Sugarcane Green Harvest Effects on Arthropod Ground Predators and Lesser Cornstalk Borer (Lepidoptera: Pyralidae) Damage[1]

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J. Entomol. Sci. 55(4): 462–468 (October 2020)

Abstract A field trial was conducted to determine the effects of harvest method (green cane harvest versus preharvest burning) and different crop residue removal treatments on the populations of ground-inhabiting arthropod predators and *Elasmopalpus lignosellus* (Zeller) (Lepidoptera: Pyralidae) in the first ratoon crop. Neither preharvest burning nor percentage crop residue removal after green cane harvest had any significant effect on the numbers of ants (Hymenoptera: Formicidae) ($F = 1.00$; df $= 4$; $P = 0.412$) or spiders (Araneae) ($F = 0.08$; df $= 4$; $P = 0.921$) captured in pitfall traps. In contrast, crop residue levels remaining after green cane harvest significantly impacted *E. lignosellus* damage to the ratoon crop, with increased damage associated with lower levels of residue. Removal of $\geq$66% of the crop residue caused a significant ($F = 132.68$; df $= 3$; $P < 0.001$) increase in *E. lignosellus* damage that would likely reduce sugarcane yield, while 33% of the residue could be removed without increasing damage. Overall, our data indicate that green cane harvesting will not affect arthropod ground predators but may reduce the risk of *E. lignosellus* damage.

Key Words preharvest burning, harvest residue, mulch, ants, spiders

Sugarcane (*Saccharum* spp. hybrid) is a major row crop in Florida. Over 152,000 ha were grown in the state in 2018–2019, with approximately 71% of the crop grown on Histosols (organic) with the remainder on mineral (sand) soils. In Florida, sugarcane is mostly harvested by a method of preharvest burning, but green cane harvest may increase in the future due to environmental concerns and increased grower interest in the practice. There are some challenges in switching from preharvest burning to green cane harvest. In green cane harvest, a crop residue layer is left on the soil surface, which lowers soil temperature and slows early ratoon growth on Histosols (Sandhu et al. 2013, 2017). Residue also affects fertilizer application, water percolation into the soil profile, and reduces the efficiency of various tillage practices. These negative effects may be minimized or avoided through partial or complete removal of crop residue immediately after green cane harvesting. Additionally, the removed residue might be used for bioenergy

[1]Received 14 December 2019; accepted for publication 28 December 2019.

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production. However, residue removal may affect populations and activity of ground-dwelling pests or beneficial arthropods.

There are numerous studies published on the effect of burning on arthropod populations in natural ecosystems. Examples include burning in forests (Harrison and Whitcomb 1974) in the United States, sclerophyllous vegetation in Australia (Anderson 1988), and cerrado in Brazil (Marini-filho 2000). However, studies on the effect of burning on arthropod populations in agricultural crops such as sugarcane are few or lacking. Hall and Bennett (1994) reported that preharvest burning in Florida sugarcane is the most disruptive practice that may interfere with naturally occurring biological control. However, they noted that because of the long harvest season (~1 yr) and ratoon cropping (~3–4 yr), a large number of arthropods continue to be present in Florida-grown sugarcane in spite of the burning practice. Unfortunately, no data on the effect of preharvest burning on arthropod predators were provided in their study. In a later study, Cherry (2003) reported on the effect of harvesting and replanting on arthropod ground predators in Florida sugarcane, noting that sugarcane harvesting, including burning, did not affect pitfall trap catches of arthropod ground predators. In contrast to burning, when sugarcane is green harvested in Florida large amounts of organic residue remain on the soil surface. Currently, there are no data to compare the effect of sugarcane burning versus green harvesting and different levels of residue removal on arthropod populations for Florida-grown sugarcane.

