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Effect of date palm cultivar on fecundity and development of *Rhynchophorus ferrugineus*

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Abstract

The reproductive behavior and development of red palm weevil *Rhynchophorus ferrugineus* (Olivier) (Coleoptera Dryophthoridae) was studied in laboratory by rearing it on five popular date palm cultivars, viz., 'Barhi', 'Beraim', 'Ruthana', 'Sukkary' and 'Wannana', and sugarcane with an objective to determine the host-plant effects. Observations were made on the number and rate of eggs laid, incubation period, hatching percentage, larval and pupal developmental periods, adult longevity and sex ratio. The cultivars 'Sukkari', 'Ruthana' and 'Barhi' favored oviposition and development of red palm weevil comparatively. The 'Ruthana' cultivar recorded highest number of eggs / female (392.50 ± 1.558 eggs) at the highest rate (4.17 ± 0.021 eggs / female / day), the longest pupal developmental period (19.30 ± 0.259 days) and the strongest female bias in the sex-ratio (56:48 per cent). The 'Sukkary' cultivar showed longest male (111.20 ± 1.426 days) and female (120.80 ± 0.188 days) lifespan, fastest completion of larval period (29.66 ± 0.132 days) and highest (96%) egg-hatching percentage. Adults from 'Barhi' recorded second longest (male 104.10 ± 0.883 and female 98.90 ± 0.613 days, respectively) lifespan. On the other hand, 'Beraim' and 'Wanana' cultivars showed developmental delay in the lifecycle of red palm weevil. Both the cultivars showed lowest egg-hatching percentage (92%), the lowest adult longevities (less than 81 days), lowest egg-laying (less than 240 eggs) in a lifetime and longest duration of immature stages (over 70 days). The observations from sugarcane revealed lower oviposition and hatching percentage, and longer period for adult emergence than the date palm cultivars.

Key words: red palm weevil, oviposition, hatchability, larval duration, pupal duration, incubation period, sex ratio, adult longevity.

Introduction

The date fruit is the most important agricultural edible commodity of Saudi Arabia in terms of both, commerce and culture. The production from the Kingdom for the year 2012-2013 was 1.05 million tons (FAO, 2013). Saudi Arabia has a rich genetic diversity of date palm with over 400 known cultivars (Anonymous, 2006) and a tree base of over 23 million date palms *Phoenix dactylifera* L. (Arecales Arecaceae) (Alhudaib *et al*., 2007). More than 6 million trees are in the Qassim region alone (Hurst, 2012) which is famous for a date fruit cultivar called 'Sukkary', though the region also produces fruits of other cultivars like 'Ruthana', 'Barhi', 'Beraim' and 'Wannana'. The Red Palm Weevil (RPW), *Rhynchophorus ferrugineus* (Olivier) (Coleoptera Dryophthoridae), which is the most devastating invasive pest of the date palm tree, has spread swiftly in the Qassim region. In the year 2009 RPW was reported from only three farms but now the number has reached to over four hundred (Aldosari S. A., unpublished data). Nationally, apart from Qassim region, this pest has a threatening presence in most of the date palm growing regions of the country. Globally, this pest has a wide distribution from Asia, Africa, North America, Central America and Carribean, Europe and Oceania (Giblin-Davis *et al*., 2013; CABI, 2015). With the increased geographic presence, the host range of RPW has been reportedly increased from 19 palm species of 15 genera (Barranco *et al*., 2000; EPPO/OEPP, 2008) to 40 palm species of 23 genera (Anonymous, 2013). Nearly all the Arecaceae species are reported to be potentially infested by the weevil (Vidyasagar and Keshava, 1991). Many probable reasons of rapid proliferation of this pest particularly in the middle-east include, leaving exposed tree tissue untreated after off-shoot removal (Azam *et al*., 2000) and transplantations of infested off-shoots (Abraham *et al*., 1998) in new areas. However, agroclimatic conditions of the middle-east region and ill-informed farming practices including sanitary and irrigation procedures have also majorly contributed to the rapid establishment of RPW in this region (Abraham *et al*., 1998).

