Sugarcane Planting Date Impact on Fall and Spring Sugarcane Borer (Lepidoptera: Crambidae) Infestations

Authors: Beuzelin, J. M., Mészáros, A., Akbar, W., and Reagan, T. E.

Source: Florida Entomologist, 94(2) : 242-252

Published By: Florida Entomological Society

URL: https://doi.org/10.1653/024.094.0218

SUGARCANE PLANTING DATE IMPACT ON FALL AND SPRING SUGARCANE BORER (LEPIDOPTERA: CRAMBIDAE) INFESTATIONS

J. M. BEUZELIN[1], A. MÉSZÁROS[1], W. AKBAR[1,2] AND T. E. REAGAN[1]
[1]Department of Entomology, Louisiana Agricultural Experiment Station,
Louisiana State University Agricultural Center, Baton Rouge, LA 70803, USA

[2]Current address: Monsanto Company, 700 Chesterfield Pkwy West GG3E, Chesterfield, MO 63017, USA

ABSTRACT

In a two-year field study, sugarcane was planted on 4 dates ranging from the first week of Aug to the third week of Nov, reproducing sugarcane phenologies associated with planting and harvesting operations in Louisiana. Sugarcane planted in early Aug offered an extended period of plant availability for sugarcane borer, *Diatraea saccharalis* (F.), infestations during the fall. Periodic sampling throughout the fall showed that early Aug plantings had higher ($P < 0.05$) *D. saccharalis*-caused deadheart densities than later planted sugarcane. Destructive sampling conducted in early Oct showed that Aug plantings harbored greater deadheart densities ($P < 0.05$ in fall 2007) and *D. saccharalis* infestations ($P < 0.05$ in fall 2006 and 2007) than Sep plantings. Data from this study suggest a potential for increased *D. saccharalis* overwintering populations in early plantings associated with greater infestations during the fall. However, differences in deadhearts and *D. saccharalis* infestations in deadhearts were not detected ($P > 0.05$) during the spring. Three commercial sugarcane cultivars ('L 99-226', 'L 97-128', 'HoCP 95-988') were studied. Differences in *D. saccharalis* injury or infestations as affected by cultivar were detected ($P < 0.05$) only in early Oct 2007 when 'HoCP 95-988' harbored 2.3-fold greater infestations than 'L 99-226'.

Key Words: *Diatraea saccharalis* (F.), cultural practices, sugarcane IPM

RESUMEN

En un estudio de campo de dos años, se sembro caña de azúcar en cuatro fechas desde la primera semana de agosto hasta la tercera semana de noviembre, que reproduce la fenología de la caña de azúcar asociada con las operaciones de siembra y cosecha en Louisiana. La caña de azúcar sembrada en el principio de agosto ofreció un período extenso de disponibilidad de la planta para infestaciones por el barrenador de la caña, *Diatraea saccharalis* (F.), durante el otoño. Muestras periódicas tomadas durante el otoño mostró que las siembras del principio de agosto tuvieron una mayor densidad ($P < 0.05$) de cañas con corazones muertos causados por *D. saccharalis* que la caña de azúcar sembrada mas tarde. El muestreo destructivo realizado en el principio de octubre mostró que las siembras de agosto albergaba mayores densidades de corazones muertos ($P < 0.05$ en el otoño de 2007) e infestaciones de *D. saccharalis* ($P < 0.05$ en el otoño de 2006 y 2007) que las siembras de septiembre. Los datos de este estudio sugieren un posible aumento de poblaciones invernantes de *D. saccharalis* en siembras tempranas asociadas a una mayor infestación durante el otoño. Sin embargo, no se detectaron ($P > 0.05$) diferencias en los corazones muertos y las infestaciones de *D. saccharalis* en los corazones muertos durante la primavera. Se estudiaron tres variedades comerciales de caña de azúcar ('L 99-226', 'L 97-128', 'HoCP 95-988'). Se detectaron ($P < 0.05$) diferencias en el daño causado por *D. saccharalis* o de infestaciones afectadas por el tipo de variedad solamente al principio de octubre del 2007, cuando 'HoCP 95-988' albergaba las infestaciones de 2.3 veces mayor que la 'L 99-226'.

The sugarcane borer, *Diatraea saccharalis* (F.), historically has been the most damaging arthropod in Louisiana sugarcane (hybrids of *Saccharum* L. spp.) (Hensley 1971; Reagan 2001). With the widespread use of susceptible high-yielding sugarcane cultivars, current *D. saccharalis* management is achieved by judiciously timed chemical control of economically damaging infestations, conservation of natural enemies, and cultural practices (Posey et al. 2006; Beuzelin et al. 2009, 2010).

In Louisiana, sugarcane is grown in a 4- to 6-year rotation cycle, i.e., 3 to 5 crops are harvested from a single planting and are followed by a fallow period (Salassi & Breaux 2002). Sugarcane vegetative seed pieces are planted from Aug to Oct, with the traditional peak in Sep. However, as farms grow larger and more diversified, planting operations have become less flexible due to simultaneous harvesting and planting activities (Garrison et al. 2000). In addition, late season production of sugarcane seed pieces has become more challenging due to early lodging of recently developed cultivars. Therefore, producers currently plant both earlier and later in the growing season

(Garrison et al. 2000; Viator et al. 2005b). Planting borer-free sugarcane seed pieces is a recommended *D. saccharalis* management tactic to reduce overwintering populations (LSU AgCenter 2010). Because of the onset of low temperatures beginning about mid-Nov, the growing and milling seasons are approximately 9 months and 3 to 4 months, respectively. Thus, harvest in Louisiana begins in Sep and is completed by early Jan. Sugarcane stalks are harvested close to the soil surface, and growers may leave post-harvest crop residue in the field. *Diatraea saccharalis* larvae infesting crop residues at that time are exposed to cold temperatures and natural enemies, which increase overwintering mortality (Kirst & Hensley 1974, Bessin & Reagan 1993). Sugarcane stubble in fallow fields should be plowed out as quickly as possible to reduce the number of overwintering larvae (LSU AgCenter 2010). For non-fallow fields, burning of crop residue occurs mostly in the early spring.

