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Susceptibility and yield response to sugarcane borer (Lepidoptera: Crambidae) infestation among sugarcanes and sorghums with potential for bioethanol production

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ABSTRACT

The U.S. Gulf Coast has ideal conditions, including abundant rainfall and a long growing season, for production of dedicated bioenergy crops. Interest in producing bioethanol from high-biomass graminaceous crops including energycanes (*Saccharum* spp.) and energy sorghums (*Sorghum* spp. hybrids) in the region has increased. However, insect pests including the sugarcane borer, *Diatraea saccharalis* (F.) (Lepidoptera: Crambidae), will likely adversely affect bioenergy crops. The impact of *D. saccharalis* infestations on yields of conventional and bioenergy sugarcanes and sorghums was investigated in three separate field studies conducted from 2012 to 2013. These studies compared *D. saccharalis* injury and crop yield parameters among insecticide-protected and unprotected plots of sugarcanes, energycanes, high biomass sorghums, and sweet sorghum. In unprotected plots, *D. saccharalis* injury ranged from 2.9 (resistant sugarcane) to 13.6% bored internodes (susceptible sugarcane). A resistant energycane cultivar was among the least injured (3.5% bored internodes) and demonstrated the greatest potential for bioethanol production with an average of > 17,000 L/ha. Linear regressions revealed negative relationships between percentage of bored internodes and ethanol yield in all cultivars. At one location, *D. saccharalis* injury resulted in a 13% reduction in bioethanol production across all years and cultivars. These studies indicate *D. saccharalis* has potential to substantially reduce yields in bioenergy crops and pest management programs will be needed to maximize ethanol production.

1. Introduction

Increasing emphasis in the U.S. on reducing dependence on fossil fuels has driven the exploration of production of bioethanol from dedicated bioenergy feedstocks (Goldemberg, 2007). Most U.S. bioethanol production is derived from corn (*Zea mays* L.) grown in the Midwest which has a high input to output ratio relative to other feedstocks (Solomon et al., 2007). Dedicated bioenergy feedstocks produced for lignocellulosic biomass can improve efficiency of ethanol production because their higher fiber content can be hydrolyzed into additional sugars and readily converted to ethanol (Solomon et al., 2007). These bioenergy feedstocks include sugarcane and energycane (*Saccharum* spp.), high-biomass sorghum (*Sorghum* spp. hybrids), and sweet sorghum (*Sorghum bicolor* (L.) Moench). Ethanol derived from sugarcane and energycane in Brazil has become a global energy commodity competitive with gasoline (Goldemberg, 2007). While production of bioenergy feedstocks in the U.S. is still in its infancy, the southeastern states have the greatest potential for the industry's development because of the availability of arable land, abundant rainfall, and a long growing season (English et al., 2006). Gulf Coast states which have well developed sugarcane industries including Louisiana, Florida, and Texas are particularly well suited for bioenergy feedstock production because much of the required infrastructure is already in place (Viator et al., 2009). However, input costs must be maintained at a minimum for biofuels production to be sustainable and many biofuel advocates often overlook environmental impacts of fertilizers and pesticides (Pimentel and Patzek, 2007).

Insect pests represent a substantial threat to the economics of

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bioethanol production. Studies by VanWeelden et al. (2015, 2016) in Texas demonstrated substantial reductions in ethanol produced from energycane, high-biomass sorghum, and sweet sorghum due to infestations of the invasive stem borer, *Eoreuma loftini* (Dyar) (Lepidoptera: Crambidae). While *E. loftini* is an emerging threat to graminaceous crops in Louisiana (Reay-Jones et al., 2008; Wilson et al., 2015a, 2017a), another crambid, the sugarcane borer (*Diatraea saccharalis* (F.)), is a well-established economic pest of sugarcane in the state (Hensley, 1971; White et al., 2008; Wilson et al., 2017b). Injury from *D. saccharalis* is directly related to reductions in both biomass and sucrose content of sugarcane (Metcalfe, 1969; White and Hensley, 1987; White et al., 2008), but the effects of this pest on bioethanol yields are not well understood. Thus, the objectives of this study are to evaluate susceptibility of sugarcane, energycane, high-biomass sorghum, and sweet sorghum, to *D. saccharalis* infestations and to determine the relationship between pest injury and bioethanol yields.

2. Materials and methods

2.1. Experimental design

A series of field studies were conducted in Rapides Parish (2012) and St. Mary Parish (2012, 2013) which evaluated susceptibility of selected bioenergy feedstocks to *D. saccharalis* infestations. Each experiment included stem borer-resistant (HoCP 85-845) and susceptible (HoCP 00-950) conventional sugarcane cultivars (Wilson et al., 2012, 2015b) in addition to energycane cultivars, Ho 02-113 and L 79-1002; high-biomass sorghums ES 5200 and ES 5140 (Blade Energy Crops, Thousand Oaks, CA, USA); and sweet sorghum cultivar M18E (MAFES Foundation Seed Stocks, Mississippi State University, MS, USA). ES 5200 and ES 5140 are *S. bicolor* and *S. bicolor* x *drummondii* (sudangrass) hybrids, respectively (Blade Energy Crops, 2012). Conventional sugarcane cultivars were selected because they are commercial lines grown in Louisiana with known levels of borer susceptibility (Wilson et al., 2015b; VanWeelden et al., 2015). Energycanes and sorghums were selected because these cultivars have been identified as potential candidates for biofuel production along the U.S. Gulf Coast (Viator et al., 2009; Hale et al., 2012; Pokhrel et al., 2017).

