LIFE PARAMETERS OF THE RED PALM WEEVIL, *RHYNCHOPHORUS FERRUGINEUS* OLIV., ON SUGARCANE AND AN ARTIFICIAL DIET

Walid Kaakeh, Ahmed A. Khamis, and Mahmoud M. Abou-Nour

Department of Plant Production,
UAE University, P. O. Box 17555, Al-Ain, U.A.E.

ABSTRACT

Various parameters of the life cycle were obtained for the red palm weevil, *Rhynchophorus ferrugineus* Olivier, reared on stem pieces of sugarcane and on an artificial diet. The average number of eggs deposited per female was 135 eggs (range: 120 – 185) and 185 eggs (range 145-265) for those females reared on an artificial diet and sugarcane, respectively. The average number of eggs deposited per female per day was 2.1 and 3.0 eggs, and the percentage of hatchability (viability of eggs) was 77.7% and 75.1% when females reared on an artificial diet and sugarcane, respectively.

The pre-oviposition period was 3.4 d (range: 3 – d) on both food types. The oviposition period for females reared on a diet and sugarcane was 3.7 and 3.6 d (range: 3 4 d), respectively. No significant differences in the developmental time of larvae occurred when reared on a diet (91 D) and sugarcane (82 d). No differences in the developmental time of pupae occurred when larvae reared on a diet (21 d) and sugarcane (19 d).

The longevity or developmental time of adults previously reared on sugarcane was significantly longer than those fed on an artificial diet. No significant differences in the development time occurred between males and females reared on either a diet or sugarcane. The generation span (a time period from the pre-oviposition period to emergence of adults from cocoons) was 118.1 d and 107.0 d on a diet and sugarcane, respectively.

The mean total number of eggs laid by females, eggs 30 d after one full copulation with males of similar age, and rate of egg hatching decreased significantly with increasing weevil age, and ranged from 65.5 eggs from 1-d-old female to 43.5 eggs from 45-d-old female. The rate of egg hatching also decreased significantly ($P < 0.05$) with increasing weevil age, and ranged from 75.6% from 1-d-old weevils to 47.4% from 45-d-old weevil. The short copulatory period was adequate for insemination of the female during copulation.

Key words: *Rhynchophorus ferrugineus*, diet, fecundity, fertility

INTRODUCTION

The red palm weevil, *Rhynchophorous ferrugineus* Olivier (Coleoptera: Curculionidae), is an economically important, tissue-boring pest of date palm in many parts of the world. The insect was first described in India as a serious pest of coconut palm (Lefroy, 1906; Nirula, 1956) and later on date palm (Lal, 1917; Buxton, 1918). The insect is a major pest of date palm in some of the Arabian Gulf States including Saudi Arabia, United Arab Emirates, Sultanate of Oman, and Egypt (Cox, 1993; Kaakeh *at al*., 2001b). The agroclimatic conditions prevalent in this region and the unique morphology of the crop, coupled with intensive modern date palm farming, have offered the pest an ideal ecological habitat (Abraham et al., 1998).

The symptoms of *R. ferrugineus* attack to date palm was summarized by Kaakeh *et al*. (2001b). Damage was categorized by the presence of tunnels on the trunk and base of leaf petiole, oozing out of thick yellow brown fluid from the tunnels, appearance of frass in and around the openings of tunnels, fermented odor of the fluid inside the infested tunnel, appearance of a dried offshoot, production of a gnawing sound by the grubs, presence of cocoon/adults in the leaf axiles, and breaking of the stem or toppling of the crown when the palm is severely infested.

Detailed life cycle of laboratory-reared *R. ferrugineus* was reported on date palm trunks (El-Ezaby, 1997) and sugarcane (Rahalaker *et al*. 1972; Aldhafer *et al*. 1998). The objective of this study is to determine the various life parameters of the red palm weevil collected from the field in UAE and reared on sugarcane and an artificial diet. Specific objectives were to (1) estimate the fecundity and egg viability (percentage of egg hatch), (2) determine the larval and adult developmental time, and (3) determine the effect of adult age on egg production.

MATERIALS AND METHODS

Test Insects

Insects used in this study were originally obtained from infested palm trees in Masafi area in the Sharja Emirate in 1997. Insect culture was maintained in a rearing room, at the Plant Protection Laboratory, at 24±2°C, 70±5% RH, and a photoperiod of 12 : 12 (L:D) h. Larvae (Figure 1) were provided with sugarcane for feeding, while the adults with cotton wicks saturated with a sugar solution for feeding and egg laying. Adults were sexed after emergence from cocoons and kept separately in small jars prior to the beginning of the observations. Sexing of adults was done according to the presence of a series of black hairs on the dorsal, frontal part of snouts of males and their absence in the females (Figure 2).

