Evaluation of Aphid Resistance Among Sugarcane Cultivars in Louisiana

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ECOLOGY AND POPULATION BIOLOGY

ABSTRACT Sugarcane (Saccharum L.) in Louisiana is colonized by the sugarcane aphid, Melanaphis sacchari (Zehntner), and the yellow sugarcane aphid, Sipha flava (Forbes). Five commercial sugarcane cultivars, ‘LCP 85-384’, ‘HoCP 91-555’, ‘Ho 95-988’, ‘HoCP 96-540’, and ‘L 97-128’, representing >95% of Louisiana’s sugarcane-growing area, were assessed under southern Louisiana field conditions for numbers of the two aphid species. Biweekly sampling during 2007 and 2008 growing seasons indicated cultivar and time effects on aphid frequency. Aphid population peaks occurred during June and July and then crashed. M. sacchari was more abundant than S. flava on almost all cultivars and on all sampling dates during both years of the study. HoCP 91-555 was found to be the most resistant compared with the susceptible Ho 95-988 and L 97-128 cultivars. HoCP 91-555 might be useful in areas of high aphid pressure, and as a source of resistance in cultivar development programs.

KEY WORDS Melanaphis sacchari, Sipha flava, Saccharum spp., varieties

The sugarcane aphid, Melanaphis sacchari (Zehntner), was first discovered in Louisiana in September 1999 on the USDA-ARS Ardoyne Research Farm in Houma, Terrebonne Parish, and a subsequent survey showed that eight of 21 sugarcane (Saccharum spp. hybrids)-producing parishes were infested (White et al. 2001). M. sacchari is a 1.1–2.0-mm-long ant-tended aphid with variable body colors depending on the host plant and environmental conditions (Blackman and Eastop 2000). Pale yellow, yellow-brown, purple, or even pinkish colors have been documented previously (Blackman and Eastop 2000). During recent years, M. sacchari has become the most abundant aphid species on sugarcane in Louisiana, capable of transmitting the persistent sugarcane yellow leaf virus (family Luteoviridae, genus Polerovirus, ScYLV) (Schenck and Lehrer 2000). The disease is important enough that Louisiana seed increase programs screen for ScYLV as part of certification standards for micropropagated seedcane to minimize its spread (McAllister et al. 2008).

Another aphid species colonizing Louisiana sugarcane is the yellow sugarcane aphid, Sipha flava (Forbes), which is yellow with dusky transverse markings on the dorsum, 1.3–2.0 mm long, and has numerous bristle-like hairs (Blackman and Eastop 2000). It occurs in the Western Hemisphere, feeding on many genera of Poaceae, including Digitaria, Hordeum, Panicum, Paspalum, Pennisetum, Saccharum, and Sorghum (Blackman and Eastop 2000). During recent years, M. sacchari has become the most abundant aphid species on sugarcane in Louisiana, capable of transmitting the persistent sugarcane yellow leaf virus (family Luteoviridae, genus Polerovirus, ScYLV) (Schenck and Lehrer 2000). The disease is important enough that Louisiana seed increase programs screen for ScYLV as part of certification standards for micropropagated seedcane to minimize its spread (McAllister et al. 2008).

Spread and incidence of ScYLV and other viruses of sugarcane can be reduced by use of aphid resistant cultivars (Smith 2005). Greenhouse studies on predominant Louisiana sugarcane cultivars have shown differences in degrees of susceptibility to M. sacchari and S. flava between L 97-128 (susceptible) and HoCP 91-555 (resistant) (Akbar et al. 2010). The purposes of this study were to assess commonly grown commercial sugarcane cultivars for resistance to aphids under field conditions, to determine peak periods of aphid infestation, and to determine the relative abundance of these two aphid species.

