Effect of Flood Depth on Rice Water Weevil (Coleoptera: Curculionidae) Populations in Florida Rice Fields[1]

Ron Cherry[2], Mohsen Tootoonchi, Jehangir Bhadha, Tim Lang, Michael Karounos, and Samira Daroub

Everglades Research and Education Center, 3200 E. Palm Beach Rd., Belle Glade, Florida 33430 USA

J. Entomol. Sci. 50(4): 311–317 (October 2015)

Abstract The rice water weevil, *Lissorhoptrus oryzophilus* Kuschel, is an important pest of rice (*Oryza sativa* L.) grown in Florida. Reports on the effect of flood depth on rice water weevil populations have been inconsistent. Our objective was to determine if flood depth has any significant effect on rice water weevil populations and other arthropods in rice grown in Florida. Sampling was conducted using adult foliar damage scars, core samples for larvae, and sweep nets for arthropods above the water. Results showed that shallow flooding reduced rice water weevil populations in Florida. Sweep net data showed that flood depth had little, if any, effect on populations of damselflies (Odonata), leafhoppers (Cicadellidae), spiders (Arachnida), or stink bugs (*Oebalus* spp.).

Key Words rice, rice water weevil, flooding, *Lissorhoptrus oryzophilus*

The rice water weevil, *Lissorhoptrus oryzophilus* Kuschel, is the most widely distributed and destructive insect pest of rice (*Oryza sativa* L.) in the United States (Way 1990). The insect is native to the eastern United States and was accidently introduced into California rice fields in the 1950s (Lange and Grigarick 1959). The rice water weevil was first reported in Florida in 1916 (Blatchley and Leng 1916). It was briefly noted first occurring in rice grown in Florida in 1979 by Genung et al. (1979). These authors reported that the weevil attacked rice at the Everglades Research and Education Center at Belle Glade, FL, and according to curculionid authority Dr. C.W. O'Brien (University of Massachusetts, Amherst), the species occurred over all of Florida. There has been recent interest in the pest by Florida rice growers, leading to a recent publication on weevil damage in Florida rice fields (Cherry et al. 2013). This study showed that adult weevil leaf scars had a uniform distribution in Florida rice fields. These data suggested that rice water weevil damage may be overlooked by Florida rice growers because it is uniform and not aggregated on field edges where it would be more conspicuous. Other than these few publications, there is little understanding of this pest and its control in Florida rice fields. Current surveys are being conducted to determine the abundance of the pest in commercial rice fields in Florida.

[1]Received 08 January 2015; accepted for publication 06 May 2015.

[2]Corresponding author (rcherry@ufl.edu).

In most rice growing regions of the world, rice is grown as a lowland crop in which the soil is flooded during the greater part of the season. Application of this permanent flood is the most important external influence on the interaction between the rice water weevil and rice (Stout et al. 2002). There are numerous publications on flooding management for rice water weevil control. These include delayed flooding, drain-dry, and managing flood depth. Reports on the effect of flood depth on rice water weevil populations have been inconsistent (Bernhardt 2007; Rolston and Rouse 1964; Stout et al. 2002, 2014). Shang et al. (2004) noted that rice water weevil biology may differ among rice producing areas so that methods used for management in one region may not be applicable in another. Our objective was to determine if flood depth had any significant effect on rice water weevil populations in Florida rice. The effect of flood depth on other arthropods in Florida rice is also noted.

Materials and Methods

Eight research plots were located at Everglades Research and Education Center at Belle Glade, FL. Each plot was 15.2 × 79.2 m in area and all plots were planted 14 April 2014. Half of each plot was planted in Taggart variety and the other half in Cheniere variety. These are the two rice varieties currently being most widely used in Florida. All plots were flooded on 5 May and, thereafter, four plots were continuously flooded at a 15-cm depth (deep flooding) and four plots at a 5-cm depth (shallow flooding) until flood draindown on 21 July for the crop harvest. Water depth in plots was maintained by monitoring water levels daily using a graduated staff. Water inflow was controlled with valves and outflow using boards. The rice was harvested 7 August.

Adult foliar damage caused by rice water weevil produces translucent, longitudinal scars (Boyd 2005), which are used for scouting purposes. Rice water weevil adult feeding scars were found to be associated with increasing larval infestations by Grigarick (1965) and Tugwell and Stevenson (1974). Adult feeding scars have been used to estimate subsequent larval infestations by Tugwell and Stephen (1981) and Morgan et al. (1989). More recently, use of this method has been reported in population dynamic studies of rice water weevil (Shang et al. 2004) and for scouting (Boyd 2005, Lorenz and Hardke 2015). Leaf scar samples were taken every 2 weeks from 7 May to 17 June (four sampling dates). These dates approximated the start of leaf feeding until few new scars were appearing in the plots. On each date, 50 randomly selected rice plants in each variety in each of the eight plots were examined for the presence or absence of leaf scars. Bang and Tugwell (1976) reported that adult weevils preferred to feed on young rice leaves. However, we examined all leaves on the plant for presence or absence of feeding damage because we were interested in feeding scars, past and recent, occurring in the area. The number of leaf scars in each variety at each depth was analyzed using the Least Significant Difference (LSD) test for each sampling date. Single-degree orthogonal contrasts also were used to compare overall leaf scar numbers in both varieties in deep flood versus shallow flood at each sampling date (SAS 2014).

