5.64±1.19 b		
T_3	R " Coriander"	11.62±1.94 a	6.2±1.25 b	7.64	3.71
	L " Cumin "	2.94±0.75 b	5.62±1.08 b		
T_4	R " Basil"	10.1±1.42 a	5.45±1.27 b	1.90	3.991
	L " lemon grass"	7.2±1.49 ab	6.68±1.40 b		
T_5	R " Mint"	8.57±1.97 a	4.7±0.76 a	1.89	3.784
	L " Camomile"	4.88±0.811 a	5.09±1.49 a		
T_6	R " Mixture 1 "	5.20±1.43 b	6.06±0.92 ab	2.75	4.186
	L " Distilled water "	4.88±2.15 b	10.24±1.24 a		
T_7	R " Mixture 1"	2.04±0.97 c	2.75±1.28 c	14.48	4.122
	L " Mixture 2"	13.8±1.23 a	9.05±1.38 b		

Different letters in each column are significantly different (P, 0.05).

3.4 Chemical composition of essentials oils

As shown in Table 4, Coriander and basil oils have also been observed to attract females at a rate of 61.6% and 51.1%, respectively (Table 2). This result may be due to the fact that the major components of coriander, *Coriandrum sativum* L., are L-Linalool (63.81), -Pinene (9.72), -Terpinene (6.60), geranyl acetate (3.11), -Myrcene (2.52%), and camphor (2.57%) (Table 5 and Fig 3).

In general, cumin oil was more appealing to males because it contains 56.33% monoterpene hydrocarbons; however, lemongrass and mint were repellent to both females and males of RPW in our experimental study because they contain a high concentration of oxymonoterpenes (Table 5 and Fig. 7).

According to the results of chemical analysis by the GCMS analyzer, lemongrass oil was repellent to both males and females of RPW (44.4%). lemongrass, *Cymbopogon citratus*, contains a lot of compounds such as D-Limonene (54.01), -Citral (16.56%), E-Citral (9.92%), Eucalyptol (3.61%), and -Pinene (4.04%). Pinene (2.93%). Lemongrass, mint, and cumin in this study found a low percentage of attracted adult *R. ferrugineus* weevils due to a lot of replanted compounds like ç-Terpinene (18.90), -Pinene (17.79), cuminic aldehyde (15.64), p-Cymene (15.57), and 2-Caren-10-al (9.46) (Table 5, Figs. 5, 6, and 7).

The highest percentages of L-Linalool (59.02%), 1,8-Cineole = Eucalyptol (9.52%), -Cadinol (6.59%), -Bergamotene (5.74%), and ç-Cadinene (2.47%) were found in Basil oil's main compounds (Table 5 and Fig 4).

According to the results of Table 6, the new formulation of mixture essential oils first revealed new chemical compounds: linalool-Linalool (benzaldehyde, 4-(1-methylethyl)cymene, o-Cymene (10.75%), followed by monoterpene hydrocarbons (24.07%), while oxygenated monoterpenes were recorded at a high percentage of 88.98% by GCMS analysis. On the other hand, in the 1st mixture was sesquiterpene hydrocarbons recorded that 6.38% while oxygenated sesquiterpenes was 5.49%.

It can be concluded that the first mixture was repellent for both sexes, males and females, while the second mixture was highly attractive for females, with 73.3% and 68.8% for males. Furthermore, the effect of oils is due to the presence of the major constituent monoterpenes: 67.95% for lemongrass, 56.33% for cumin oil, and 25.54% for coriander, mint (90.96%), and oxidised monoterpenes for basil (12.74%). Sesquiterpene hydrocarbons and chamomile (87.96% oxygenated sesquiterpenes) Table 6.

The results obtained here are considered promising for natural products derived from plants, our research used essential oils (EOs) for a new technology for controlling insect pests by a technique of attraction and killing and also their major components, which are mostly monoterpenes, hydrocarbons, oxygenated monoterpenes, and sesquiterpene hydrocarbons. The biological properties of oxygenated monoterpenes attract RPW. Terpenoids are very important, but our findings also discuss their characterization in terms of synergistic or antagonistic attractiveness (repellent effects).

