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EFFECT OF TRAP COLOUR AND TRAP HEIGHT ABOVE THE GROUND ON PHEROMONE MASS-TRAPPING OF THE RED PALM WEEVIL *RHYNCHOPHORUS FERRUGINEUS* (COLEOPTERA: DRYOPHTHORIDAE) IN DATE PALM GROVES IN ABU DHABI, U.A.E.

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Abstract: The Red Palm Weevil (RPW) *Rhynchophorus ferrugineus* (Olivier) is one of the most destructive insect pests of palm trees in the Old World. In the United Arab Emirates it appeared in 1985, attacking date palms. Mass-trapping with male aggregation pheromone traps was used in date palm plantations in Abu Dhabi, U.A.E., from November 2008 through to July 2009. The goal was to see what combination of trap colour/height was best at collecting the weevils.

Five palm plots and 40 traps (8 per plot) were used in the trials. Traps were either red or white, placed at ground level, 0.5 m, 1.0 m and 1.5 m. 5,478 weevils were collected. Red traps attracted more weevils (61.34%, 3,360 captures) than white ones (38.66%, 2,118 captures). The Wilcoxon statistical test showed significant differences in the number of captures grouped by trap colour in all cases. Male/female ratio for captures was reported to be 1/ 2.12. Trap height showed no statistical significance (except for red traps placed at heights of 0.5 m and 1.5 m), therefore no specific height could be determined as the best option for either red or white traps.
Key words: Coleoptera, Dryophthoridae, *Rhynchophorus ferrugineus, Phoenix dactylifera,* pest control, mass-trapping, pheromone traps, Abu Dhabi.

Efecto del color de las trampas y su altura respecto al suelo en el trampeo masivo con feromonas del picudo rojo *Rhynchophorus ferrugineus* (Coleoptera: Dryophthoridae) en palmerales de Abu Dhabi, E.A.U

Resumen: El picudo rojo *Rhynchophorus ferrugineus* (Olivier) es una de las plagas de insecto más destructivas para las palmeras del Viejo Mundo. En los Emiratos Árabes Unidos apareció en 1985 atacando palmeras datileras. Se realizó trampeo masivo en plantaciones de palmera datilera de Abu Dhabi, E.A.U., con trampas de feromonas de agregación masculinas, de noviembre de 2008 a julio de 2009. El objetivo era ver qué combinación de color/altura de trampa era la ideal para colectar los gorgojos.

Se colocaron 40 trampas en cinco parcelas (8 por parcela). Las trampas eran rojas o blancas, y se situaron al nivel del suelo, a 0,5 m, 1,0 m y 1,5 m de altura. Se recogieron 5478 gorgojos. Las trampas rojas atrajeron más ejemplares (61,34%, 3360 capturas) que las blancas (38,66%, 2118 capturas). El test estadístico de Wilcoxon mostró diferencias significativas, en todos los casos, en el número de capturas según el color de las trampas. La ratio macho/hembra resultó ser de 1/ 2.12. La altura de las trampas respecto al suelo no resultó estadísticamente significativa (exceptuando las trampas rojassituadas a 0,5 m y 1,5 m), y por lo tanto no se pudo estimar una altura óptima para ninguno de los dos colores de trampa.
Palabras clave: Coleoptera, Dryophthoridae, *Rhynchophorus ferrugineus, Phoenix dactylifera,* control de plagas, trampeo masivo, trampas de feromonas, Abu Dhabi.

