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Evaluation of neonicotinoids as pyrethroid alternatives for rice water weevil management in water-seeded rice

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ABSTRACT

The rice water weevil (RWW), *Lissorhoptrus oryzophilus* (Kuschel) (Coleoptera: Curculionidae), is the most destructive insect pest of rice in the United States. Water-seeded rice, which is flooded at an earlier stage of crop development than drill-seeded rice, is at heightened risk of loss from root-feeding RWW larvae. Pyrethroids, the most widely used group of foliar insecticides for RWW control, have inherent limitations such as limited residual activity, narrow window of activity and extreme toxicity to non-target aquatic organisms. An array of field, lab and greenhouse experiments was conducted to compare the activity of two neonicotinoids with that of λ-cyhalothrin, a widely used pyrethroid, against the RWW. Small-plot efficacy trials were conducted during 2009, 2010 and 2011. Foliar clothianidin (Belay 2.13 SC) and a granular formulation (3%) of dinotefuran applied to plots were as effective as, and showed greater residual activity than, foliar applications of λ-cyhalothrin. Topical bioassays on adult weevils revealed that clothianidin possessed lower contact toxicity than λ-cyhalothrin. Residual assays using weevils placed on foliage of sprayed plots revealed that the toxic and sublethal behavioral effects of clothianidian on adult weevils were more persistent for clothianidin than for λ-cyhalothrin. Granular dinotefuran applied to greenhouse-grown plants previously infested with weevil larvae showed excellent larvicidal activity. Overall, these studies showed that neonicotinoids have potential as pyrethroid replacements against the RWW in water-seeded rice culture.

1. Introduction

The rice water weevil (RWW) is the most important insect pest of rice in the United States (Way, 1990). Over the past few decades, this insect has invaded important rice growing regions of the world, including Asia and Europe, and thus has now assumed global importance as a pest of rice (Saito et al., 2005). The interaction of the RWW with rice involves all life stages of the insect. Adult weevils feed on leaves of young rice plants causing characteristic feeding scars parallel to the venation of leaves. Oviposition is triggered by the presence of standing water and eggs are laid in leaf sheaths at or below the water line; thus, the majority of egg-laying occurs after fields are flooded (Everett and Trahan, 1967; Muda et al., 1981; Smith, 1983; Stout et al., 2002). Eggs hatch after an incubation period of 5–9 days (Raksarart and Tugwell, 1975). Neonates mine through leaf sheaths or shoots, then quickly move down to the roots and establish feeding sites on or in rice roots (Zhang et al., 2004). Larvae pass through four instars to undergo pupation in 27–30 days (Zou et al., 2004a). Adult feeding is not considered economically important except under unusually heavy infestations, but root pruning can result in poor crop stand and reduced tillering at the vegetative stage and reduced panicle size and grain weight at the reproductive stage of rice (Zou et al., 2004b). This pest has the potential to cause economic losses in excess of 10% under heavy weevil pressure (Stout et al., 2011).

Rice in the United States is direct-seeded rather than transplanted as it is in much of Asia. The majority of rice in the southern United States is cultivated under a drill-seeded system in which a dry seed bed is prepared, seed is sown using a grain drill, and the field is typically flooded when rice starts tillering, three to five weeks after planting (Blanche et al., 2009). Alternatively, rice can be cultured by water-seeding, in which dry or sprouted seeds are broadcast into standing water (Blanche et al., 2009). After seeding, the flood may be maintained continuously until the field is drained for harvest or, more commonly, the field may be drained for a short period of time after seeding to allow plants to establish, and the

Abbreviations: AI, active ingredient; DPF, days post-flooding.

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flood re-established a short time later (Blanche et al., 2009). Regardless of whether water-seeded rice is flooded continuously or drained temporarily before applying a permanent flood, water-seeding involves flooding fields at an earlier stage of crop development than does drill-seeding. As a result, water-seeded rice is subject to infestation by RWW at an earlier stage of crop development and is, therefore, at a greater risk of loss from RWW. Water seeding is practiced on approximately 30–40% of rice acreage in southwest Louisiana (J. Saichuk, LSU AgCenter, personal communication).

Until recently, RWWs in rice were managed largely through the use of foliar applications of pyrethroids to eliminate adult female weevils before they oviposited. Use of pyrethroids in rice has several limitations. Because pyrethroids have limited residual activities, and because the damaging larval stages are shielded from insecticides, timing of application is critical for pyrethroid-based control of RWWs. Untimely pyrethroid applications may result in inadequate control. In addition, there is widespread concern over the use of pyrethroids because they are extremely toxic to non-target aquatic invertebrates such as the red swamp crawfish, *Procambarus clarkii* (Girard) (Decapoda: Cambaridae), a major aquaculture commodity that is co-cultivated with rice in southwest Louisiana (Jarboe and Romaire, 1991; Barbee and Stout, 2010). Finally, heavy use of a single class of insecticide against RWW is an unwise strategy because it has a history of developing resistance to insecticides (Bowling, 1968) which calls for development of alternative insecticides for weevil management in rice.

