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EFFECTS OF BLACKBIRDS (*AGELAIUS PHOENICIUS*) ON STINK BUG (HEMIPTERA: PENTATOMIDAE) POPULATIONS, DAMAGE, AND YIELD IN FLORIDA RICE

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Abstract

Blackbirds are important agricultural pests that can cause major economic losses in a variety of crops. Although birds in other agro-ecosystems may perform biological control services by controlling insect pests, the potential of blackbirds to provide these services in rice had not been evaluated. We used bird exclosures to evaluate the effects of blackbirds on stink bugs in rice and on crop damage and yields in the Everglades Agricultural Area in southern Florida. Experiments were conducted in both the main rice crop and the ratoon crop. We found no difference in the abundance of rice stink bugs (*Oebalus* spp.) in exclosures vs. controls, indicating that predation by birds did not reduce stink bug populations. Damage to rice by stink bugs (pecky rice) was similar between exclosures and controls, as well. However, bird damage, quantified as the percentage of panicles damaged, differed by as much as an order of magnitude in exclosures vs. controls. Mean damage estimates were 3.5% in the bird exclosures vs. 35.3% in the control for the main crop and 4.5% and 20.5%, respectively, in the exclosures and controls for the ratoon crop. Nonetheless, mean yields did not differ between exclosures and controls. Our results suggest that despite their conspicuous presence, blackbirds have little effect on stink bug populations or rice yield in Florida rice fields.

Key Words: biological control; exclosures; pecky rice; wildlife damage control

Resumen

El tordo sargento (*Agelaius phoenicius*) es una plaga de importancia agrícola que puede provocar mayores perdidas económicos en varios cultivos. Aunque las aves en otros ecosistemas agrícolas pueden realizar servicios de control biológico al controlar las plagas de insectos, el potencial del tordo sargento de proveer estos servicios en arroz no ha sido evaluado. Utilizamos un recinto (área excluída) para aves para evaluar los efectos del tordo sargento sobre las chinches en el arroz, el rendimiento de las cosechas y los daños en el Área Agrícola de los Everglades en el sur de Florida. Se realizaron los experimentos en la cosecha principal de arroz y en la cosecha de retoños de arroz. No se encontraron diferencias en la abundancia de chinches del arroz (*Oebalus* spp.) en los recintos versus en el control, lo cual indica que la depredación por aves no reduce las poblaciones de chinches hediondas. También, el daño al cultivo de arroz hecho por las chinches hediondas (granos de arroz manchados) fue similar en los recintos y en el control. El daño hecho por los pájaros, cuantificada como el porcentaje de panículas dañado, varió en un orden de magnitud en el arroz sambrado. El estimado de la promedia de daño en los recintos para aves fue 3.5% versus 35.3% en el control para la cosecha principal y el 4.5% y 20.5%, respectivamente, en los recintos y en el control para la cosecha de retoños. Sin embargo, el promedio del rendimiento no varió entre los recintos y el control. Nuestros resultados sugieren que a pesar de su presencia visible, el tordo sargento tiene poco efecto sobre la poblacion de las chinches en el arroz o el rendimiento de arroz en los campos de arroz en la Florida.

Blackbirds are important agricultural pests and can cause damage in the millions of dollars to crops such as sunflowers, corn and rice. Bird damage to rice was estimated at $3 million in Arkansas (Pierce 1970), $4 million in Louisiana (Wilson et al. 1989), $4.2 million in Texas and $11.5 million overall in the United States (Cummings et al 2002). The term "blackbird", when used in reference to agricultural pests, refers to red-winged blackbirds of various sub-specific designations (*Agelaius phoenicius* Linnaeus; Passiformes: Icteridae) and boat-tailed grackles (*Quiscalus major* Vieillot; Passiformes: Icteridae) as well as other blackbird and grackle species. Because red-winged blackbirds (*A. p. floridanus* Maynard and *A. p. mearnsi* Howell and Van Rossem) are dominant in southern Florida, far outnumbering grackles in rice, they were the focus of our study.