The larval feeding within the tree trunk causes extensive damage to the vascular system. The larvae bore into the internal date palm tissues and eventually cause collapse and death of the date palm tree (Abraham *et al*. 1998). The weevil is multivoltine and several generations and all the life-stages have been observed within the same host plant (Rajamanickam *et al*., 1995; Faghih, 1996). The boring by the larvae is not directional and therefore consequent formation of the tunnels is haphazard (Gomez and Ferry, 1998; Martin and Cabello, 2005). The adults may feed and further reproduce inside the host or may leave the current host to scout for another as a survival tactic. The cryptic nature of this pest poses biggest management challenge as it is often late to detect the infestation before the tree has been damaged fatally (Kranz *et al*., 1982; Abraham *et al*., 1998; Gomez and Ferry, 1998).

The biology of RPW has been studied extensively (Wattanapongsiri, 1966; Kalshoven, 1981; Abraham *et*

al., 1998; Faghih, 1996; Murphy and Briscoe, 1999; Esteban-Duran *et al*., 1998; Ramachandran, 1998; Farazmand *et al*., 2000; Abdel-Azim *et al*., 2012). The life cycle of laboratory-reared RPW was reported on date palm trunks (El-Ezaby, 1997; Aldhafer *et al*., 1998) and date palm stem bolts (Aldawood and Rasool, 2011). However, little is known about its biological characteristics and especially the effects of host plants on its development and reproduction. Quality of host plant tissue may significantly affect biological characteristics of insects including feeding behavior of immature stages and their consequent development, reproductive ability and longevity of adults, and cause modulation of oviposition clutch and site by female adults (Leather, 1990; Rossiter *et al*., 1991; Albert and Bauce, 1994; Dodds *et al*., 1996; Tammaru, 1998; Awmack and Leather, 2002). Host plants may exert their resistance effects constitutively (genetically inherited) or they can be induced (defense response) to produce resistance factors after the pest attack. Farazmand (2002) compared five date palm cultivars in Iran for susceptibility to RPW infestation and found 'Mazafati' cultivar to be the most preferred host by the pest due to higher sugar content. In another study with an aim to formulate an artificial diet for mass-rearing RPW, 'Sukkary' out of four date palm cultivars was found to be ideal due to its support for the larval feeding, survival and development, adult longevity and reproductive ability (Al-Ayedh, 2008). Unlike the two studies mentioned above which did not describe the host plants' effects in terms of resistance, Al-Bagshi *et al*. (2013) reported oviposition preferences in 25 date palm cultivars, whereas, Faleiro *et al*. (2014) have showed resistance mechanisms in seven date palm cultivars. Barranco *et al*. (2000), Dembilio *et al*. (2009) and Ju *et al*. (2011) have described resistance mechanisms in other palm species, whereas recently, like 'Mazafati' and 'Sukkary' mentioned above, the latter group found 'Khalas' as the most susceptible cultivar. The objective of the present study was to determine those cultivars which affected growth, development and reproductive ability of RPW. The influence of selected five popular date palm cultivars of the Qassim region and Saudi Arabia viz., 'Barhi', 'Beraim', 'Ruthana', 'Sukkary', and 'Wannana', and sugarcane as host plants was examined on reproduction and development of RPW under laboratory conditions, including their effect on (1) fecundity, incubation period and egg viability (percentage of egg hatching), (2) larval and pupal developmental periods and, (3) adult longevity and sex ratio. This study was the first in the series to promote use of resistant or less preferred cultivars in the farms with high infestation levels of RPW. Depending upon the observed level of non-preference, the *in vivo* studies will be taken up to confirm the results and discover the factors of resistance.

Materials and methods

Cultivars and sugarcane

Fresh stem pieces of five pesticide-free date palm cultivars ('Barhi', 'Beraim', 'Ruthana', 'Sukkary', and 'Wannana') from Qassim area were harvested from 5-10 years old date palm trees, and were cut into pieces of about 6 cm length × 3 cm width × 2 cm height. The pieces of sugarcane stem (sourced from the local market) of about 2-3 cm diameter were cleaned and cut into 9 cm long bits and were then split longitudinally.

Experimental insects

The larvae of RPW were collected in April, 2012 and brought to laboratory from the infested orchards with known pesticide spraying history in the Qassim region of Saudi Arabia. The collections were made from only those orchards which had no pesticide sprays for the last three months. The culture of RPW was established on sugarcane (*Saccharum officinarum* L.) stems in the rearing room at 27 ± 2 °C and 30-40% RH, with a photoperiod of 12:12 (L:D) h and checked daily for pupation. Two weeks after pupation, cocoons were harvested from the sugarcane stems and incubated individually in round plastic jars (70 mm diameter × 90 mm height) with perforated screw cap and were checked daily for adult emergence.