Introduction

The Red Palm Weevil, *Rhynchophorus ferrugineus* (Olivier, 1790) (Coleoptera: Dryophthoridae), is one of the most destructive insect pests of coconut palm *Cocos nucifera* L. 1753, in South and Southeast Asia (Sivapragasam *et al*., 1990; Sadakathullah, 1991), its larvae being concealed tissue borers (Faleiro *et al*., 1998; Faleiro & Satarkar, 2003a,b). According to Wattanapongsiri (1966) this weevil was perhaps first found on sago palm, *Metroxylon sagu* Rottboell, 1783, in Ceylon (present day Shri Lanka) by Georg Eberhard Rumpf (1750), who also first described and figured the larva, cocoon and dorsal and ventral views of the adults. However the name given to it (*Cossus saguarios*) was not valid according to the International Commission on Zoological Nomenclature. The weevil was later described as *Curculio ferrugineus* by Guillaume-Antoine Olivier (1790), and this species name has been used since. Shortly after the German naturalist and entomologist Johann Friedrich Wilhelm Herbst (1795) described the genus *Rhynchophorus* and adscribed the species *ferrugineus* to it.

It was first mentioned as a pest of date palm, *Phoenix dactylifera* (L., 1734) from the Indian Punjab (Lal, 1917); in this country Lefroy (1906) first reported it as a pest of coconut palm.

Buxton (1920) noted this weevil as causing serious damage to date palm in Mesopotamia (Iraq) but according to Hallett *et al*. (1999) it was mostly during the 1990s that multiple introductions to the Middle East from Pakistan and India occurred. As a result the Red Palm Weevil became a serious pest of date palms in the Arab Gulf States (Bokhari & Abuzuhari, 1992) and Egypt (Cox, 1993).

The Red Palm Weevil was first reported from the United Arab Emirates in 1985 (El-Ezaby, 1997) and from the Kingdom of Saudi Arabia (Al Qatif region) in 1987 (Abraham & Vidyasagar, 1992). In both countries it soon spread to almost all date producing areas becoming a major pest of date palms (Bokhari & Abuzuhari, 1992; Abraham *et al*., 1998, 2000, 2002; Al-Saoud, 2006, 2011; Al-Saoud *et al*., 2010).

In Saudi Arabia initial attempts to control this weevil using insecticides were not successful (Bokhari & Abuzuhari, 1992). Therefore since 1994 an Integrated Pest Management (IPM) strategy based on that used in India for coconut palms was implemented in the Kingdom for date palms. According to Abraham *et al*. (1998) such a strategy successfully suppressed the pest in the date plantations of Saudi Arabia, being the use of pheromone traps the major component of it. Based on those results an IPM strategy similar to that used in Saudi Arabia was established in the U.A.E. with pheromone traps playing a major role. Aggregation pheromone traps are the main component of any IPM programme; these traps attract both male and female weevils (Abraham *et al*., 1998; Oehlschlager, 1998; Abraham *et al*., 2001; Oehlschlager *et al*., 2002; Al-Saoud, 2006, 2007, 2011, 2009b; Al-Saoud *et al*., 2010).

It is generally accepted that pheromone trapping along with other components of the IPM strategy contributes in hindering the buildup of the pest. For instance, in Al-Hassa (Saudi Arabia) the total number of weevils trapped during 1997 decreased to 3,806 as compared to 5,308 and 5,533 weevils captured during 1995 and 1996, respectively (Abraham *et al*., 1998). In this context it is relevant to point out that Oehlschlager *et al*. (1995) obtained over 90 per cent reduction in weevil captures of *Rhynchophorus palmarum* (L., 1758) after two years of pheromone trapping in oil palm plantations of Costa Rica; there the captures were female dominated too.

Trap efficacy of any Red Palm Weevil trap is affected by many factors: trap color (Hallett *et al*., 1999; Abdallah & Al-Khatri, 2005; Al-Saoud *et al*., 2010), pheromone type, trap structure, food bait, and trap sites (Hallett *et al*., 1999; Faleiro, 2004; Al-Saoud, 2011). The purpose of the present study was to evaluate the efficacy of pheromone traps at collecting weevils according to trap site location above the ground and trap color. Trials were carried out within date palm plantations in Al-Rahba (Abu Dhabi), U.A.E.