With standard sugarcane management practices, early planting typically provides a better root establishment and higher yields (Viator et al. 2005a). Viator et al. (2005b) conducted a study to determine how Aug, Sep, and Oct planting dates impacted the yield of 5 sugarcane cultivars in Louisiana. Plant cane sugar yields for cultivar 'LCP 85-384' did not differ with planting dates, whereas for 'HoCP 85-845' and 'CP 70-321' sugar yields were higher for the Aug planting date. Charpentier & Mathes (1969) reported that fields planted in Aug show increased *D. saccharalis* infestations because they are highly suitable for moth oviposition. Fall sugarcane shoots (plant cane crop) and fall stubble (ratoon cane crop) are not considered to be *D. saccharalis* overwintering habitats but can serve as means of entry for larvae into seed pieces and stubble portions underground where overwintering occurs (Kirst 1973). The earlier sugarcane is planted or harvested, the greater the period of time during the late summer and fall that shoots are available for *D. saccharalis* oviposition and larval establishment. Early planted and early harvested fields may, therefore, represent a substantial refuge for overwintering *D. saccharalis*, and serve as a source of borers in the spring. Two field experiments were conducted between 2006 and 2008 to determine the effect of sugarcane field phenology associated with planting and harvesting dates on *D. saccharalis* infestations from the fall to the spring.

Materials and Methods

Planting Date Experiment 2006-2007

A field experiment was conducted from 2006 to 2007 near Patoutville (N 29.872°, W 91.744°) in Iberia Parish, LA. A randomized split-plot complete block design with 10 blocks (1 replication per block) was used. Each block was 36.9 m long and 11.0 m wide (6 rows) with 4 main plots, each containing 2 subplots. The range of phenological conditions occurring throughout the Louisiana sugarcane industry was mimicked by assigning early Aug, early Sep, early Oct, and late Nov planting dates to main plots. Each main plot was 6.4 m long and 11.0 m wide (6 rows), separated by a 1.2-m gap. Subplots were planted either with cultivar 'L 97-128' (*D. saccharalis* susceptible, White et al. 2008) or 'L 99-226' (*D. saccharalis* moderately resistant, White et al. 2008). Each subplot was 6.4 m long and 3 rows wide. Sugarcane was planted as whole stalks on Aug 4, Sep 2, Oct 5, and Nov 22 at a density of 6 stalks per 6.4-m row. For each subplot, sugarcane density (shoot counts) and growth (height) were recorded from the center row during subsequent planting dates. On the third planting date (Oct), the number of *D. saccharalis*-caused deadhearts was recorded from the center row of each subplot for the first and second planting dates. Deadhearts are shoots with dead whorl leaves caused by herbivores damaging the apical meristem before above ground internodes are formed (Bessin & Reagan 1993). Insects such as the lesser cornstalk borer (*Elasmopalpus lignosellus* (Zeller) Lepidoptera: Pyralidae) and wireworms (Coleoptera: Elateridae) also cause deadhearts in sugarcane. Therefore, only deadhearts exhibiting entrance holes and frass characteristic of *D. saccharalis*, but no silken tubes (characteristic of *E. lignosellus*), were recorded. Additionally, a 2.1-m long section of row was randomly selected from 1 outer row of each subplot, and plants from this section were destructively sampled for *D. saccharalis*. The number of injured shoots, injured shoots turned into deadhearts, as well as the abundance and size of *D. saccharalis* immatures found within the injured shoots were recorded. The size of *D. saccharalis* larvae was visually determined, with small, intermediate, and large larvae corresponding approximately to first-second, third, and fourth-fifth instars, respectively. On the fourth planting date (Nov), the number of *D. saccharalis*-caused deadhearts was recorded from the center row of each subplot from the first, second, and third planting dates. The following spring (May 18 and Jun 7), numbers of shoots and deadhearts found in the center row were recorded. Deadhearts were collected and dissected for *D. saccharalis* immatures, whose number and size were recorded.

Planting Date Experiment 2007-2008

A second field experiment was conducted from 2007 to 2008 near Bunkie (N 30.950°, W 92.163°) in Avoyelles Parish, LA. A randomized split-plot complete block design with 4 blocks (1 replication per block) was used. Each block was 53.6 m long and 14.6 m wide (8 rows), and contained 4 main plots, 1 for each planting date. Main plots were 12.5 m long and 14.6 m wide (8 rows), separated by a 1.2-m gap. Subplots were planted with cultivar 'HoCP 95-988' (*D. saccharalis* susceptible, White et al. 2008) or 'L 99-226'. Each subplot was 12.5 m long and 7.3 m wide (four rows). Sugarcane was planted as whole stalks, at a density of 14 to 20 stalks per 12.5-m row, on Aug 6, Sep 5, Oct 10, and Nov 21. Sugarcane emergence and growth data collection was conducted on the 2 center rows of each subplot in the same manner as that of the 2006-2007 experiment. On the third planting date, the number of *D. saccharalis*-caused deadhearts was recorded from the 2 center rows of each subplot from the first and the second planting dates. Additionally, sugarcane shoots for each subplot were examined from one randomly selected outer row. The number of injured shoots, injured shoots turned into deadhearts, and the abundance and size of *D. saccharalis* immatures found within the injured shoots were recorded. On the fourth planting date, the number of *D. saccharalis*-caused deadhearts was recorded from the 2 center rows of each subplot from the first, second, and third planting dates. The following spring (May 12 and 28), numbers of shoots and deadhearts found in the 2 center rows were recorded. Deadhearts were collected and dissected for *D. saccharalis* immatures, with immature number and larval size recorded.

Data Analyses

Data from experiments initiated in 2006 and 2007 were analyzed separately. Analyses of variance (ANOVAs) were conducted with Proc GLIMMIX (SAS Institute 2008), and linear regressions were conducted by Proc REG (SAS Institute 2008). Data collected in early Oct from destructive sampling (*D. saccharalis*-caused deadheart, *D. saccharalis*-injured shoot, and *D. saccharalis* immature counts), and data collected during the spring (shoot, *D. saccharalis*-caused deadheart, and *D. saccharalis* immature counts) were compared in two-way ANOVAs with planting date and cultivar as factors. Shoot count, plant size, and deadheart count data collected from periodic sampling of subplot center rows during the fall were compared by three-way repeated measures ANOVAs with planting date, cultivar, and observation date as factors. A variance component covariance structure was used to model the effects of repeated measures. In the experiment initiated in 2007, each of the 2 subplot center rows was considered a sampling unit. The Kenward-Roger adjustment for denominator degrees of freedom was used in all the ANOVA models to correct for inexact F distributions (Proc GLIMMIX, SAS Institute 2008). When ANOVA effects were detected ($P < 0.05$), least square means were separated by the least significant difference (LSD, $\alpha = 0.05$). Least square means ± standard errors on a per hectare basis are reported.

