Mexican Rice Borer (Lepidoptera: Crambidae) Injury to Corn Greater Than to Sorghum and Sugarcane Under Field Conditions

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ABSTRACT The Mexican rice borer, *Eoreuma loftini* (Dyar) (Lepidoptera: Crambidae), is the key pest of sugarcane (*Saccharum* spp.) in Texas; it can attack several grassy crop and noncrop host plants and has spread into Louisiana. Through small-plot, commercial field, and pheromone trap experiments, this study demonstrates that the pest uses corn, *Zea mays* L., more than sugarcane and sorghum, *Sorghum bicolor* (L.) Moench, but when corn is harvested in late summer, injury to nearby sugarcane strongly increases during the next ≈2 mo to harvest. Corn was more infested than sugarcane and sorghum in commercial fields regardless of whether sampling occurred on field edges or farther into field interiors. Differences in numbers of infested stalks and in numbers of larval entry holes between field edges and interiors were not detected. We found that Mexican rice borer infestation of corn can cause loss of ears, and lodging, shattering, and complete destruction of maturing stalks. The larger quantities of adult Mexican rice borers captured in pheromone-based traps placed at corn field edges compared with sorghum and sugarcane field edges further indicates that corn is preferred to sugarcane and sorghum. The basis for the pest's attraction to corn and implications to potential range expansion to other U.S. sugarcane-growing regions are discussed.

KEY WORDS areawide, ecology, host plant, *Eoreuma*, *Saccharum*

The Mexican rice borer, *Eoreuma loftini* (Dyar) (Lepidoptera: Crambidae), originally from Mexico (Van Zwaluwenburg 1926, Johnson 1984), is a stalk-boring insect first detected in the United States in the Lower Rio Grande Valley of Texas during the early 1980s (Johnson 1981, 1984). Since then, the Mexican rice borer has become the dominant stalk-boring pest of sugarcane (*Saccharum* spp.) in South Texas (Youm et al. 1988), representing >95% of the stalk borer population (Legaspi et al. 1999). The insect deposits eggs mostly within folds of dry leaves (Showler and Castro 2010b). On hatching, early instars either bore into leaf midribs (Wilson 2011) or consume green leaf tissue before boring into the stalk, usually as a third instar, tunneling vertically and horizontally (Van Zwaluwenburg 1926). Resulting injury to sugarcane causes stunting, lodging, reduced juice quality and quantity, and "dead hearts" (dead whorl center) (Legaspi et al. 1997). Mexican rice borers injure ≈20% of sugarcane internodes in the Lower Rio Grande Valley and inflict annual losses valued at US$575/ha (Meagher et al. 1994). Insecticide applications have not increased sugarcane yields in Mexican rice borer-infested areas (Meagher et al. 1994), and although they were discontinued in the Lower Rio Grande Valley (Legaspi et al. 1997), promising compounds and improved scouting methods have been recently suggested (Akbar et al. 2009, Wilson et al. 2010, Wilson 2011). Attempts at biological control were unsuccessful (Meagher et al. 1998), largely because larvae seal themselves within the stalk by using packed frass (Legaspi et al. 1997). By 1987, the pest's range expanded to encompass 40 counties in Texas, by 1989 it invaded eastern Texas rice (*Oryza sativa* L.)–producing areas (Browning et al. 1989), and by 2011 it was detected in four parishes of western Louisiana (Reagan et al. 2011, Showler and Reagan 2012). Reay-Jones et al. (2008) predicted the moth would continue to spread, infesting all of Louisiana's rice- and sugarcane-growing areas by 2035.