Materials and methods

The experimental trial was conducted at five date palm plots at Al-Rahba, Abu Dhabi (U.A.E.), 2.9 hectares each, from November 20, 2008 through July 31, 2009. The plots contained palms of different ages (6-25 years), their total numbers being 155, 216, 137, 165, 200 respectively; all together 873 trees (mean = 175 trees). No IPM practices for Red Palm Weevil management had ever been implemented in these plots.

The period studied (November to July, 253 days) was chosen because it includes the part of the season when Red Palm Weevil adults are more active and reach population peaks, so it was expected this would increase weevil captures and provide sounder results.

The pheromone traps

Ten-liter capacity, high density polyethylene, bucket-like pheromone traps were used. Four rectangular (3 cm x 7 cm) windows were cut equidistantly below the upper rim of the bucket, at 16 cm from the bottom; four more similar windows were cut atop on the bucket lid. To help the beetles climb and enter the trap, the buckets had a rough external surface. Two trap colors were used: white and red (Figure 1).

To attract the beetles each trap contained the following materials: (i) dispenser for Red Palm Weevil male aggregation pheromone (Ferrolure^{TM}) containing 700 mg of the active ingredient (4-Methyl-5-Nonanol 90% + 4-Methyl-5-Nonanone 10%) at 95% purity, (ii) 350 grams of fodder date fruits and (iii) 5 Liters of water. The dispenser was hung of the lid with a wire. The fodder was used to increase the traps attractive power acting as food bait. Finally 5 liters water were added so that the water level reached up to 4-5 cm below the cut side windows (Figure 1).

Eight traps were set per plot (one replicate), numbered 1 through 8, inter-trap distance was about 50 m (Figure 2); therefore 40 traps were set in the five plots (five replicates) together. They were attached to the palm trunks with nylon thread. The water was replenished weekly to keep sufficient moisture in the traps. Monthly the traps were cleaned and the food bait (dates) changed. New pheromone dispensers were added to the buckets every 45 days during the cold period (November-April) and every 30 days during the warm period (May-July). Dispensers already used were not removed, so they stayed in the buckets together with newly added ones (see Figure 1).

Weevils were removed from the traps weekly and their numbers/sexes recorded. After removal of the weevils the trap content was shaken well to help prevent growth of any fungi/mold. To avoid a location effect all traps were shifted weekly to its neighbor site, in a rotary manner.

The plots

Figure 2 is a satellite photo showing the layout of the farms at Al-Rahba, Abu Dhabi, as well as the five plots (numbered 1 to 5) where the trials were carried out. Each white-edged square (11.6 ha) in the center of the photo is delimited by road trails and contains four farms, *ca.* 2.9 hectares each. Within the squares spiky wire meshes delimit the boundaries among farms.

Typically, in these farms palm trees are planted in two rows surrounding the farm edges as well as on both sides of an internal farm track used to service the farm (Figure 3). Generally fodder crops and vegetables are grown in the interior areas as shown in Figure 4 which illustrates experimental farm number 5.