Linear regressions were conducted to determine whether a relationship between *D. saccharalis* and deadheart counts (recorded from destructive sampling in early Oct) was detected. In addition, linear regressions between fall (late Nov) and spring deadheart counts (recorded from subplot center rows) were conducted to investigate the relationship between end and beginning of the year *D. saccharalis* infestations in newly planted sugarcane.

RESULTS

Sugarcane Availability

Planting date, observation date, and planting date by observation date interaction effects were detected ($P < 0.05$) for plant availability estimates (shoot density and plant height) from periodic sampling during the fall of 2006 and 2007 (Table 1). In 2006, differences in shoot densities between cultivars 'L 99-226' and 'L 97-128' were not detected ($F = 0.00$; $df = 1{,}54$; $P = 0.984$). August plantings had 33,178 ± 1,764 shoots/ha (LS mean ± SE) by early Sep. In early Oct, Sep plantings had emerged with 47% lower shoot densities (Fig. 1) than the Aug plantings. In late Nov, the Oct plantings had the lowest shoot densities, 5.1-fold and 2.9-fold less than Aug and Sep plantings, respectively. Plant height followed a pattern similar to that observed for shoot density (Fig. 1). In early Sep, Aug plantings measured 47.0 ± 1.3 cm (LS mean ± SE). By late Nov, the Oct plantings had the smallest plants, 3.7-fold and 2.3-fold smaller than Aug and Sep plantings, respectively. In addition to a numerical trend ($F = 3.19$; $df = 1{,}27$; $P = 0.085$) for 'L 99-226' plants being taller than 'L 97-128' plants, a significant cultivar by planting date two-way interaction was detected ($F = 7.87$; $df = 2{,}27$; $P = 0.002$). 'L 99-226' plants from Aug plantings were 9% taller than 'L 97-128' plants whereas cultivar differences were not detected in other plantings. Whereas shoots growing from the first 3 plantings were available during the fall, shoots from the Nov plantings did not emerge until the following year (Fig. 1).

Shoot density and plant height during the fall of 2007 showed patterns comparable to those observed in 2006, with early plantings having increased availability and the last planting not emerging until the following year (Fig. 1). In early Sep, the Aug plantings had 53,808 ± 2,538 shoots/ha that measured 50.7 ± 1.9 cm. In late Nov, Aug plantings shoot density was 1.4-fold and 10.9-fold greater than that of Sep and Oct plantings, respectively. August plantings were 1.9-fold and 5.9-fold taller than those from Sep and Oct plantings, respectively. Shoot density and plant height

TABLE 1. SELECTED STATISTICAL COMPARISONS FOR SHOOT DENSITIES, PLANT HEIGHT, AND DEADHEART DENSITIES FROM SUGARCANE PLANTED ON 4 DATES RANGING FROM EARLY AUG TO LATE NOV, 2006 AND 2007.

Comparison	Fall 2006			Fall 2007		
	F	*df*	P > F	F	*df*	P > F
Shoot density						
Planting date	746.46	2,54	<0.001	504.34	2,18	<0.001
Observation date	993.33	2,108	<0.001	541.07	2,84	<0.001
Planting date × Observation date	105.03	4,108	<0.001	115.35	4,84	<0.001
Plant height						
Planting date	1047.71	2,18	<0.001	853.93	2,6	<0.001
Observation date	1141.93	2,108	<0.001	890.50	2,108	<0.001
Planting date × Observation date	74.33	4,108	<0.001	113.46	4,108	<0.001
Deadheart density						
Planting date	54.23	2,54	<0.001	11.67	2,9	0.003
Observation date	20.81	1,54	<0.001	13.13	1,42	<0.001
Planting date × Observation date	4.20	2,54	0.020	8.49	2,42	<0.001

were also affected by cultivar (F = 5.41; df = 1,18; P = 0.032 and F = 49.99; df = 1,9; P < 0.001, respectively), with 'L 99-226' showing greater density (13%) and height (23%) than 'HoCP 95-988'. However, two-way and three-way interactions involving cultivar effects also were detected (P < 0.05). Although 'L 99-226' generally had higher shoot densities than 'HoCP 95-988' (Fig. 1), the cultivar by collection date interaction (F = 3.38; df = 2,84; P = 0.039) and the planting date by collection date by cultivar (F = 12.34; df = 4,84; P < 0.001) interaction showed that differences in shoot density between 'L 99-226' and 'HoCP 95-988' at each collection date changed to varying extents for each planting date (Fig. 1). For Aug plantings, 'L 99-226' had 50% higher shoot densities than 'HoCP 95-988' in early Sep; however, differences were not detected (LSD P > 0.05) during later sampling. For Sep plantings, 'L 99-226' had 39 and 31% higher shoot densities than 'HoCP 95-988' in early Oct and late Nov, respectively. For Oct plantings, differences in shoot densities between 'L 99-226' and 'HoCP 95-988' in late Nov were not detected (LSD P > 0.05). The cultivar by collection date (F = 4.66; df = 2,108; P = 0.011), cultivar by planting date (F = 9.45; df = 2,9; P= 0.006), and the three-way (F = 2.95; df = 4,108; P = 0.023) interactions showed that differences in plant height between 'L 99-226' and 'HoCP 95-988' at each collection date changed to varying extents for each planting date (Fig. 1). For Aug plantings, 'L 99-226' was 35, 22, and 13% taller than 'HoCP 95-988' in early Sep, early Oct, and late Nov, respectively. For Sep plantings, 'L 99-226' was 24 and 26% taller than 'HoCP 95-988' in mid-Oct and late Nov, respectively. For Oct plantings, 'L 99-226' was 51% taller than 'HoCP 95-988' in late Nov.

Diatraea saccharalis Fall Infestations

Planting date, collection date, as well as planting date by observation date two-way interaction effects were detected (P < 0.05) for *D. saccharalis*-caused deadheart densities from periodic sampling during the fall of 2006 and 2007 (Table 1). Differences in deadheart densities as affected by sugarcane cultivar were not detected (F = 0.26; df = 1,54; P = 0.614 in 2006 and F = 0.51; df = 1,9; P = 0.492 in 2007). In early Sep, deadhearts in Aug plantings were not observed in 2006 and 2007 (Fig. 2). In early Oct, Aug plantings had higher deadheart densities than Sep plantings (4,313 vs. 43 and 1,093 vs. 0 deadhearts/ha in 2006 and 2007, respectively). In late Nov 2006, Oct plantings had the lowest deadheart densities, 37.8-fold and 9.8-fold less than Aug and Sep plantings, respectively. September plantings had intermediate deadheart densities, 3.9-fold less than Aug plantings (Fig. 2). *Diatraea saccharalis* adult emergence holes, indicating life cycle completion, were observed in deadhearts from sugarcane planted in Aug (641 ± 1,069 exit holes/ha [mean ± SD]). In late Nov 2007, deadhearts were not observed in Oct plantings whereas early Sep plantings had 13.0-fold less deadhearts than Aug plantings (Fig. 2).