Table 1. Rice weevil leaf scars on rice plants at two flood depths.

	Date Sampled*			
	7 May	20 May	2 June	17 June
Deep				
Cheniere	0 A	12.0 A	28.5 A	36.5 A
Taggart	0 A	9.5 AB	23.0 A	36.0 A
Shallow				
Cheniere	0 A	6.0 BC	8.0 B	19.8 B
Taggart	0 A	3.8 C	10.5 B	19.3 B

* Means in a column with the same letter are not significantly different (alpha = 0.05) using the Least Significant Difference test. Contrast values of deep versus shallow were $F = 0$, $P = 1$ on 7 May, $F = 10.9$, $P < 0.01$ on 20 June, $F = 14.1$, $P < 0.01$ on 2 June, $F = 26.8$, $P < 0.01$ on 17 June (SAS 2014).

Population densities of immature stages of the weevil were estimated by counting larvae and pupae in a root-soil core sample. The cylindrical core sampler used had a 12-cm diameter and 12-cm length and was taken on a rice plant. Random samples were taken from each variety in each plot. Samples were taken four times during 2–5 June. One sample was taken from each variety and each water depth on each day ($N = 16$) to remove any possible temporal bias. After each core sample was taken, it was placed in a plastic bucket in the field and then taken to a laboratory for processing. There samples were immersed in saturated salt water and gently torn apart, and immatures floating to the surface were counted. Statistical analysis was conducted using the LSD test and contrast analysis as previously described.

Sweep net samples were taken to determine if arthropod populations above water level were affected by water depth. Sweeps were taken 16 June when arthropod populations were starting to increase, 30 June, and 17 July when the rice was heading before the 21 July water drawdown for harvest. On each date, one 50-sweep sample was taken on a transect through the middle of each variety in each plot. Sweep nets were 38 cm in diameter and one sweep was made with each step forward. Samples were taken late morning and all sampling concluded in 1–2 h so that changing weather conditions such as wind, temperature, etc., were fairly constant throughout sampling. Two individuals swept and each did the same number of samples between varieties and water depth to remove personal bias in sweep samples. Sweep samples were frozen and arthropods were eventually counted using a microscope. Damselflies, leafhoppers, spiders, stink bugs, and rice water weevils were the most numerous arthropods in sweep samples and, hence, were counted for statistical analysis. Statistical analysis was conducted as previously described.

Table 2. Rice weevil larvae in core samples at two flood depths.

	N	Mean*	SD	Range
Deep				
Cheniere	16	2.4 A	2.1	0–8
Taggart	16	3.8 A	1.7	1–7
Shallow				
Cheniere	16	1.7 B	1.9	0–5
Taggart	16	1.3 B	1.2	0–3

* Means in the column with the same letter are not significantly different (alpha = 0.05) using the Least Significant Difference test. Contrast values of deep versus shallow were $F = 13.8$, $P = 0.0004$ (SAS 2014).

Results and Discussion

No feeding scars were observed in the 7 May sampling (Table 1). This was expected because water levels had not yet risen in the plots and adult feeding damage typically occurs after a rice field is flooded (Bernhardt 2007, Shang et al. 2004, Stout et al. 2002). By 20 May, fields were fully flooded and leaf scars were found at both water depths and in both varieties. Scars in all treatments accumulated over time being a function of old scars and new scars. There were no significant differences in scars between the two varieties at any time at either the deep flood or the shallow flood. In contrast to variety, flood depth had a significant effect on numbers of leaf scars. On all three dates with leaf scars present, more leaf scars were found in both varieties in the deep flood than the shallow flood. Contrast analysis showed that there were significantly ($P < 0.01$) fewer leaf scars in the shallow flood than deep flood on all three dates.

As noted earlier, leaf scars are considered predictors of later larval populations. Our data showed this trend as later larval populations in core samples mirrored adult scar samples. There were no significant differences in larval populations between the two varieties at either flood depth (Table 2). Again, in contrast to variety, flood depth had a significant effect on larval populations. More larvae were found in both varieties in the deep flood than the shallow flood, and contrast analysis showed significantly ($P = 0.00004$) more larvae in deep versus shallow flooding.