Table 5: GCMS analysis of some essential oil

No	Compounds	Rt.	Basil	Camomile	Coriander	Cumin	Mentha	Lemongrass
1	α-thujene	4.09	-	-	-	-	-	0.13
2	camphene	4.68	-	-	-	-	-	0.78
3	α-Pinene	4.69	-	-	9.72	1.34	0.51	4.04
4	sabinene	5.24	-	-	-	-	0.33	3.53
5	β-Pinene	5.86	1.23	-	-	17.79	0.63	2.93
6	6-methyl-5-hepten-2-one	5.89	-	-	-	-	-	0.22
7	α-Myrcene	6.14	1.24	-	2.52	-	-	1.93
8	l-Phellandrene	6.71	-	-	-	0.93	-	-
9	p-Cymene	7.34	-	-	2.88	15.57	-	-
10	D-Limonene	7.43	0.81	-	1.77	1.8	2.44	54.01
11	1,8-Cineole	7.57	9.52	-	0.95	-	3.59	3.61
12	cis-Ocimene	7.63	-	-	1.11			0.08
13	γ-terpinene	7.88	-	-	-	-	0.48	0.44
14	cis-Ocimene	7.98	-	-	-	-	-	0.08
15	ç-Terpinene	8.42	-	-	6.6	18.9	0.35	-
16	Artemisia ketone	8.44	-	3.16	-	-	-	-
17	dihydromyrcenol	8.45	-	-	-	-	-	0.23
18	Artemisia alcohol	9.20		0.79	-	-	-	-
19	L-Linalool	10.07	59.02	-	63.81		0.94	0.51
20	limonene oxide, cis-	10.73	-	-	-	-	-	0.13
21	trans-limonene oxide	10.90	-	-	-	-	-	0.12
22	p-menthone	11.73	-	-	-	-	0.42	-
23	Camphor	12.05			2.57	-	-	-
24	l-menthone	12.06	-	-	-	-	0.33	-
25	terpinen-4-ol	12.65	-	-	-	-	3.2	-
26	cis-verbenol	12.94	-	-	-	-		0.11
27	Borneol	13.05	0.84	-	1.13	-	0.45	-
28	β fenchyl alcohol	13.42	-	-	-	-	-	0.13
29	p-menth-8-en-2-ol	13.59	-	-	-	-	0.62	-
30	α-Terpineol	14.04	1.28		3.11		1.12	-
31	Estragole	14.16	-	-	-	5.58	-	-
32	6-methyl-cyclodec-5-enol	14.26	-	-	-	-	0.37	-
33	cis-carveol	14.47	-	-	-	-	0.28	-
34	pulegone	15.10	-	-	-	-	19.88	-
35	β-citral	15.13	-	-	-	-	-	16.56
36	e-citral	16.45	-	-	-	-	-	9.92
37	(r)-carvone	15.47	-	-	-	-	59.42	
38	Cuminic aldehyde	16.14	-	-	-	15.64	-	-
39	carvol	16.80	-	-	-	-	0.18	-
40	(+)-carvone	17.06	-	-	-	-	0.16	-
41	Bornyl acetate	17.55	2.42	-	-	-	-	-
42	2-Caren-10-al	17.97	-	-	-	9.46	-	-
43	3-Caren-10-al	18.14	-	-	-	9.35	-	-
44	β bourbonene	20.68	-	-	-	-	0.68	-
45	β-elemene	21.01	-	-	-	-	0.26	-
46	Geranyl acetate	21.60	-	-	3.11	-	-	-
47	caryophyllene	22.17	-	-	-	-	1.43	-
48	α-Bergamotene	23.51	5.74	-	-	-	0.38	-
49	Trans-á-Farnesene	24.43	-	5.87	-	-	-	-
50	α-Humulene	24.45	2.03	5.87	-	-	-	-
51	GERMACRENE-D	25.50	2.5	-	-	-	0.33	-
52	β-copaene	24.76	-	-	-	-	0.35	-
53	bicyclogermacrene	25.33	-	-	-	-	0.23	-

54	cis-calamenene	26.48	-	-	-	-	0.27	-
55	γ-Cadinene	26.84	2.47	-	-	-	0.22	-
56	cubenol	30.21	-	-	-	-	0.14	-
57	α-Cadinol	31.95	6.59	0.78	-	-	-	-
58	α-Bisabolol oxide B	32.33	-	6.39	-	-	-	-
59	Bisabolone oxide	33.40	-	5.59	-	-	-	-
60	α-Bisabolol	33.61	-	2.01	-	-	-	-
61	Chamazulene	35.28	-	0.83	-	-	-	-
62	Bisabolol oxide A	35.90	-	71.83	-	-	-	-
63	En-in-dicycloether	40.79	-	1.36	-	-	-	-
Monoterpene hydrocarbons			3.28	0	25.54	56.33	4.74	67.95
Oxygenated monoterpenes			73.08	3.95	71.57	40.03	90.96	31.54
Sesquiterpenes hydrocarbons			12.74	6.7	0	0	2.72	0
Oxygenated Sesquiterpenes			6.59	87.96	0	0	1.57	0
Total Identified			95.69	98.61	97.11	96.36	99.99	99.49

Table 6: Comparison between two chemical compounds of the essential oil mixture (1) and (2)

No	Compounds	R.T.	Mix 1	Mix 2
1	α-Pinene	3.67	2.52	0.28
2	Propylene Glycol	4.09	-	0.42
3	β-Pinene	4.45	4.07	1.04
4	o-Cymene	5.37	10.75	9.42
5	Eucalyptol	5.54	0.89	2.19
6	γ-Terpinene	6.00	6.73	-
7	Benzyl alcohol	5.97	-	8.05
8	β-Linalool	7.02	24.78	1.33
9	(-)-Alcanfor	8.22	0.5	9.38
10	L-Menthone	8.32	4.09	-
11	D-menthone	8.55	1.27	0.8
12	Isomenthol	8.63	0.35	-
13	Menthol	8.83	6.87	1.82
14	α-Terpineol	9.26	-	0.28
15	Citronellol	9.87	-	3.54
16	Pulegone	10.22	-	2.74
17	Benzaldehyde, 4-(1-methylethyl)-	10.43	22.03	12.04
18	Citronellylformate	10.77	-	1.28
19	Menthol, acetate	11.14	1.15	-
20	Cinnamaldehyde	11.32	-	11.84
21	Thymol	11.54	-	14.07
22	Glycerol 1,2-diacetate	12.62	-	12.17
23	Eugenol	12.80	-	7.03
24	Geranyl acetate	13.11	1.16	-
25	trans-α-Bergamotene	14.05	0.33	-
26	(E)-á-Famesene	14.46	5.56	-
27	γ -Muurolene	18.48	0.49	-
28	Bisabolol oxide A	20.50	5.49	-
Monoterpene hydrocarbons			24.07	10.74
Oxygenated monoterpenes			63.09	88.98
Sesquiterpenes hydrocarbons			6.38	-
Oxygenated Sesquiterpenes			5.49	-
Total Identified			99.03	99.72