In early Oct 2006, after shoot examination and destructive sampling from border rows of Aug and Sep plantings, differences in deadheart densities were not detected (Table 2). Even in the absence of deadheart symptoms, some sugarcane shoots were injured with *D. saccharalis* feeding signs in leaf sheaths and boring into the stem. The density of these non-deadheart injured sugarcane shoots was greater (2.3-fold) in Aug vs. Sep plantings (Ta-

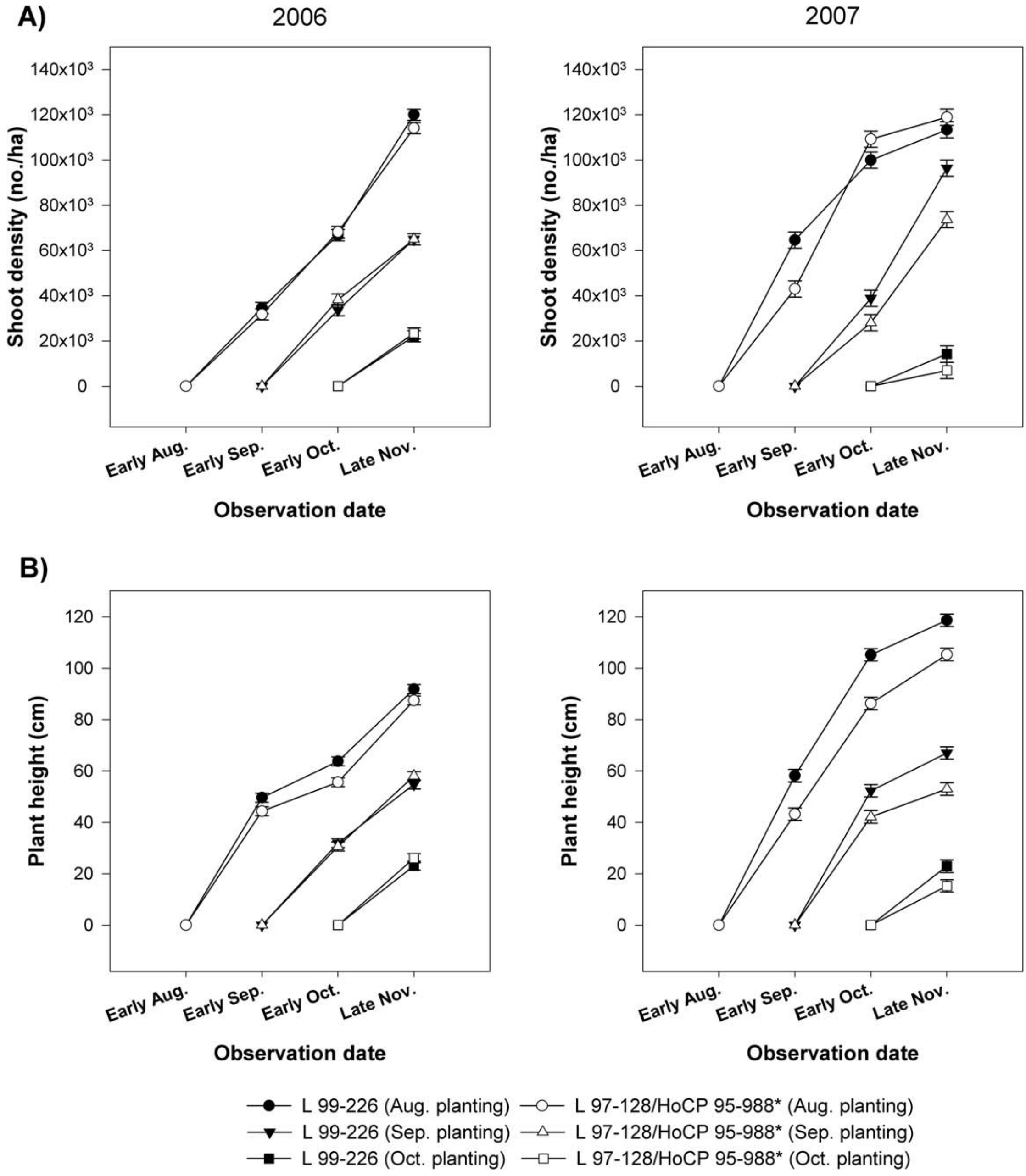

Fig. 1. A) Sugarcane shoot density (LS means ± SE) and B) plant height (LS means ± SE) during the fall from planting date field experiments in Patoutville, LA (2006) and Bunkie, LA (2007). *Cultivar 'L 97-128' for 2006 plantings and 'HoCP 95-988' for 2007 plantings.

ble 2). In addition, there were differences in *D. saccharalis* infestations (Table 2), with Aug plantings harboring 4.7-fold more borers than Sep plantings. Differences between cultivars 'L 99-226' and 'L 97-128' for deadheart densities, non-deadheart injured shoot densities, and *D. saccharalis* infestations were not detected ($P >$ 0.05, Table 2). Among the *D. saccharalis* larvae that were collected in Aug and Sep plantings, 25 and 27% were small, 40 and 18% were intermediate, 35 and 55% were large, respectively. A linear regression ($F = 9.09$; $df = 1,38$; $P = 0.005$; $R^2 = 0.193$) showed that *D. saccharalis* infestations in early Oct (dependent variable) were

