Flight Response of the Rice Water Weevil (Coleoptera: Curculionidae) to Simulated Habitat Conditions

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ABSTRACT The flight response of parthenogenic female rice water weevils, *Lissorhoptrus oryzophilus* Kuschel, to various simulated habitats and substrate types was investigated in the greenhouse. Study insects were obtained following flight from natural overwintering sites. Simulated habitats were dry soil, moist soil, flooded soil, moist soil with rice, and flooded soil with rice. Substrate types were dry fine soil, dry cloddy soil, dry soil with emergent vegetation, dry soil with a slender dowel, and flooded soil. Dry, moist, and flooded habitat conditions without rice were associated with greater flight initiation than the flooded condition with emergent rice. The flight response from moist soil with rice was variable. Flight initiation was generally >50% in each of the nonflooded substrate types. No flight activity was detected from the flooded soil substrate.

KEY WORDS *Lissorhoptrus oryzophilus,* flight behavior, rice

THE RICE WATER WEEVIL, *Lissorhoptrus oryzophilus* Kuschel, is an important pest of rice, *Oryza sativa* L., throughout the rice growing areas of the United States (Bowling 1967). Owing to the availability of rice during the weevils' spring flight period, and the practice of cultivating rice under flooded conditions, this crop has become an important host for the semi-aquatic weevil (Tucker 1912, Bang & Tugwell 1976). Adult weevils prefer to feed on rice and other grasses that are flooded (Isely & Schwardt 1934, Lauck 1972), and oviposition occurs in the submerged leaf sheath (Grigarick & Beards 1965, Everett & Trahan 1967). In the southern states the species is bisexual. In California only parthenogenic females occur (Grigarick 1984).

Rice water weevils overwinter as adults at the base of perennial grasses on levees or in uncultivated areas (Grigarick & Beards 1965, Grigarick 1984). In the spring, weevils leave the overwintering sites and move to suitable oviposition habitats (Tucker 1912, Webb 1914, Grigarick & Beards 1965, Muda et al. 1981). Weevils usually fly between late March and early June over a period of ≈2 mo, depending on weather variables (Grigarick 1984; A.A.G., unpublished data). Peak infestation by the adult rice water weevil is associated with an ≈2-wk period following the establishment of emergent flooded rice (Isely & Schwardt 1932, Grigarick & Washino 1983, Morgan et al. 1989). In California, the first half of the spring migratory flight usually occurs before emergent flooded rice is available (Grigarick & Beards 1965). Previous studies suggest that migratory rice water weevils can undertake repeated flights until flooded rice becomes available (Isely & Schwardt 1934, Rolston & Rouse 1964, unpublished data). The condition of a rice field during the period of weevil migration may affect weevil flight behavior and subsequent infestation levels.

Habitat Study. The objective was to measure the preference for five simulated rice field conditions by flight-capable rice water weevils after emergence from overwintering sites. For example, weevils may prefer flooded, emergent rice to dry soil, thereby resulting in greater adult concentrations in the former habitat. Early-season field draining may influence the tendency of adults to land or remain in that habitat.

Substrate Study. This study concerned the effect of substrate quality on flight initiation. After a weevil lands in a dry, newly flooded, or drained field, can it fly again? Captive weevils exhibit a strong tendency to climb vertical substrates, and observations of rice water weevils climbing vegetation before flight indicated that a perch may be necessary for flight initiation. The surface condition of a field or levee may affect the ability of weevils to fly from that site.

Materials and Methods

Habitat Study. Experiments were conducted in a greenhouse at Davis, CA, during 1989 and 1990. The climatic conditions in the greenhouse during these tests, particularly temperature, solar radiation and humidity, fell within the range normally encountered in the Sacramento Valley during the weevils migration period. Stockton adobe clay soil was obtained from the Rice Experiment Station (RES) near Biggs, CA, and sifted through a 1.25-cm mesh screen. One-liter plastic cups (10 cm diameter, 14 cm tall) were filled with ≈470 cc of soil and 0.5 g of ammonium sulfate fertilizer was incorporated.

