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Organic Insecticides for Control of the Rice Stink Bug (Hemiptera: Pentatomidae)[1]

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Although many different insects can be found in rice fields in Florida, stink bugs are currently considered the most important pest. Jones and Cherry (1986, J. Econ. Entomol. 79: 1226–1229) reported that the rice stink bug, *Oebalus pugnax* (F.), was the dominant species, comprising more than 95% of the total stink bug population. Cherry et al. (1998, Florida Entomol. 81: 216–220) reported that the stink bug *Oebalus ypsilongriseus* (DeGeer) was widespread in Florida rice fields. This was the first report of this species being found in commercial rice fields in the United States. Cherry and Nuessly (2010, Florida Entomol. 93: 291–293) reported that the stink bug *Oebalus insularis* (Stal) is now widespread in Florida rice fields. This was the first report of this species being found in commercial rice fields in the United States. The stink bug complex attacking Florida rice is the most diversified and unique stink bug complex in U.S. rice production.

Organic rice is grown in Florida and other rice-producing states. Control of insects in organic rice is limited to organic insecticides. However, currently there is no information on efficacy of any organic insecticides for controlling stink bugs in organically grown rice. The rice stink bug, *O. pugnax*, is a key pest of heading rice in the southern United States (Cato et al., 2019, J. Econ. Entomol. 112: 2713–2718). Our objective was to determine efficacies of four organic insecticides with different active ingredients to control *O. pugnax*. Results of these tests should be of interest to organic rice growers in potentially controlling stink bugs in organic rice.

Rice production in Florida is found in the southern part of the state in two contiguous counties around the southern end of Lake Okeechobee. Adult *O. pugnax* were collected from rice fields and adjacent weeds at the Everglades Research and Education Center in Palm Beach Co., which is the largest rice-producing county in Florida. These fields were not sprayed with insecticides so that insects were not exposed to insecticides before subjecting them to test treatments.

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Table 1. Insecticide treatments used in bioassays for control of *O. pugnax.*

Product (% Active Ingredient)	Active Ingredient	Manufacturer	Recommended Field Rate (g ai/ha)*
AzaMax (1.2%)	Azadirachtin	Parry America Inc., Arlington, TX	50
Conserve SC (11.6%)	Spinosad	Dow AgroSciences, Indianapolis, IN	770 is the maximum rate on the label
M-Pede (49%)	Potassium salts of fatty acids	Gowan Company, Yuma, AZ	170–340 (maximum allowable rate is 680)
PyGanic (1.4%)	Pyrethrins	MGK, Minneapolis, MN	15 to 56

*Recommended field rates are based on control of stink bug on fruiting vegetables or small grain field crops indicated on the label. The highest rate for another pest or crop was used when the product was not labeled for stink bug.

Stink bug adults were collected by sweep nets in rice fields and adjacent weeds during May to October 2020 to test for insecticidal efficacy. Within 2 to 4 h of collection, adults were placed into cages (15 $\times$ 15 $\times$ 2 cm) made from standard aluminum window screen. Ten adults were placed into a single cage. Adults were not sexed because Cherry et al. (2018, J. Entomol. Sci. 53: 372–378) showed that mortality caused by three insecticides showed little difference between the sexes in *O. pugnax*. Before spraying, each cage was placed into a clear plastic bag containing a moistened paper towel and lightly sprayed with water inside to maintain high humidity. Each cage was one replicate, and four cages were sprayed plus four unsprayed control cages were tested at each active ingredient (ai) rate. Cages were sprayed the same day as field collection of stink bugs. Only one ai rate and controls were tested on any 1 d because of time needed for catching insects, setting up replicates, and adjusting the spray chamber for each ai rate to be tested. Four organic insecticides, listed in Table 1, were selected for testing (AzaMax, M-Pede, PyGanic, and Conserve SC) for their diversity of active ingredients.