In rice fields, red-winged blackbirds cause damage and reduce yields by consuming sprouted seeds and through consumption of rice at maturity. Rice is planted in the Everglades Agricultural Area in the spring and summer to be harvested from late summer through fall. A ratoon crop is harvested from 40-50% of the rice acreage (Ron Rice, Palm Beach Cooperative Extension, pers. comm.). Resident blackbirds are present year-round and will nest in and near rice fields. From late summer through late fall, large numbers of blackbirds migrate through Florida and many of them stay through the winter, greatly augmenting the local breeding population (Pearlstine et al. 2005).

Red-winged blackbirds nest in Florida from mid-March through early August (Stevenson & Anderson 1994), coinciding with the rice-growing season. During the breeding season, the percentage of insects in their diet increases and nestlings are fed insects exclusively (Yasukawa & Searcy 1995). However, birds in agricultural areas eat fewer insects and more plant material than do birds in wetlands and other non-agricultural habitats (Yasukawa & Searcy 1995). During the non-breeding season, the diet of adult red-winged blackbirds shifts toward plant matter and is composed primarily of seeds, although some insects are consumed (Yasukawa and Searcy 1995). Insects commonly taken by red-winged blackbirds include odonates, lepidopterans, and dipterans (Orians & Horn 1969).

In some agro-ecosystems, it has been suggested that insectivorous birds and other vertebrate insectivores may provide a service to growers by preying upon insect pests in crops (Mantyla et al. 2011; Van Bael et al. 2008; Whelan et al. 2008). For example, birds have been shown to reduce the number of insects, including pest species, in coffee (Borkhataria et al. 2006; Johnson et al. 2010), tea (Sinu 2011), vegetables (Hooks et al. 2003), and fruit (Mols and Visser 2002), and in some cases to increase plant productivity or yield (Hooks et al. 2003; Mols and Visser 2002). In southern Florida, red-winged blackbirds were found to regularly eat many economically important insect pest species, including corn earworm [*Helicoverpa zea* (Boddie) (Lepidoptera: Noctuidae)], fall armyworm [*Spodoptera frugiperda* (J. E. Smith) (Lepidoptera: Noctuidae)], two-lined spittlebug [*Prosapia bicincta* (Say), (Hemiptera: Cercopidae, and southern green stink bug [*Nezara viridula* (L.) (Hemiptera: Pentatomidae)]; however, these are still considered important pests in agriculture (Genung et al. 1976).

Although many different insects can be found in rice fields in Florida, stink bugs (Hemiptera: Pentatomidae) are currently considered the most important pests. Jones & Cherry (1986) reported that the rice stink bug, *Oebalus pugnax* (F.), was the dominant species comprising >95% of the total stink bug population. Later, Cherry et al. (1998) reported that a congener, *Oebalus ypsilongriseus* (DeGeer) also was widespread in Florida rice fields. More recently, Cherry and Nuessly (2010) reported another stink bug, *Oebalus insularis* (Stal) as now widespread in Florida rice fields. Both of these latter findings were first reports of these 2 species in commercial rice fields in the United States.

Bird predation on stink bugs has been reported in rice fields in Arkansas (Neff & Meanley 1957, Douglas & Ingram 1957), Louisiana, and Texas (Douglas & Ingram 1957), and diverse habitats in Ohio (Williams & Jackson 1981). Bird predation on stink bugs also was reported in agricultural fields in southern Florida (Genung & Green 1974; Genung et al. 1976), and more specifically, rice fields (Genung et al. 1979). However, these earlier studies were largely based on stomach analyses and did not show the actual impact of bird predation on stink bug populations.

Given the perception of blackbirds as a major pest in rice, our objective was to determine whether blackbirds provide a valuable service to growers by decreasing stink bug abundance and stink bug damage to rice. If birds were found to function as an effective natural control on stink bugs, our secondary objective was to determine whether such services compensate for the loss of rice caused by blackbird consumption. We used bird exclosures to quantify bird predation on stink bugs and damage to rice by both birds and stink bugs.

