

Effect of Humidity and Soil Type on Survival and Behavior of Red Palm Weevil *Rhynchophorus ferrugineus* (Oliv.) Adults

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تأثير الرطوبة ونوع التربة على حياة وسلوك سوسة النخيل الحمراء

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خلاصة: أجريت هذه الدراسة لتحديد أثر مستويات الرطوبة ونوع التربة على حياة وسلوك سوسة النخيل الحمراء. حيث تؤثر نسبة الرطوبة المحيطة على حياة الحشرات البالغة بشكل كبير. وقد بقيت الحشرة الكاملة حية لمدة 2.5، 39.5، 23.5، 22.5 يوماً عندما تم وضعها في بيئات بدون غذاء متباينة الرطوبة مثل بيتموس جاف وبيتموس رطب وماء على التوالي. بلغ متوسط فقد المائي من جسم الحشرة من الإناث والذكور 54.9% و 55.7% على التوالي وحدث معظم الفقد في اليوميين الأولين من بداية التجربة. وقد سجل فرق معنوي طول فترة عمر الحشرة الكاملة كما لم يكن الوسط المائي عائقاً للتزاوج، فقد استطاعت 50% من الإناث حديثة الخروج من التزاوج في الوسط المائي. وقد تمكنت الحشرات الكاملة من اختراق مستويات تربة مختلفة الرطوبة للإختفاء فيها، إذ كانت أعماق الإختراق 12.6، 5.1، 6.4 سم في كل من البيتوموس الرطب والرمل الرطب والتربة الرطبة على التوالي. كما استطاعت الحشرة استشعار الرطوبة على عمق 22 سم في التربة.

ABSTRACT: Experiments were conducted to study the effect of humidity and soil type on the survival and behavior of red palm weevil (RPW) *Rhynchophorus ferrugineus* (Oliv.) adults. Adult survival was highly influenced by the surrounding moisture content. It was 2.5, 39.5 and 23.5 days when kept in dry peat moss, moist peat moss and tap water, respectively. Total body water loss was 55.7 and 54.9% for females and males, respectively. Most water loss occurred in the first two days. Virgin adults were able to mate in water with 50% of tested females mating successfully. Adults were able to use moist soil as temporary harborage and penetrated through different moist soils. The depth of penetration was 12.6, 5.1 and 6.4 cm in moist peat moss, moist sand and moist loam soils, respectively. Adults were able to perceive soil humidity at different depths and were able to detect moist peat moss at a depth of up to 22 cm.

Keywords: *Rhynchophorus*, palm trees, humidity, survival, behavior.

Date palm is one of the oldest known fruit trees in the Arabian Peninsula and has been of considerable importance for the last 7,000 years (Thomson, 1949). Among the insect pests attacking date palm trees (Abu-Zoherah *et al.*, 1993; Al-Ahmadi and Salem, 1999), the red palm weevil (RPW), *Rhynchophorus ferrugineus* (Oliv.) is the most predominant (Bokhari and Abuzuhaira, 1992; Abraham *et al.*, 1998; Faleiro and Chellapan, 1999; Zaid *et al.*, 1999; Vidyasagar *et al.*, 2000). It is native to eastern Asia, mainly India, Pakistan, Sri Lanka and Indonesia (Rahalkra *et al.*, 1985). It was introduced to the Eastern coast of the Arabian Peninsula in the mid-1980s and then quickly spread to many date palm plantations. It

has also invaded other countries such as Egypt, Iran, Jordan and Spain (Vidyasagar *et al.*, 2000).

RPW is considered a wound parasite because the infestation usually starts in the wounds. One of the main causes of wounds is the detachment of offshoots from the mother tree. The infestations therefore, mostly occur in the lower part of the trunk, less than one-meter above the soil surface (Lukmah and Alquat, 2002). The offshoots provide good harborage for RPW adults because of favorable moisture and shade conditions.

The spread of the infestation is highly influenced by humidity of the habitat. Aldryhim and Albukiri (2003) found that most of the trees infested by RPW were within flood irrigation plots compared with drip

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irrigation plots. The sensitivity of the RPW to dry conditions was studied by Aldhafer (1997) and Nirula (1956). They showed that the adults of RPW when exposed to dry conditions, died after four to six days.

RPW adults, outside the host plant, seek wounds in a palm trunk to start a new infestation (Abraham, 1971; Faleiro and Rangnekar, 2001). In the absence of wounds, the RPW adults have been observed in the field with their bodies inside moist soil that acts as a temporary harborage.

The effect of the humidity on the survival and behavior of RPW adults is not well understood. The current study focused on the effect of humidity on the survival of RPW adults and their ability to penetrate soil as a temporary harborage.

Materials and Methods

The experiments were conducted at the Red Palm Weevil Laboratory, Dept of Plant Protection, College of Agriculture, King Saud University, at temperatures of 25-28 °C. Eight replicates (four females and four males) were designated for each treatment in all experiments. Adults were collected from the field as pupae and allowed to emerge. The emerged adults were reared in plastic boxes (22.5 x 12.0 x 7.5 cm) and provided with sugarcane slices.