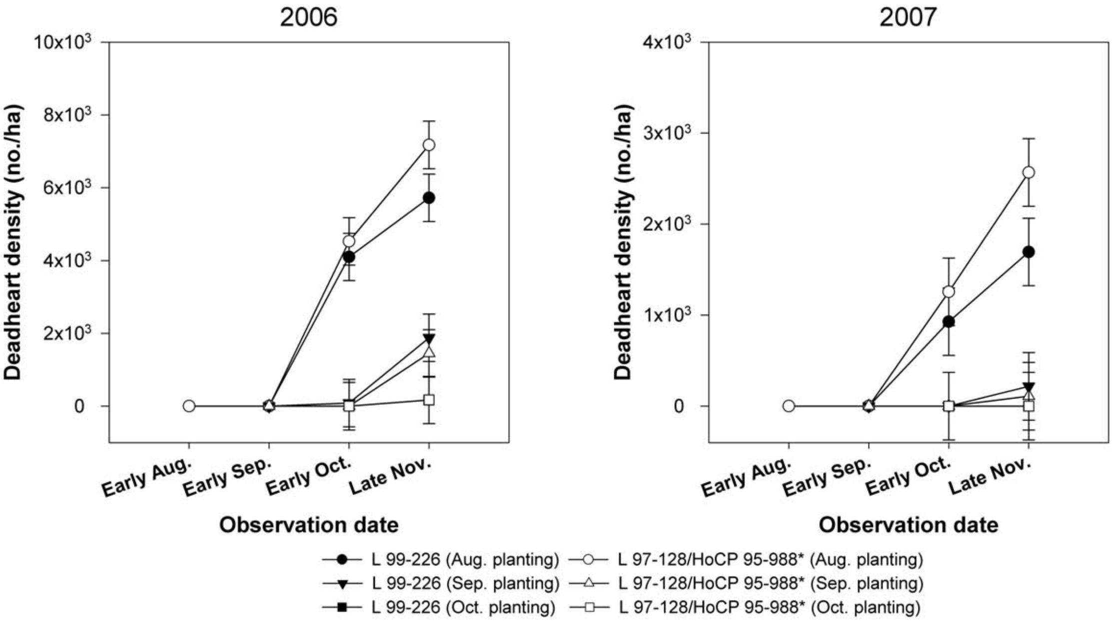

Fig. 2. *Diatraea saccharalis*-caused deadheart densities (LS means ± SE) during the fall in sugarcane from planting date field experiments in Patoutville, LA (2006) and Bunkie, LA (2007). *Cultivar 'L 97-128' for 2006 plantings and 'HoCP 95-988' for 2007 plantings.

positively correlated with deadheart densities (slope: 0.694, 95% C.I. = 0.228, 1.161; intercept: 0.655, 95% C.I. = -0.331, 1.642).

In early Oct 2007, shoot examination and destructive sampling from border rows showed that more *D. saccharalis*-caused deadhearts (24.0-fold) occurred in Aug than in Sep plantings (Table 2). There was a numerical trend for greater deadheart differences between Aug and Sep plantings in cultivar 'HoCP 95-988' ($P < 0.10$ for the planting date by cultivar two-way interaction, Table 2) than in 'L 99-226'. More *D. saccharalis* larvae were collected in Aug than in Sep plantings (19.0-fold), and in 'HoCP 95-988' than in 'L 99-226' (2.3-fold). The significant ($P < 0.05$) planting date by cultivar interaction showed that differences in *D. saccharalis* infestations between Aug and Sep plantings occurred to a greater extent in cultivar 'HoCP 95-988' than in 'L 99-226' (Table 2). Among the *D. saccharalis* larvae that were collected from Aug plantings, 3, 11, and 86% were small, intermediate, and large, respectively. All larvae recovered from Sep plantings were large. A linear regression ($F = 241.60$; $df = 1,14$; $P < 0.001$; $R^2 = 0.945$) showed that *D. saccharalis* infestations in early Oct (dependent variable) were positively correlated with deadheart densities (slope: 0.500, 95% C.I. = 0.431, 0.569; intercept: 0.158, 95% C.I. = -0.396, 0.712). Destructive sampling data collected in Oct 2006 did not differentiate *D. saccharalis* in deadhearts from *D. saccharalis* in non-deadheart injured shoots. However, data from 2007 showed that 68% of recovered borers were infesting deadhearts from the Aug planting date. Despite the presence of deadhearts, all *D. saccharalis* larvae collected from the Sep planting date were feeding in non-deadheart injured shoots.

Diatraea saccharalis Spring Infestations

Differences in sugarcane shoot densities during the spring changed with planting dates (Table 3, Fig. 3). During the spring of 2007 and 2008, sugarcane planted in Aug (2006 and 2007, respectively) had higher shoot densities than that planted in Sep (14 and 25%, respectively), Oct (51 and 76%, respectively), and Nov (87 and 97%, respectively). Sugarcane planted in Sep (2006 and 2007) had higher shoot densities than that planted in Oct (33 and 41%, respectively) and Nov (65 and 58%, respectively). However, the effect of planting dates during the spring of 2007 occurred to a different extent in 'L 99-226' vs. 'L 97-128' (Fig. 3), as shown by the significant two-way planting date by cultivar interaction (Table 3). In addition, shoot densities in 'L 99-226' plots were 30% higher than those in 'HoCP 95-988' plots during the spring of 2008 (Fig. 3).

Differences in deadheart densities and *D. saccharalis* infestations from deadhearts during the spring were not detected among planting dates (Table 3). Among *D. saccharalis* immatures infesting deadhearts during the spring of 2007, 25% were intermediate, 71% were large, and 4% were

TABLE 2. DEADHEART DENSITIES, NON-DEADHEART INJURED SHOOT DENSITIES, AND *D. SACCHARALIS* INFESTATIONS (LS MEAN/HA ± SE) OBSERVED IN EARLY OCT FROM SUGARCANE PLANTED IN EARLY AUG AND EARLY SEP 2006 AND 2007.

	Fall 2006			Fall 2007		
Sugarcane	Deadheart density	Non-deadheart injured shoot density	*D. saccharalis* density	Deadheart density	Non-deadheart injured shoot density	*D. saccharalis* density
Planting date						
Early Aug	1,196 ± 384	2,306 ± 422 a	2,220 ± 541 a	3,933 ± 990 a	819 ± 326	2,076 ± 432 a
Early Sep	1,068 ± 384	982 ± 422 b	470 ± 541 b	164 ± 990 b	55 ± 326	109 ± 432 b
F[1]	0.06	4.92	5.24	7.25	3.59	12.46
P > F	0.817	0.033	0.034	0.036	0.155	0.039
Cultivar						
'L 99-226'	1,110 ± 331	1,708 ± 422	1,324 ± 481	1,475 ± 786	492 ± 274	656 ± 362 b
'L 97-128'/'HoCP 95-988'[2]	1,153 ± 331	1,580 ± 422	1,366 ± 481	2,622 ± 786	382 ± 274	1,530 ± 362 a
F[3]	0.01	0.05	0.01	2.57	0.32	8.73
P > F	0.911	0.831	0.943	0.160	0.595	0.026
Planting date × Cultivar						
Early Aug						
'L 99-226'	1,110 ± 468	2,477 ± 597	2,050 ± 680	2,622 ± 1,112	874 ± 354	1,093 ± 480 b
'L 97-128'/'HoCP 95-988'[2]	1,281 ± 468	2,135 ± 597	2,391 ± 680	5,244 ± 1,112	765 ± 354	3,059 ± 480 a
Early Sep						
'L 99-226'	1,110 ± 468	939 ± 597	598 ± 680	328 ± 1,112	109 ± 354	219 ± 480 b
'L 97-128'/'HoCP 95-988'[2]	1,025 ± 468	1,025 ± 597	342 ± 680	0 ± 1,112	0 ± 354	0 ± 480 b
F[3]	0.11	0.13	0.26	4.25	0.00	13.64
P > F	0.739	0.723	0.615	0.085	1.000	0.010

[1] *df* = 1,18; 1,36; 1,18; 1,6; 1,3; and 1,3, respectively,
[2] Cultivar 'L 97-128' for fall 2006 and 'HoCP 95-988' for fall 2007,
[3] *df* = 1,18; 1,36; 1,18; 1,6; 1,6; and 1,6, respectively.
LS means in columns followed by the same letter are not different (LSD, $\alpha = 0.05$).

