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Impact of nitrogen fertilization on Mexican rice borer (Lepidoptera: Crambidae) injury and yield in bioenergy sorghum

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A B S T R A C T

The Mexican rice borer, *Eoreuma loftini* (Dyar) (Lepidoptera: Crambidae), is a serious pest of sugarcane (*Saccharum* spp.), sorghum (*Sorghum bicolor* (L.) Moench), corn (*Zea mays* L.), rice (*Oryza sativa* L.), and related graminaceous bioenergy crops. A two-year field study was conducted in Jefferson County, TX to examine the impact of nitrogen (N) fertilization on *E. loftini* infestations and subsequent yields in cultivars of high-biomass and sweet sorghum. In 2013, percentage of bored internodes and number of adult emergence holes per stalk increased with higher N rates; however, only the percentage of bored internodes was impacted by N in 2014. Yields from both years indicated that N rate was positively associated with increases in stalk weight and ethanol productivity, but not sucrose concentration. Because higher N rates were associated with increased yields despite having greater levels of *E. loftini* injury, our data suggest that increases in yield from additional N outweigh decreases from additional *E. loftini* injury. Fertilization rates maintained between the recommended 45 and 90 kg N/ha minimize risks of negative area-wide impacts from increased production of *E. loftini* adults, while still allowing for optimum yields.

1. Introduction

The Mexican rice borer, *Eoreuma loftini* (Dyar), has become one of the dominant pests of graminaceous crops in Texas and Louisiana since its introduction into the Lower Rio Grande Valley in 1980 (Johnson and van Leerdam, 1981; Legaspi et al., 1997; Reay-Jones et al., 2007a; Wilson et al., 2015a). Hosts of this invasive species include sugarcane (*Saccharum* spp.), rice (*Oryza sativa* L.), corn (*Zea mays* L.), and grain sorghum (*Sorghum bicolor* (L.) Moench) (Dyar, 1917; Van Zwaluwenburg, 1926, 1950; Osborn and Phillips, 1946; Johnson, 1984; Showler et al., 2012), as well as related bioenergy crops (VanWeelden et al., 2015). Recent demands in the United States for increased production of dedicated bioenergy feedstocks high in sucrose or lignocellulosic biomass (United States Environmental Protection Agency, 2007), including high-biomass sorghum (*Sorghum* spp. hybrids), sweet sorghum (*Sorghum bicolor* (L.) Moench) and energycane (*Saccharum* spp.), are anticipated to increase the host availability for *E. loftini*, which could impact area-wide infestations in conventional and bioenergy crops.

Current integrated pest management tactics to mitigate *E. loftini* infestations in sugarcane include judiciously timed insecticide applications (Wilson et al., 2012), irrigation (Reay-Jones et al., 2005), and host-plant resistance (Reay-Jones et al., 2003; Way et al., 2006; Wilson et al., 2015b; VanWeelden et al., 2015). However, little research has been conducted on management strategies in cultivars of sorghum produced as dedicated bioenergy feedstocks, specifically with regard to the impact of soil fertilization. Current nitrogen (N) fertilization recommendations for sweet sorghum range from 45 to 90 kg/ha in the Gulf Coast region (Viator et al., 2010), but little is known whether this regime is optimal for production of newly emerging high-biomass sorghum cultivars. In addition, the compatibility of recommended N regimes with current management strategies for *E. loftini* is unknown. Because N is essential for all biological processes and greater availability of N results in greater productivity among organisms, it is considered a limiting factor in ecosystems (Mattson, 1980). Impacts on insect pest biology resulting from enhancements in available N have been documented on numerous crops, including grain sorghum (Wale

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et al., 2006), corn (Sétamou et al., 1995; Wale et al., 2006), sugarcane (Atkinson and Nuss, 1989; Showler, 2015), and wheat (*Triticum* spp. L.) (Honek, 1991; Gash, 2012). Thus, manipulation of N fertilization can be a useful tool in an integrated pest management strategy. Quantity of available N is linked to many plant characteristics in sugarcane, including concentrations of free amino acids and vigor (Showler, 2015), which in turn can impact host preference for oviposition and larval performance of *E. loftini*. The objective of this study was to assess *E. loftini* injury and yield response across varying N fertilization regimes in high-biomass and sweet sorghum cultivars.

2. Materials and methods

2.1. Experimental design

A field experiment was conducted in 2013 and 2014 at the Texas A&M AgriLife Research and Extension Center at Beaumont, TX (Jefferson County) to evaluate the impact of N fertilization on *E. loftini* injury and yield in three cultivars of sorghum used in the production of biofuels. Cultivars included two high-biomass sorghum cultivars, ES 5200 and ES 5140 (Blade Energy Crops, Thousand Oaks, CA, USA), and one sweet sorghum cultivar, M81E (MAFES Foundation Seed Stocks, Mississippi State University, MS, USA). High-biomass sorghum cultivars ES 5200 and ES 5140 are *S. bicolor* and *S. bicolor* × *drummondii* (sudangrass) hybrids, respectively, bred to produce thick-stemmed, late maturing crops for use as dedicated bioenergy feedstocks (Blade Energy Crops, 2012). Sweet sorghum cultivar, M81E, is a *S. bicolor* inbred released by the USDA-ARS U.S. Sugar Crops Field Station for production of fermentable sugar (Broadhead et al., 1981), and has potential for ethanol production (Tew et al., 2008; Erickson et al., 2012).