Figure 1. Different larval stages of *R. ferrugineus*.

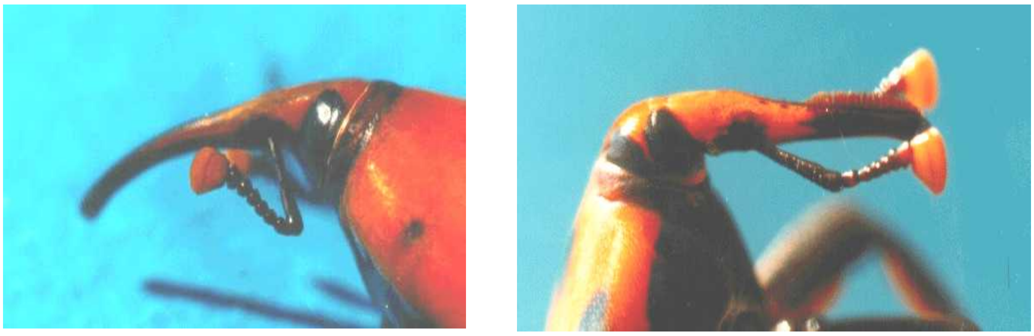

Figure 2. Male (right) and female (left) *R. ferrugineus*. Males are characterized by the presence of a series of black hairs on the dorsal, frontal part of snouts; females do not have hairs.

Artificial Diet

The artificial diet, used in this study, was prepared in the laboratory and consisted oat (57%), sugar (22%), molasses (11%), brewers yeast (9%), and salt (1%). The ingredients and water (1 - 2 liter of water for a diet weighing 500 - 1000 g) were blended for approximately 5 minutes. The diet also included bacto-agar, multi-vitamins, chemical preservatives. Bacto-agar was dissolved in water and added to other ingredients. The mixture of the diet was then autoclaved for 20 min at 120ºC. The diet was poured in diet stainless-steel round trays or cups while still warm. All trays and cups were stored at room temperature until required. Larvae were placed on diets after total coolness. The authors illustrated the methodology of rearing *R. ferrugineus* in sugarcane and artificial diets (Kaakeh *at al*. 2001a, in press).

Adult Fecundity and Egg Viability

Cocoons, harvested from the sugarcane stems were placed in plastic containers until adult emergence (Figure 3). Adults after emergence were sexed and one male and one female were placed in small 1-liter glass jars (n = 35). Adults were provided with cotton wicks saturated with a 10% honey solution for feeding and egg laying. Jars were staked side by side (or on the top of each other) on working benches. Few holes were made on all lids of boxes and jars for ventilation. Paired males and females were kept together for 63 days. Deposited eggs (Figure 4) were transferred from the cotton wicks, using a camel hair brush, and placed on wet filter papers inside the Petri dishes. The total number of eggs deposited from each female, and the number of hatched eggs and hatching rate (%) were determined.

Larvae and Adult Development Time

Newly hatched larvae on cotton wicks were transferred with a camel's hair brush to an artificial diet or pieces of sugarcane stems (the diameter of stems was based on the size of larvae at different developmental stages) (Figure 5, 6). Last larval instars fed on an artificial diet were transferred to sugarcane stems to make cocoons. The developmental characteristics of adults were recorded.

Effect of Adult Age on Egg Production

To determine the effect of age of mated females on the production of eggs 30 d after one full copulation, females of different ages (1, 7, 21, and 45 d; n = 12) were separated from males after the termination of copulation. Each female was placed in a jar and provided with one cotton wick saturated with sugar solution for feeding and egg laying. The cotton wick was replaced weekly and the number of eggs recorded. The viability of the eggs was determined by counting the number of hatched larvae. LSD test was used for data analysis (SAS, 1990).

A

B

C

Figure 3. Cocoons and adults of *R. ferrugineus*. (A) Cocoons, (B) Emergence of an adult, and (C) Adults.

Figure 4. Deposited eggs on filter papers.

Figure 5. Development of *R. ferrugineus* larvae on sugarcane stems.

Figure 6. Development of *R. ferrugineus* larvae on an artificial diet.