TABLE 3. STATISTICAL COMPARISONS FOR SHOOT DENSITIES, DEADHEART DENSITIES, AND *D. SACCHARALIS* INFESTATIONS IN DEADHEARTS FROM SUGARCANE PLANTED ON 4 DATES RANGING FROM EARLY AUG TO LATE NOV.

	Spring 2007			Spring 2008		
Comparison	F	*df*	P > F	F	*df*	P > F
Shoot density						
Planting date	38.43	3,27	<0.001	19.26	3,24	<0.001
Cultivar	5.50	1,36	0.025	13.58	1,24	0.001
Planting date × Cultivar	15.62	3,36	<0.001	0.52	3,24	0.675
Deadheart density						
Planting date	0.80	3,72	0.497	1.51	3,9	0.277
Cultivar	1.08	1,72	0.303	0.49	1,44	0.486
Planting date × Cultivar	0.55	3,72	0.647	2.07	3,44	0.118
D. saccharalis density						
Planting date	1.16	3,36	0.337	0.97	3,9	0.448
Cultivar	0.28	1,36	0.601	0.00	1,44	1.000
Planting date × Cultivar	1.54	3,36	0.221	1.75	3,44	0.170

pupae. Pupae were recovered from deadhearts collected from Sep and Nov plantings. Among *D. saccharalis* larvae infesting deadhearts during the spring of 2008, 26% were intermediate and 74% were large. No pupae were recovered. Linear regressions conducted on data from experiments initiated in 2006 and 2007 did not detect a correlation (F = 0.30; df = 1,78; P = 0.583; R^2 = 0.004 and F = 3.74; df = 1,62; P = 0.058; R^2 = 0.057, respectively) between deadheart densities observed during the fall (late Nov) and the subsequent spring (May-June).

DISCUSSION

In this two-year study, sugarcane was planted on 4 dates from the first week of Aug to the third week of Nov to reproduce sugarcane phenologies associated with planting and harvesting operations in Louisiana. Because several crops are harvested from a single planting, 25-30% of the Louisiana sugarcane production area is replanted each year with vegetative seed pieces produced from the harvest of 6.5% of the acreage (Legendre & Gravois 2001, 2006, 2010). This study showed that sugarcane fields planted (or harvested) in early Aug offer an extended period of plant availability for *D. saccharalis* infestations, with higher shoot densities and taller plants (increased biomass) than fields planted (or harvested) later in the summer or fall. Late Nov plantings did not produce vegetation until the following spring, suggesting that sugarcane fields planted (or harvested) after late Nov preclude the growth of a

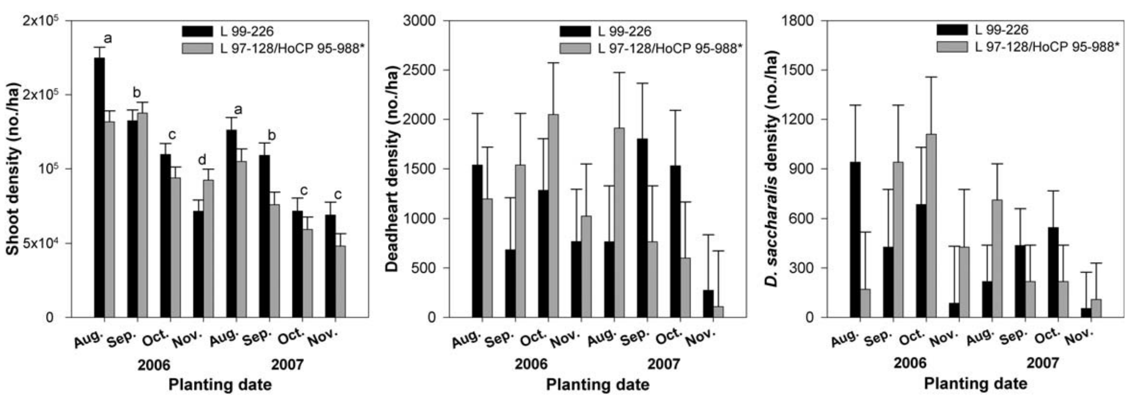

Fig. 3. Shoot densities, deadheart densities, and *D. saccharalis* infestations in deadhearts (LS means ± SE) during the spring from sugarcane planted on 4 dates ranging from early Aug to late Nov, 2006 and 2007. Planting dates within a year followed by the same letter are not different (LSD, α = 0.05). *Cultivar 'L 97-128' for 2006 plantings and 'HoCP 95-988' for 2007 plantings.

suitable host substrate for *D. saccharalis* oviposition.

Sampling throughout the fall showed that early Aug plantings had higher *D. saccharalis* deadheart densities than later planted sugarcane. This suggests that sugarcane earlier availability and greater biomass associated with early plantings increased *D. saccharalis* infestations. Destructive sampling conducted in early Oct confirmed that greater deadheart densities were associated with higher *D. saccharalis* infestations. Although Charpentier & Mathes (1969) commented that Aug planting dates were associated with increases in *D. saccharalis* infestations in Louisiana, our study is the first to quantify and compare fall infestations in newly planted sugarcane under current Louisiana production practices. Data from this study suggested a potential for increased *D. saccharalis* overwintering populations in early plantings associated with greater infestations during the fall. However, differences in deadhearts and *D. saccharalis* infestations in deadhearts were not detected during the spring. Four to 5 overlapping *D. saccharalis* generations occur annually in Louisiana (Hensley 1971). After being induced within the first 2 larval stadia (Roe et al. 1984), *D. saccharalis* enters a form of diapause as a large larva, with a peak incidence (63 to 71% of field populations) between Oct and Dec under Louisiana conditions (Katiyar & Long 1961). Although crop residues that are left in the field after harvest may initially be infested with larvae, they decay rapidly and do not serve as habitat for overwintering *D. saccharalis* populations (Kirst & Hensley 1974). The main overwintering habitats are underground portions of vegetative seed pieces and stubble. Because *D. saccharalis* larvae can use fall shoots to gain access to their underground overwintering habitat (Kirst & Hensley 1974) and greater fall infestations were found in early plantings, differences in deadhearts and *D. saccharalis* infestations were expected during the spring.

