# LIFE HISTORY OF THE RED PALM WEEVIL, *RHYNCHOPHORUS FERRUGINEUS* (COLEOPTERA: DRYOPHTORIDAE), IN SOUTHERN JAPAN

FUKIKO ABE[1], KUNIHIKO HATA[2] AND KOICHI SONE[2]
[1]United Graduate School of Agriculture, Kagoshima University, Kagoshima 890-0065, Japan

[2]Faculty of Agriculture, Kagoshima University, Kagoshima 890-0065, Japan

ABSTRACT

We surveyed the life history of the red palm weevil, *Rhynchophorus ferrugineus* (Olivier) (Coleoptera: Dryophthoridae), in southern Japan, including seasonal changes in the flight activity of adults and composition of *R. ferrugineus* in different developmental stages in a total of 17 infested *Phoenix canariensis* trees which were cut down in 2003-2005. The flight of adults began in Mar, showed some peaks in summer and autumn, and ceased in mid-Dec. Various stages of individuals inhabited infested *P. canariensis* trees throughout the year. The composition of individuals at different stages in late fall was dependent on the resource (white intact tissue) availability in *P. canariensis* trees. In *P. canariensis* trees where considerable resource remained, all stages of larvae, pupae, and adults were found, whereas in palm trees with no resource, few young- and medium-stage larvae were observed. The temperature in the infested part of a palm trunk was 30°C or higher even in winter. From these results, we view the life history of *R. ferrugineus* in southern Japan as follows: Adults emerge from host trees in spring and continue to attack host trees until late fall. *Rhynchophorus ferrugineus* grows even in winter if intact tissue remains at the peripheral part of trunks, and there may be 3 or 4 generations per year. A cold winter probably does not have any negative effects on successful colonization of *R. ferrugineus* in Japan.

Key Words: red palm weevil, *Rhynchophorus ferrugineus*, southern Japan, developmental stage structure

RESUMEN

Estudiamos el ciclo de vida del picudo rojo de la palma, *Rhynchophorus ferrugineus* (Olivier) (Coleoptera: Dryophthoridae), en el sur del Japón, incluyendo los cambios estacionales en la actividad de vuelo de los adultos y la composición de *R. ferrugineus* en diferentes etapas de desarrollo en un total de 17 árboles infestados de *Phoenix canariensis* que fueron tumbados en los años 2003-2005. Los adultos empezaron a volar en marzo, mostraron un incremento en verano y otoño, y terminaron en el medio de diciembre. Varias estadios de picudo rojo de la palma habitaron los árboles infestados de *P. canariensis* por todo el año. La composición de los individuos en diferentes etapas de la ultima parte del otoño fue dependiente de la disponibilidad de material (tejido blanco intacto) en los árboles de *P. canariensis*. En los árboles de *P. canariensis* donde quedo una cantidad considerable de tejido, todos los estadios de larva, pupa y adulto fueron encontrados, mientras en las palmeras sin material, pocos estadios jóvenes y medios de larvas fueron observados. La temperatura en la parte infestada del tronco de la palmera fue 30°C o más alta aun durante el invierno. De estos resultados, vemos el ciclo de vida de *R. ferrugineus* en el sur de Japón como la siguiente manera: los adultos salen de los árboles hospederos en la primavera y continuan su ataque en los árboles hospederos hasta el fin de otoño. *Rhynchophorus ferrugineus* crece aun en invierno si hay tejido intacto en la parte periférica de los troncos, y pueden haber 3 o 4 generaciones por año. Probablemente un invierno frío no tiene un efecto negativo sobre el éxito en la colonización de *R. ferrugineus* en Japón.