Over the past few years, seed treatment formulations of two neonicotinoid insecticides, Cruiser Maxx® Rice (AI: thiamethoxam) and Nipsit INSIDE® (AI: clothianidin), and an anthranilic diamide insecticide, Dermacor® X-100 (AI: chlorantraniliprole), have been labeled for RWW control in drill-seeded rice. These seed treatments provide effective protection of rice from damaging populations of *Lissorhoptrus oryzophilus*. More recently, the use of Dermacor X-100 has been extended to water-seeded rice in Louisiana under a special "local need" (Section 24c) label. However, because of the high price of Dermacor X-100, and because damaging weevil populations do not always occur in rice fields, some rice growers are unwilling to take this prophylactic approach.

Neonicotinoids target nicotinic acetylcholine receptors and are less toxic to vertebrates due weak affinity of neonicotinoids toward mammalian receptors (Tomizawa and Casida, 2003, 2005). The fast growing commercial use of these compounds has been attributed largely to their long residual activities, favorable physico-chemical properties, and amenability to diverse use patterns in agriculture such as seed treatments, surface applications on stem, foliar applications and soil drenching. Therefore, several formulations of these compounds are available for use.

In the present study, the efficacies of two neonicotinoid insecticide formulations, one containing clothianidin (Belay® 2.1 SC; Valent Corporation, USA) and another containing dinotefuran, (Dinotefuran 3G; Mitsui Chemicals, Inc. USA), were compared with that of a commercially registered pyrethroid, λ-cyhalothrin (Karate Z™; Syngenta Corporation, USA) against the RWW in water-seeded rice. Clothianidin and λ-cyhalothrin were evaluated as foliar sprays while dinotefuran was evaluated as a granule applied to soil after permanent flooding. Also, the contact toxicities of clothianidin and λ-cyhalothrin on RWW adults were determined by conducting topical bioassays during 2008 and 2010. In addition, these insecticides could affect insects through complex modes of activity when populations are exposed to residues (Lanka et al., 2013). Therefore, the residual activities of clothianidin and λ-cyhalothrin were compared by conducting feeding assays with adult weevils using foliage from insecticide-treated plots. Effects on both adult survival and behavior were measured. Finally, the larvicidal efficacy of dinotefuran on root-feeding larval stages was evaluated under greenhouse conditions.

2. Material and methods

2.1. Small-plot efficacy trials

Small-plot field experiments were conducted during the 2009, 2010, and 2011 growing seasons at the Louisiana State University Agricultural Center Rice Research Station, Crowley, LA. The soil type at this location is a Crowley silt loam (fine, montmorillonitic, thermic typic albaqualf). The rice variety CL-131, a conventional, herbicide-tolerant, long-grain variety was used for all experiments. Plots in all experiments measured 1.5 × 6.0 m and were surrounded by metal flashing, approximately 25 cm in height, to restrict movement of water and insecticides among plots. Plots were separated by at least 1.5 m on all sides. Plots were flooded and sprouted seed was hand sown into plots at a rate of 135 kg per ha. Fields were drained two to three days after planting to allow plants to peg down. Permanent floods were applied to plots when rice plants possessed 1 or 2 leaves on the main stem (V1 or V2 stage) (Counce et al., 2000). Dates of planting and permanent flooding are shown in Table 1. Fertilization and weed control practices followed

Table 1
Rice planting dates, flooding dates, rates and timings of insecticide treatments used in three small-plot evaluations of the insecticides λ-cyhalothrin, clothianidin, and dinotefuran, LSU-Agricultural Center Rice Research Station, Crowley, Louisiana, 2009–2011.

Date at		Insecticide treatment[a]		Timing (DPF)[b]	
Planting	Flooding	Active ingredient	Rate (g/ha)	Application	Sampling
21-May-09	9-Jun-09	Clothianidin	100.9 & 100.9	1 & 7	21, 31 & 42
			121.5	7	
		Dinotefuran	223.2 & 223.2 (split)[c]	1 & 7	
			446.4	14	
		λ-Cyhalothrin	33.7 & 33.7	1 & 7	
24-Mar-10	5-Apr-10	Clothianidin	91	16	32, 38 & 49
		Dinotefuran	372	16	
			372	32	
		λ-Cyhalothrin	33.7	16	
28-Apr-11	11-May-11	Clothianidin	91	5	21, 27 & 34
			91	12	
		Dinotefuran	372	21	
		λ-Cyhalothrin	33.7	5	

[a] Formulations: clothianidin (Belay™ 2.1SC); dinotefuran granular (3G); λ-cyhalothrin (Karate™ Z).
[b] Days post-flooding.
[c] Split treatment was half of a full dose applied two times.