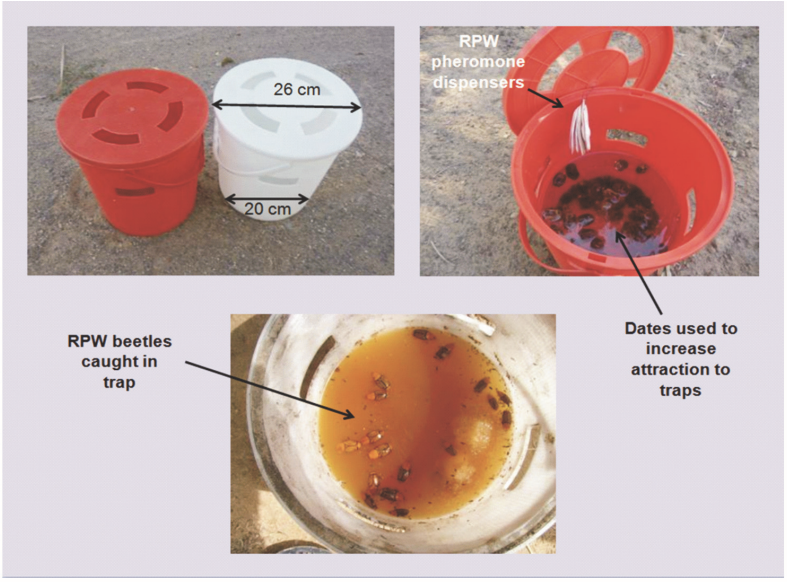
Experimental Design

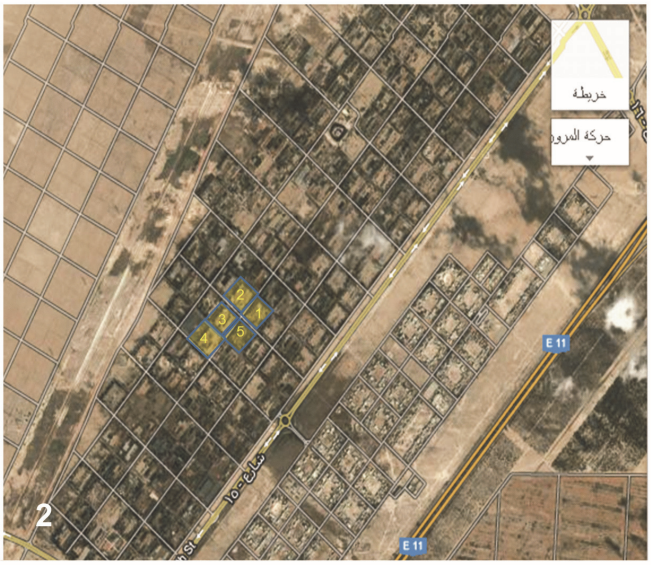
The experimental design was a randomized complete block design with two variables. (i) Trap color, with two options: white and red, (ii) location of the trap above the ground in meters (set on old palm trunks), with four options: 0.0 m (trap on ground level), 0.5 m, 1.0 m and 1.5 m. Figure 5 shows one of those traps (white) with its bottom set at 0.5 m above the ground. Therefore this design implied eight combinations per plot and five replicates (since five plots were used with the same combinations). Within the plots the distance between traps was about 50 m.

Statistical analyses

Captured weevils according to trap color, trap height and sex, i.e. three variables, were independently tested. Considering the small amount of the different kind of samples tested, the nonparametric Wilcoxon Rank Sum test was chosen to study sex and trap color variables.

The distribution of captures by trap height was previously analyzed with Shapiro-Wilk test to determine normality degree. In this case the ANOVA test was performed to check for statistical significance.





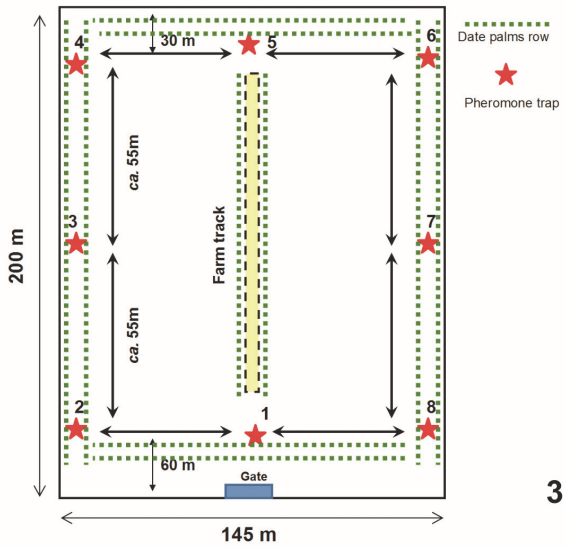
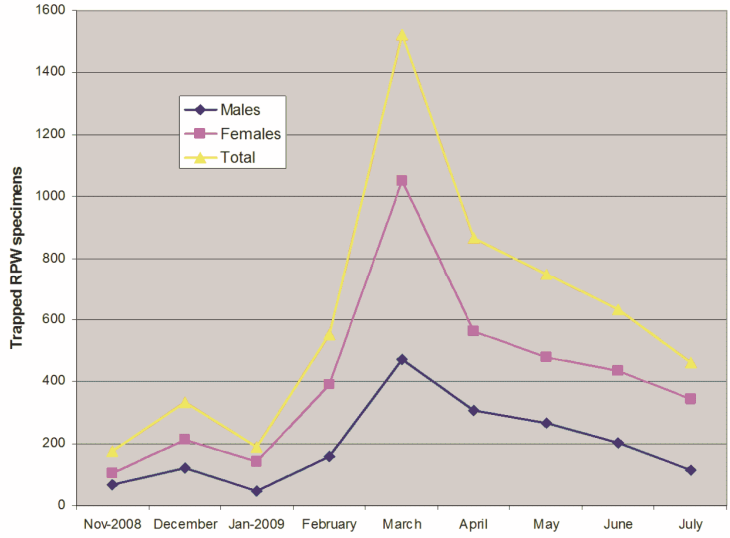