MATERIALS AND METHODS

Study Area

The study was conducted at the University of Florida Everglades Research and Education Center (EREC) in Belle Glade, Palm Beach County, Florida. The EREC is in the center of the Everglades Agricultural Area (EAA), a 280,000 ha area in southern Florida that is dedicated to growing sugarcane, rice, sod and vegetables. Although sugarcane is the dominant crop in the EAA, over 7,600 ha of rice were grown in 2000 in rotation with sugarcane (Schueneman and Deren 2000). Rice acreage has been lower in the last 3 seasons, ranging from 5330 to 5709 ha (Ron Rice, Palm Beach Cooperative Extension, unpublished). Test plots of these crops are planted and maintained at EREC for experimental purposes.

Rice fields at the EREC field station were prepared for planting by disking and rolling. Soil tests of the Dania Muck soil indicated that no fertilization was required to produce the primary or ratoon rice crops. On 1 Apr 2010, rice cv. 'Wells' seed was drilled into rows on 20 cm centers at the rate of 100 kg/ha. Four fields (17 m × 86 m) were planted for the trial. Fields were flushed with water 10 d after planting (DAP) and permanent flooding was maintained beginning 17 DAP. A treatment and control were established in each of the 4 fields.

Bird Exclosures

Polypropylene bird netting (1.27 cm or 0.5 inch mesh) (Premium Pollynet, Nixalite of America, East Moline, Illinois) was installed over PVC pipes (10.16 cm or 4 inch diameter) cut to approximately 2.25 m in length and inserted approximately 0.3 m into the ground to exclude birds in an area 17 m × 17 m in each of 4 fields. Netting came in panels that were 4.27 m wide, and panels were attached to one another using plastic twist locks (Nixalite of America) to secure the seams. Pipes supported the bird screen material 1.5 to 2 m above the soil surface in each exclusion plot. Doors were cut in one side of each exclusion plot to allow access for sampling and fastened closed using twist locks. Control plots consisted of a 17 m × 17 m unenclosed portion of each field.

During the study, exclosures were checked a minimum of every 2 to 3 d. On two dates, birds were observed in exclosures having gained entry through holes in the netting. These birds were driven out and the netting repaired. Except for these two occurrences, the exclosures remained bird free for the duration of the study. Weather measurements were taken at various times of d on 5 different d during the study. These measurements were temperature (°C), wind velocity (km/h), and solar intensity (micromoles/m^2). Samples were taken for paired controls and treatments within 5 min of each other for each of these parameters each day.

Stink Bug Assessment

Sweep net samples were taken on July 1 between 1000 and 1500 (EDT) in the main crop. Rice was heading at this time, which is when various species of rice stink bugs are most abundant in Florida rice fields (Cherry & Nuessly 2010). Except for rainy, stormy, or very windy conditions, time of day is not a significant factor in sweep net catches of stink bugs in Florida rice fields (Cherry & Deren 2000). Each sample consisted of twenty consecutive sweeps. Each horizontal stroke in one direction was one sweep and one sweep was made with each forward step. Two parallel samples were taken near the center of each plot for exclosures and controls. Exclosures were large enough that they could be entered for sampling. Samples were frozen after collection for later counting. Analysis of data was restricted to 3 species of *Oebalus* being *O. insularis*, *O. pugnax*, and *O. ypsilongriseus*. These three species are most numerous in Florida rice accounting for 92% of all stink bugs and *Oebalus* are generally important as rice pests in many rice growing areas of the world (Cherry & Nuessly 2010). Adults and nymphs of the 3 species were counted. The same methods were repeated in the ratoon crops swept October 25 at heading.

Bird Assessment

We counted the number of birds present within the complex of rice fields on 3 occasions during the main crop (7 July, 20 July, and 27 July 2010) and 3 occasions during the ratoon crop (17 September, 18 October, 29 October 2010) to characterize the suite of bird species present in the study plots.