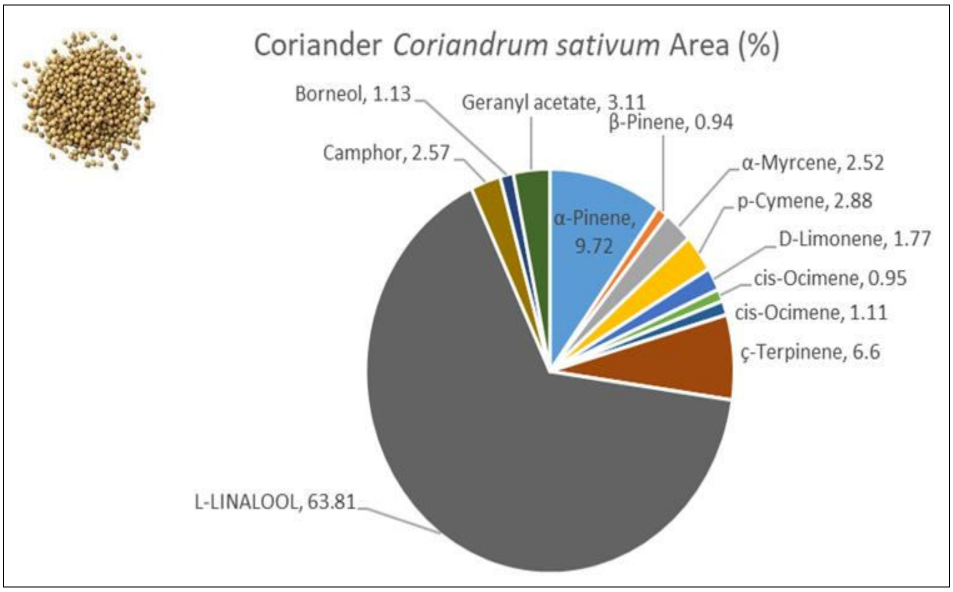

Fig 3: Major compounds of Coriander

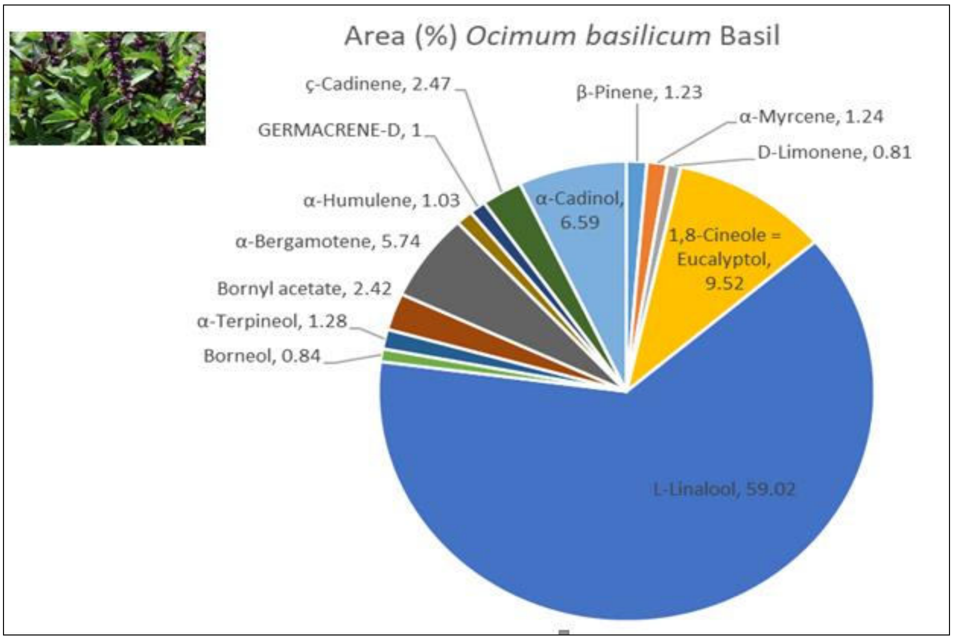

Fig 4: Major compounds of Basil

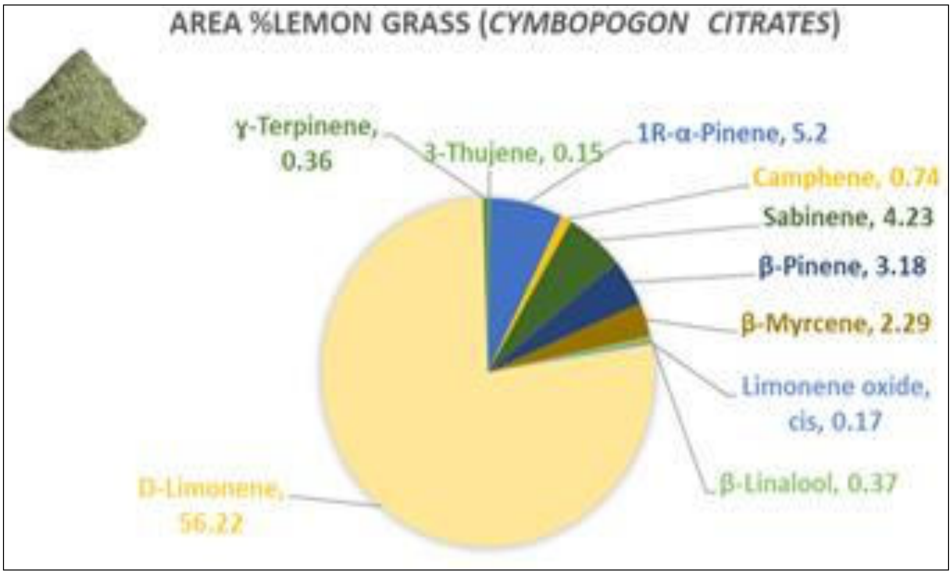

Fig 5: Major compounds of Lemongrass

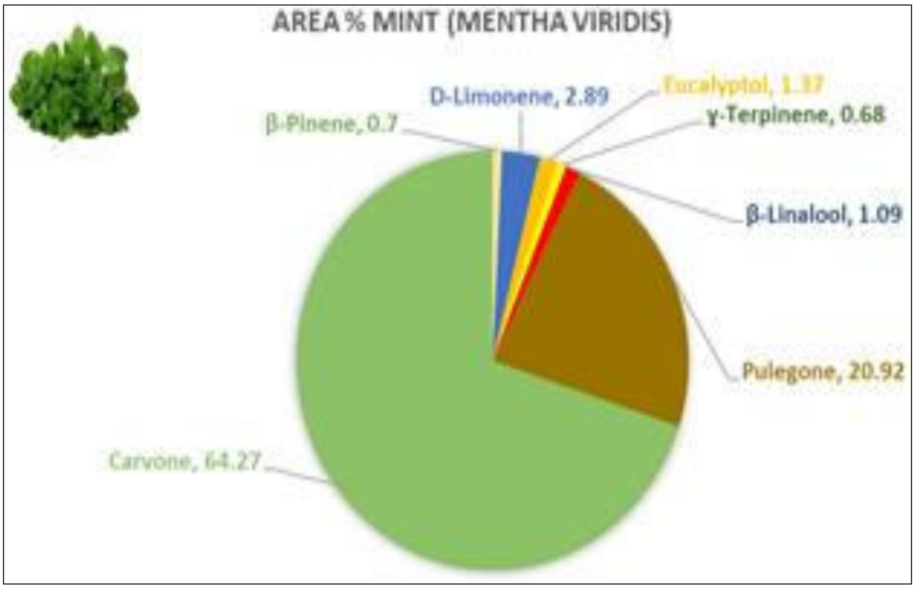

Fig 6: Major compounds of Mint

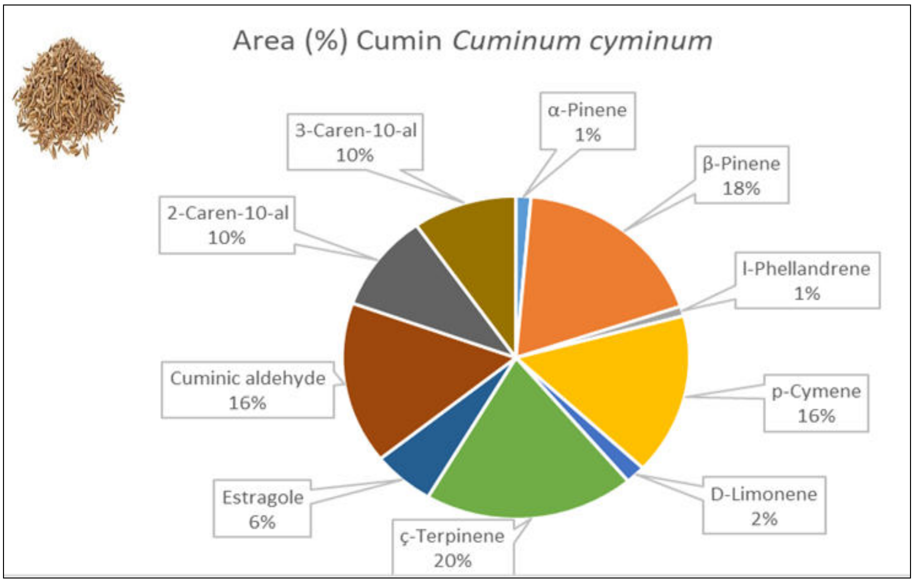

Fig 7: Major compounds of Cumin

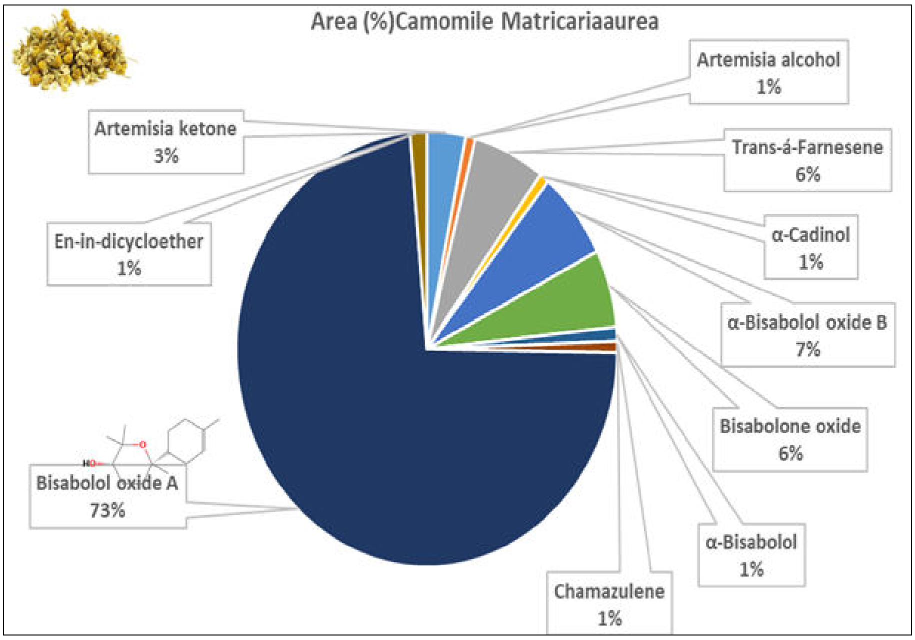

Fig 8: Major compounds of Camomile

Discussion

This finding is consistent with Faleiro *et al*., 2019 [21] who discovered that mass pheromone trapping systems using aggregation pheromone and food bait with or without kairomons are effective IPM strategies for *R. feresultus*. Vidyasagar and Aldosari (2010) [37], who investigated that, found that over the experimental period, we used ethyl acetate and date fruits and the weekly capture had an average about 3.38 weevils per trap. While when the trap was alone with date fruits as "kairomones," the weekly number of weevils was reduced to 2.46 per trap, when the trap contained only date stem pieces, the number of weevils was much lower at about 1.66 per trap.

As a result of our study, as well as those of Zheljazkov *et al*. (2014) [40], who discovered that the major constituent of essential oil, which is extracted from coriander seeds, accounts for the flavour, aroma, and also seeds and leaves contain very mixed linalool, terpenes and polyphenols Al-Khayri *et al*. (2023) [3], have a variety of biological activities such as antioxidant, antimicrobial, and insecticidal.