Materials and Methods

Five commercial sugarcane cultivars representing >95% of Louisiana’s sugarcane growing area in 2005 (Legendre and Gravois 2009), ‘LCP 85-384’ (Milligan 2011 Entomological Society of America 2003-5746/11/0699-0704/04/0 © 2011 Entomological Society of America

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et al. 1994), ‘HoCP 91-555’ (Legendeur et al. 2000), ‘Ho 95-988’ (Tew et al. 2005b), ‘HoCP 96-540’ (Tew et al. 2005a), and ‘L 97-128’ (Gravois et al. 2008), were planted using whole stalks in Youngsville, Lafayette Parish, LA, on 15 August 2006. Plots were comprised of single 7.3-m-long sections of row with a 1.2-m gap at the end of each plot. Treatments were arranged in a randomized complete block design with five replications. Conventional agronomic and cultural practices were used in the field but foliar insecticides were not applied. Sampling for natural populations of aphids on sugarcane plants during the first year of the study began 4 April and continued until 29 August 2007. The second year of the study was conducted on a first ratoon crop at the same location 4 April–26 August 2008. Aphids of each species were counted on 10 randomly selected whole sugarcane plants in each plot during the first and third weeks of every month.

Yield data were not collected from the experiments because the focus of the study was plant resistance to aphids, and in Louisiana sugarcane, aphids alone (in the absence of the viruses they transmit) are not known to reduce crop production. Because part of this study aimed at establishing the existence of resistance among the selected sugarcane cultivars, virus transmission by aphid vectors and consequent levels of infection were considered to be outside the realm of our investigation.

Aphid count data were log (x + 1)-transformed before statistical analyses to conform with analysis of variance (ANOVA) assumptions regarding normality and homogeneity of data. Season-long cultivar effects were compared using repeated measures ANOVA (PROC MIXED, SAS Institute 2006). Replication and replication × cultivar were entered into the model as random effects, and replication × cultivar was entered as the within-subject (repeated) effect. Separate analyses were conducted for each sampling date to compare cultivar effects on total aphid numbers (PROC MIXED, SAS Institute 2006). Similar analyses were performed to compare numbers of each aphid species on the cultivars during peak population times (June and July of each year). Comparisons among cultivar means were made using Tukey’s honestly significant difference (HSD) test at α = 0.05 (Tukey 1953). Between-year differences, not germane to the objectives of this study, were not analyzed.

**Results**

Repeated measures ANOVA showed that both cultivar and sampling date influenced aphid numbers, and the two factors interacted for both experiments (2007: cultivar $F = 32.01, df = 4, 16; P < 0.0001$; sampling date $F = 63.74, df = 9, 180; P < 0.0001$; cultivar × sampling date $F = 2.98, df = 36, 180; P < 0.0001$; 2008: cultivar $F = 55.93, df = 4, 16, P < 0.0001$; sampling date $F = 9.23, df = 9, 180; P < 0.0001$; cultivar × sampling date $F = 1.59; df = 36, 180; P = 0.0255$). Peak aphid populations on all five cultivars occurred during late June or in July (Fig. 1A and B), but population differences between cultivars in 2007 were detected as early as late April ($F = 19.41; df = 4, 16; P < 0.0001$), when LCP 85-384 had 10- and 4-fold more aphids than HoCP 91-555 and HoCP 96-540, respectively (Fig. 1A). After May, aphid numbers on all cultivars increased by 2.1-fold on LCP 85-384, 1.6-fold on HoCP 91-555, two-fold on Ho 95-988, 1.9-fold on HoCP 96-540, and four-fold on L 97-128 (Fig. 1A). In early and late June, L 97-128 supported four-fold (early June, $F = 7.70; df = 4, 16; P = 0.0012$) more than HoCP 91-555 when aphid populations on the latter cultivar were greatest. Early July populations were 4.8- and 3.4-fold greater on Ho 95-988, when populations peaked, than on HoCP 91-555 and HoCP 96-540, respectively ($F = 11.0; df = 4, 16; P = 0.0002$). Two weeks later, aphid populations on L 97-128 peaked again, with 8- and 5.5-fold more than were found on HoCP 91-555 and HoCP 96-540, respectively ($F = 6.12; df = 4, 16; P = 0.0035$). L 97-128 had 27.3-, 18-, and 9.1-fold more aphids by early August than LCP 85-384, HoCP 91-555, and HoCP 96-540, respectively ($F = 9.65; df = 4, 16; P = 0.0004$); and 2 wk later these differences increased to 28-, 18.4-, and 17-fold ($F = 12.76; df = 4, 16; P < 0.0001$ (Fig. 1A).