The lesser cornstalk borer, *Elasmopalpus lignosellus* (Zeller) (Lepidoptera: Pyralidae), is a major sugarcane pest in Florida (Beuzelin et al. 2019). Larval feeding on sugarcane shoots results in dead heart symptoms that can reduce sugarcane and sugar yield (Sandhu et al. 2011a). Lesser cornstalk borer outbreaks in sugarcane are frequently associated with the preharvest burning of sugarcane to remove leaf material and with the postharvest burning of harvest residues. This practice improves fertilizer penetration and water percolation into the soil profile (Plank 1928). Preharvest burning of sugarcane exposes most of the soil surface after harvest, whereas leaf and stalk residues remain on the soil surface following green cane harvest. These residues help maintain high moisture levels at the soil surface. High levels of soil moisture have been linked to high larval mortality (Knutson 1976) and low egg deposition (Mack and Backman 1984) of lesser cornstalk borers whose adults deposit eggs in soil (Leuck 1966). A covering of crop residue in sugarcane production may hinder oviposition and larval survival of lesser cornstalk borer. Indeed, Sandhu et al. (2011b) reported that lesser cornstalk borer injury to young sugarcane plants can be significantly decreased by retaining residue on the soil surface after green cane harvest. However, partial or complete harvest residue removal may also affect lesser cornstalk borer injury to sugarcane. The objective of this study, therefore, was to measure residue removal impacts on lesser cornstalk borer damage as well as numbers and activity of arthropod ground predator populations in Florida-grown sugarcane.

Materials and Methods

A field trial was conducted at the Everglades Research and Education Center, Belle Glade, FL, in 2015–2016. Soil at this site was classified as Lauderhill series muck (euic, hyperthermic Lithic Haplosaprist). The field was planted with CP 96-1252 (Edme et al. 2005) cultivar in November 2016 and managed using standard commercial sugarcane production practices in Florida. No data were collected in the plant cane crop. Sugarcane harvest (green versus burn) and residue removal treatments were implemented after plant cane harvest, which occurred at 12 mo age. Data on arthropod ground predators and lesser cornstalk borer damage were collected in the first ratoon crop. In green harvested plots, residue removal treatments (0, 33, 66, and 100% residue removal) were conducted immediately after harvest. Residue was removed manually, and in partial residue removal treatments the remaining residue was spread uniformly over the plot. The experimental design was a randomized complete block with six replications. Plots were four rows, 6 m wide and 10 m long.

Populations of ground-dwelling arthropod predators were measured with pitfall traps, which have been used extensively for studies of soil surface dwellers (Southwood and Henderson 2000). More specifically, pitfall traps have been used to measure populations of arthropods in Louisiana sugarcane fields (Hensley et al. 1961; Negm and Hensley 1969; Reagan et al. 1972) and Florida sugarcane fields (Cherry 2003; Sandhu and Cherry 2014). Each pitfall trap consisted of a 9-cm-diameter plastic cup containing 100 ml of ethylene glycol. A 5-cm-deep plastic collar was also cut from another 9-cm cup, the top of which was glued in the middle of a 26-cm plastic plate with its center removed. This collar was then inserted into the pitfall trap and the plate loosely covered with soil. This arrangement prevented soil subsidence around the trap, thus facilitating arthropod access to the trap. A small metal roof was also placed above each trap to prevent rainfall from filling the traps. One trap was located in a sugarcane row in the middle of each plot.

Tests were conducted for 4 mo during May through August 2016. Traps remained in the plots for 2 weeks (mid-month of each of the 4 mo), when trap contents were taken to a laboratory and samples drained into paper towels and frozen. Thereafter, ants (Formicidae), centipedes (Chilopoda), earwigs (Dermaptera), ground beetles (Carabidae), rove beetles (Staphylinidae), and spiders (Araneidae) were counted under a microscope. The only arthropod identified to the species level was the red imported fire ant (*Solenopsis invicta* Buren); this is because these ants are well-documented and important predators in Florida sugarcane (Cherry 2003), were abundant in samples, and are easily identified. The relative abundance of predators in all traps was determined. Ants and spiders were the only two groups of arthropods captured in sufficient numbers to warrant statistical analysis. Mean numbers of ants and spiders captured in the five treatments were compared using Tukey's honestly significant different (HSD) test ($P = 0.05$).