The major components of essential oil were extracted from *O. basilicum* monoterpenes that observed by Dolatabad *et al*. (2014) [14].

Furthermore, we can increase the efficacy of aggregation pheromones by mixing them with kairomones, or the volatiles that were emitted from the host.

Ibrahim *et al*., 2022 [28], discovered that a mixture of certain essential oils, such as coriander, basil, chamomile, and cumin, could increase attraction when used with pheromones only. We used 50 microliters of the tested oils that were put in a transparent capsule on a funnel trap containing pheromones. The results recorded the highest number of moths, *Spodoptera littoralis*, compared to the lower number of moths observed on the control trap in September 2017.

Baby 2022 [11] recorded that there are 17 different amino acids that make up the major chemical composition of the heart's palm, such as isoleucine, histidine, methionine, lysine, threonine, phenylalanine, valine, and tryptophan. Also, the heart's palm is a very rich source of protein, has lower fats, is high in fiber and sugar, and contains the highest number of minerals and healthy vitamins.

Our results probably come from Lee *et al*. (2005) [29] and Zheljazkov *et al*. (2014) [40]; they recorded that the chemical compounds of Basil (*Ocimum basilicum* L.) oil that were extracted had high concentrations of methyl chavicol, linalool, 1,8-cineole, myrcene, eugenol, and estragole, while Linalool is the major constituent of coriander seeds and leaves; it also contains the high levels of mixed terpenes and polyphenols.