Fig. 1 (Top left) Bucket-like pheromone traps used in the trials; traps were either red or white. (Top right) Bucket showing red palm weevil male aggregation pheromone dispensers hanging from the lid and date fodder placed in the water where weevils will drown after entering the trap. (Bottom) red palm weevil beetles caught and drowned in trap. **Fig. 2** Farms layout at Al-Rahba Abu Dhabi and the five farms (experimental plots numbered 1 to 5) where the trials were carried out. **Fig. 3** One of the five 2.9 Ha plots at Al-Rahba (U.A.E.). Red stars indicate the sites for the pheromone traps; green dots mean date palm rows. **Fig. 4** Experimental farm number 5 at Al-Rahba (U.A.E.). **Fig. 5** One of the pheromone traps used (this white colored) with its bottom set at 0.5 m above the ground



◄ **Fig. 6** Seasonality of *R. ferrugineus* at Al-Rahba (Abu Dhabi) U.A.E. from November 20th 2008 to July 31st 2009. Data pooled for all 40 traps used

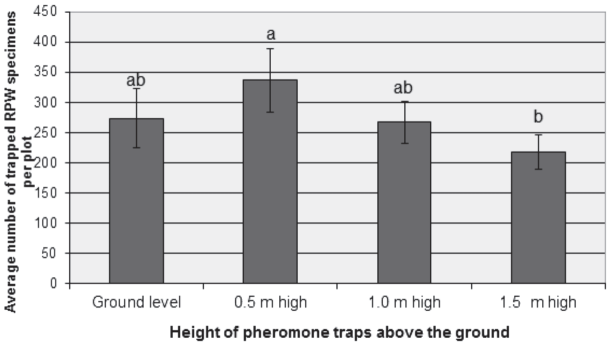


Fig. 7 Effect of trap height above the ground on the captures of *R. ferrugineus* at Al-Rahba (Abu Dhabi) U.A.E. from November 20th 2008 to July 31st 2009. Same letters on top of columns indicate that there are no statistically significant differences between treatments according to Tukey test.

To study the importance of trap height above the ground in captures conditioned by trap color, the Shapiro-Wilk test was used to determine normality. To confirm significant differences, one-way ANOVA and Krustal-Wallis tests were performed independently over red and white trap captures. Post-hoc Tukey test was performed to determine differences between trap captures at different heights.

All statistical analyses were performed using R version 2.15.0 statistical data treatment software.

Results and Discussion

Red Palm Weevil monthly captures (male, female and total) pooling together the 40 pheromone traps set in the five plots studied are shown in Figure 6, from November 20th 2008 through July 31st 2009. There is a clear peak in March and April, when the capture rate weevil / trap / month was 38.1 and 21.7 respectively. From December to February the rates were 8.3, 4.8 and 13.8 and from May to July 18.7, 15.9 and 11.5 respectively. This seasonality coincides with that reported by Al-Saoud (2004, 2006, 2009b) and Al-Saoud *et al.* (2010) in the U.A.E., and by Abraham *et al.* (1999) and Vidyasagar *et al.* (2000) in Saudi Arabia. Abraham *et al.* (1999) also reported that in some years the peaks were two; for instance, in 1996 these fell in May/July and October whereas in 1997 they fell in May and September.