The emerged adults were collected, sexed, paired and shifted to new round plastic transparent jars (11.5 cm diameter and 9 cm height) covered with muslin cloth, rubber band and perforated caps. Sexing the adults was done according to the presence of tuft of small hairs on dorsal apical region of the short and stout snout in males whereas in females, the snout was without tuft of hairs, smooth, slender, shiny and slightly longer. Adult pairs were introduced into the rearing jar with two host plant stem pieces of specific date palm cultivar or split sugarcane. Each jar was checked daily for the eggs and food pieces were replaced with fresh ones when needed. The eggs were collected and incubated until hatching. Newly emerged larvae were shifted to larval rearing boxes (round plastic transparent jars of 6 cm diameter and 4 cm height covered with perforated caps) individually with each box containing a fresh host plant stem piece. The bigger larvae (fifth and more larval instars) were transferred to bigger jars (11 cm diameter and 7 cm height) and stem pieces were replaced every 4 days until pupation. After emergence, the adults were fed with fresh maternal host plant stem pieces. The eggs from each of the five cultivars and sugarcane food groups were harvested and incubated for hatching.

Treatment

For testing the five cultivars and sugarcane, 33 neonate larvae obtained from each of the six host plant group were shifted to larval rearing jars individually and were provided with the same but fresh host plant stem piece to feed. The stem pieces were replaced with fresh ones when needed and larval and pupal durations were recorded. The newly emerged adults were collected and sexed to determine the sex ratio. The adults were paired and reared on the same host plant stem pieces till death for recording longevity periods. All jars in all treatments were inspected daily for the collection of eggs. The eggs collected from each jar were counted daily for recording fecundity and oviposition rate. 99 eggs (33 in three replicates) in each treatment were subsequently incubated to determine the hatching percentage.

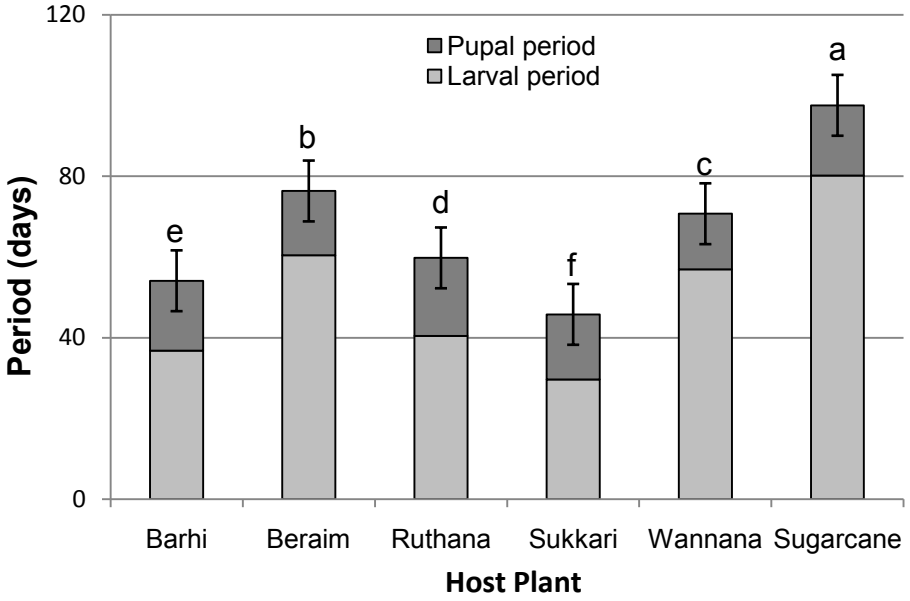

Figure 1. Larval and pupal development periods of *R. ferrugineus* in different date palm cultivars and sugarcane. Columns with the same letter are not significantly different. (df = 5, 197; $P < 0.001$)

Statistical analysis

Results were given as mean ± SE. Data were subjected to statistical analysis using SPSS one-way ANOVA (SPSS, 1999). Means were separated using Tukey's multiple test and the least significant difference (LSD) test at $p = 0.05$. The confidence limit was 95%. The mean differences were considered significant at values $p \leq 0.05$ level.