The five treatments were (1) dry soil, (2) moist soil, (3) flooded soil, (4) moist soil with rice, and (5) flooded (submerged) soil with rice. A completely randomized design with five treatments and five (1990) or four (1989) replications was used.

Rice seeds (var. M-202) were presoaked for 48 h, then drained for 24 h before planting. The cups for both treatments containing rice were flooded to a depth of ≈10 cm (4 in), then planted with eight seeds and thinned to five plants per cup ≈16 d later. The moist soil with rice treatment was drained before weevils were introduced. Weeds were generally not a problem in the cups, perhaps because of presoaking of the rice seed and the immediate seeding of the cups following flooding; i.e., the rice had an early growth advantage over any weed seed present. An occasional emergent weed was removed at the time of thinning.

Flight chambers were made by sealing the mouth of each cup with an inverted, translucent funnel (Nalgene PF100), which had a base diameter of 10 cm, a tip diameter of ≈3 cm, and a height of 6 cm. A band of tropical formula Stikem (Seabright Enterprises, Emeryville, CA) was placed around the inside of the funnel near the tip to prevent weevils from crawling out. A 22-cm length of 3.5-mm (1/8 in) dowel was pressed into the soil of each cup until ≈5 mm projected beyond the opening of the funnel. The dowel served as a standardized flight perch for each treatment in the habitat study. The cup and funnel were then placed inside a clear acetate cylinder (34 cm high, 23 cm diameter) and covered with aluminum screen to confine weevils that flew from the cups.

Flight-capable rice water weevils were captured at the RES by reflecting a black light onto a white linen sheet beginning ≈1 h before sunset. Weevils were collected from the sheet and confined in plastic cups containing clipped leaves of Dallis grass, *Paspalum dilatatum* Poir., which begins naturally at the collection sites. Collection dates were 26 May 1989, and 27 April and 5 May 1990. On the following day they were placed into the flight chambers before the time when flight normally occurs (≈1 h before sunset). No artificial light was provided in the greenhouse; however, a low level of external artificial light was present. The approximate greenhouse temperature range during the flight period on each of the three respective dates was 29–22°C, 29–22°C, and 32–21°C. The number of weevils added per flight chamber in each experiment varied depending on availability (1989, 8; 1990, 16 and 10).

Chambers were checked the following day to determine the number of rice water weevils that had flown. The proportions of weevils that departed were transformed using arcsine $(x)^{1/2}$, then subjected to analysis of variance (ANOVA). Significant differences ($P = 0.05$) among habitats were separated by Tukey's studentized range test (SAS Institute 1985).

Substrate Study. Experiments were conducted in a greenhouse at Davis, CA, during 1991. Stockton adobe clay soil was obtained from the RES and sifted through one or more screens of different mesh size according to the treatment.

The five treatments were (1) dry fine soil surface, (2) dry cloddy soil surface, (3) dry soil with emergent vegetation, (4) dry soil with a slender dowel, and (5) flooded (submerged) soil. All treatments were prepared such that the uppermost surface of each substrate type (e.g., the soil surface, the uppermost surface of the clod, the tip of the leaf vegetation, the top of the dowel, or the water surface, respectively) was ≈17 mm below the lip of the open, one-liter plastic cup (10 cm diameter, 14 cm tall). A thin layer of Stikem was applied to the inner rim of the cup to prevent weevils from crawling out. A completely randomized design consisting of five treatments and four or five replications was used.