Experiments were arranged as split plot randomized block designs with cultivars assigned to main plots and treatments (insecticide protected or unprotected) assigned to subplots. Because there are differences in production practices between sorghum which is planted in spring and sugarcane and energycane which are planted in the fall, sorghum replications were planted adjacent to sugarcane/energycane replications. Thus, the cultivars were randomized within replications nested in the respective crops. In all experiments, cultivars were randomized to two-row, 7.3-m-long plots (0.0027 ha) which were divided into two subplots (2 rows wide and 3.6 m long, 0.0013 ha). Protected subplots received biweekly applications of tebufenozide (Confirm® 2F, Gowan Company, Yuma, AZ, USA) at a rate of 140 g ai/ha applied with a CO_2-pressurized backpack calibrated to deliver 96 L/ha from June–September in each growing season (10 applications/year). In St. Mary Parish, sugarcane and sorghum cultivars were randomized to five replications; in Rapides Parish, sugarcane cultivars were planted to five replications, while sorghum cultivars were planted to six replications. Sugarcane was planted on 10 October 2010 (Rapides Parish) and 2 November 2011 (St. Mary Parish). Evaluations were conducted in plant cane (St. Mary 2012) and first ratoon (Rapides 2012; St. Mary 2013). Sorghum was planted using a hand-planter (Precision Garden Seeder, Earthway, Bristol, IN, USA) calibrated to deliver 210,000 seeds per ha on 3 May 2012 (Rapides Parish) and 25 April 2012 and 16 April 2013 (St. Mary Parish). In all experiments, standard productions practices were followed throughout the growing season for sugarcane (Gravois, 2014) and high-biomass sorghum (Blade Energy Crops, 2012).

2.2. Data collection

Sorghum was harvested according to recommended maturity (Blade Energy Crops, 2012) on 20 September 2012 (Rapides Parish) and 18 September 2012 and 9 September 2013 (St. Mary Parish) after season long exposure to natural *D. saccharalis* infestations. Sugarcane and energycane plots were harvested consistent with traditional sugarcane harvest schedules for Louisiana on 10 October 2012 (Rapides Parish) and 5 October 2012 and 8 Oct 2013 (St. Mary Parish). For all experiments, millable stalk populations were recorded from each subplot prior to harvest. Borer injury data were collected at harvest on separate samples of 10 randomly selected stalks from each row of each sub-plot by recording the total number of internodes, number of bored internodes, and number of adult emergence holes per stalk (White and Hensley, 1987; Bessin et al., 1990; White et al., 2008). Samples were then processed for yield parameters at the LSU AgCenter Sugar Research Station (St. Gabriel, LA, USA) according to the methods of VanWeelden et al. (2015, 2016). Stalk samples were weighed to determine fresh stalk weights (mean kg/stalk) and crushed using an industrial roller mill to separate juice from bagasse (stalk fiber). Juice volume was recorded and a 1 mL sample was analyzed to determine Brix (% w/w soluble solids) using a handheld refractometer (Reichert Technologies, Depew, NY, USA). Sucrose concentration (% w/w sucrose) was calculated using the equation:

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

where 1 is a 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, and 1.72 is a constant from the relationship between stalk weight and juice volume (Reay-Jones et al., 2005; VanWeelden et al., 2015, 2016). Experiment-wide stalk population estimates for each cultivar were used for calculation of biomass and bagasse yields. Biomass yield was calculated by multiplying mean stalk density (stalks/ha) for each cultivar in each experiment by stalk weights from each sample and converted to per ha estimates prior to analysis. Bagasse was weighed after crushing each sample and adjusted for remaining moisture, and multiplied by mean stalk density to estimate bagasse yield per ha.

Ethanol productivity was estimated by summing the ethanol outputs from both sucrose and cellulosic biomass. Sucrose ethanol output was calculated for each sample using the equation (Vasilakoglou et al., 2011):

$$\mathit{Sucrose\ ethanol} = \mathit{sucrose\ concentration} \times \mathit{biomass\ yield} \times 6.5 \times 0.85 \times 1.27 \tag{2}$$

where sucrose concentration is calculated using equation (1), biomass yield is the total fresh 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. Cellulosic ethanol production was estimated by multiplying bagasse yields from each sample by a factor of 465.3, the theoretical ethanol yield in L/Mg from bagasse (United States Department of Energy Bioenergy Technologies Office, 2013; VanWeelden et al., 2015, 2016).

2.3. Data analysis

For all analyses, generalized linear mixed models (PROC GLIMMIX, SAS Institute, 2009) with Gaussian distributions were used. Kenward-Roger method was used for all calculations of error degrees of freedom and Tukey's HSD was used for all mean separations. Analyses of the 2012 data from Rapides Parish included treatment, cultivar, and treatment × cultivar as fixed effects and the random effects were crop, replication(crop), cultivar × replication(crop), and treatment × cultivar × replication(crop). St. Mary Parish analyses included treatment, cultivar, and cultivar × treatment as fixed effects, while