Lesser cornstalk borer damage was measured by counting dead hearts in each plot at 45 and 90 d after harvest (DAH) of the plant cane. Percent dead hearts was calculated based on number of tillers with dead hearts compared to total number of tillers in the plot. Data were analyzed using one-way analysis of variance and the means were compared using Tukey's HSD ($P = 0.05$).

Table 1. Ants and spiders in different harvest treatments in Florida sugarcane.

		Green Harvest Percent Residue Removal*			
Predators	Burned	0	33	66	100
Ants**	21.1 ± 10.2 a	27.8 ± 41.2 a	15.5 ± 11.3 a	20.5 ± 19.4 a	25.5 ± 14.4 a
Spiders**	7.4 ± 4.0 a	7.7 ± 4.5 a	7.8 ± 3.7 a	7.8 ± 4.0 a	7.2 ± 5.4 a

* Residue refers to dead vegetation (leaves + stalks) left on soil surface after green harvesting.
** Means ± standard deviation of insects caught in pitfall traps from May to August. Means in a row followed by different letters are significantly different ($P = 0.05$) using Tukey's HSD test.

Results and Discussion

Ground-dwelling arthropods. A total of 3,080 arthropod ground predators were captured in all pitfall traps during this study. Of these, 67% were ants, 1% centipedes, 2% earwigs, 2% ground beetles, 25% spiders, and 3% rove beetles. Imported red fire ants (*S. invicta*) accounted for 80% of all ants captured in the traps. Negm and Hensley (1967) reported that ant populations were relatively higher and more important than spider populations as predators of the sugarcane borer, *Diatraea saccharalis* (F.), in sugarcane in Louisiana. Negm and Hensley (1969) again evaluated biological control agents of the sugarcane borer in Louisiana sugarcane. In that later study (Negm and Hensley 1969), their statistical analysis was conducted only on ants and spiders as biological control agents, thus suggesting their importance as predators in sugarcane grown in Louisiana.

Solenopsis invicta was first reported in Florida sugarcane in 1970 (Carroll 1970). Cherry and Nuessly (1992) showed that, since 1970, *S. invicta* became the dominant ant species in Florida sugarcane fields, resulting in a large reduction in the relative abundance of other ant species. In a study of the effect of harvesting and replanting on arthropod ground predators in Florida sugarcane fields, Cherry (2003) concluded that ants, especially *S. invicta*, had the highest relative abundance of the predators, followed by spiders and minor numbers of other predatory groups. Sandhu and Cherry (2014), in a study on the effects of tillage practices on arthropod ground predators in Florida sugarcane, found that ants, especially *S. invicta*, spiders, and earwigs were the most abundant ground predators captured in pitfall traps. Our results in this present study are consistent with those previous studies showing that ants and spiders are the most abundant and important ground predators found in sugarcane fields both in Louisiana and Florida.

The response of ants and spiders to different harvest treatments in Florida sugarcane are shown in Table 1. Arthropod responses to habitat burning are highly variable. Some species are attracted to burned areas (Evans 1971; Force 1981; Gillon 1972a, 1972b; Holliday 1984; Komarek 1969), others are repelled by fire (Odum et al. 1974; Rice and Parenti 1978), while still others appear not to be affected by fire (Komarek 1969; Rickard 1970). In our study, there were no significant differences in the numbers of ant ($F = 1.0$; df $= 4$; $P = 0.412$) or spider ($F = 0.08$; df $= 4$; $P = 0.921$) populations captured in pitfall traps in the burn versus the

Table 2. Percent dead hearts (mean ± standard deviation) caused by lesser cornstalk borer damage in different residue removal treatments in Florida sugarcane.