Fine soil was obtained by sifting through a number 20 (0.841 mm) U.S. standard sieve. Clods were obtained by sifting soil through chicken wire (25 by 30 mm, hexagonal openings) to remove oversized clods, then through wire mesh (15 by 15 mm); the clods that did not pass through the wire mesh were used. Three of these clods were placed onto a bed of fine soil (0.841 mm) in a circular pattern around the center of the cup for treatment 2. Dallis grass seedlings were grown in small glass vials to the two- to three-leaf stage to serve as emergent vegetation. Dallis grass was chosen because it is generally present on levees during the spring flight period, and adult weevils show a feeding preference for it before flooded rice becomes available (Lauck 1972). The vials were then embedded in a soil base and fine soil (0.841 mm) was added around the vial until only the seedling remained exposed. In treatment 4, three sections of dowel (13 by 3.5 mm) (1/8 in) were inserted in a circular pattern into fine soil (0.841 mm) which measured ≈6 cm in depth. The soil in treatment 5 was sieved through wire mesh (12.5 by 12.5 mm) and covered with ≈6 cm of water.

Flight-capable rice water weevils were obtained and handled as described previously, and the experiment was repeated three times. Collection dates were 20 May, 22 May, and 24 May 1991, with the flight tests occurring ≈24 or 48 h after the initial capture. The approximate greenhouse temperature range during the three flight

Table 1. Rice water weevil flight frequency from simulated habitats with flight perches, Davis, CA, 1989 and 1990

Treatment (habitat)	% Weevils that flew from confinement chambers (mean ± SEM)		
	28 May 1989	29 April 1990	7 May 1990
	n = 8; r = 4	n = 16; r = 5	n = 10; r = 5
Dry soil	75.0 ± 11.4a	68.8 ± 8.1a	90.0 ± 4.5a
Moist soil	43.8 ± 19.4a	71.3 ± 4.2a	86.0 ± 9.8a
Flooded soil	68.8 ± 10.8a	62.5 ± 5.9a	84.0 ± 5.1a
Moist soil with rice	40.6 ± 11.8a	65.0 ± 7.3a	30.0 ± 3.2b
Flooded soil with rice	21.9 ± 6.0a	32.5 ± 5.4b	36.0 ± 11.2b

n, number of weevils per cup; r, number of replications. Means within each column followed by the same letter are not significantly different ($P > 0.05$, Tukey's studentized range test, SAS GLM procedure [SAS Institute 1985]). Data were transformed to arcsine $(x)^{1/2}$ for analysis.

periods was 28–24°C. Ten weevils were added to each open cup in test's 1 and 2, and eight were added in test 3. The following day, the cups were inspected to determine the number of weevils that remained. The proportions of weevils that departed were transformed using arcsine $(x)^{1/2}$, then subjected to ANOVA. Significant differences ($P = 0.05$) among treatments were separated by post-hoc test and Tukey's studentized range test (SAS Institute 1985). The flooded treatment had 0% of the weevils leaving the substrate for all replications; therefore, it had zero variability. This is a clear violation of the assumptions on an ANOVA; therefore, the flooded treatment was excluded from the ANOVA. The remaining treatments were compared with zero using Tukey's multiple comparison procedure, effectively comparing them with the flooded treatment. This is a so-called "post-hoc" comparison.

Results

Habitat Study. In 1989, the mean number of weevils that flew from each chamber did not differ significantly among the five treatments (Table 1). There was some indication, however, that flooded soil with rice was the least repellent, and dry and flooded soil treatments the most repellent habitats to the weevils ($F = 2.58$; df = 4, 15; $P = 0.0798$).

In both experiments conducted in 1990, the number of weevils flying out of the flooded soil with rice habitat was significantly lower than the three habitats without rice plants ($F = 6.05$; df = 4, 19; $P = 0.0026$ [29 April] and $F = 11.09$; df = 4, 20; $P < 0.0001$ [7 May]). In the first experiment (29 April), the number of weevils that left the moist soil with rice habitat was nearly equal to the numbers that left the three habitats without rice. In the second experiment, however, the moist and flooded soil with rice treatments produced similar flight responses. In both 1990 experiments, the three habitats without rice were equally repellent to the weevils.