Results

This study clearly demonstrated that host plants had significant effects on the RPW fecundity, larval and pupal development, sex ratio and adult longevity.

Development periods of immature stages

The 'Sukkary' palm showed most expedited RPW larval development, completing the stage within 30 days ($P < 0.0001$) but lagged behind 'Wannana' and 'Beraim' palm in completing pupal stage, which showed the fastest (13.79 ± 0.329 days) and the second-fastest (15.92 ± 0.296 days) pupal development, respectively (figure 1). The two latter palm cultivars, however, showed slowest larval development amongst all the date palm cultivars included in the study as the larvae took 56.91 ± 0.195 and 60.41 ± 0.289 days to reach pupal stage. The 'Barhi' exhibited 36.82 ± 0.159 days of larval developmental period after 'Sukkary' cultivar but both cultivars showed similar pupal developmental period along with the 'Beraim' cultivar and sugarcane. After 'Barhi', the third fastest larval development was observed in case of 'Ruthana' palm cultivar which, on the other hand, showed slowest pupal development (19.30 ± 0.259 days) amongst all the date palm cultivars and sugarcane. The larvae reared in the sugarcane took over 80 days to enter pupal stage. Overall, the fastest development to adulthood was achieved in case of 'Sukkary' palm cultivar followed by 'Barhi', 'Ruthana', 'Wannana' and 'Beraim' cultivars ($P < 0.0001$). The combined larval and pupal developmental period was the longest in case of sugarcane.

Adult longevity

In general, males of RPW outlived the females in all date palm cultivars except the 'Sukkary' where females lived longer (table 1). The longest male and female

Table 1. Longevity and sex ratio of adult *R. ferrugineus* reared on different cultivars of date palm and sugarcane.

Food type	Adult longevity (days)		Sex ratio %	
	Females	Males	Female	Male
Barhi palm	98.90 ± 0.613 b	104.10 ± 0.883 b	52 ± 0.577 b	48 ± 0.577 b
Beraim palm	74.17 ± 0.440 f	74.70 ± 0.458 d	48 ± 0.577 c	52 ± 0.577 a
Ruthana palm	95.03 ± 0.839 c	102.80 ± 0.655 b	56 ± 0.577 a	44 ± 0.577 c
Sukkari palm	120.80 ± 0.188 a	111.20 ± 1.426 a	55 ± 0.577 a	45 ± 0.577 c
Wannana palm	77.27 ± 0.172 e	80.90 ± 0.246 c	51 ± 0.577 b	49 ± 0.577 b
Sugarcane	85.93 ± 0.862 d	69.20 ± 0.769 e	52 ± 0.577 b	48 ± 0.577 b
F, *P*	506.026, < 0.000	456.256, < 0.000	24.48, < 0.000	24.800, < 0.000

Mean (± SE) in a column of the same variable not followed by the same letter are significantly different at the $P = 0.05$ level (df = 5, 174); Means were separated with Tukey's and LSD tests. (n = 99 for each cultivar and sugarcane).

Table 2. Effect of date palm cultivars and sugarcane on fecundity, oviposition rate, incubation period and egg hatching of *R. ferrugineus*.

Host Plant	Number of eggs laid	Oviposition rate	Incubation period (days)	Eggs hatching (%)
Barhi palm	284.10 ± 6.096 b	2.87 ± 0.044 c	2.20 ± 0.141 b	95 a
Beraim palm	227.50 ± 0.792 d	3.07 ± 0.022 b	2.53 ± 0.198 b	92 b
Ruthana palm	392.50 ± 1.558 a	4.17 ± 0.021 a	2.57 ± 0.105 b	95 a
Sukkari palm	385.20 ± 3.090 a	3.19 ± 0.036 b	2.37 ± 0.097 b	96 a
Wannana palm	242.90 ± 1.574 c	3.14 ± 0.183 b	2.49 ± 0.130 b	92 b
Sugarcane	180.50 ± 1.440 e	2.10 ± 0.025 d	3.30 ± 0.128 a	90 b
F, *P*	830.501, < 0.0001	515.558, < 0.0001	7.663, < 0.0001	16.400, < 0.0001

Mean (± SE) in a column of the same variable not followed by the same letter are significantly different at the $P = 0.05$ level (df = 5, 197); Means were separated with Tukey's and LSD test. For egg hatching n = 99 for each host plant.

adult lifespan was observed in case of the 'Sukkary' palm cultivar. Apart from the 'Sukkary' cultivar, the adults reared on 'Barhi' and 'Ruthana' cultivars also showed over 95 days of lifespan. Amongst the date palm cultivars, the shortest lifespan for both males and females was recorded in case of the 'Beraim' cultivar. The shortest adult lifespan of this study was recorded in case of males from sugarcane.