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The red palm weevil, *Rhynchophorus ferrugineus* (Olivier) (Coleoptera: Dryophthoridae), is widely distributed in southern Asia and Melanesia, and attacks various palm species such as *Phoenix sylvestris*, *Cocos nusifera* and *Metroxylon sago* in India, Pakistan, Sri Lanka, Myanmar, Indonesia, the Philippines, and the Gulf states (Rahalkar et al. 1985; Murphy & Biscoe 1999). After being first recorded in Okinawa in 1975, damage to palms, almost exclusively Canary Island date palm (*P. canariensis*), extended to southern Japan in 1998 and thereafter (Usui et al. 2006). The adults of *R. ferrugineus* are attracted to and deposit eggs in palm sheaths and stems. Larvae develop primarily in the crown region and damage a growing point of palm trees located at the top of a trunk. Infestations are problematic because *R. ferrugineus* is not detectable until it has caused permanent damage (Rahalker et al. 1985). To control infestation of palm trees by *R. ferrugineus*, infested palm trees are cut down and crushed or burned in Japan. However, these mechanical methods are laborious and costly. Thus, cheaper alternative methods are desired. Injection of insecticides into palm trunks and the use of natural enemies such as entomopathogenic nematodes have been tested (Shaseldean 2004; Iiboshi et al. 2004; Toshima 2006; Yoshimoto 2006).

Knowledge of the life history of *R. ferrugineus* would allow us to determine the optimal time to intervene with insecticides and entomopathogenic nematodes for more effective control. To date, adult longevity, fecundity, and larval development of *R. ferrugineus* have been studied only under laboratory conditions (Rahalker et al. 1985). In the field, oviposition behavior has been observed in Indonesia (Kalshoven 1981), and the seasonal patterns of flight activity have been estimated from adult captures with pheromone traps in Kagoshima and Miyazaki Prefecture, southern Japan (Aman et al. 2000; Sato & Irei 2003). However, studies in the development and the seasonal changes in the composition of *R. ferrugineus* inhabiting *P. canariensis* trees have not been conducted.

To this end, we examined the composition of inhabiting *R. ferrugineus* individuals at different developmental stages in infested *P. canariensis* trees cut down in different months of the year. Additionally, we measured the temperature inside the trunk of infested *P. canariensis* trees during winter to evaluate the thermal conditions of *R. ferrugineus.* We also reaffirmed the flight activity pattern reported by Aman et al. (2000) and Sato & Irei (2003) by collecting adults and observing adult flight in the field. Using this information, we inferred the life-history of *R. ferrugineus* in southern Japan.

## MATERIALS AND METHODS

### Seasonal Patterns of Flight Activity of Adults

The seasonal patterns of flight activity of adults were surveyed in the Korimoto Campus of Kagoshima University (31°34'N, 130°32'E), Kagoshima, southern Japan, where about 30 *P. canariensis* were planted in a small area (<1 ha), and most were dead due to the infestation by *R. ferrugineus* since the first record in 2002. On Jun 1, 2004, we set a collision trap (Sankei-shiki Konchu Yuinki, Sankei Chemical Co., Kagoshima) using pheromones (Biobset Belugium) as lure on the rooftop of the building of the University (about 15 m above the ground) near the planted *P. canariensis* trees. Checks on the trap were carried out daily and lure replenished at 2-week to 1-month intervals until Mar 31, 2005.

Observation of flying adults and collection of fresh adult carcasses in the Korimoto Campus of Kagoshima University, as adults flying into our laboratory, were used to estimate the seasonal pattern of flight activities of adults.

### Composition of *R. ferrugineus* at Different Developmental Stages in *P. Canariensis* Trees

We examined the composition of *R. ferrugineus* at different developmental stages in 17 infested *P. canariensis* trees in Kagoshima that were cut down at different seasons from Nov 22, 2003 to Oct 31, 2005. In 11 of the 17 *P. canariensis* trees which were cut down on Nov 22 in 2003, Jan 10, Feb 25, Apr 9, May 29, Aug 24, Nov 4, 6, 10, 19 in 2004 and May 28 in 2005, the peripheral part of the trunks and the base of petioles had been destroyed by the larvae and intact tissue was already discolored white to brown when they were cut down. In the 6 *P. canariensis* trees cut down on Dec 28, 2004 and Oct 9, 20, 31, 2005, infestation had not so progressed that leaves were only partly discolored and considerable white intact tissue remained at the crown part of the trunks and the base of petioles. We collected eggs, larvae, pupae, and adults from infested part of the 17 *P. canariensis* trees, and recorded their numbers.