BODY WATER CONTENT: The average body-water content of weevil was determined in a dry oven at 45 °C using the method outlined in Weissling and Giblin-Davis (1993).

EFFECT OF MOISTURE ON SURVIVAL OF ADULTS: This experiment was comprised of three treatments, with eight replicates each. In the first treatment, adults were kept individually in a plastic rearing box with 33 g of dry peat-moss. The second treatment was done in peat-moss with a moisture content of 15% of its maximum water holding capacity (Cassel and Nielsen, 1986). To maintain moisture content, the peat-moss was changed every 48 hours. In the third treatment, adults were kept individually in 400 mL-jars containing 300 mL tap-water. No food was provided to all tested weevils during this study. Adults were examined daily until all had expired.

ABILITY OF NEW EMERGED ADULTS TO MATE IN WATER: Pupae of RPW collected from the field were kept singly in a rearing box provided with a moist piece of cotton. Newly emerged, unmated adults were sexed and kept singly in a rearing box containing two sugar-cane slices, 15 cm in length, for five days for maturity. A virgin pair (male and female) was placed in 400 mL-jar containing 300 mL tap-water for 24 hrs. Each female was then transferred to a new rearing box with

two sugar-cane slices. Sugar-cane slices were inspected for larvae to confirm fertility of the female.

ABILITY OF ADULTS TO PENETRATE SOIL: Peat-moss (organic matter), sand-loam soil (70% sand, 15% silt and 15% clay), and sand (pure sand) were used to test the ability of RPW adults to penetrate soil. The moisture content of the three selected materials was brought to 15% of their maximum water holding capacity.

Twenty-four measuring cylinders, one-liter size, were arranged into six rows. The distance between rows and cylinders within the same row was 10 cm. Cylinders were randomly divided into three groups. The first, second and third cylinder groups were filled to 33 cm height with peat-moss, sand-loam soil and sand, respectively. In each cylinder one adult was placed on the top surface of the soil. The cylinders were covered with plastic sheets to prevent adult escape. The depth of adult penetration was measured after 24 hrs.

ABILITY OF ADULTS TO PENETRATE PEAT-MOSS AT DIFFERENT MOISTURE LEVELS: The experiment design was in the previous section, except that only peat-moss was used. The column height of each measuring cylinder (33 cm) was externally marked (superficially) into three sections (11 cm each). The three sections were called top, middle, and bottom. Each section was filled by peat-moss at a predetermined moisture content. The maximum water holding capacity of peat-moss in the three sections from top to bottom, for the five treatments were: 0, 0, 0; 15, 15, 15; 0, 15, 30; 0, 0, 15 and 0, 0, 30%, respectively.

Results

No statistical differences were observed in the total body-water loss between females and males. The percentage of the body-water loss was 55.7 and 54.9 %, respectively. The highest water loss rate occurred in the first day (39.1 and 32.2%) and second day (15.4 and 21.4%) for females and males respectively, while the percentage of the water loss for the last five days (day 3-7) was less than 1.3% (Table 1).

The survival of RPW adults was highly influenced by the humidity of the habitat in the absence of the food.

TABLE 1

Percentage of water loss of red palm weevil adults through seven days at 45 °C.

| Sex | Day | | | | | | | Total ¹ |
|--------|------|------|-----|-----|-----|-----|-----|--------------------|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
| Female | 39.1 | 15.4 | 1.0 | 0.1 | 0.0 | 0.1 | 0.0 | 55.7 |
| Male | 32.2 | 21.4 | 0.9 | 0.1 | 0.1 | 0.2 | 0.0 | 54.9 |

¹No significant difference in total water loss between males and females.

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TABLE 2

Effect of moisture content on the survival period in days (mean ± SE) of the red palm weevil adults.

| Treatment | Sex | Survival Period in Days ¹ | Mean Survival Period for Both Sexes ² |
|-----------------|--------|--------------------------------------|--|
| Dry peat-moss | Female | 2.5 ± 0.5a | 2.5 ± 0.3 a |
| | Male | 2.5 ± 0.5a | |
| Moist peat-moss | Female | 31.5 ± 4.2a | 39.3 ± 5.4 b |
| | Male | 47.0 ± 8.9b | |
| Water | Female | 22.5 ± 5.4a | 23.5 ± 4.1 c |
| | Male | 24.5 ± 7.0a | |

¹Within each treatment, means followed by the same letter are not significantly different (LSD, SAS 1988).

²Means followed by the same letter, in this column, are not significantly different (LSD, SAS 1988).

Adults survived for 2.5, 39.3 and 23.5 days when were kept in dry peat-moss, moist peat-moss and pure tap-water, respectively. The longevity of both sexes was not significantly different when kept in dry peat-moss or water. However, female longevity was significantly shorter (31.5 days) than male longevity (47.0 days) when kept in the moist peat-moss (Table 2). Adults were observed embedding their bodies inside the peat-moss.