Our results showed that the two previously mentioned terpenes were repellents for the RPW. Iso-eugenol and -pinene were also attractive to both sexes of *S. littoralis* moths but repellent to the RPW. Geraneol was repellent to females and attractive to males of the indicated RPW. Bettaieb *et al*. (2011) [12] explained that the essential oil cumin (*Cuminum cyminum* L.) contains the major volatile components cuminaldehyde, terpenoids, and cymene. As a result of their agreement with Sharaby and Aldosary (2014) [34], they discovered that lemongrass oil was repellent, while sweet basil and thyme were only attractive to females and they also observed that 31 natural plant volition oils were studied and tested as attractants or repellants, with terpene-rich Juniper oil and terpene-rich Camphene oil being the most appealing to both sexes, while Fenugreek oil was attractive to males but repellent to females. Female RPW are more active in the field than males, which may account for their capture in pheromone traps (Avand Faghih, 1998) [10].

Moreover, Said *et al*. (2003) [33] found that the basioconic sensillae on the female antennas of RPW *R. palmarum* have more than their male antennas, and they also observed that the basioconic sensillae are very sensitive to the aggregation pheromone.

Generally, after red palm weevils complete their development, females mate with males, and they try to find more suitable mates and hosts for oviposition due to their highly sensitivity to aggregation pheromones that enhanced the chances of being captured as adults in the traps (Avand-Faghih, 1998; Abbas *et al*., 2006) [10, 2].