Cultivar effects during 2008 were detected in late April when a steep increase in aphid frequency occurred on Ho 95-988, resulting in 28.5-, 28.5-, 30.6-, and 5.3-fold more aphids than on LCP 85-384, HoCP 91-555, HoCP 96-540, and L 97-128, respectively ($F = 18.32; df = 4, 16; P < 0.0001$ (Fig. 1B), but differences thereafter were not detected between Ho 95-988 and L 97-128. In early May, Ho 95-988 had 11.5-, 12.7-, and 8.9-fold more aphids than LCP 85-384, HoCP 91-555, and HoCP 96-540, respectively ($F = 8.20; df = 4, 16; P = 0.0009$); and those differences increased to 12.9-, 18.1-, and 21.1-fold by late May, whereas L 97-128 had 4.6- and 5.4-fold more aphids than HoCP 91-555 and HoCP 96-540, respectively ($F = 5.30; df = 4, 16; P = 0.0005$) (Fig. 1B). Infestation counts peaked in late June (excluding L 97-128) when aphids on Ho 95-988 were 3.8-, 8-, and 4.1-fold more abundant than on LCP 85-384, HoCP 91-555, and HoCP 96-540, respectively, and 4.1-fold more abundant on L 97-128 than on HoCP 91-555 ($F = 7.47; df = 4, 16; P = 0.0014$) (Fig. 1B). L 97-128, however, supported peak aphid populations in early July that were 17.5- and 5.4-fold greater than populations on HoCP 91-555 and HoCP 96-540, respectively, whereas Ho 95-988 had only 12- and 3.6-fold more aphids ($F = 11.57; df = 4, 16; P = 0.0001$). There were 13-, 13.2-, and 8.1-fold more aphids on Ho 95-988 than on LCP 85-384, HoCP 91-555, and HoCP 96-540, respectively, by late July, whereas L 97-128 had 10.5-, 10.7-, and 6.5-fold more ($F = 14.68; df = 4, 16; P = 0.0001$). The only detected difference 2 wk later, however, was 24-fold, between Ho 95-988 and the less infested HoCP 91-555 ($F = 6.18; df = 4, 16; P = 0.0033$) (Fig. 1B). Late August 2008 populations were 24.4-, 34.5-, and 13.6-fold greater on Ho 95-988 than on LCP 85-384, HoCP 91-555, and HoCP 96-540, respectively, and 11.2-, 15.8-, and 6.3-
fold greater on L 97-128 ($F = 18.47$, df = 4, 16; $P < 0.0001$) (Fig. 1B).

*M. sacchari* was more abundant than *S. flava* on most all cultivars and on all sampling dates in both experiments. Early June 2007, *M. sacchari* populations were 3.2-, 15-, 3.8-, and 9.3-fold greater than *S. flava* populations on LCP 85-384, Ho 95-988, HoCP 96-540, and L 97-128, respectively ($F = 42.37$, df = 1, 36; $P < 0.0001$) (Table 1), and 2 wk later, 3.2-, 5.3-, and 9.5-fold more *M. sacchari* than *S. flava* were on the latter three.