RESULTS AND DISCUSSION

Adult Fecundity and Egg Viability

The average number of eggs deposited per female was 135 eggs (range: 120 – 185) and 185 eggs (range 145-265) for females reared on an artificial diet and sugarcane, respectively (Table 1). These numbers are comparable to the previous estimate of 127-276 eggs (Ghosh, 1912), 162-350 eggs (Viado and Bigornia, 1949), 204 eggs (Frohlich and Rodewald, 1970), and 77-283 eggs (El-Ezaby, 1997). The numbers also are lower than the previous estimate of 531 eggs (Leefmans, 1920), 355-760 eggs (Nirula, 1956), 200-500 eggs (Lever, 1969; Hartley, 1977), and 55-412 eggs (Aldhafer *et al*., 1998).

In this study, the average number of eggs per female per day was 2.1 and 3.0 eggs deposited by females reared on a diet and sugarcane, respectively (Table 1). The percentage of hatchability (viability of eggs) was 77.7% and 75.1% when females reared on a diet and sugarcane, respectively (Table 1). These results agree with the estimates of 79% and 83% egg viability when females reared on coconut and sugarcane, respectively (Nirula, 1956), 87% (Leefmans, 1920), 86% (Viado and Bigornia, 1949), and 65-95% (Aldhafer *et al*. 1998). The rate of egg hatching increases as temperatures increases 9el-Ezaby, 1977). The comparable and lower estimates of fecundity and egg viability by this study and the previous studies may have been due to suboptimal conditions (food type, temperature, and rearing methodology), decreasing or increasing the number of eggs deposited by the females and the rate of egg hatching. In addition, males in this study were confined with females throughout the course of the study. The presence of males in small jars may have interfered with oviposition or increased damage to larvae and eggs (Giblin-Davies *et al*. (1989). Rannavare et al. (1975) reported that *R. ferrugineus* females laid less eggs when confined with males than without.

Larvae and Adult Development Time

No significant differences in the pre-oviposition period and oviposition period when females reared on a diet or sugarcane (Table 2). The pre-oviposition period was 3.4 d (range: 3 – d) on both food types. The oviposition period for females reared on a diet and sugarcane was 3.7 and 3.6 d (range: 3 4 d), respectively. These results agree with the estimate of 3-4 d (Ghosh, 1912; Aldhafer *et al*. 1998), 3-5 d (Frohlich and Rodewald, 1970), 3 d (Lever, 1969; Hartley, 1977) and 4.5 d (El-Ezaby, 1977).

No significant differences in the developmental time of larvae occurred when reared on a diet (91 D) and sugarcane (82 d) (Table 2). These time periods were similar to previous estimates of 60-120 d (Lever, 1969) and 69-85 d (El-Ezaby, 1977). In other cases, our results are not comparable (lower or high) with the estimates of 30-35 d (Ghosh, 1912), 35-38 d (Viado and Bigornia, 1949), 55 d (Nirula, 1956), 60 d (Hartley, 1977), 105 d (Leefmans, 1920), and 165-182 d (Aldhafer *et al*. 1998).

No differences in the developmental time of pupae occurred when larvae reared on a diet (21 d) and sugarcane (19 d) (Table 2). The results agree with the estimates of Aldhafer et al. (1998) where the pupal period last for 21.1 d (range: 19-25 d) for males and 23.3 d (range: 21-26 d) for females.

The longevity or developmental time of adults previously fed (i.e., reared during their larval stages) on sugarcane was significantly ($P < 0.05$) longer than those fed on an artificial diet (Table 2). The apparent differences of development period of adults on sugarcane was not clearly understood, especially that the oviposition, larval, and pupal periods were similar for both adults previously reared on a diet and sugarcane. The development times of adults reported here were similar to the previous estimates of 50-90 d (Ghosh, 1912), 83.6 d for males and 60 d for females (Viado and Bigornia, 1949), and 60-90 d (Nirula, 1956). The results were considerably lower than those reported by Aldhafer *et al*. (1998), where the adult longevity period was 161 d (range: 67-257 d) for males and 113 d (range: 70-150 d) for females; and 90-120 d (Lever, 1969) and 120 d (Hartley, 1977). No significant differences in the development time occurred between males and females reared on either a diet or sugarcane. The development time of males and females on a diet was 49.0 d and 44.5 d, respectively, while the development time on sugarcane was 75.0 d and 84.0 d, respectively.

Table 1. Production of eggs by females *R. ferrugineus* kept with males for 63 days and exposed to multiple copulations.

Food type at larval stage	No. eggs per female	No. eggs per female per day	No. hatched eggs	% hatching
Artificial diet	135 b	2.1	105 b	77.7 a
Sugarcane	185 a	3.0	137 a	75.1 a

Means, in the same column, followed by the same letter are not significantly different at the $P = 0.05$ level (LSD test, SAS, 1995).