Integrated pest management of palm pests had more success when elements such as aggregation pheromones were used on traps, resulting in the highest catches of adult females of RPW, which could result in lower oviposition of RPW and also decreased population and lower losses to date palm plantations. (Al-Saoud, 2010) [8].

Chemical volatiles are defined as "semiochemicals," which are informative molecules that are very important tools in conveying specific chemical messages from plant to insect and insect to plant.

Recently, kairomones have become part of integrated pest management (IPM) strategies as an alternative or complementary component to insecticides, kairomones are defined as chemicals that are emitted from any organism, such as plants, and that stimulate an extremely attractive response in an individual of another species, like an insect, parasite, or predator.

Pheromones can be used in agricultural systems for monitoring and mass trapping to control insect pests alone or in conjunction with other control strategies. RPW was controlled using chemical insecticides, aggregated pheromone traps, and agricultural practices, according to Al-Turaihi (2013) [9]. Organic agriculture, tissue culture, pheromone traps, plant extracts, and biological control were cost-effective tools for reducing the highly damaging effects of RPW. Gonzalez *et al*., 2019 [25] used an aggregation pheromone by trapping palm-produced kairomones (ethylacetate), to maintain a highly good attraction it must be replaced in the traps every 2-4 weeks.

The coconut oil-induced attract and kill formulation was more effective for at least 9 months in monitoring traps that may reduce adult captures compared to traps without these formulations. Elshafie *et al*. 2011 [17].

Sesquiterpenes, and monoterpenes are the major important aroma compounds include amino-acid-derived compounds, phenolic derivatives and lipid-derived compounds,. Wilfried *et al*., 2010 [39].

The phytochemicals of different varieties of date palm, such as phenolics, carotenoids, sterols, and flavonoids, and their biological significance, quality parameters, and organoleptic properties may be responsible for colour, taste, texture, and smell. The ratio and concentration of these compounds depend on the variety of palm and depend on the efficiency of the stage of maturation and the pollination process. (Farboodniay Jahromi *et al*., 2014) [20].

This result is consistent with the findings that the adults of RPW *R. ferrugineus* showed significant differences in their responses to the tested lures. However, when using pheromones alone or when mixing pheromone with kairomone, that recorded the very highest attractiveness for adults RPW with no significant differences, while the low numbers of RPW adults that used the 3rd group were significant only for kairomone (acetyl ether) on traps, and these methods were more preferred for control, a similar conclusion was obtained by Vacas *et al*., 2014 [36].

Al-Dosary *et al*., 2016 [4] Globally, the genus Rhynchophorus has the widest geographical range among weevils; Red Palm Weevil (RPW) *R. ferrugineus* causes more complete destruction of palm trees, often resulting in widespread damage to cultivated date palms.

According to Bettaieb *et al*. (2011) [12], the biochemical composition of the essential oil of cumin seeds is a single variety of *P. dactylifera* L., and the oils are rich in petroselinic acid and unusual fatty acids. Moreover, these varieties contain a lot of compounds, such as terpinene, cuminaldehyde, and 3,4-dimethoxy toluene. Demirci *et al*. (2013) [15] included the major components caryophyllene oxide, caryophyllene, 2,4-dimethoxytoluene, p-cresyl methyl ether, farnesyl acetone, 2,6-dimethoxytoluene, 3,4-dimethoxytoluene, and geranylacetone. However, some authors reported that oxygenated monoterpenes, carvacrol, and thymol.

Hamedi *et al*., 2013 [26]. Farboodniay *et al*. (2014) [20] investigated that the chemical components essential oil of *P. dactylifera* varieties were methyl geranate (1.1–5.6%), farnesyl acetone (E,E) (1.74–20.85%), p-methylanisole (0.53–4.43%), geranyl acetone (1.3–4.81%), and 2,6-dimethoxytoluene (6.89–15.95%). Abdel Kareim *et al*., 2017. Were recorded in 1st year that total capture and the highest number of weevils of *R. ferrugineus* in traps with 27.7%, 23.5, 19.5and 14.3 of the total capture of weevils in traps containing 1kilogramme (Kg), 0.7, 0.4 and 02 of date fruit, respectively, while during the 2nd year, RPW were 24.6%, 23.9, 13.2, 17.8 and 15.0, respectively,

Conclusion

The successful management requires innovative technologies for RPW management programmers. Our results indicated that the females' coefficient of attraction to palm hearts increased by 55%, while males were attracted to water. The coriander and basil oils also recorded high female attraction rates of 61.6% and 51.1%, respectively, but the lemongrass and peppermint oils were repellent to both females and males. When mixing oils in an innovative formulation, the attraction rate was increased by 86.6% and 84.4% for both females and males, respectively. It would be expected that the new technology for controlling *R. ferrugineus* on the field.