We tentatively categorized larvae into 3 stages based on head capsule widths of 855 larvae; young (<2.8 mm), medium (2.8-6.0 mm), and mature (>6.0 mm) stages (Fig. 1). In order to reveal the effects of resource (white intact tissue) availability on the composition of larvae of different stages, the stage was determined for each larva based on head-capsule width.

We collected adults from the *P. canariensis* trees cut down and reared them at room temperature with fresh sliced apple to obtain eggs. We placed each egg in a Petri dish (ϕ 6 cm) with bottom surface covered with a moistened filter paper. Newly hatched larvae were placed individually in separate Petri dishes (ϕ 9 cm) and provided fresh sliced apple as food. The molting of over 100 larvae was checked daily.

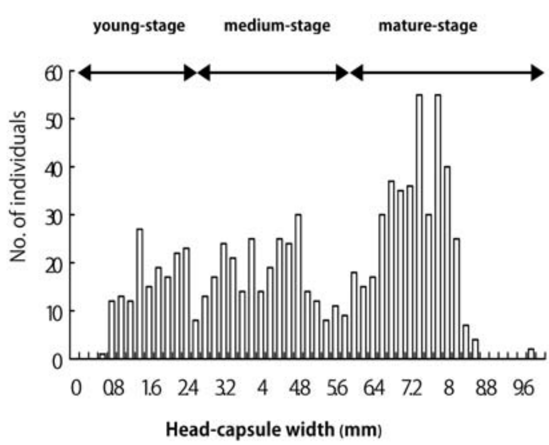


Fig. 1. Frequency distribution of head-capsule width of the larvae of *Rhynchophorus ferrugineus*.

Temperature Inside the Trunk

Because *R. ferrugineus* was originally distributed in tropical and subtropical areas, the establishment of invading population and the development of *R. ferrugineus* were thought to be impeded by a low temperature during winter in Japan. Thus, using an alcohol-etched stem thermometer, we measured the temperature in the infested part of the trunk of *P. canariensis* trees on Nov 9, 2004, Oct 9, Oct 20, Oct 20, 2005, and Jan 5, 2007, to evaluate the thermal condition of *R. ferrugineus* during winter.

## Results and Discussion

### Seasonal Patterns of Flight Activity of Adults

From Jun 14, 2004 to Dec 12, 2004, a total of 22 adults (13♂, 9♀) were captured by the trap. The number of captured adults was greatest (6♂, 3♀) in Aug. Five adults (2♂, 3♀) flew into the laboratory in Jun and Jul. We observed the adults flying around the trap on 4 occasions in Jul and Aug, and twice in Sep (Table 1). In addition, we collected a fresh carcass on the Korimoto Campus of Kagoshima University on Mar 3, 2005. This collection of a fresh carcass indicates that this weevil emerged from a host tree and might fly at the beginning of Mar. Sato & Irei (2003) caught *R. ferrugineus* adults from Mar 10 to Dec 10 in Kagoshima with peaks in Jun and Sep to Oct. In Miyazaki Prefecture, adjacent to Kagoshima Prefecture, Aman et al. (2000) caught adults from early May to late Nov with 3 peaks in mid-Jun, late Jul, and early Sep. Taking together the results of the 3 studies, we can deduce that *R. ferrugineus* adults begin to emerge from their host plant in Mar and their flight lasts until mid-Dec, with some peaks occurring during summer and fall in southern Japan. It is also likely that weevils remain stationary within *P. canariensis* trees in winter.