Arthropods caught in sweep samples are shown in Table 3. There were no temporal trends in damselflies or leafhoppers in that numbers caught were similar on all three dates. In contrast, data show that spider populations increased over time. There were no clear trends in varietal differences in the damselflies, leafhoppers, or spiders. Contrast analysis showed no significant ($P > 0.05$) effect of water depth on damselfly, leafhopper, or spider populations on any of the three sample dates. Genung et al. (1979) provided brief comments about the occurrence of these three groups in rice grown in Florida. Cherry et al. (1986) reported on the

Table 3. Arthropods in sweep samples in Florida rice at two flood depths.

	Sample Date**		
Arthropods*	**16 June**	**30 June**	**12 July**
Damselflies			
Cheniere—Deep	15.3 A	11.5 AB	14.0 B
Cheniere—Shallow	17.3 A	20.0 A	13.3 B
Taggert—Deep	8.8 A	5.5 B	21.0 AB
Taggert—Shallow	13.3 A	12.3 AB	24.3 A
Leafhoppers			
Cheniere—Deep	18.5 AB	35.3 A	22.0 B
Cheniere—Shallow	22.0 A	24.0 A	20.3 B
Taggert—Deep	4.3 C	35.0 A	44.3 A
Taggert—Shallow	11.5 BC	39.3 A	19.5 B
Spiders			
Cheniere—Deep	7.0 A	15.6 A	20.5 A
Cheniere—Shallow	6.3 A	12.8 A	10.3 A
Taggert—Deep	3.5 A	7.8 A	18.3 A
Taggert—Shallow	6.5 A	12.3 A	10.0 A
Stink bugs			
Cheniere—Deep	0.5 A	0.8 A	21.0 A
Cheniere—Shallow	1.0 A	2.5 A	46.5 A
Taggert—Deep	0.3 A	0.5 A	25.8 A
Taggert—Shallow	0.3 A	2.5 A	39.8 A
Weevils			
Cheniere—Deep	8.3 A	0.8 A	0.5 A
Cheniere—Shallow	1.3 B	0.8 A	0.8 A
Taggert—Deep	2.5 B	1.3 A	1.0 A
Taggert—Shallow	0.5 B	1.0 A	0.3 A

* Damselflies = Odonata; leafhoppers (nymphs + adults) = Cicadellidae; spiders = Arachnida; stink bugs (nymphs + adults) = *Oebalus* spp.; and weevils = adult rice water weevils.

** For each arthropod group, means in a column with the same letter are not significantly different (alpha = 0.05) using the Least Significant Difference test. Contrast values of deep versus shallow were not significant (alpha = 0.05) for any arthropod group on any date except weevils on 16 June ($F = 33.0$, $P < 0.0001$).

relative abundance of leafhoppers (Cicadellidae) and planthoppers (Delphacidae) in rice grown in Florida.

In stink bugs, there was a major increase in numbers caught in the last 12 July samples. This is easily explained because the rice in all plots was heading at that time. The three stink bug species sampled were *Oebalus insularis* (Stal) (22%), *O. pugnax* (F.) (60%), and *O. ypsilongriseus* (DeGeer) (18%). These species are all known primarily to be pests of rice during heading as the rice panicle develops (Cherry and Nuessly 2010). Stink bug catches were not significantly different between varieties at any time. Contrast analysis showed no significant effect of water depth on stink bug catches on any of the three sample dates.

In contrast to stink bugs, there was a major decrease in rice water weevil adults caught after the earliest 16 June sample date. This is consistent with Shang et al. (2004), who reported that populations of adult rice water weevils decreased later in the rice crop cycle. Weevil catches showed little difference between varieties, indicating varieties were not important in adult population densities. Contrast analysis showed no significant effect of water depth on adult populations at the two later dates when few adults were caught. However, there was a significant effect ($F = 32.9$, $P < 0.0001$) of water depth on 16 June when many adults were caught, thus facilitating statistical analysis. At that time, more adults were caught in both varieties in the deep floods which is consistent with earlier results from feeding damage and larval core data.

Stout et al. (2002) have noted that studies on the direct and indirect effects of flooding on plant–arthropod interactions are needed. Our sweep net data show that flood depth had little, if any, effect on five groups of above-water arthropods except for rice water weevil adults early in the rice crop cycle.