In the Abu Dhabi area Red Palm Weevil adults could be found on the wing during the whole period studied so, unlike in Europe where there is a winter break, in U.A.E. and Saudi Arabia control measures are needed throughout the year. Such control, if chemical, is difficult to implement since farmers stop using pesticides on their date palms for two periods each season:

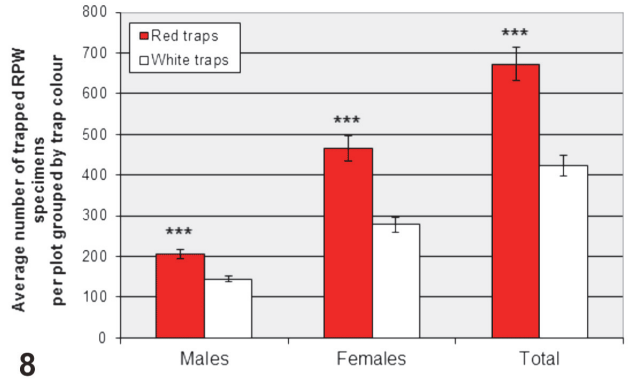
(i) During date palm flowering (generally from February through the end of March, although this differs according to the palm variety); during this period Red Palm Weevil adult activity is at its maximum peak.

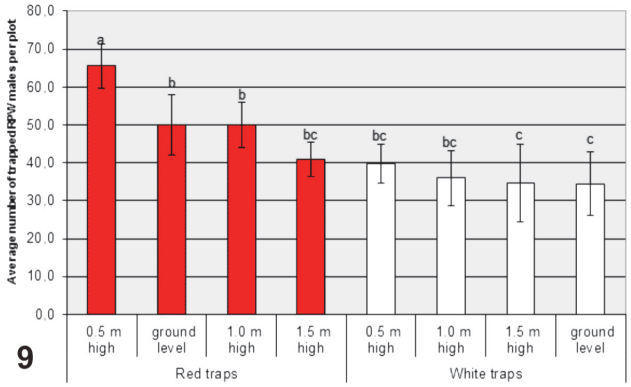
(ii) From June until harvesting the date -which depends on the varieties but it generally goes from August-September (early ones) to October- November (late ones).

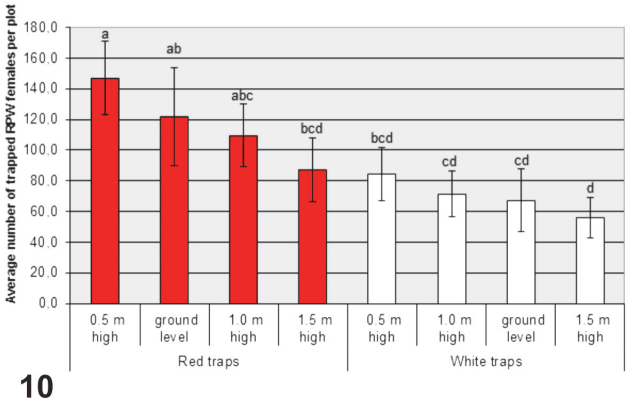
Results show that the sex ratio (male:female) was 1: 2.12 (based on a total 5,478 specimens), i. e. females caught in the traps more than doubled males. Wilcoxon statistical test showed significant differences in captured weevils grouped by sex (W= 6400; p-value < 0.001). In the Middle East as well as in India the sex ratio of weevil captures was reported to be female dominated in aggregation pheromone traps (Abraham *et al.*, 1999; Faleiro, 2000; Faleiro & Rangnekar, 2000; Faleiro & Satarkar, 2003a; Al-Saoud, 2004, 2006 2009b; Al-Saoud *et al.*, 2010). In nature, male to female population was reported as 1: 1.32 (Nirula, 1956), while Abraham *et al.* (1999) found in Saudi Arabia that this ratio varied from 1: 2.35 to 1: 3.06, with an overall average of 1: 2.68 in favour of females (based on weevil collections done in different operational areas between mid-1994 and December 1997). In U.A.E. Al-Saoud (2006, 2007, 2009b) reported sex ratios varying from 1: 1.33 to 1: 2.20.