Table 1. Captures and flight observations of *R. ferrugineus* adults.

| Month | The number of adults | | Flight observation date |
|---|---|---|---|
| | captured by a trap | flew into the laboratory | |
| Jan | — | — | — |
| Feb | — | — | — |
| Mar | — | — | — |
| Apr | — | — | — |
| May | — | — | — |
| Jun | 1♂, 1♀ | 1♂, 2♀ | 4 |
| Jul | 4♂ | 1♂, 1♀ | — |
| Aug | 6♂, 3♀ | — | 4 |
| Sep | 1♂, 1♀ | — | 2 |
| Oct | — | — | — |
| Nov | 1♂, 3♀ | — | — |
| Dec | 1♀ | — | — |

### Determination of the Number of Instars

The reared larvae molted a maximum of 12 times before pupation. Vaido & Bigornia (1949) reported that *R. ferrugineus* molted 9 times before pupation. These results indicate that *R. ferrugineus* has 10 to 13 instars.

### Composition of *R. ferrugineus* at Different Developmental Stages in *P. canariensis* Trunks and Life History

We collected 6 to 213 *R. ferrugineus* individuals from the 11 *P. canariensis* trees with no white intact tissue. In these trees, pre-pupae, pupae, and adults composed 42% or more of the population. Adults composed all and 95% of individuals in the palm trees felled on Feb 25, 2004 and Apr 9, 2004 respectively, and about half of the adults were in cocoons. The adult-biased composition was also recorded in the *P. canariensis* tree cut down on May 28, 2005, where most adults were still in cocoons. However, larvae and pupae predominated in the others *P. canariensis* trees (Table 2).

We collected 36 to 305 individuals from the 6 *P. canariensis* trees whose tissue was destroyed only partly. Larvae composed 67% or more of the individuals in them (Table 3), and the relative frequency of larvae was higher than that in the 11 *P. canariensis* trees with no white intact tissue (Table 2) (Mann-Whitney $U$-test; $P < 0.05$).

The composition of larvae of the 3 stages differed with resource (white intact tissue) availability in infested *P. canariensis* trees. In *P. canariensis* trees there remained no white intact tissue at the peripheral part of the trunk and the base of petioles, all or most of the larvae (more than 90%) were mature. In the 6 *P. canariensis* trees where the peripheral part and petioles were destroyed partly, the larval composition varied. The larval population consisted of 0-20% of young-, 6-60% of medium-, and 20-94% of mature-stage of larvae (Table 4). In *P. canariensis* trees cut down on Dec 28, 2004, Oct 9, 2005, and Oct 31, 2005, young- and medium-stage larvae comprised 80, 33, and 43% of the larval population, respectively. These results suggest that the composition of individuals at different developmental stages in infested trees was dependent on resource availability in trunks and petioles. A low rate of young- and medium-stage larvae in trees with no resource suggest the possibility that young- and medium-stage larvae starved to death from the lack of sustenance in the trees with no resource, leaving only the stronger, more adaptable mature-stage larvae, pupa, and adults.

TABLE 2. COMPOSITION OF RHYNCHOPHORUS FERRUGINEUS INDIVIDUALS AT DIFFERENT STAGES IN PALM TREES WITH NO WHITE INTACT TISSUE.

| Year | Date | Relative frequency (%) | | | | | Total weevils |
|---|---|---|---|---|---|---|---|
| | | Larvae | Prepupa | Pupae in cocoon | Adults in cocoon | Adults | |
| 2003 | Nov 22 | 14 | 12 | 60 | 9 | 5 | 58 |
| 2004 | Jan 20 | 55 | 17 | 4 | 4 | 21 | 102 |
| | Feb 25 | 0 | 0 | 0 | 50 | 50 | 6 |
| | Apr 9 | 0 | 5 | 0 | 43 | 52 | 21 |
| | May 29 | 56 | 24 | 3 | 0 | 18 | 34 |
| | Aug 24 | 52 | 13 | 17 | 9 | 9 | 23 |
| | Nov 4 | 23 | 8 | 34 | 19 | 16 | 213 |
| | Nov 6 | 22 | 12 | 39 | 20 | 7 | 95 |
| | Nov 10 | 28 | 17 | 47 | 8 | 0 | 78 |
| | Nov 19 | 58 | 5 | 20 | 8 | 8 | 84 |
| 2005 | May 28 | 0 | 0 | 5 | 82 | 13 | 39 |