Reports have been inconsistent on the effect of flood depth on rice water weevil populations. Rolston and Rouse (1964) in plot studies in Arkansas reported that flood depth had no apparent effect on larval abundance as long as the rice remains vigorous. In contrast, Stout et al. (2002) in greenhouse tests in Louisiana reported that flood depth had a direct influence on ovipositional behavior of the weevils. Bernhardt (2007) in plot studies in Arkansas reported that shallow flooding had fewer larvae than deeper flooding, but significant differences were not found between treatments. Nonetheless, he concluded that the use of flood depth as a cultural practice to lower weevil populations could be successfully used by rice growers. Lastly, Stout et al. (2014) surmised that shallow flooding can help reduce weevil damage. To our knowledge, our study used the largest plots of any field study yet to determine if water depth had any significant effect on rice water weevil populations. Admittedly, this study was conducted for only 1 yr. However, our data using three different sampling techniques were consistent in showing that shallow flooding reduced rice water weevil populations. These data corroborate previous studies in other states, suggesting the use of water depth as a cultural control technique for rice water weevil.

References Cited

Bang, Y.H. and P. Tugwell. 1976. Adult rice water weevil feeding preferences for rice plants and leaves of different ages. Arkansas Agric. Exp. Stn. Rep. Ser. 231. 12 pp.

Bernhardt, J. 2007. Influence of flood depth on rice water weevil infestation and damage, Pp. 99–102. *In* Norman, R., J. Meullenet, and K. Moldenhaur (eds.), B.R. Wells Rice Research Studies. Univ. Arkansas, Fayetteville.

Blatchley, W. and C. Leng. 1916. Rhynocophora or weevils of North Eastern America. Nature Publishing Co., Indianapolis, IN.

Boyd, M. 2005. Univ. of Missouri rice insect management guide. 14 November 2014. (aes.missouri.edu/delta/muguide.ricegsh.stm).

Cherry, R., D. Jones and F. Mead. 1986. Leafhoppers (Homoptera: Cicadellidae) and planthoppers (Homoptera: Delphacidae) in southern Florida rice fields. Fla. Entomol. 69: 180–184.

Cherry, R. and G. Nuessly. 2010. Establishment of a new stink bug pest, *Oebalus insularis* (Hemiptera: Pentatomidae), in Florida rice. Fla. Entomol. 93: 291–293.

Cherry, R., B. Sakr, L. Trotta and G. Nuessly. 2013. Distribution of rice water weevil (Coleoptera: Curculionidae) adult damage in Florida rice fields. J. Entomol. Sci. 48: 265–269.

Genung, W., G. Snyder and C. Green. 1979. Rice field insects in the Everglades. Belle Glade Res. Rep. EV. 1979-7. Univ. of Florida.

Grigarick, A.A. 1965. The rice water weevil in California, Pp. 40. *In* Proceedings of the 10th Rice Technical Working Group, Fresno, CA. 111 pp.

Lange, W. and A. Grigarick. 1959. Rice water weevil: Beetle pest in rice growing areas of southern states discovered in California. Calif. Agric. 13: 10–11.

Lorenz, G. and J. Hardke. 2015. Insect management in rice, Pp. 139–162. *In* Hardke, J. (ed.), Arkansas Rice Production Handbook. MP 192. Univ. Arkansas Division of Agriculture, Little Rock.

Morgan, D., N. Tugwell and J. Bernhardt. 1989. Early rice field drainage for control of rice water weevil (Coleoptera: Curculionidae) and evaluation of an action threshold based on leaf-feeding scars of adults. J. Econ. Entomol. 82: 1757–1759.

Rolston, L. and P. Rouse. 1964. Some factors influencing larval infestations of the rice water weevil. J. Kans. Entomol. Soc. 37: 29–35.

SAS. 2014. SAS/STAT Users Guide. SAS Institute, Cary, NC.

Shang, H., M. Stout, Z. Zhang and J. Cheng. 2004. Rice water weevil (Coleoptera: Curculionidae) population dynamics in Louisiana. J. Entomol. Sci. 39: 623–642.

Stout, M., N. Hummel, S. Lanka, J. Hamm, A. Meszaros, W. McClain, M. Frey and G. Barbee. 2014. Rice water weevils—New tactics for managing this insect pest, Pp. 1–3. 22 June 2014. (www.lsuagcenter.com).

Stout, M., M. Rigio, L. Zou and R. Roberts. 2002. Flooding influences ovipositional and feeding behavior of the rice water weevil (Coleoptera: Curculionidae). J. Econ. Entomol. 95: 715–721.

Tugwell, N. and F. Stephen. 1981. Rice water weevil seasonal abundance, economic levels and sequential sampling. Arkansas Agric. Exp. Stn. Bull. 849. Fayetteville.

Tugwell, N. and T. Stevenson. 1974. Possible scouting procedure for rice water weevil, p. 41. Proc. 15th Rice Technical Working Group, New Orleans, LA.

Way, M. 1990. Insect management in rice in the United States, Pp. 181–189. *In* Grayson, B., M. Green, and L. Copping (eds.), Pest Management in Rice. Elsevier Science Publishing Co. Inc., New York.