Substrate Study. In all three experiments, weevil flight did not occur in the flooded soil treatment (Table 2). Flight from each of the nonflooded substrates was significantly greater than from the flooded substrate in two of the three experiments. From Tukey's studentized range test, the minimum significant difference expressed as a percentage was ≈30% in test 1; 35% in test 2; and 32% in test 3; df = 12; alpha = 0.05%). Only in the first experiment was flight from the grass vegetation treatment significantly lower than in the other three dry treatments ($P = 0.05$).

Discussion

Habitat Study. The flight response of rice water weevil adults confined in habitats without rice was approximately twice that of weevils confined under the flooded rice condition, suggesting a weevil preference for habitats with rice.

Table 2. Rice water weevil flight frequency as influenced by substrate, Davis, CA, 1991

Treatment (substrate)	% Weevils that flew from open cups (mean ± SEM)		
	Exp. 1	Exp. 2	Exp. 3
	n = 10; r = 4	n = 10; r = 4	n = 8; r = 5
Fine soil	67.5 ± 4.8a	67.5 ± 8.5a	58.0 ± 5.1a
Cloddy soil	70.0 ± 7.1a	60.0 ± 9.1a	50.0 ± 4.5a
Soil with vegetation	22.5 ± 8.5b	57.5 ± 13.1a	58.0 ± 7.5a
Soil with a dowel	62.5 ± 4.8a	65.0 ± 8.7a	80.0 ± 9.3a
Flooded soil	0b	0b	0b

n, number of weevils per cup; r, number of replications. Means within each column followed by the same letter are not significantly different ($P > 0.05$, Tukey's studentized range test, SAS GLM procedure [SAS Institute 1985]). Data were transformed to arcsine $(x)^{1/2}$ for analysis.

The response to flooded soil alone was similar to that of the moist and dry soil habitats, indicating that the flooding of soil does not make that habitat more preferable to the weevil. In 1989, the lower response in the moist soil and moist soil with rice treatments, relative to the dry and flooded soil treatments, suggested that moist soil might act to inhibit weevil flight. However, this trend was not evident in the second experiment (29 April 1990) in which the moist soil with rice and the three habitats without rice were equally repellent to the weevil, and all were significantly greater in flight response than the flooded rice habitat. This result indicates that rice in the flooded condition is an important combination in arresting weevil flight. This conclusion is consistent with previous observations made of rice water weevil abundance in established rice paddies before and after reflooding. Isely & Schwardt (1932) and Bang & Tugwell (1976) observed notably greater weevil populations soon after establishment of emergent, flooded rice.

In the third experiment of the habitat study, the low flight response to flooded rice reinforced the interpretation that these conditions arrest flight. The response to the moist rice habitat was also significantly lower than to the treatments without rice, suggesting that rice itself, serving as a food source, is a flight arrestant.

Substrate Study. Flooded soil (without a dowel) was the only substrate from which weevils did not fly, indicating the importance of a firm surface for flight. This suggests that weevils landing in a newly flooded paddy would be unable to fly unless floating debris or other suitable exposed perches were present.

Significantly reduced flight occurred from the soil with vegetation substrate, compared with the other three dry soil substrates, in only one of the three experiments. This difference may have been caused by a preference for the Dallis grass rather than an inhibitory effect on the flight frequency. Flight frequency from the other dry soil treatments was not significantly different. This suggests that rice water weevils can fly from most, if not all, of the nonflooded rice field conditions that are present during the spring weevil flight period. These results show that an elevated perch (e.g., a leaf blade) is not necessary and imply that substrate uniformity is not a limiting factor in rice water weevil flight initiation.

In summary, field condition may be an important factor in weevil flight behavior. There was a consistently lower flight response by rice water weevils in the habitat containing emergent, flooded rice compared with treatments without rice, indicating the importance of this combination in arresting weevil flight. The absence of standing water in a rice field may increase the tendency of weevils to leave, but this effect is more variable. Consequently, rice water weevil abundance may be influenced by water management in which flooding and planting or reflooding following early drainage occurs after peak weevil flights.

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