Sex ratio

The sex ratios were slightly biased towards females in all the date palm cultivars and sugarcane except the 'Beraim' cultivar (table 1). The maximum bias was recorded in the cases of 'Ruthana' and 'Sukkary' cultivars ($P < 0.0001$).

Egg-laying and oviposition rate

The female adults from 'Ruthana' cultivar laid highest number of eggs ($P < 0.001$) and exhibited highest rate of oviposition ($P < 0.001$) closely followed by the ones from 'Sukkary' cultivar (table 2). Amongst the palm cultivars, lowest numbers of eggs were laid by female adults reared on the 'Beraim' palm whereas those reared on the 'Barhi' palm showed lowest fecundity rate. However, the least oviposition and at the lowest rate were recorded from female adults reared on sugarcane.

Incubation period

All the RPW eggs deposited by females reared on date palm cultivars showed similar incubation period, whereas eggs from females reared on sugarcane showed longer egg incubation period (table 2; $P < 0.001$).

Egg hatching (viability)

The eggs laid by females reared on cultivars 'Sukkary', 'Ruthana', and 'Barhi' exhibited higher percentage of hatching (table 2) than the remaining two cultivars. The latter two cultivars, viz. 'Beraim' and 'Wannana', along with sugarcane showed less egg hatching percentage ($P < 0.001$).

Discussion

Fecundity

The host plants included in the present study affected oviposition in RPW significantly. A previous study on date palm cultivars reported similar results but hypothesized that the reason behind increased egg-laying could be due to higher sugar content of the cultivar 'Sukkary' (Al-Ayedh, 2008). The study claimed that the stem of 'Sukkary' cultivar had higher sugar content than 'Khalas', 'Khasab' and 'Sillaj' but the qualitative or quantitative data was not presented. In the present study, compared to 'Sukkary', the 'Ruthana' cultivar showed higher oviposition and fecundity rate by RPW. Also, sugarcane stem which typically yields 10-15% sucrose recorded significantly lower egg-laying and oviposition rate by RPW females than all the five date palm cultivars. Therefore, in addition to the content, sugar type may also affect egg-laying by RPW.

Previously, in case of herbivorous insects including coleopterans, Awmack and Leather (2002) emphasized importance of quality of host-plant fed to both larvae and adults as a key determinant of insect fecundity at both individual and population levels. The host-availability was reported to be of prime importance for monophagous coleopterans which are known to modulate oviposition rate as depicted in case of *Henosepilachna niponica* (Lewis) (Ohgushi, 1995). Such a modulation in accordance with the availability of suitable host (even to the extent of degree of host-suitability) was also observed in case of oligophagous pollen beetle, *Meligethes aeneus* (F.) (Hopkins and Ekbom, 1999). In case of polyphagous coleopterans too, such as red palm weevil, many studies on egg-laying have highlighted the presence and absence of oviposition antixenosis in the plants which otherwise are natural hosts. For example, in a study on 25 date palm cultivars which are natural hosts of RPW, 'Shahal' and 'Ajwa' were reported to be the least and most preferred cultivars, respectively, for oviposition (Al-Bagshi *et al*., 2013). In another study, 'Chowghat dwarf green' and 'Malayan dwarf' coconut cultivars were found to be most and least preferred cultivars, respectively, for oviposition by female adults of RPW (Faleiro and Rangnekar, 2001). Salama *et al*. (2009) in their multiple-host study reported results similar to the present study where highest number of eggs was laid on date palm crown (338 ± 37.24 eggs/female) and lowest on sugarcane (117 ± 18.9 eggs/female). A recent study showed oviposition antixenosis in Silver date palm (*Phoenix sylvestris*) when they reported a significant difference of over 136 eggs from Canary Island date palm (*Phoenix canariensis*) in the average lifetime

fecundity of RPW (Ju *et al*., 2011). Notably, in the present study, the 'Beraim' showed significant oviposition antixenosis as the RPW females laid minimum eggs on it (f = 830.501, P < 0.0001) amongst the five date palm cultivars.