Deadheart incidence estimates the level of *D. saccharalis* infestations that occur during the spring in sugarcane (Bessin & Reagan 1993). *Diatraea saccharalis* larvae found in spring deadhearts from our study were a combination of intermediate and large larvae, indicating that both overwintering and first generation borers were infesting the deadhearts. Although deadhearts provide appropriate estimates for *D. saccharalis* spring infestations, they were not adequate for determining infestations that had successfully overwintered in newly planted sugarcane. In addition, the small size of our experimental plots likely increased the redistribution rate of adults among plots in the late fall and spring, thus mitigating potential differences in overwintering larval infestations. Red imported fire ants (*Solenopsis invicta* Buren), the primary *D. saccharalis* natural enemies in Louisiana sugarcane (Bessin & Reagan 1993; Beuzelin et al. 2009), were not artificially suppressed and may also have increased variability in spring *D. saccharalis* infestations. Some overwintering mortality factors (i.e., temperature, flooding) likely impacted overwintering populations to the same extent regardless of *D. saccharalis* densities. However, density dependent mortality factors (i.e., predation, parasitism) may have decreased infestations to a greater extent in more heavily infested sugarcane. Because of methodological weaknesses and potential interactions among overwintering mortality factors, a better assessment of overwintering populations should have been conducted during the winter and spring. During the experiment initiated in 2006, destructive sampling of underground seed pieces was conducted in Jan from 2.1-m long sections of border row for each subplot. Only one overwintering *D. saccharalis* larva was recovered and sampling was extremely labor intensive. The use of field cages collecting moths emerging from overwintering larvae may assist in better determining the role of sugarcane phenology during the fall on *D. saccharalis* overwintering populations (e.g., Kfir et al. 1989).

Although a practice of some insect pest management programs (Pedigo 2002), the manipulation of planting dates is more often associated with the agronomic management of crops. Because sugarcane stalks are the shortest in Aug, greater areas have to be harvested for seed piece production to achieve optimal planting rates. However, seed pieces are easier to harvest and plant in Aug before sugarcane stalks bend due to lodging (Viator et al. 2005a, 2005b). In addition, early planted sugarcane tends to produce higher yields (i.e., cane tonnage, sucrose concentration, sugar yield) associated with better root establishment (Viator et al. 2005a, 2005b; Hoy et al. 2006). Nevertheless, the effect of planting dates on yields is dependent on cultivar, with cultivar-specific optimal planting dates. Different cultivars may also show varying degrees of yield response to planting dates. In addition, planting date effects on yields vary with planting methods (Viator et al. 2005a; Hoy et al. 2006). In our study, sugarcane was planted as whole stalks. Louisiana growers also plant sugarcane as billets (stalk sections of 50-60 cm, Viator et al. 2005a). The yield response to planting dates of billet- vs. whole stalk-planted sugarcane seems less consistent (Viator et al. 2005a; Hoy et al. 2006). Whereas early planted sugarcane may increase regional *D. saccharalis* populations during the spring, better root establishment and greater biomass may help compensate for borer injury during the spring, which might help protect yields. Early planting dates have also been reported to reduce losses associated with root injury from wireworms (Charpentier & Mathes 1969).

'L 99-226', 'L 97-128', and 'HoCP 95-988' are 3 commercial sugarcane cultivars, respectively, grown over 11, 17, and 5% of the Louisiana sugarcane production area (Legendre & Gravois 2010). These cultivars have shown varying levels of resistance to *D. saccharalis* (White et al. 2008) and differences in shoot population and growth during the fall and spring were observed in our study. However, differences in *D. saccharalis* injury or infestations as affected by cultivar were only detected in early Oct 2007 when 'HoCP 95-988' harbored greater (2.3-fold) infestations than 'L 99-226'. In a previous study, Bessin & Reagan (1993) observed greater deadheart densities in 'CP 61-37' (*D. saccharalis* susceptible) than in 'CP 70-330' (resistant) during the spring. Cultivar resistance to *D. saccharalis* has traditionally been determined based on measures of mature stalk injury (% bored internodes), adult production (number of moth exit holes in stalks), and tolerance to injury (% yield loss relative to % bored internodes) (Bessin et al. 1990; White et al. 2008). When comparing 10 sugarcane cultivars with varying levels of resistance, White & Dunckelman (1989) found limited differences in *D. saccharalis* deadheart injury. However, the percentages of deadhearts were typically consistent with resistance rankings based on independent assessment of stalk injury levels (% bored internodes). Although differences in *D. saccharalis* resistance levels may not be observed when deadhearts occur (i.e., early in sugarcane phenology before the formation of elongated internodes), the potential of cultivars with increased resistance to minimize fall and spring borer infestations deserves further research.

Diatraea saccharalis infestations in newly planted sugarcane and stubble growth during the fall do not contribute directly to economic damage and have not been considered in management (Hensley 1971). *Diatraea saccharalis* late summer and fall populations are the source for overwintering borers, which will emerge in the spring the following year and cause economic damage. Our study showed that early planting and harvesting enhance late summer and fall *D. saccharalis* populations, thus having the potential for enhancing overwintering populations and subsequent economic damage. In areas where *D. saccharalis* is a severe problem, when susceptible cultivars are planted, or when insecticides cannot be applied, optimization of planting dates (e.g., Sep) may help minimize *D. saccharalis* population build-up.

ACKNOWLEDGMENTS

This work was supported by USDA CSREES Crops-At-Risk IPM program grant 2008-51100-04415. We thank sugarcane growers Gerald Quebedeaux, Patoutville, Louisiana and Blake Newton, Bunkie, Louisiana for letting us use their farmland and for technical assistance. We thank D. C. Blouin (Louisiana State University) for assistance with data analyses, J. W. Hoy, N. A. Hummel, and B. E. Wilson (Louisiana State University) for review of earlier versions of the manuscript. This paper is approved for publication by the Director of the Louisiana Agricultural Experiment Station as manuscript number 2011-234-5534.