The objective of our statistical analysis was to determine insecticidal rates needed to kill different percentages of adults. These data can then be compared to recommended field rates to determine their expected efficacy in killing adults when sprayed on rice fields. Linear regression was conducted on each insecticide where $Y =$ percentage survival and $X =$ dosage in g ai/ha. Five insecticide rates for each insecticide were chosen for testing giving a range of percentage survival to determine the linear response. These rates varied among the insecticides depending on g ai/ha of each needed to kill a range of adults for analysis. These data were then used to calculate the linear equation, r, P, and dosage rate to cause 90% mortality (Table 2). These 90% mortality rates were then compared with recommended field rates (Table 1) to determine whether recommended field rates of the insecticides would be expected to provide control (i.e., 90% mortality) of the adults following application to rice fields.

Table 2. Correlation of stink bug survival with dosage of four organic insecticides.

Name	Equation*	r	P	g ai/ha for 90% Mortality**
Aza-Max	$Y = 169.5 - 0.30X$	−0.76	<0.05	530
Conserve	$Y = 174.0 - 0.08X$	−0.79	<0.05	2,000
M-Pede	$Y = 105.8 - 0.04X$	−0.82	<0.05	2,400
PyGanic	$Y = 81.4 - 0.04X$	−0.66	<0.05	1,785

*Y = % survival and X = dosage rate in g ai/ha.
**Estimated from equation = g ai/ha.

Cages containing stink bugs were removed from plastic bags and laid flat, and insecticides were applied evenly over the tops at a spray volume of 37.42 L/ha (equivalent to 4 gal/A). Insecticides were applied using a moving-nozzle spray chamber (Generation II Spray Booth; Devries Manufacturing Corp., Hollandale, MN) equipped with a TeeJet 8001VS nozzle tip (Spraying Systems Co., Wheaton, IL).

Within 15 min of insecticidal spraying, all sprayed cages were placed in a cabinet maintained at 5°C to immobilize the insects. After 30 min, these insects were removed from the sprayed cages and placed in new unsprayed cages. This procedure was conducted to ensure that insecticide residue on sprayed cages would not possibly kill insects by fumigation in plastic bags because fumigation would not be expected to occur in sprayed rice fields. Thereafter, each unsprayed cage containing the treated insects was again placed in a plastic bag lightly sprayed with water and a moistened paper towel to maintain high humidity. Preliminary testing showed that using these bags to maintain high humidity provided a higher untreated control survival over time than insects left unbagged. Blackman et al. (2015, Florida Entomol. 98: 18–26) also reported the importance of an adequate water source when conducting insecticide tests on *O. pugnax*. In our tests, this allowed a greater holding period of 24 h to measure mortality, as control survival was still high (95–100%) after 24 h. Moreover, we believe this yielded a more realistic mortality measurement expected under field conditions because insect mortality was observed to increase over time up to our 24-h reading. This proved most useful at lower ai rates in which insects simply took longer to die.

Bags were stored for 24 h at 25°C and 12-h dark/12-h light conditions after insecticidal spraying. Adults were then removed from cages and placed on a moistened filter paper (for traction) in a Petri dish and observed for 15 s. If they did not right themselves and remain in an upright position within 15 s, they were considered dead (Blackman et al. 2015). These criteria are consistent with Miller et al. (2010, J. Vis. Exp. 46: e2129), who reported that, in bioassays for monitoring insecticide resistance, the most commonly used criterion to classify insects as moribund or dead is a lack of coordinated movement.

Azadirachtins are derived from the neem tree, *Azadirachta indica* Adrien-Henri de. Jussieu, a member of the Meliaceae family, and have a wide range of insect growth and behavioral effects on insects (Schmutterer, 1990, Annu. Rev. Entomol. 35: 271–297). The active ingredient in Aza-Max is azadiractin. The recommended field rate is 50 g ai/ha (Table 1). Our equation in Table 2 estimates that 530 g ai/ha is needed to achieve 90% mortality for adult *O. pugnax* to control them when sprayed in rice fields.