As far as numbers are concerned, in the present study, the mean number of eggs laid by females fed on five different cultivars ranged from minimum 227.5 to maximum 392.5 eggs, whereas females which fed on sugarcane laid 180.5 mean number of eggs. These are comparable to the previous records of 127-276 (Ghosh, 1912), 162-350 (Viado and Bigornia, 1949), 204 (Frohlich and Rodewald, 1970) eggs on coconut palm, and 77-283 (El-Ezaby, 1997) and 338 (Salama *et al*., 2009) eggs on date palm. However, other studies have reported as high as 531 (Leefmans, 1920), and wide ranges such as 355-760 (Nirula, 1956), and 200-500 (Lever, 1969) eggs on coconut palm, and 211-380 (Prabhu and Patil, 2009) and 117 (Salama *et al*., 2009) eggs on sugarcane. The wide variation observed in fecundity could be due to the host plants apart from the differences in mating behavior (Abdel-Azim *et al.* 2012) and rearing temperature (Salama *et al*., 2009; Li *et al*., 2010; Dembilio *et al*., 2012).

Incubation period

Incubation period of eggs ranged between 2.20-2.57 days on the tested cultivars, whereas on sugarcane, the eggs took significantly longer to hatch (3.30 days) which could be due to the residual effect from larval and adult feeding. The results of the present study were in agreement with those of previous studies (El-Muhanna *et al*., 2000; Abdel-salam *et al*., 2008; Prabhu and Patil, 2009). The studies on other host plants reported similar developmental time of eggs of RPW. For example, Murphy and Briscoe (1999) reported an incubation period of 3 to 4 days for natural egg clutches of RPW on coconut palm in India, Indonesia, and Myanmar. A study on Canary Island date palm, Chusan palm (*Trachycarpus fortunei*), Pindo palm (*Butia capitata*), Washington palm (*Washingtonia filifera*) and Silver date palm, egg developmental time of RPW ranging from 3.3 to 3.6 days was reported (Ju *et al*., 2011).

Egg hatching (fertility)

In the present study, the percentage of hatching (viability) of RPW eggs ranged from 90% in case of females reared on sugarcane to 96% on the 'Sukkary' date palm. The other studies which have also reported similar egg-hatching percentage estimates are 87% (Leefmans, 1920) and 86-93% (Viado and Bigornia, 1949) on coconut palm, 65-96% (Aldhafer *et al*., 1998) on date palm and 70-90% (Prabhu and Patil, 2009) on sugarcane. Considering the present study results of the cultivar 'Sukkary', such a high percentage of egg-hatching can lead to faster buildup of the pest population in an agro-ecosystem, such as that of Qassim region, which is devoid of effective natural enemies of RPW.

Duration of immature stages

Amongst the immature stages, larvae are the most damaging stage of this pest's life cycle. But duration of larval development presents a paradox. On one hand, slower development of larvae involves feeding for longer duration and consequent greater damage to the host plant, whereas, on the other hand, faster maturity and successful transition of larvae into pupae results in pests' rapid multiplication within the host and eventually in the agro-ecosystem. The latter situation causes more damage due to higher infestation levels and frequent dispersals. In this study, the larval duration was significantly different in the studied cultivars and was shortest in the cultivars 'Sukkary', 'Barhi', and 'Ruthana'. But notably, the short larval duration in each of these three cultivars corresponded with longest adult life spans observed, thus pointing against paucity of nutrition due to short larval duration which in turn means less feeding time. A direct implication of this finding is that if the farmers intend to grow these cultivars, there is a higher probability of increased damage and spread of the infestation due to relative absence of resistance mechanisms for stopping or slowing-down multiplication of the pest. The quality of host plant tissue has been reported extensively to play an important role in influencing larval development (Leather 1990; Albert and Bauce 1994; Dodds *et al*., 1996; Tammaru, 1998). The larval duration showed high variability in the five cultivars tested in this study, ranging from 30 ('Sukkary') to 60 ('Beraim') and in case of sugarcane, 80 days. This range was lower and less variable than the previous studies which reported a wide range of 60-120 days on coconut (Lever, 1969), 25 to 182 days (Aldafer *et al*., 1998) and 25 to 105 days (Faghih, 1996; Abraham *et al*., 2002) on date palm and as less as only 16-day variability (69-85 days) in date palm trunks (El-Ezaby, 1997). But in comparison with 'Sukkary', 'Barhi' and 'Ruthana' cultivars, the sugarcane, 'Beraim' and 'Wannana' showed lesser larval feeding. Apart from *P. dactylifera*, the mean larval durations during rearing of RPW on Washington palm, Canary Island date palm, Chusan palm, Pindo palm and Silver date palm have been reported to range from 37 to 56 days (Ju *et al*., 2011). The pupal duration in the present study differed significantly despite showing a variation of 6 days amongst the five cultivars and sugarcane (f = 28.362, P < 0.0001). However, in a study on five other palm species (Ju *et al*., 2011), no significant difference was reported in the pupal period of RPW and the variation was of mere 3 days.