	Green Harvest Percent Residue Removal*			
Sampling Time	0	33	66	100
45 DAH**	1.4 ± 0.3 c	1.7 ± 0.6 c	3.8 ± 1.2 b	8.9 ± 1.8 a
90 DAH**	1.9 ± 0.3 c	2.7 ± 0.6 c	4.9 ± 1.5 b	13.2 ± 1.8 a

* Residue refers to dead vegetation (leaves + stalks) left on soil surface after green harvesting.
** DAH = Days after harvest of plant cane crop. Means in a row followed by different letters are significantly different ($P = 0.05$) using Tukey's HSD test.

four green harvest treatments, and this may be due to less change in soil temperature at burning than occurs in seasonal variations in the Histosols (Sandhu et al. 2013). Our results with burning are consistent with those of Cherry (2003), who reported that Florida sugarcane harvesting, including burning, did not affect pitfall trap catches of arthropod ground predators. In contrast to the extensive literature on the effect of fire on arthropod populations, there are no data on the effect of differing amounts of crop residue left in sugarcane fields after green harvest on ground arthropods. In our study, the percentage of residue removal had no significant effect on numbers of ant or spider populations found in pitfall traps. It is, of course, possible that predators may have dispersed among the different plots. However, the data clearly show that none of the burned or residue removal plots were preferred as habitats, resulting in greater pitfall trap catches of ants or spiders, which were the main soil arthropod predators found in Florida sugarcane.

Lesser cornstalk borer damage. The percentage of cane dead hearts caused by lesser cornstalk borer larval feeding damage at 45 DAH ranged from 1.4% in the treatment with no residue removed to 8.9% in plots from which all residue was removed (Table 2). Damage occurrence significantly ($F = 56.99$; df = 1; $P = 0.001$) increased with crop age and, at 90 DAH, ranged from 1.9% in the treatment with no residue removed to 13.2% in the treatment with all residue removed. At both sampling dates, residue removal had a significant effect ($F = 44.17$; df = 3; $P < 0.001$ at 45 DAH; $F = 88.72$; df = 3; $P < 0.001$ at 90 DAH) on the percentage of dead hearts observed in among treatments. Percent dead hearts increased when 66% and 100% of the residue was removed versus when 0% and 33% residue was removed. Removal of all crop residue resulted in the highest percentage of damage, with more than double the number of dead hearts compared to treatment of 66% residue removal. These results demonstrate that 33% of the crop residue can be removed after green harvest without increasing lesser cornstalk borer damage to the first ratoon crop; however, removal of ≥66% of the crop residue after harvest may result in a significant increase in the occurrence of dead hearts due to lesser cornstalk borer feeding damage. Furthermore, it is likely that such a level of damage may be translated into sugarcane yield loss.

Our results on lesser cornstalk borer damage agree with those of Hall (1999), who reported that only 0.5% of sugarcane shoots were killed by lesser cornstalk borer in fields with residue blankets compared with 7.0% in fields without residue. Similarly, Sandhu et al. (2011b) reported that mulching with sugarcane residue significantly reduced lesser cornstalk borer damage in plant cane. The observed reductions in lesser cornstalk borer damage may be at least partially due to the inhibition of oviposition by the presence of the residue and mulch in those studies. Bennett (1962) reported that the sugarcane residue blanket provided unfavorable conditions for oviposition in green harvested fields. Another possible reason for less damage in plots with residue might be attributed to the maintenance of higher soil moisture levels than in exposed soil, which either inhibited lesser cornstalk borer egg deposition (Leuck 1966) or increased larval mortality (Knutson 1976).

In summary, our data indicate that green cane harvesting in Florida will not affect arthropod ground predators but may reduce lesser cornstalk borer damage. These data should prove useful to Florida sugarcane growers in selecting management strategies.

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