Spinosyns are derived from the fermentation of the soil microbe *Saccharopolyspora spinosa* Mertz and Yao, which act on the nicotinic receptor site of postsynaptic nerves (Horowitz and Ishaaya, 2004, Biorational insecticides: mechanisms, selectivity and importance in pest management, Pp. 1-20, Insect Pest Management: Field and Protected Crops. Springer, Berlin). Spinosad demonstrated high toxicity to the green stink bug, *Chinavia hilaris* (Say), and brown stink bug, *Euchistus servus* (Say), in the laboratory (Kamminga et al., 2009, J. Econ. Entomol. 102: 1915–1921). The active ingredient in Conserve SC is spinosad. The maximum labeled field rate is 770 g ai/ha. Our equation estimates that 2,000 g ai/ha is needed for 90% mortality for the adults to control them when sprayed in rice fields.

Potassium salts of fatty acids were recommended by Trdan et al. (2006, J. Pest Manag. 52: 79–87) as a control measure for cabbage stink bug, *Eurydema* sp., and shown by Durmusoglu et al. (2003, J. Pest Sci. 76: 151–154) to control the southern green stink bug, *Nezara viridula* (L.) when combined with azadirachtins. The active ingredients in M-Pede are potassium salts of fatty acids. The recommended field rate is 170–340 g ai/ha. Our equation estimates that 2,400 g ai/ha is needed for 90% mortality for the adults to control them when sprayed in rice fields.

Pyrethrins are derived from *Chrysanthemum* spp. and have neurotoxic effects on many insects (Casida, 1980, Environ. Health Perspect. 34: 189-202). The active ingredients in PyGanic are pyrethrins. The recommended field rate is 15 to 56 g ai/ha. Our equation estimates that 1,785 g ai/ha is needed for 90% mortality for adults to control them when sprayed in rice fields.

As noted earlier, all four organic insecticides we tested have been shown to kill insects in numerous other studies. However, results from these studies have been shown to be highly variable depending on the insect tested, insect stage, laboratory versus field, and so on. For example, Morehead and Kuhar (2017, J. Pest Sci. 90: 1277–1285) tested organic insecticides against marmorated stink bug, *Halyomorpha halys* (Stål). They found that several natural insecticides had toxic activity on *H. halys* in laboratory bioassays. However, in the field, they were not able to significantly reduce stink bug injury to fruiting vegetables with any of the natural insecticide treatments. Similarly, Kamminga et al. (2009, J. Econ. Entomol. 102: 1915–1921) did not observe differences in stink bug injury to tomatoes in the field from applications of pyrethrins, Spinosad, and azadirachtin or combinations of the aforementioned insecticides. Carson et al. (2014, Arthropod Manag. Tests 39: E6) also found that foliar applications of *Burkholderia* sp. did not reduce stink bug and other heteropteran feeding injury to tomatoes in California.

Variables such as testing different insect stages, oviposition, repellence, reduced feeding sites, and so on, found in other organic insecticide studies were not carried out in this study. For example, Cira et al. (2017, J. Pest Sci. 90: 1257–1268) correctly pointed out that sublethal effects of organic insecticides may be important in helping control insects. For example, they found that several organic insecticides did not cause mortality to the stink bug, *H. halys*, but reduced feeding sites/individual. Their data also suggested that early instars are more susceptible to insecticides than adults. However, adults of *O. pugnax* are typically the most abundant life stage in Florida rice fields at heading as the adults quickly immigrate into fields to feed on developing rice grains. Control of adults at this time is essential because the adults can inflict much economic damage on the developing rice grains both through reduced yield and importantly grain quality of harvested rice because of consumer demands. Hence, the focus on adult mortality of organic insecticides found in this study.

Our data show that using simulated field sprays all four insecticides tested required much higher ai rates to kill 90% of *O. pugnax* adults for control than the recommended field rates for the four insecticides (Tables 1 and 2). Furthermore, our results show that using lower rates would result in poor control (Table 2), and good control of $\geq$90% of adults would require high insecticide rates that would probably be exceedingly expensive.