Although the Mexican rice borer is known to attack rice; sugarcane; sorghum, *Sorghum bicolor* (L.) Moench; and corn, *Zea mays* L., as well as ≈19 species of grassy weeds (Showler et al. 2011), most research efforts have focused on protecting rice and sugarcane. Greenhouse assays wherein female Mexican rice borers could chose between paired combinations of corn, sorghum, and sugarcane plants, however, revealed that the pest prefers to oviposit on corn ≥3.5- and ≥5.9-fold more than on sorghum and sugarcane, respectively (Showler et al. 2011), and that sugarcane, on a whole plant basis, was preferred over rice (Reay-Jones et al. 2007). Under field conditions, preference for corn over sorghum and sugarcane would mean that

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corn has not only been greatly underestimated as a source of Mexican rice borers that can infest other host crops but also possibly the Mexican rice borer is a pest of corn itself. In South Texas, corn is one of the most widely grown crops, and the impacts of Mexican rice borers on it are unknown. The purpose of this study was to assess the Mexican rice borer's preference for corn in relation to sorghum and sugarcane under field conditions.

Materials and Methods

Small Field Plot Experiment. Sugarcane (variety CP70-321) was planted on 16 November 2009, and field corn (variety BH8919) and sorghum (variety Pioneer 81G63) were planted on 8 March 2010 and on 15 March 2011 in seven field plots on 2-m row spacing at the USDA–ARS Kika de la Garza Subtropical Agricultural Research Center's North Farm, Hidalgo Co., TX. Each plot, six rows wide by 20 m in length (0.028 ha), was planted to one of the three crops, and the three crop treatments were arranged in a randomized complete block design. Irrigation occurred as needed, on 23 March and 5 May 2010 (otherwise rain-fed) and 25 February 2011, and 20–0–8 (N–P–K) fertilizer was applied by side-dressing with tractor-pulled knives at 110 kg N/ha on 27 January 2010 and on 1 February 2011 in the sugarcane plots, and on 3 March 2010 and 9 March 2011, respectively, for the corn and sorghum.

When the corn and sorghum plants were mature and ready for harvest on 18 August 2010 and on 30 August 2011, 15 stalks of crop plants, including sugarcane, were cut at the base from each plot, the stalks were stripped of leaves, and larval Mexican rice borer entry holes and adult exit holes counted. Only holes that led to tunnels were counted, confirmed by slicing the stalks open with a knife. When the sugarcane was ready for harvest on 12 November 2010 and on 9 November 2011, 15 more sugarcane stalks were cut from each sugarcane plot, stripped of leaves, and numbers of Mexican rice borer entry and exit holes were recorded. Numbers of missing stalks were not recorded in this experiment.

Pheromone Trap Experiment. On 7 July 2011, a Universal Moth Trap (Great Lakes IPM, Vestaburg, MI) with a Mexican rice borer pheromone septa lure (Hercon Environmental, Emigsville, PA) was placed at the north edge of each of 16 commercial ≥25-ha fields of non-*Bacillus thuringiensis* corn, sorghum, and sugarcane in Cameron and Hidalgo counties. Numbers of captured moths were counted in each trap after 3 d.

Commercial Field Experiment. Eighteen commercial fields in Hidalgo Co., each ≥50 ha, were used in this experiment. Treatments were corn, sorghum, and sugarcane (same varieties as in the small field plot experiment), where the corn was ≈1.4 m in height, sorghum was ≈1 m in height, and sugarcane was ≈1.8 m in height. Each treatment was replicated six times (one commercial field constituted a replicate). To determine the effect of field position on crop injury, 50 consecutive stalks were counted along a row in each of the fields on 14 June 2010, the first and last stalk marked by plastic flagging, located ≥20 m (row spacing was 1 m) from the outermost rows, beginning with the first plant at the row's end (field "edge" stalks). Another set of 50 consecutive stalks was similarly flagged, but the end closest to the edge was ≥30 m inside the field (field "interior" stalks). Three weeks later, on 7 July 2010, the plants were counted again to determine numbers of missing stalks. Also at that time, 10 randomly selected stalks in each group of 50 were cut at the base, the leaves were stripped off, and numbers of larval Mexican rice borer entry holes and adult exit holes were counted. Entry holes were not counted unless they led to a tunnel, verified by slicing the stalks open with a knife. The commercial field experiment was repeated using different fields 8–30 July 2010.