Reference

1. Abdel Kareim AI, Mohamed AM, Rashed AA, Said Ahmed FM, Qasim MA, Saad MM. Oviposition deterrent effect of four essential oils against the date palm weevil, *Rhynchophorus ferrugineus* Olivier, Middle East J Agric. Res. 2017;6(4):1336-1345.
2. Abbas MS, Hanounik SB, Sahdad AS, Al-Bagham SA. Aggregation pheromone traps, a major component of IPM strategy for the red palm weevil, *Rhynchophorus ferrugineus* (Coleoptera: Curculionidae) in date palms. J Pest Sci. 2006;79(2):69-73. https://doi.org/10.1007/s10340-005-0113-6.
3. Al-Khayri JM, Banadka A, Nandhini M, Nagella P, Al-Mssallem MQ, Alessa FM. Essential Oil from *Coriandrum sativum*: A review on Its Phytochemistry and Biological Activity. Molecules. 2023;28:696. https://doi.org/10.3390/ molecules28020696
4. Al-Dosary NM, Al-Dobai S, Faleiro RJ. Review on the management of red palm weevil *Rhynchophorus ferrugineus* olivier in date palm *Phoenix dactylifera* L, Emirates Journal of Food and Agriculture. 2016;28(1):34-44.
5. Aldryhim, Al Ayedh. Diel flight activity patterns of the red palm weevil (Coleoptera: Curculionidae) as monitored by smart traps, Florida Entomologist. 2020;98(4):1019-1024.
6. Aldryhim YN, Al Ayedh HY. Diel flight activity patterns of the red palm weevil (Coleoptera: Curculionidae) as monitored by smart traps, Florida Entomologist. 2015;98(4):1019-1024.
7. Alotaibi BA, Ahmed A, Al-Zaidi AA, Kassem HS. Adoption of Integrated Pest Management for Red Palm Weevil Control among Farmers in Saudi Arabia. Horticulturae. 2022;8:1005. https://doi.org/10.3390/ horticulturae8111005.
8. Al-Saoud AH. Effect of red palm weevil *Rhynchophorus ferrugineus* (Coleoptera: Curculionidae) aggregation pheromone traps' height and colors on the number of captured weevils. IV International Date Palm Conference. 2010;882:419-429 http://doi.org/10.17660/ActaHortic.2010.882.47.
9. Al-Turaihi EH. Integrated Pest Managment of The Red Palm Weevil (*Rhynchophorus ferrugienus* Olivier) Afpp – Palm Pest Mediterranean Conference Nice – 16, 17 And 18 January 2013.
10. Avand-Faghih A. Research on the Control of red palm weevil, *Rhynchophorus ferrugineus* Oliv. (Coleoptera: Curculionidae) with synthetic attractants in Sistan & Blouchestan province (Iran). A thesis submitted in partial fulfilment for the degree of M.Sc. in Agricultural Entomology, Department of Plant Protection, College of Agriculture, University of Tehran; c1998. p. 162.
11. Baby DP. Health Benefits of Heart of Palm; c2022. https://www.webmd.com/diet/health-benefits-heart-of-palmPreiato, D. 2020. What Is Heart of Palm, and How Is It Eaten?
12. Bettaieb I, Bourgou S, Sriti J, Msaada K, Limam F, Marzouk B. Essential oils and fatty acids composition of Tunisian and Indian cumin (*Cuminum cyminum* L.) seeds: a comparative study. Journal of the Science of Food and Agriculture. 2011;91(11):2100-7. doi:10.1002/jsfa.4513.
13. Del Socorro AP, Gregg PC, Alter D, Moore JC. Development of a synthetic plant volatile based attracticide for female noctuid moths. I. Potential sources of volatiles attractive to *Helicoverpa armigera* (Hübner) (Lepidoptera: Noctuidae). Australian Journal of Entomology. 2010;49:10-20.
14. Dolatabad SS, Moghaddam M, Chalajour H. Essential oil composition of four Ocimum and varieties grown in Iran. J Essen. Oil Res. 2014;26:315-321.
15. Demirci B, Tsikoli M, Bernier UR, Agramonte NM, Alqasoumi SI, Al-Yahya MA, *et al*. *Phoenix dactylifera* L. spathe essential oil: Chemical composition and repellent activity against the yellow fever mosquito. Acta Tropica. 2013;128:557-60.