Crop Damage and Yields

We measured "pecky" rice as an indicator of feeding damage by insects. Pecky rice is the name given to the grain damaged by stink bug feeding at the milky or pasty stage of rice and stained probably by bacteria or fungi, which invaded the grain at the penetration point. If rice contains pecky grains, the quality is lowered and thus the price is lowered (Ito 1978). In addition to visual damage by staining, pecky grains are structurally weakened and often broken by mechanical stresses encountered during the milling process. This breakage further reduces rice value because whole unbroken rice demands a premium price (Swanson & Newsom 1962).

Pecky kernels were identified by directing light from a microscope lamp up through a shallow layer of rice in the bottom of a petri dish. Rice hulls and normal endosperm permit considerable light transmission, whereas chalky areas caused by stink bug feeding are opaque (Swanson & Newsom 1962). Five random samples per plot were taken to quantify pecky rice from each yield sample on each sampling date (see below). These samples were taken before the rice was thrashed as pecky grains break more easily, thus biasing the sample. Fifty rice grains were randomly taken from each sample and the number of pecky grains counted. Because this was non-destructive sampling, these samples were added to the thrashed seed (see below) to determine yield.

We measured bird damage by walking transects through each study plot (8 total), and examining panicles for damage at 5 evenly spaced locations along each transect. We considered bird damage to have occurred if panicles showed evidence of having had at least some grains removed by birds (i.e., there was a characteristic grainless portion of the panicle generally adjacent to intact grains or panicles). For the main crop we walked 4 transects through each field, whereas for the ratoon crop we walked 2 transects through each field. Twenty-five panicles were examined at each location and the number with visible evidence of grain predation was recorded. Damage was analyzed as the number of damaged panicles divided by 25.

Rice yield was sampled 120 d after planting (DAP) by harvesting 20 samples of one linear meter in a single row from each plot. Seven samples were taken from the northern and southern portions of each plot (i.e., near edges of the field) and 6 samples were taken from the central portion of each plot. All panicles within each 1-m sample were placed in a paper bag and dried in a walk-in drying room (Vollrath, Refrigeration Division, River Falls, WI) maintained at 50 °C for 30 d to remove all moisture. Following drying, panicles were threshed and the grain collected was weighed to determine yield. Rice grains are commercially dried to 12% moisture; therefore, to adjust for the excess weight loss in the ovens, the weight of each sample was multiplied by 1.12 prior to analysis. The plots were mowed 127 DAP to allow the growth of a uniform ratoon crop. The ratoon crop was sampled and harvested 210 DAP using the same method as before.

Statistical Analysis

A one-way analysis of variance (ANOVA) was conducted using JMP 8.0 (SAS Institute, Cary, NC) to test the effects of treatment (TREAT), replicate (REP), and the interaction between treatment and replicate (TREAT * REP) on abundance of *Oebalus,* proportion of pecky rice, proportion of bird damaged panicles, and yield. Stink bug numbers and yield were square-root transformed and proportions of pecky rice and bird damage were arcsine square-root transformed to better meet assumptions of normality. The main and ratoon crops were analyzed separately for all analyses. For ease of interpretation, we report untransformed means (± SD) in the results.

Table 1. Comparisons of rice stink bugs, pecky rice, bird damage, and yield in bird-exposed controls versus bird exclosures.

	Stink bugs[a]/sweep sample	
	Main crop[b]	Ratoon crop[b]
Control	79.0 ± 55.3	58.4 ± 22.0
Exclosure	70.6 ± 34.8	79.9 ± 32.1
	Pecky rice[c]	
	Main crop[b]	Ratoon crop[b]
Control	33.7 ± 17.7*	38.5 ± 8.2
Exclosure	25.7 ± 13.9	41.9 ± 7.6
	Bird Damaged	
	Main crop[b]	Ratoon crop[b]
Control	35.3 ± 31.1*	20.5 ± 22.0*
Exclosure	3.5 ± 7.4	4.5 ± 7.8
	Yield (g)[e]	
	Main crop[b]	Ratoon crop[b]
Control	114.8 ± 36.5	10.3 ± 4.5
Exclosure	121.8 ± 43.7	10.4 ± 4.3