Statistical Analyses. For the small plot field experiment and the pheromone trap experiment, treatment differences were detected using two-way analysis of variance (ANOVA), with treatments and blocks as sources of variation, and means were separated using Tukey's honestly significant difference (HSD) test (Analytical Software 1998) (difference between years was not included as a factor). Treatment differences were analyzed using ANOVA as a factorial, with three different crops and two field positions as sources of variation and means were separated using Tukey's HSD test (Analytical Software 1998). Data were not transformed before analysis because normality and homogeneity of variance assumptions were not violated in any of the experiments.

Results

Small Field Plot Experiment. When corn and sorghum were harvested in mid-August 2010, 5.1- and 7.7-fold more corn stalks were injured by larval Mexican rice borer tunneling than sorghum and preharvest sugarcane stalks, respectively ($F = 26.83$; df = 3, 27; $P < 0.0001$), and in 2011, 4.1- and 7-fold more corn stalks were damaged than sorghum and preharvest sugarcane ($F = 54.78$; df = 3, 27; $P < 0.0001$) (Fig. 1). Nearly 11 wk later when the sugarcane was ready to harvest, differences in numbers of injured stalks were not found between corn and sugarcane (Fig. 1). Corn stalks in 2010 had 4.1- and 8.1-fold more ($F = 14.52$; df = 3, 27; $P < 0.0001$) larval Mexican rice borer entry holes than sorghum and preharvest sugarcane stalks, respectively, and 7.3- and 9.9-fold more ($F = 45.61$; df = 3, 27; $P < 0.0001$), respectively, in 2011 (Fig. 2). Sugarcane harvested at its normal time during the fall, however, had increased numbers of entry holes (incurred during the intervening weeks) such that differences between corn and sugarcane were not as great, although still statistically significant, as when the corn was compared against late summer (preharvest) sugarcane (2010, 1.4-fold: $F = 14.52$; df = 3, 27; $P < 0.0001$; and 2011, 1.8-fold, $F = 45.61$; df = 3, 27; $P < 0.0001$) (Fig. 2). Exit holes, however, were relatively few (≤1.1 ± 0.5 per 15 stalks) and differences between the three crops were not found in either year.

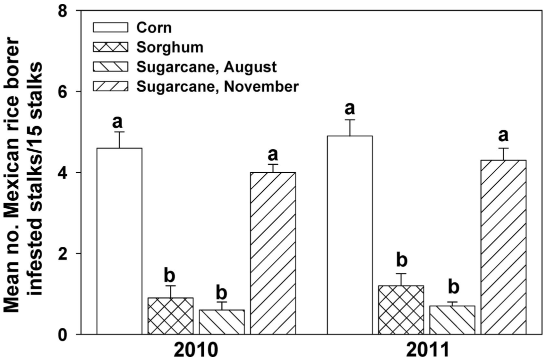

Fig. 1. Mean (±SE) numbers of larval Mexican rice borer–injured stalks per 15 stalks of sugarcane, corn, and sorghum when the corn and sorghum were harvested (August of each year) and of sugarcane at its harvest (November of each year), field plot experiment, Hidalgo Co., TX, 2010 and 2011 (n = 7 replicate plots per crop).

Pheromone Trap Experiment. Traps at the corn fields collected 1.6-fold more adult Mexican rice borers than traps at sugarcane fields, and those two crops were associated with 10.8- and 6.9-fold more captured moths, respectively, than sorghum (F = 29.10; df = 2, 47; $P < 0.0001$) (Fig. 3).