Water was not an obstacle for mating. Fifty per cent of tested females were successfully mated in water. Larvae were seen in the sugar-cane pieces as an indication to the success of mating. Mating behavior in water was different compared with natural mating. The tested females showed more desire than males for mating. Females and males used their legs to grasp each other longitudinally on the ventral side.

RPW adults were able to penetrate moist peat-moss, moist sandy loam and moist sand. Adults used their front legs and snout for digging and their hind legs for pushing. The depth of penetration was significantly higher in peat-moss (12.6 cm) than in other types of soil. No statistical differences were observed in the depth of penetration between males and females through the same soil material. (Table 3).

The depth of the adult penetration was highly affected by peat-moss moisture content at different depths. No penetration was attempted by adults that were placed in the dry peat-moss in the three sections of the cylinder. The depth of the penetration was the deepest when the peat-moss at the top level was the driest and that of the bottom level was the most humid. The depth of penetration was 12.6, 16.5, 24.5 and 23.7 cm when the peat-moss moisture contents from top to bottom levels were 15,15,15; 0,15,30; 0,0,15 and 0,0,30, respectively (Table 4). There was no significant difference in male and female penetration within the same treatment.

TABLE 3

The ability of the red palm weevil to penetrate through three types of soil.

| Treatment | Sex | Depth of Penetration (cm) ¹ | Mean of Penetration (cm) ² |
|-----------|--------|--|---------------------------------------|
| Peat-moss | Female | 12.5 ± 4.1a | 12.6 ± 2.3a |
| | Male | 12.8 ± 2.7a | |
| Sand | Female | 2.1 ± 0.2a | 5.1 ± 1.6b |
| | Male | 8.1 ± 2.5a | |
| Loam | Female | 8.7 ± 4.8a | 6.5 ± 2.4b |
| | Male | 4.2 ± 1.1a | |

¹Within each treatment, means followed by the same letter are not significantly different (LSD, SAS 1988).

²Means followed by the same letter are not significantly different (LSD, SAS 1988).

Discussion

RPW adults showed a hygropositive response towards humidity. Adults died in less than three days when they were placed in dry peat-moss but the longevity of the adults extended to 39.3 days when kept within moist peat-moss, in the absence of food. This indicates that the dryness of the habitat is a more critical factor than the absence of the food for the survival of RPW adults. Aldryhim and Albukiri (2003) found that more date palm trees were infested by RPW within plots that were flood-irrigated than the drip-irrigated plots. The current results confirm that the soil humidity affects the behavior and the survival of RPW adults. Furthermore, field observations revealed that the infestation levels and damage caused by RPW are higher on the Eastern coast than in the central region of the Saudi Arabia. This may be due to the high relative

TABLE 4

Effect of moisture content of peat-moss at different depths on the penetration of red palm weevil adults.

| Level of Moisture Content at Different Depth (Top, Middle and Bottom) | Sex | Depth of Penetration (cm) ¹ (mean ± SE) | Mean of Penetration (cm) ² (mean ± SE) |
|---|--------|--|---|
| 0,0,0 | Female | 0 | 0 c |
| | Male | 0 | |
| 15,15,15 | Female | 12.5 ± 4.1 a | 12.6 ± 2.3 b |
| | Male | 12.8 ± 2.7 a | |
| 0,15,30 | Female | 18.8 ± 2.3 a | 16.5 ± 1.8 b |
| | Male | 14.2 ± 2.6 a | |
| 0,0,15 | Female | 26.1 ± 3.8 a | 24.5 ± 2.4 a |
| | Male | 22.8 ± 3.2 a | |
| 0,0,30 | Female | 23.9 ± 2.1 a | 23.7 ± 1.6 a |
| | Male | 23.5 ± 2.8 a | |

¹Within each treatment, means followed by the same letter are not significantly different (LSD, SAS 1988).

²Means followed by the same letter are not significantly different (LSD, SAS 1988).

humidity of the Eastern coast. Leefmans (1920) mentioned that RPW adults were negatively affected by a dry environment. Nirula (1956) found that RPW adults survived less than six days when kept in a dry environment. Giblin-Davis and Howard (1989) found that adults of the closely related species, *R. cruentatus* suffered from high mortality when placed in Petre-dishes that lacked moisture. Moreover, Weissling and Giblin-Davis (1993) found that longevity and behavior of the adults of *R. cruentatus* were controlled by humidity. Furthermore, adults of the banana borer, *Cosmopolites sordidus*, exhibited abnormal walking behavior when exposed to dry air and frequently fell on their sides or back (Roth and Willis, 1963).

Conclusions

RPW adults tend not to leave an infested tree unless it becomes totally unsuitable for the next generation. Adults outside the host may suffer high mortality due to dryness. Therefore, adults seek temporary shelters such as the inner base of the leaves or embed their body in moist soil. The current study confirmed that RPW adults were able to penetrate moist soil. Furthermore, adults were able to detect and penetrate moist soil to a depth of more than 20 cm. This indicates that adults may possess hygroreceptors. This could explain the reason why adults hide inside moist soil where it's surface was dry. Understanding such behavior may be a useful tool to set traps that contain moist peat-moss contaminated with a pathogenic nematode or other agents that attack RPW adults.

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