[a]Adults and nymphs of 3 *Oebalus* species in 20-sweep samples.
[b]Means (± SD) within a column labelled with a "*" had statistically significant (alpha = 0.05) treatment effects (see Table 2).
[c]Percentage of pecky grains in 50-grain sample.
[d]Percentage of bird-damaged panicles in a 25 panicle sample
[e]Total dry weight of rice grains multiplied by 1.12.

Results and Discussion

Although there were no differences in sweep counts of stink bugs in the controls compared to the exclosures in the main or ratoon crops, pecky rice was more abundant in the controls in the main crop (Table 1). The percentage of pecky rice was highly variable in the main crop, ranging from 8-46%, and differences appeared to be largely attributable to a single replicate in which pecky rice was nearly twice as abundant in the control than the exclosure (39.6 ± 7.8 vs. 21.6 ± 5.9%, respectively) despite similar numbers of stink bugs (58.0 ± 2.83 vs. 53.5 ± 2.12). While the reason for the difference in pecky rice is unknown, taken together, the preceding data are consistent in showing that birds had no significant impact on stink bug populations or damage.

A shift in the relative abundance of the 3 *Oebalus* species was noted between the main crop and ratoon crop. *Oebalus* nymphs were not identified to species; however, nymphs were only 5% of stink bugs collected in the main crop and 7% in the ratoon crop. Adults of the 3 species are fairly easy to identify and were determined to the species level. In the main crop, *O. pugnax* was clearly the dominant species, comprising 97% of *Oebalus* adults. In the ratoon crop, *O. ypsilongriseus* was clearly the dominant species, constituting 88% of *Oebalus* adults sampled. This changing *O. y./O. p.* ratio during the growing season has been confirmed in other commercial rice fields in Florida (Cherry et al. 1998). However, the reasons for these shifting population dynamics are still unknown.

Dragonflies (Order Odonata) were observed in exclosures, although it is unknown whether they entered the exclosures in their larval or adult phase. Nonetheless, even large invertebrate predators had access to the exclosures. Therefore, stink bug population differences would be caused by bird exclusion and not exclusion of invertebrate predators such as dragonflies, spiders, etc. from the exclosures. Temperatures inside versus outside the exclosures were similar being < 1 °C different on all 5 d. Wind speed consistently was lower within exclosures, averaging 29% lower inside than outside. Solar intensity consistently was lower within the exclosure averaging 12% lower than outside the exclosure. Therefore, we concluded that decreased wind speed or slightly decreased solar intensity had no observable effect

TABLE 2. EFFECTS TESTS FOR RICE STINK BUGS, PECKY RICE, BIRD DAMAGE, AND YIELD IN BIRD-EXPOSED CONTROLS VERSUS BIRD EXCLOSURES.

	Stink bugs[a]					
	Main			Ratoon		
	DF	F	P	DF	F	P
Treat	1	0.1815	0.6814	1	3.3469	0.1047
Rep	3	1.664	0.2509	3	2.6771	0.1180
Rep * Treat	3	6.8854	0.0132	3	1.2754	0.3467
	Pecky Rice[b]					
	Main			Ratoon		
	DF	F	P	DF	F	P
Treat	1	9.0186	0.0052	1	2.5782	0.1182
Rep	3	32.4399	<0.0001	3	6.276	0.0018
Rep * Treat	3	2.2934	0.0968	3	0.3718	0.7739
	Bird Damage[c]					
	Main			Ratoon		
	DF	F	P	DF	F	P
Treat	1	1116.82	<0.0001	1	43.5369	<0.0001
Rep	3	7.053	0.0002	3	2.3572	0.0791
Rep * Treat	3	4.2124	0.0068	3	2.5934	0.0594
	Yield[d]					
	Main			Ratoon		
	DF	F	P	DF	F	P
Treat	1	1.2359	0.2681	1	0.0483	0.8264
Rep	3	14.7459	<0.0001	3	15.6482	<0.0001
Rep * Treat	3	0.2995	0.8267	3	0.2277	0.8770