Commercial Field Experiment. On field edges, 1.4 ± 0.5 of 50 stalks, or 2.8% of the corn stalks, rotted and were no longer standing during the 3 wk of the first experiment compared with no such collapsed stalks in sorghum and sugarcane (F = 10.97; df = 2, 14; P = 0.0020), and during the second 3-wk experiment, 2.2 ± 0.6, or 4.4%, were missing, but all of the sorghum and sugarcane stalks remained intact even if they were infested (F = 35.73; df = 2, 14; $P < 0.0001$). Sorghum and sugarcane stalks in the field interiors also were not destroyed, whereas in the first and second experiments, 0.8 ± 0.4, or 1.6% (F = 5.30; df = 2, 14; P = 0.0225) and 1.6 ± 0.4, or 3.2% (F = 41.31; df = 2, 14; $P < 0.0001$), respectively, of the corn stalks were missing. In experiment 1, Mexican rice borer injured stalks that remained were ≥1.5-fold more abundant in corn fields than in sugarcane, and injured sugarcane stalks were ≥1.4-fold more numerous than injured sorghum stalks (F = 79.82; df = 2, 35; $P < 0.0001$) (Fig. 4). Larval entry holes were ≥1.7-fold more abundant on corn stalks than on sugarcane, and entry holes were ≥1.4-fold more abundant on sugarcane stalks than on sorghum stalks (F = 75.76; df = 2, 35; $P < 0.0001$) (Fig. 5). Adult exit holes were 1.6-fold more common on corn stalks at the field edges than the interior of the fields, and the field interior corn stalks had 1.8-fold more adult exit holes than in the sugarcane and sorghum regardless of location (edge or interior) in those fields (F = 34.06; df = 2, 35; $P < 0.0001$) (Fig. 6). Edge and interior locations were not statistically different in terms of adult exit holes, although factorial analysis for location was nearly so (F = 3.93; df = 1, 35; P = 0.0565). Mexican rice borer-injured stalks in experiment 2 were ≥1.4-fold more abundant in corn than in sugarcane, and ≥2.1-fold more abundant in sugarcane than

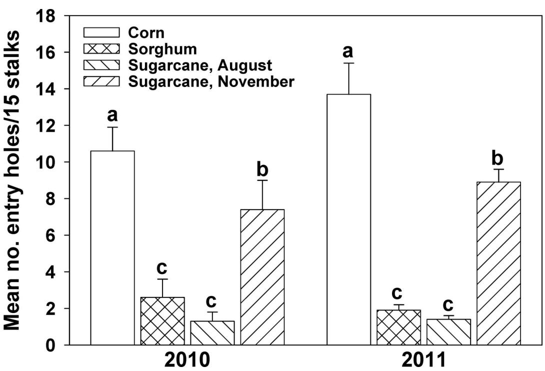

Fig. 2. Mean (±SE) numbers of larval Mexican rice borer entry holes per 15 stalks of sugarcane, corn, and sorghum when the corn and sorghum were harvested (August of each year) and of sugarcane at its harvest (November of each year), field plot experiment, Hidalgo Co., TX, 2010 and 2011 (n = 7 replicate plots per crop).

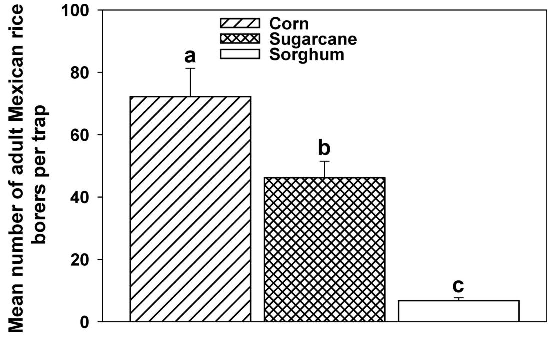

Fig. 3. Mean (±SE) numbers of adult Mexican rice borers trapped at edges of commercial corn, sugarcane, and sorghum fields, Cameron and Hidalgo counties, TX, 7–10 July 2011 (n = 16 fields of each crop).

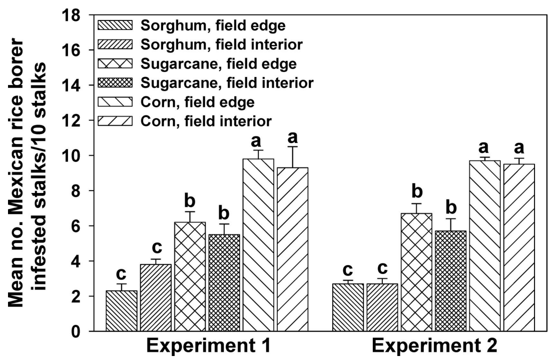

Fig. 4. Mean (±SE) numbers of stalks injured by larval Mexican rice borer out of 10 crop host stalks in commercially grown sugarcane, corn, and sorghum, Hidalgo Co., TX; experiment 1, 14 June–7 July; experiment 2, 8–30 July 2010; field edge, within the first 50 consecutive stalks on a row beginning from the edge of the field; field interior, within 50 consecutive stalks on a row beginning ≥30 m inside field (n = 6 fields of each crop during each experiment).