The experiment was arranged using a randomized block, split-plot design with four blocks (one replication per block). Each block was 22.7 m long and 25.4 m wide (24 rows). Rates of N fertilization were randomized to six-row plots (22.7 m long and 6.4 m wide) and sorghum cultivars were randomized to two-row subplots (22.7 m long and 2.1 m wide). Prior to planting, soil samples consisting of single 2.5 cm wide by 30 cm deep cores at 15 locations within the field were collected and analyzed for available N at the Louisiana State University Agricultural Center Soil Testing and Plant Laboratory, Baton Rouge, LA. Soil analysis showed that available N ranged from 0.08 to 0.13% (mean: 0.10%, standard deviation: 0.02%), and available N in field plots prior to fertilization was not expected to interfere with the experimental design. High-biomass sorghum and sweet sorghum cultivars were planted using a four-row precision cone planter (Kinkaid Equipment Manufacturing, Haven, KS, USA) on 10 May in 2013 and 9 May in 2014 at a rate of 210,000 seeds per hectare. Two weeks after planting, urea granules were applied by hand to plots at one of four fertilization rates: 0, 45, 90, 135 kg N/ha. Nitrogen granules were applied to plots to reduce any confounding effects resulting from N mobility in the soil if applied to smaller subplots. The study was conducted on adjacent field sites in 2013 and 2014, and N fertilization rates and sorghum cultivars were re-randomized each year.

2.2. *Eoreuma loftini* within-season injury

Plants were sampled throughout the growing season during both years to determine within-season *E. loftini* injury. Subplots were sampled on 17 July, 7 August, 4 September, and 26 September in 2013 and 17 July, 4 August, 21 August, 5 September, and 3 October in 2014. At each date, 10 plants were randomly selected in each subplot and inspected for leaf sheath feeding and bored internodes from *E. loftini*. In addition, the height and total number of internodes were recorded for each plant. Injury was expressed as the percentage of injured internodes [(internodes with leaf sheath feeding or bored internodes/total internodes) × 100].

2.3. *Eoreuma loftini* end-of-season injury and yield

Experiments were harvested on 2 October in 2013 and 24 October in 2014 to collect *E. loftini* end-of-season injury and yields. Twelve stalks were sampled from each row of each subplot (24 stalks per subplot), stripped of leaf material, and the numbers of internodes, bored internodes, and *E. loftini* adult emergence holes were recorded for each stalk. Each 12-stalk sample was then weighed to determine fresh stalk weight (kg), and crushed using a sugarcane stalk crusher (Skyfood Equipment, Miami, FL, USA) to separate juice from bagasse. A 1-mL aliquot of juice from each sample was analyzed using a handheld refractometer (Reichert Technologies, Depew, NY, USA) to determine Brix (% w/w of soluble solids). From the Brix reading, sucrose concentration in stalks (% w/w) from each sample was calculated using the model (VanWeelden et al., 2015):

$$\text{Sucrose concentration} = \text{Brix}/1 \times 0.85/1.72 \tag{1}$$

where 1 is the factor converting *Brix* to soluble solid concentration in juice (% w/v) assuming a juice relative density of 1; 0.85 is the purity factor for converting juice sucrose to normal juice sucrose (Reay-Jones et al., 2005); and 1.72 is a constant estimated from calculating the relationship between fresh stalk weight and juice volume from data collected in the experiment. Bagasse from each sample was weighed, and a sub-sample of bagasse was removed, weighed, and dried for two weeks to remove moisture content. Dry weights of samples were used to estimate percent moisture remaining in the bagasse.

Estimation of ethanol productivity (liter/ha) was determined to be the sum of ethanol outputs from both sucrose and lignocellulosic biomass. Predicted ethanol output from sucrose was calculated for each sample using the model (Vasilakoglou et al., 2011):

$$\text{Predicted sucrose ethanol output} = \text{sucrose concentration} \times \text{fresh biomass} \times 6.5 \times 0.85 \times 1.27 \tag{2}$$

where *sucrose concentration* is calculated using model (1) for each sample; *fresh biomass* is the total fresh stalk weight in Mg/ha; 6.5 is the conversion factor of ethanol from sucrose; 0.85 is the efficiency constant from converting sucrose into ethanol; and 1.27 is the specific gravity of ethanol in g/mL. Because stands were low but spatially homogenous, stalk populations were standardized using published stand counts (Blade Energy Crops, 2012) to estimate fresh biomass per hectare. Dry bagasse weight (following adjustment for moisture remaining after crushing) from each sample was multiplied by a factor of 465.3, the theoretical ethanol yield in liter/metric ton from bagasse (United States Department of Energy, 2013) to determine lignocellulosic ethanol productivity.

2.4. Statistical analyses

Data were analyzed separately by year. Within-season *E. loftini* injury data for each subplot were analyzed using a linear mixed model (PROC GLIMMIX) (SAS Institute, 2008) with N fertilization rate, cultivar, and sampling date, along with all two and three-way interactions, as fixed effects. Random effects included block, block × N fertilization rate, and block × N fertilization rate × cultivar. For end-of-season data, a multivariate analysis was