How the height above the ground of the set traps affected Red Palm Weevil captures is shown in Figure 7. As mentioned above traps, excluding those at ground level, were hung attached to date palm trunks. Statistical analysis for trap height vs. Red Palm Weevil captures included an initial Shapiro-Wilk test to check on data distribution, showing captures grouped by trap height distributed close to normality (W= 0.9778; p-value = 0.9032). Therefore, considering a near normal distribution, significant differences in captures were confirmed through one-way ANOVA test (F = 6.758; df = 3.16; p-value < 0.01). However, Tukey test results reported no significant differences in captures between 0 m, 0.5 m and 1 m trap height groups, neither between 0.5 m, 1 m and 1.5 m groups. Only captures at 0.5 m (30.72%; 1,683 weevils) and 1.5 m (19.95%; 1,093) showed significant differences. Therefore, statistically, we cannot determine that there is a specific height with more reported captures than the rest.

In India Faleiro (2004) obtained the best results on 1 m high traps (attached to coconut and date palm trunks). In West Java, Indonesia, Hallett *et al.* (1999) placed traps at ground level, 2, 5, and 10 m above ground, attaching them to coconut palms. Those at ground level caught significantly more weevils than at 5 m high, while those at 2 m were intermediate in effectiveness between those at ground level and at 5 m high; traps at 10 m caught no weevils.







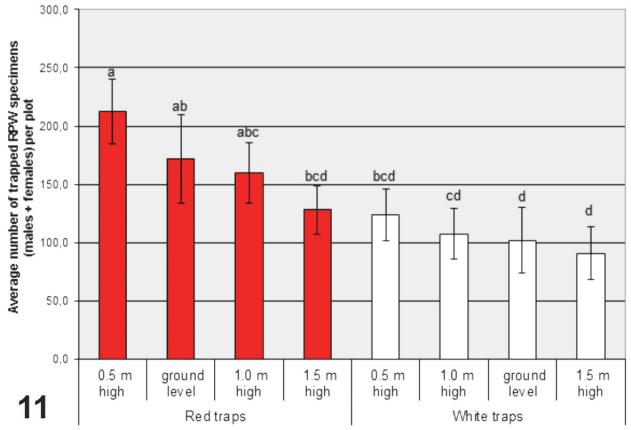


Fig. 8 Effect of trap color on the captures of *R. ferrugineus* at Al-Rahba (Abu Dhabi) U.A.E. from November 20th 2008 to July 31st 2009. Symbols according to Wilcoxon test: "***" P value < 0.001; "**"P value < 0.01; "*"P value < 0.1; "." P value < 0.5. **Fig. 9** Effect of combined trap color and height of trap above the ground on the captures of *R. ferrugineus* males at Al-Rahba (Abu Dhabi) U.A.E. from November 20th 2008 to July 31st 2009. Same letters on top of columns indicate that there are no statistically significant differences between treatments according to Tukey test. **Fig. 10** Effect of combined trap color and height of trap above the ground on the captures of *R. ferrugineus* females at Al-Rahba (Abu Dhabi) U.A.E. from November 20th 2008 to July 31st 2009. Same letters on top of columns indicate that there are no statistically significant differences between treatments according to Tukey test. **Fig. 11** Effect of combined trap color and height of trap above the ground on the captures of *R. ferrugineus* specimens (males + females) at Al-Rahba (Abu Dhabi) U.A.E. from November 20th 2008 to July 31st 2009. Same letters on top of columns indicate that there are no statistically significant differences between treatments according to Tukey test.