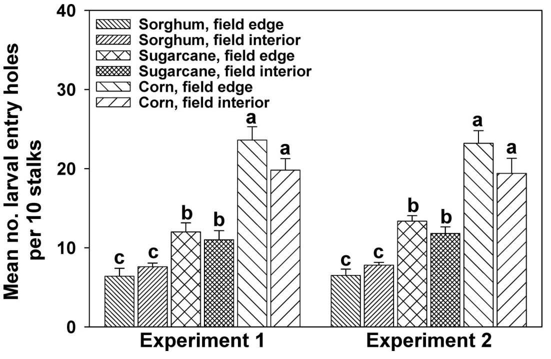

Fig. 5. Mean (±SE) numbers of larval Mexican rice borer entry holes per 10 crop host stalks in commercially grown sugarcane, corn, and sorghum, Hidalgo Co., TX; experiment 1, 14 June–7 July; experiment 2, 8–30 July 2010; field edge, within the first 50 consecutive stalks on a row beginning from the edge of the field; field interior, within 50 consecutive stalks on a row beginning ≥30 m inside field (n = 6 fields of each crop during each experiment).

in sorghum (F = 109.25; df = 2, 35; P < 0.0001) (Fig. 5). Larval entry holes were ≥1.6-fold more numerous on corn than on sugarcane, and ≥1.5-fold more numerous on sugarcane than on sorghum (F = 74.36; df = 2, 35; P < 0.0001) (Fig. 5). Corn stalks at field edges had 1.4-fold more adult exit holes than the interiors, corn stalks in field interiors had 1.9-fold more than sugarcane at the field edges, and sugarcane at field edges had ≥2.2-fold more than sorghum regardless of position (F = 111.94; df = 2, 35; P < 0.0001) (Fig. 6). Sugarcane in field interiors did not have different numbers of adult exit holes than field edge sugarcane and sorghum at either location (Fig. 6), but the factorial analysis detected differences in quantities of exit holes by field location (F = 6.69; df = 1, 35; P = 0.0148) and an interaction was found between crop and field location factors (F = 4.85; df = 2, 35; P = 0.0150).

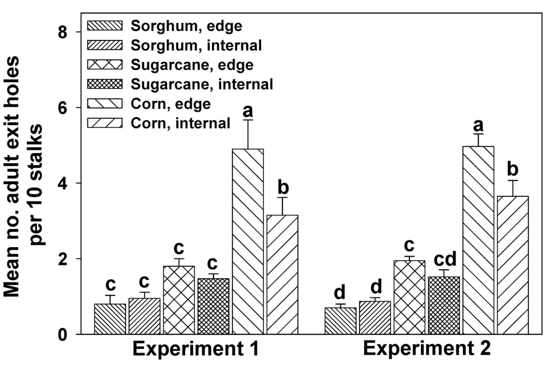

Fig. 6. Mean (±SE) numbers of adult Mexican rice borer exit holes per 10 crop host stalks in commercially grown sugarcane, corn, and sorghum, Hidalgo Co., TX; experiment 1, 14 June–7 July; experiment 2, 8–30 July 2010; field edge, within the first 50 consecutive stalks on a row beginning from the edge of the field; field interior, within 50 consecutive stalks on a row beginning ≥30 m inside field (n = 6 fields of each crop during each experiment).