Table 2. The developmental time (d) of different stages of *R. ferrugineus* reared on sugarcane and an artificial diet.

Criteria (days)	Food Type	
	Oat-based Diet	Sugarcane
Pre-oviposition period	3.4 a	3.4 a
Oviposition period	3.7 a	3.6 a
Larval period	91.0 a	82.0 a
Pupal period	21.0 a*	19.0 a
Adult male development time	49.0 b	75.0 a
Adult female development time	44.5 b	84.0 a
Generation span**	118.1**	107.0

Means, in the same raw, followed by the same letter are not significantly different at the $P = 0.05$ level (LSD test, SAS, 1995).
* Last larval instars were transferred to pieces of sugarcane stems for pupation.
** Generation span includes a time period from the pre-oviposition period to emergence of adults from cocoons (pupal period).

The generation span (a time period from the pre-oviposition period to emergence of adults from cocoons) was 118.1 d and 107.0 d on a diet and sugarcane, respectively (Table 2). These time periods were similar to previous estimates of 96 d (Nirula, 1956), 100.5 d for the first generation (El-Ezaby, 1997). The generation times reported here were considerably lower than the estimates of 95-210 d (Kalshoven, 1981) and 223 d (Aldhafer *et al*, 1998).

Effect of Adult Age on Egg Production

The effect of age of mated females on the production of eggs 30 d after one full copulation with males of similar age, and the rate of egg hatching is given in Table 3. The mean total number of eggs laid by the females decreased significantly ($P < 0.05$) with increasing weevil age, and ranged from 65.5 eggs from 1-d-old female to 43.5 eggs from 45-d-old female. The rate of egg hatching also decreased significantly ($P < 0.05$) with increasing weevil age, and ranged from 75.6% from 1-d-old weevils to 47.4% from 45-d-old weevil.

Females separated from males for periods as long as 30 d still produced fertile eggs. This may indicate that sperm from one mating can produce fertile eggs for the reproductive life of the female. The high capability of females *R. ferrugineus* for sperm storage would assure the continuation of production of offspring under low densities and where the chances of encountering a mate would be greatly reduced. The short copulatory period (2.9 – 4.8 min) reported previously (Kaakeh, 1998) was adequate for insemination of the female during copulation. Females may not need to frequently mate with other males. Insemination of the female by several males may be necessary in the field for maintaining genetic variability in the population.

All parameters were estimated at constant temperatures under laboratory conditions. Therefore, direct comparison with results reported here cannot be made, but similar trends are evident. Under field conditions, many factors such as ambient temperatures, affect developmental and reproductive times and enhance the fecundity at different times over constant temperatures.

Table 3. Production of eggs by females *R. ferrugineus* mated with males of similar age, 30 days after one full copulation.

	Age of mated female, d			
	1	7	21	45
No. of Eggs Laid	65.5 a	68.0 a	51. b	43.0 c
No. of Eggs Hatched	49.5	41.0	25.3	20.4
Hatching Rate (%)	75.8 a	60.3 b	49.1 c	47.4 c

Means, in the same raw, followed by the same letter are not significantly different at the $P = 0.05$ level (n = 12; LSD test, SAS, 1995).

Fecundity of *R. ferrugineus* varies among individuals within the same population fed on different food types (unpublished data). Feeding on different host species or varieties may result in different fecundity rates. In this study, differences were detected in weevil life parameters on different food types. Differences in total fecundity appeared more closely related to insect physiology than to any other factors.

Many factors, both density dependent and independent (such as day length, light intensity, and tree nutrition), affect weevil developmental time and growth rate in the field; some of which were controlled in this study. Other factors affecting the variability in weevil performance were not controlled and were difficult to quantify. Temperature fluctuation may directly affect the weevil itself through its effect on developmental time, total fecundity, fertility rate, and survival of weevils. The high temperatures during the summer in UAE might have reduced the reproductive rates and increased the mortality rates of weevils in the field.

The interrelationship of various factors regulating weevil population may not necessarily all apply, or have the same importance for every individual, or at different population densities, and locations. However, when normal regulating mechanisms break down as a result of unusual phenomena, conditions of weevils may change. Variations in results between food types, locations of experiments, would be expected when experiments are conducted under different conditions.