Adult longevity and sex ratio

Unlike the paradoxical view discussed above regarding the duration of larval period, the longer lifespan of both males and females of RPW is detrimental to the crop. The longevity of male adults translates into dispersal as they usually scout for food locations and invite their species by producing aggregation pheromone, whereas the female adult longevity translates into re-infestation and spread to newer hosts. It was shown that infested hosts are more likely to be re-infested (Gunawardena and Bandarage, 1995; Murphy and Briscoe, 1999). Amongst the five date palm cultivars tested in the present study, the 'Sukkary' cultivar supported longest lifespan for both the sexes but female adults outlived males in an otherwise males-outliving-females scenario. But the 'Sukkary' cultivar was not an exception to the other cultivars in show-

ing selectivity towards females as a significant bias was observed in the female:male sex ratio of 55:45 per cent, which was bettered only by the cultivar 'Ruthana' (56:44 per cent). In fact, the female bias in the sex-ratio exists in the natural environment also as observed in many field studies (Aldafer *et al*., 1998; Abraham *et al*., 1999; Vidyasagar *et al*., 2000; Abdel-Azim *et al*., 2014, Ávalos and Soto, 2015). On the other hand, the 'Beraim' cultivar recorded significantly lower adult longevity. Intriguingly, in the present study, the adult lifespan of male and female registered a difference of over 9 days on 'Sukkary' cultivar, whereas in case of sugarcane the difference was 15 days. Amongst the various factors influencing developmental periods, the host plants play an important role in causing the wide variation in the adult lifespan. As against the present study on the five date palm cultivars and sugarcane with results of 69 to 111 days and 74 to 121 days of male and female lifespan ranges, respectively, the previous studies on different host plants have reported an adult lifespan of 50-90 days (Ghosh, 1912), 107 days (Leefmans, 1920), 83.6 days for males and 60 days for females (Viado and Bigornia, 1949), 60-90 days for males and 67-113 days for females (Nirula, 1956), 90-120 days (Lever, 1969), and 60-90 days (Frohlich and Rodewald, 1970) on coconut palm, whereas on date palm lifespan ranges of 70-100 days (Abraham and Vidyasagar, 1992), 67-257 days for males and 70-150 days for females (Aldhafer *et al*., 1998) and 74-101 days for females and 76-103 days for males (Abdel-Salam *et al*., 2008) have been reported. On sugarcane, the reported adult longevities, 62-78 days for males and 59-75 days for females (Prabhu and Patil, 2009) were close to results in the present study. The mean longevity of RPW female adults reared on other palm species was reported to be 71 days (Pindo palm), 72 days (Chusan palm), 85 days (Washington palm), 92 days (Canary Island date palm) and 138 days (Silver date palm) (Ju *et al*., 2011).

Conclusion

The 'Sukkary' cultivar was found to be most favorable for development of RPW in this study. This is an alarming result for a region like Qassim in Saudi Arabia which has a major 'Sukkary' cultivar plantation in the country. On the other hand, 'Beraim' and 'Wannana' cultivars deserve further investigations to reveal the factors responsible for providing least facilitation in development and reproduction of RPW. Such investigations to screen date palm cultivars for host plant resistance against RPW will support future research on determining the basis of resistance with the help of both field and laboratory studies. The discovery of host plant resistance factors will pave way for investigation of resistance factors at molecular level.

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