Discussion

Our study is the first to demonstrate substantial Mexican rice borer injury to corn stalks under field conditions compared with lesser infestations in sorghum and sugarcane. Direct injury, however, occurs on the corn stalks, not on the harvested portion of the plant, and we have observed that as much as 4.4% of infested corn plants, unlike sugarcane and sorghum, sometimes simply collapse or rot into ooze at ground level (Showler et al. 2011), that, unless carefully tracking of numbers of stalks over time, might easily be overlooked. Of the three crops in our study, only corn plants vanished in that way, and we observed that Mexican rice borer infestation can lead to standing or lodged dead stalks, but the influence of sublethal stalk injury on corn yield and quality, and on the extent to which Mexican rice borer–inflicted wounds act as portals for infection by plant pathogens, have not been reported.

In greenhouse cage experiments, using the same numbers of plants of each crop in choice assays, sorghum was the least preferred (Showler et al. 2011). In commercial fields, sorghum is planted more densely than corn and sugarcane, but our pheromone trap data suggest that the greater population of sorghum plants does not contribute toward production of large numbers of adult Mexican rice borers as compared with the other two crops.

As the preferred crop host, corn serves as a reservoir for the pest and might be used as a "trap" crop to temporarily divert Mexican rice borers away from local rice, sorghum, and sugarcane. Our study demonstrated that, when grown near corn, sugarcane had relatively low levels of injury even though preharvest sugarcane plants are phenologically suitable for attack by the Mexican rice borer (Reay-Jones et al. 2007, Showler and Castro 2010a), but removal of the corn was followed by a substantial increase in numbers of injured sugarcane stalks and larval entry holes. In a similar vein, studies with the sugarcane borer, *Diatraea saccharalis* (F.), emphasize keeping corn production far away from sugarcane to minimize infestations on sugarcane (Hensley 1971, Flynn and Reagan 1984).

Although numbers of adult exit holes were uniformly low, they were more numerous in greenhouse corn choice assays with the other two crops (Showler et al. 2011), suggesting greater natural mortality of larvae and pupae under field conditions. Biological control of the Mexican rice borer, however, has not been effective largely because the larvae block their tunnels with frass (Showler and Reagan 2012) (this was also observed in the corn and sorghum stalks); hence, it is unlikely that the extent of predation and parasitism against larvae in any of the three crops was a substantial mortality factor. Because some highly infested mature corn plants that seemed to have maintained the pest through pupation "disintegrated" (this is how some stalks went missing in our commercial field experiment) they were not available for counting adult exit holes; hence, in corn, our exit hole data might be conservative. But even if, hypothetically, the F_1 generation of Mexican rice borers is not greater than the parent generation, the large populations displaced by drying and harvest of corn, would move into vulnerable crop plants that have not yet been harvested, such as sugarcane.

In South Texas, we determined that Mexican rice borers tunnel into corn stalks more than sugarcane and sorghum stalks and that cornfields are associated with the most adults. As a host for the Mexican rice borer, corn has been greatly underestimated or unreported. The utility of corn as a trap crop, and corn products as baits, for suppressing Mexican rice borer populations also have not been assessed. In South Africa, the sugarcane borer *Eldana saccharina* Walker prefers corn to sugarcane for ovipositioning by as much as 15-fold (Cochereau 1982). More importantly, our study suggests that the influence of corn in an agricultural landscape involving other host crops is substantial. Although it is known that the Mexican rice borer spread from South Texas to rice- and sugarcane-growing areas in eastern Texas (Reay-Jones et al. 2008), the pest's range expansion on corn, which is grown in many states outside Texas, has not been investigated. Because Mexican rice borers overwinter in temperate rice-growing areas of eastern Texas on crop stubble and on weeds common to other agricultural systems [e.g., Vasey's grass, *Paspalum urvillei* Steud.; Johnsongrass, *Sorghum halepense* Pers; and barnyardgrass, *Echinochloa crus-galli* (L.) P. Beauv.] (Beuzelin et al. 2011), it is expected that the pest has already spread to other areas of Texas, and potentially to other states, where rice and sugarcane are not grown. Surveys in the South Africa have shown that *E. saccharina*'s distribution is substantially more widespread than being confined to sugarcane-growing areas because of the insect's presence in corn-producing regions (Assefa et al. 2008). Unlike *E. saccharina,* northward expansion of the Mexican rice borer will probably be limited by colder temperate winters and an associated absence of living host plants.

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