TABLE 3. COMPOSITION OF *RHYNCHOPHORUS FERRUGINEUS* INDIVIDUALS AT DIFFERENT DEVELOPMENTAL STAGES IN PALM TREES WHOSE TISSUE WAS PARTIALLY DESTROYED.

| Year | Date | Relative frequency (%) | | | | | Total weevils |
|---|---|---|---|---|---|---|---|
| | | Larvae | Prepupa | Pupae in cocoon | Adults in cocoon | Adults | |
| 2004 | Dec 28 | 89 | 3 | 4 | 2 | 2 | 305 |
| 2005 | Oct 9 | 97 | 0 | 0 | 0 | 3 | 72 |
| | Oct 20 | 78 | 7 | 8 | 3 | 5 | 167 |
| | Oct 20 | 67 | 8 | 20 | 1 | 4 | 130 |
| | Oct 31 | 83 | 8 | 3 | 6 | 0 | 36 |
| | Oct 31 | 78 | 3 | 3 | 5 | 13 | 40 |

TABLE 4. COMPOSITION OF *RHYNCHOPHORUS FERRUGINEUS* LARVAE AT DIFFERENT DEVELOPMENTAL STAGES IN PALM TREES WHOSE INTACT TISSUE WAS PARTIALLY DESTROYED.

| Year | Date | Relative frequency (%) | | | Total larvae |
|---|---|---|---|---|---|
| | | Young-stage | Medium-stage | Mature-stage | |
| 2004 | Dec 28 | 20 | 60 | 20 | 272 |
| 2005 | Oct 9 | 1 | 32 | 67 | 69 |
| | Oct 20 | 3 | 10 | 87 | 129 |
| | Oct 20 | 1 | 12 | 87 | 87 |
| | Oct 31 | 10 | 33 | 57 | 30 |
| | Oct 31 | 0 | 6 | 94 | 31 |

Based on information in the present study and data on the capture of adults in Kagoshima and Miyazaki (Sato & Irei 2003; Aman et al. 2000), the life history of *R. ferrugineus* in southern Japan can be summarized as follows. Adults emerge from host plants and fly in the field from early Mar to mid-Dec. Because females, if they feed, can deposit a total of about 300 eggs almost daily for at most 3 months (unpublished data), the oviposition season of *R. ferrugineus* covers a long period from spring to late fall, and various stages of individuals are found in an infested *P. canariensis* tree throughout the year until the intact inner tissue is completely destroyed and sustenance for the *R. ferrugineus* runs out.

The monthly mean temperature of the winter months (Dec to Feb) in southern Japan is about 10°C with a minimum temperature falling below 0°C (Japan Meteorological Agency). Yoshitake et al. (2001) reported that the temperature 10 cm deep inside the trunk of healthy *P. canariensis* tree agrees with air temperature in winter. However, on Nov 9, 2004, Oct 9, Oct 20, Oct 20, 2005, and Jan 5, 2007, the temperature in the infested part of the trunk of *P. canariensis* trees was 37, 33-35, 30-40, 32 and 32°C, respectively. During the winter, *R. ferrugineus* was feeding in a peripheral part of *P. canariensis* trees where the temperature was 30°C or higher. These results indicate that a low air temperature during winter in Japan does not have lethal effects on *R. ferrugineus* in host trees and that *R. ferrugineus* can grow during winter if there remains sufficient intact inner tissue in host trees. The lifetime from egg to adult of *R. ferrugineus* reared at 29°C was reported as about 80 d by Rahalkar et al. (1985), and flight activity showed peaks in summer and fall (Sato & Irei 2003; Aman et al. 2000). Thus, this weevil can have at least 3-4 generations a year in southern Japan.

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