In order to minimize infestations of date palms as a collateral effect of pheromone traps being placed in palm groves, Al-Saoud (2004, 2006) suggested setting the traps 3-4 m away from the closest palm tree and buried 12-15 cm deep in the sand. However when comparing traps set as indicated above to traps set 1 m high on date palm trunks, Al-Saoud (2011, 2009a) obtained better results with the latter ones. However, our results shown in figure 7 conclude that pheromone traps to collect Red Palm Weevil do not yield statistically different number of captures when placed on the ground than at different heights above the ground. To our experience Red Palm Weevil prefers attacking date palms aged 5-15 years, so old palms (>20 years) were chosen to hang the traps.

How the color of the traps, either red or white, affected Red Palm Weevil captures is shown in Figure 8. The red traps were more effective at collecting weevils (61.34%, 3,360) than the white ones (38.66%, 2,118). In this case Wilcoxon statistical test showed significant differences in the number of captures grouped by trap color in all cases, i.e. when adding together male plus female captures (W= 361; p-value < 0.001) or for only male captures (W= 757.5; p-value < 0.001) or for only female captures (W= 361; p-value < 0.001). In the Sultanate of Oman Abdallah & Al-Khatri (2005) obtained similar results. In the U.A.E., until 2010 only white and yellow traps had been used; red traps started being widely used since Al-Saoud *et al*. (2010) reported them as more efficient at collecting weevils. Faleiro (2005), though, in Indian coconut palm groves, found no significant differences in captures by different colored traps.

How Red Palm Weevil male captures distributed among the eight possible treatments or combinations (trap color and its position relative to ground level) is shown in Figure 9. Red traps set at 0.5 m recorded the maximum captures of males (328, 18.67%) whereas red traps at other heights did not report statistical differences in captures. For male capture in white traps there were no differences in captures at any height. Figure 10 shows female captures. Red traps reported no specific height with more female captures than the rest, as only captures between 0.5 m and 1.5 m red traps reported significant differences. Female captures in white traps did not show differences at any specific height. Results differ from those reported by Al-Saoud *et al*. (2010) in a previous study carried out in the same area.

Total red trap captures (males plus females) grouped by trap height were tested with distribution-shape Shapiro-Wilk test, showing acceptable normality (W = 0.9487; p-value = 0.3474). Later significant differences were confirmed with two different tests: one-way ANOVA test (F = 7.287; df = 3.16; p-value < 0.005) and nonparametric Krustal-Wallis test (chi-squared = 11.2998; df = 3; p-value < 0.05).

When combining male plus female captures and looking at the overall distribution among the eight possible combinations mentioned above we obtain the results shown in Figure 11. In this case to analyze trap height influence by trap color, the number of caught weevils in red and white traps were separated and then grouped by trap height. Statistically, no specific trap height captured more weevils for red traps. Only captures in red traps at 0.5m (1,063, 19.41%) and 1.5 m (640, 11.68%) showed significant differences between them, although any other height combination reported to be non-significant.

White trap captures also showed acceptable normality in Shapiro-Wilk test (W = 0.9657; p-value = 0.6648), and both ANOVA and Kruskal-Wallis tests were used. Again, results in Figure 11 confirmed there are no significant differences in captures by height for white traps (one –way ANOVA test (F = 1.660; df = 3, 8.851; p-value = 0.2449) and Krustal-Wallis test (chi-squared = 4.4185; df = 3; p-value =0.2197)).

In sum results conclude that red aggregation pheromone traps attached to old date palm trunks are better option than white traps for mass–trapping Red Palm Weevil specimens (either males or females) in infested palm groves, but it remains unclear the best trap height option to maximize captures. In the U.A.E. this should be done all over the year, in properly and regularly maintained traps.

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