REFERENCES

Aldhafer, H. M., A. Z. Alahmadi, and A. M. Alsuhaibani. 1998. Biological studies on the red palm weevil, Rhynchophorus ferrugineus Oliv. (Coleoptera, Curculionidae) in Riyadh, Saudi Arabia. King Saud University Agric. Res. Center. Research Bulletin No. (75), 30 pp.

Buxton, P. A. 1918. Report on the failure of date crops in Mesopotamia in 1918. Agric. Directorate, M. E. F. Bassarah Bull. No. 6.

Cox, M. L. 1993. Red palm weevil, *Rhynchophorus ferrugineus*, in Egypt. FAO-Plant-Protection-Bulletin 41: 1, 30-31.

El-Ezaby, F. 1997. A biological *in-vitro* study on the red Indian date palm weevil. Arab J. Plant Protection 15 (2): 84-87.

Frohlich, G. and J. W. Rodewald. 1970. Pests and diseases of tropical crops and their control. Oxford, New York, pp. 204-207.

Giblin-Davies, R. M. K. Gerber, and R. Griffith. 1989. Laboratory rearing of *Rhynchophorus cruentatus* and *R. palmarum* (Coleoptera: Curculionidae). Florida Entomol. 72: 480-488.

Ghosh, C. C. 1912. Life history of Indian insects – III. The Rhinoceros beetle (*Oryctes rhinoceros*) and the red palm weevil (*Rhynchophorus ferrugineus*). Memoirs of the Dept. of Agric. India (Int.Ser.) II (10): 205-217.

Hartley, C. W. S. 1977. The oil palm. Longmans, London, 706 pp.

Kaakeh, W. 1998. The mating behavior of the red palm weevil, *Rhynchophorus ferrugineus* Oliv. (Coleoptera: Curculionidae). Emir. J. Agric. Sci. 10: 24-46.

Kaakeh, W, F. El-Ezaby, M. M. Aboul-Nour, and A. A. Khamis. 2001a. Mass rearing of the red palm weevil, Rhynchophorus ferrugineus Olivier, on sugarcane and artificial diets for laboratory studies:

Illustration of methodology. Proceedings of the Second International Conference on date Palm (in press).

Kaakeh, W, A. A. Khamis, and M. M. Aboul-Nour. 2001b. The red palm weevil: The most dangerous agricultural pest. UAE University Printing Press, 165 pp.

Kalshoven, L. G. E. 1981. Pests of crops in Indonesia. P . T. Ichtiar Baru-Von Hoeve, Jakarta, pp. 487-492.

Leefmans, S. 1920. De Palmsnuitkever (Rhynchophorus ferrugineus Oliv.). Mededeeclingen 43. Institut voor Plantenzickten (Buitenzorg) 1-90.

Lefroy, H. M. 1906. The more important insects injurious to Indian Agriculture. Govt. Press, Calcutta, India.

Lever, R. J. W. 1969. Pests of the coconut palm. FAO, Agricultural Studies report No. 77, Rome, pp: 113-119.

Lal, Madan Mohan. 1917. Rept. Asst. Prof. Entomol; Rept. Dept. Sagr. Punjab, for the year ended 30th June, 1917.

Nirula, K. K. 1956. Investigations on the pests of coconut palm (*Rhynchophorus ferrugineus* F.). Indian Coconut J. 9 (4): 229-247.

Rahalaker, G. W., M. R. Harwalkar, and H. D. Rananavare. 1972. Development of red palm weevil, *Rhynchophorus ferrugineus* Oliv. Indian J. Entomol. 34: 213-215.

Rahalaker, G. W., M. R. Harwalkar, H. D. Rananavare, A. J. Tamhankar, and K. Shanthram. 1985. *Rhynchophorus ferrugineus*, pp. 279-286. In P. Singh and R. F. Moor [eds.]. Handbook of insect rearing. Elsevier, New York, NY. Vol. 1.

SAS Institute 1995. SAS user's guide: statistics, ver. 6 ed. SAS Institute, Cary, North Carolina.

Weissling, T. J. and R. M. Giblin-Davis. 1994. Fecundity and fertility of *Rhynchophorus cruntatus* 9Coleoptera: Curculionidae). Florida Entomol. 77: 373-376.

Weissling, T. J. and R. Giblin-Davis. 1995. Oligidic diets for culture of *Rhynchophorus cruntatus* (Coleoptera: Curculionidae). Florida Entomologist 78: 225-234.

Viado, B. G and E. A. Bigornia. 1949. A biological study of the Asiatic palm weevil, *Rhynchophorus ferrugineus* (Olivier) (Curculionidae: Coleoptera). The Philippine Agri. 33: 1-27.