[a]Adults and nymphs of 3 *Oebalus* species in 20-sweep samples, square-root transformed.
[b]Proportion of pecky grains in 50-grain sample, arcsine square-root transformed.
[c]Proportion of bird-damaged panicles in a 25 panicle sample, arcsine square-root transformed.
[d]Total dry weight (g) of rice grains multiplied by 1.12, square-root transformed.

on stink bug populations or rice yields inside versus outside the exclosures.

Birds were more abundant within the rice fields during the main crop than during the ratoon, although the low sample size and high variability precluded statistical comparison. For the main crop, we counted 20 birds on our first count, 111 birds on our second count, and 317 birds on our third count. Since all counts were in July, these were likely resident blackbirds. Of these, 97% were red-winged blackbirds, with boat-tailed grackles and ground doves (*Columbina passerina* L.) comprising the other species counted. For the ratoon crop, we counted 42 birds on the first count, 1 bird on the second count, and 7 birds on the third count. During this time period, we would expect to see both migrant and resident blackbirds. Only 62% of birds counted were red-winged blackbirds, owing to a flock of 17 barn swallows (*Hirundo rustica* L.) in the study area during the first count. When barn swallows were excluded from the counts, red-winged blackbirds comprised 94% of birds counted, with 2 palm warblers (*Dendroica palmarum* Gmelin) comprising the other 6%.

Rice yields did not differ between treatments for either the main crop or the ratoon crop (Tables 1 and 2), although bird damage differed between treatments and replicates for both the main crop and ratoon crop (Tables 1 and 2). Ratoon crop yields are generally < 40% of main crop yields due to declining temperature and day length (Dunand & Saichuk 2009), so differences in yield between crops were expected. Mean damage estimates (percentage of panicles damaged) were an order of magnitude higher outside than inside the exclosures (3.5% vs. 35.3% for the main crop). The similarity in yield despite differences in damage indicates that blackbirds may not be an economically significant pest on rice in southern Florida. Although blackbirds were conspicuous in rice fields and removed at least some rice grains from a substantial portion of panicles, the total number of rice grains removed was not enough to significantly affect yield estimates in this study. However, it is possible that the temporal and spatial scale of our experiment did not capture the full range of variability in blackbird damage to rice. It also may be that the small size of our rice fields did not attract migratory blackbirds for the second harvest. In other areas of the EAA, large numbers of blackbirds and bobolinks (*Dolichonyx orrzivorus* L.) were observed over rice fields in late summer and autumn (E. Pearlstine, pers. obs.).

A variety of bird-repellents have been marketed to reduce bird damage on rice (Werner et al. 2008a; Werner et al. 2008b). However, their application is both expensive and time-consuming, and their efficacy in the field may be low. In a recent study, there was no difference in rice yields in field tests of treated and untreated rice despite laboratory evidence that the application of bird repellent decreased bird consumption of rice (Werner et al. 2008b). The researchers attributed the similarity in yield to a failure of the pesticide to repel birds. Our results offer a different explanation: the effect of birds on rice yield may be so low as to be undetectable in paired comparisons of plots with and without rice consumption by birds. Lethal methods (e.g. shooting) also are used to control blackbird damage to crops, and can be a major source of mortality for blackbirds. Additionally, spent lead shot can be a hazard to ground-feeding birds, raptors and other scavengers (Pokras & Kneeland 2008). The long-term effects of lethal control methods on populations of blackbirds at the species and sub-species level are unknown. One study of the costs and benefits of lethal controls of blackbirds in sunflower found only marginal economic benefits (Blackwell et al. 2003). Our study indicates a need to better quantify the economic effects of blackbirds on rice in the EEA in order to determine the true economic losses from blackbirds and the costs and benefits of blackbird control programs.

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