16. Devrnja N, Milutinovi CM, Savi CJ. When Scent Becomes a Weapon-Plant Essential Oils as Potent Bioinsecticides. Sustainability. 2022;14:6847. https://doi.org/ 10.3390/su14116847.
17. El-Shafie HAF, Faleiro JR, Al-Abbad AH, Stoltman L, Mafra-Neto A. Bait-free attract and kill technology (Hook™ RPW) to suppress red palm weevil, *Rhynchophorus ferrugineus* (Coleoptera: Curculionidae) in date palm. Florida Entomologist. 2011;94:774-778. https://doi.org/10.1653/024.094.0407
18. EPPO, 2021, European and Mediterranean Plant Protection Organization https://gd.eppo.int/taxon/RHYCFE/hosts
19. FAO. 2019. Proceedings of the Scientific Consultation and High-Level meeting on Red Palm Weevil management - 29-31 March 2017, Rome, Italy. Rome, 200 pp. Licence: CC BY-NC-SA 3.0 IGO.
20. Farboodniay Jahromi, Mohammad Ali, Reza Moeina M, Etemadfard H, Jahromi Z. Variation of spathe essential oil composition of ten Iranian date varieties (*Phoenix dactylifera* L.). International journal of plant, animal and environmental sciences. 2014;4(4):51-56.
21. Faleiro JR, Al-Shawaf AM, El-Shafie HAF, Raikar PS. Studies on service free semiochemical mediated technologies to control red palm weevil *Rhynchophorus ferrugineus* Olivier based on trials in Saudi Arabia and India. 2019;37(2):136-142.
22. Gregg PC, Socorro AP, Alter D, Moore CJ. Development of a synthetic plant volatile-based attracticide for female noctuid moths. II. Bioassays of synthetic plant volatiles as attractants for the adults of the cotton bollworm, *Helicoverpa armigera* (Hübner) (Lepidoptera: Noctuidae).30.Australian Journal of Entomology. 2010;49:21-30.
23. Giblin-Davis RM. Borers. In: Howard, F.W., Moore, D., Giblin-Davis, R.M. and Abad, R. Insects on Palms. CABI Publishing, London; c2001. p. 267-304.
24. Giblin-Davis RM, Faleiro RJ, Jacas JA, Peña EJ, Vidyasagar PSPV. Biology and Management of the Red Palm Weevil, *Rhynchophorus ferrugineus*, CAB International 2013. Potential Invasive Pests of Agricultural Crops (ed. J. Peña); c2014.
25. Gonzalez F, Kharrat S, Rodríguez C, Calvo C, Oehlschlager AC. Red palm weevil (*Rhynchophorus ferrugineus* Olivier): Recent advances. Arab Journal of Plant Protection. 2019;37(2):178-187. http://dx.doi.org/10.22268/AJPP-037.2.178187
26. Hamedi A, Mohagheghzadeh A, Rivaz S. Preliminary pharmacognostic evaluation and volatile constituent analysis of spathe of *Phoenix dactylifera* L. (Tarooneh), Pharmacog. J. 2013;5:83-86.
27. Ibrahim SS, El gendy AA, Omer EA. Identification and Evaluation of Cotton and Tomato Plant Volatiles as Attractants for Certain Lepidopterous Insect Pests, J Plant Prot. and Path., Mansoura Univ. 2018;9(2):65-71.
28. Ibrahim SS, Eldeeb YA, Elsayed A Omer, Rasha Fouad, El Gendy AG. Field Study for Control Insect Pests by Innovation Formulated of Essential Oil. Journal of Plant Protection and Pathology. 2022;13(12):311-318.
29. Lee Seung-Joo, Umano Katumi, Shibamoto Takayuki, Lee Kwang-Geun. Identification of Volatile Components in Basil (*Ocimum basilicum* L.) and Thyme Leaves (*Thymus vulgaris* L.) and Their Antioxidant Properties. Food Chemistry. 2005;91:131-137. doi:10.1016/j.foodchem.2004.05.056 (https://doi.org/10.1016%2Fj.foodchem.2004.05.056).
30. Murphy ST, Briscoe BR. The red palm weevil as an alien invasive: Biology and the prospects for biological control as a component of IPM. Biocontrol News and Information. 1999;20(1):35-46.
31. Nasser RA, Salem MZM, Hiziroglu S, Al-Mefarrej HA, Mohareb AS, Alam M, Aref IM. Chemical Analysis of Different Parts of Date Palm (*Phoenix dactylifera* L.) Using Ultimate, Proximate and Thermo-Gravimetric Techniques for Energy Production, Energies. 2016;9:374.
32. SAS Institute Inc. SAS/STAT Software. Changes and Enhancements through Release 6.12.SAS Institute Inc., Cary, North Carolina; c1996.
33. Said I, Tauban D, Renou M, Mori K, Rochat D. Structure and function of the antennal sensilla of the palm weevil *Rhynchophorus palmarum* (Coleoptera, Curculionidae). J Ins Physio. 2003;49(9):857-872.
34. Sharaby A, Al-Dosary M. An Electric Air Flow Olfactometer and the Olfactory Response of *Rhynchophorus ferrugineus* Weevil to Some Volatile Compounds Journal of Agriculture and Ecology Research International. 2014;1(1):40-50.
35. Soomro HM, Mari JM, Nizamani AI, Gilal AA. Performance of Ferrolure+ pheromone in the red palm weevil, *Rhynchophorus ferrugineus* (Coleoptera: Dryophthoridae) management in date palm growing areas of Sindh, Pakistan, Journal of the Saudi Society of Agricultural Sciences. 2021;21:114-124.
36. Vacas S, Abad-Payá M, Primo J, Navarro-Llopis V. Identification of pheromone synergists for *Rhynchophorus ferrugineus* trapping systems from Phoenix canariensis palm volatiles. J Agric Food Chem. 2014;62:6053-6064.
37. Vidyasagar P, Aldosari AS. Role of food and Kairomone in trapping of adult weevils of Red Palm Weevil, *Rhynchophorus ferrugineus* in date palm orchards, Conference: 95th ESA Annual Convention; c2010.
38. Venugopal V, Kesavan S. Olfactory response of red palm weevil, *Rhynchophorus ferrugineus* (Olivier) (Coleoptera: Dryophthoridae), to host / food volatiles Journal of Plantation Crops 2019;47(1):41-47.
39. Wilfried S, Rachel DR, Efraim L. Biosynthesis of plant-derived flavor compounds, Plant J Cell Mol. Biol. 2010;54(4):712-732.
40. Zheljazkov VD, Astatkie T, Schlegel V, Hydrodistillation extraction time effect on essential oil yield, composition, and bioactivity of coriander oil (https://doi.org/10.5650%2Fjos.ess14014). Journal of Oleo Science. 2014;63(9):857-65. Doi:10.5650/jos.ess14014 (https://doi.org/10.5650%2Fjos.ess14014). PMID 25132088 (https://pubmed.ncbi.nlm.nih.gov/25132088).