REFERENCES CITED

BESSIN, R. T., AND REAGAN, T. E. 1993. Cultivar resistance and arthropod predation of sugarcane borer (Lepidoptera: Pyralidae) affects incidence of deadhearts in Louisiana Sugarcane. J. Econ. Entomol. 86: 929-932.

BESSIN, R. T., REAGAN, T. E., AND MARTIN, F. A. 1990. A moth production index for evaluating sugarcane cultivars for resistance to the sugarcane borer (Lepidoptera: Pyralidae). J. Econ. Entomol. 83: 221-225.

BEUZELIN, J. M., AKBAR, W., MÉSZÁROS, A., REAY-JONES, F. P. F., AND REAGAN, T. E. 2010. Field assessment of novaluron for sugarcane borer (Lepidoptera: Crambidae) management in Louisiana sugarcane. Crop Prot. 29: 1168-1176.

BEUZELIN, J. M., REAGAN, T. E., AKBAR, W., FLANAGAN, J. W., CORMIER, H. J., AND BLOUIN, D. C. 2009. Impact of Hurricane Rita storm surge on sugarcane borer (Lepidoptera: Crambidae) management in Louisiana. J. Econ. Entomol. 102: 1054-1061.

CHARPENTIER, L. J., AND MATHES, R. 1969. Cultural practices in relation to stalk moth borer infestations in sugar cane, pp. 163-174 *In* J. R. Williams, J. R. Metcalf, R. W. Mungomery, and R. Mathes [eds.], Pests of Sugarcane. Elsevier publishing Co., New York, New York.

GARRISON, D. D., DUFRENE, E. O., AND LEGENDRE, B. J. 2000. Effect of planting date on yields of sugarcane cultivars grown in Louisiana. J. American Soc. Sugar Cane Technol. 20: 115.

HENSLEY, S. D. 1971. Management of sugarcane borer populations in Louisiana, a decade of change. Entomophaga 16: 133-146.

HOY, J. W., ARCENEAUX, A. E., AND SAVARIO, C. F. 2006. Effects of date and rate of billet planting on sugarcane yield. J. American Soc. Sugar Cane Technol. 26: 116-124.

KATIYAR, K. P., AND LONG, W. H. 1961. Diapause in the sugarcane borer, *Diatraea saccharalis* (F.). J. Econ. Entomol. 54: 285-287.

KFIR, R., VAN HAMBURG, H., AND VAN VUUREN, R. 1989. Effect of stubble treatment on the post-diapause emergence of the grain sorghum stalk borer, *Chilo partellus* (Swinhoe) (Lepidoptera: Pyralidae). Crop Prot. 8: 289-292.

KIRST, L. D. 1973. A Study of Overwintering Populations of *Diatraea saccharalis* (F.) in Louisiana. Ph.D. Dissertation, Louisiana State University, Baton Rouge, Louisiana.

KIRST, L. D., AND HENSLEY, S. D. 1974. A study of the overwintering populations of *Diatraea saccharalis* (F.) in Louisiana. Proc. Int. Soc. Sugar Cane Technol. 15: 475-487.

LEGENDRE, B. L., AND GRAVOIS, K. A. 2001. The 2000 Louisiana sugarcane variety survey, pp. 105-112 *In* Sugarcane Research Annual Progress Report 2000. Louisiana State University Agricultural Center, Baton Rouge, Louisiana.

LEGENDRE, B. L., AND GRAVOIS, K. A. 2006. The 2005 Louisiana sugarcane variety survey. The 2005 Louisiana sugarcane variety survey, pp. 89-98 *In* Sugarcane Research Annual Progress Report 2005. Louisiana State University Agricultural Center, Baton Rouge, Louisiana.

LEGENDRE, B. L., AND GRAVOIS, K. A. 2010. The 2009 Louisiana sugarcane variety survey. The 2009 Louisiana sugarcane variety survey, pp. 83-96 *In* Sugarcane Research Annual Progress Report 2009. Louisiana State University Agricultural Center, Baton Rouge, Louisiana.

LSU AGCENTER, LOUISIANA STATE UNIVERSITY AGRICULTURAL CENTER. 2010. Louisiana recommendations for control of sugarcane insects, pp. 130-131 *In* Louisiana Insect Pest Management Guide 2010. Louisiana State University Agricultural Center, Pub. 1838, Baton Rouge, Louisiana.

PEDIGO, L. P. 2002. Entomology and Pest Management (4th edition). Prentice Hall, Upper Saddle River, New Jersey.

POSEY, F. R., WHITE, W. H., REAY-JONES, F. P. F., GRAVOIS, K., SALASSI, M. E., LEONARD, B. R., AND REAGAN, T. E. 2006. Sugarcane borer (Lepidoptera: Crambidae) management threshold assessment on four sugarcane cultivars. J. Econ. Entomol. 99: 966-971.

REAGAN, T. E. 2001. Integrated pest management in sugarcane. Louisiana Agric. 44(4): 16-18.

ROE, R. M., HAMMOND, A. M., JR., DOUGLAS, E. E., AND PHILOGENE, B. J. R. 1984. Photoperiodically induced delayed metamorphosis in the sugarcane borer, *Diatraea saccharalis* (Lepidoptera: Pyralidae). Ann. Entomol. Soc. America 77: 312-318.

SALASSI, M. E., AND BREAUX, J. 2002. Economically optimal crop cycle length for major sugarcane varieties in Louisiana. J. American Soc. Sugar Cane Technol. 22: 53-62.

SAS INSTITUTE. 2008. User's Manual, version 9.2. SAS Institute, Cary, North Carolina.

VIATOR, R. P., GARRISON, D. D., DUFRENE, E. O., JR., TEW, T. L, AND RICHARD E. P., JR. 2005a. Planting method and timing effects on sugarcane yield. Crop Management: online (doi:10.1094/CM-2005-0621-02-RS).

VIATOR, R. P., RICHARD, E. P., JR., GARRISON, D. D., DUFRENE, E. O., JR., AND TEW, T. L. 2005b. Sugarcane cultivar yield response to planting date. J. American Soc. Sugar Cane Technol. 25: 78-87.

WHITE, W. H., AND DUNCKELMAN, J. W. 1989. The response of sugarcane selections to sugarcane borer in the greenhouse and field. J. American Soc. Sugar Cane Technol. 9: 56-61.

WHITE, W. H., VIATOR, R. P., DUFRENE, E. O., DALLEY, C. D., RICHARD, E. P., JR., AND TEW, T. L. 2008. Reevaluation of sugarcane borer (Lepidoptera: Crambidae) bioeconomics in Louisiana. Crop Prot. 27: 1256-1261.