![Fig. 1. Mean ± SE aphid populations per sugarcane plant in 2007 (A) and 2008 (B) during the first and third weeks of each of 5 mo, Youngsville, Lafayette Parish, LA. One-way ANOVA for each sampling time, n = 10 (*, $P < 0.05$).](https://academic.oup.com/aesa/article-abstract/104/4/699/70093)

Table 1. Mean ± SE populations of *M. sacchari* and *S. flava* per sugarcane plant on five cultivars June–July 2007 and 2008, Youngsville, Lafayette Parish, LA

| Cultivar | Yr    | Early June | Late June | Early July | Late July |
|----------|-------|------------|-----------|------------|-----------|
|          |       | *M. sacchari* | *S. flava* | *M. sacchari* | *S. flava* | *M. sacchari* | *S. flava* | *M. sacchari* | *S. flava* | *M. sacchari* | *S. flava* |
| LCP 85-384 | 2007  | 22.1 ± 7.2a | 6.7 ± 2.2b | 18.0 ± 1.7a | 21.8 ± 8.3a | 34.5 ± 12.5a | 16.7 ± 15.0b | 20.2 ± 7.8a | 3.0 ± 2.1b |
| HoCP 91-555 | 4.4 ± 1.7a | 6.0 ± 2.2a | 4.1 ± 1.4a | 9.4 ± 3.4a | 6.5 ± 1.7a | 5.4 ± 1.6a | 5.5 ± 3.6a | 2.9 ± 0.9a |
| Ho 95-988 | 35.2 ± 8.1a | 2.4 ± 0.5b | 40.7 ± 15.8a | 7.6 ± 4.4b | 51.9 ± 5.1a | 5.3 ± 3.9b | 18.0 ± 4.2a | 3.6 ± 2.6b |
| HoCP 96-540 | 11.5 ± 2.1a | 3.1 ± 1.9b | 12.6 ± 3.9a | 4.0 ± 1.9b | 11.2 ± 4.7a | 5.5 ± 1.6a | 10.6 ± 3.5a | 1.3 ± 0.5b |
| L 97-128 | 37.4 ± 15.1a | 4.0 ± 1.8a | 49.7 ± 8.2a | 5.2 ± 5.4b | 46.0 ± 8.2a | 5.8 ± 4.0b | 63.0 ± 20.0a | 1.7 ± 0.7b |
| LCP 85-384 | 2008  | 16.2 ± 5.7a | 6.1 ± 4.3b | 34.4 ± 20.2a | 0.4 ± 0.4b | 20.5 ± 4.8a | 0b | 6.6 ± 2.5a | 0b |
| HoCP 91-555 | 7.1 ± 5.7a | 0.4 ± 0.2a | 15.2 ± 8.9a | 1.2 ± 0.6b | 4.4 ± 2.9a | 1.3 ± 0.8a | 4.8 ± 2.6a | 1.7 ± 0.8a |
| Ho 95-988 | 115.3 ± 34.9a | 0b | 130.9 ± 29.7a | 0b | 66.2 ± 7.1a | 0b | 85.9 ± 13.1a | 0b |
| HoCP 96-540 | 8.8 ± 3.1a | 0b | 28.7 ± 15.7a | 3.1 ± 2.0b | 17.8 ± 8.3a | 0.6 ± 0.4b | 9.1 ± 4.0a | 1.5 ± 0.9b |
| L 97-128 | 37.3 ± 7.2a | 2.6 ± 1.8b | 64.0 ± 12.2a | 2.9 ± 1.3b | 97.1 ± 20.7a | 2.5 ± 1.6b | 48.8 ± 7.9a | 20.5 ± 15.4b |

Means in the same rows and within the same sampling time followed by the same lowercase letter are not significantly different ($P > 0.05$; Tukey’s HSD test); April, May, and August populations were too small to include in the table.
culturats, respectively ($F = 18.06; \text{df}= 1, 36; P = 0.0001$). Early July populations were predominantly comprised of $M. \text{sacchari}$ on LCP 85-384, HoCP 9-988, and L 9-128 by 2.1-, 10.0-, and 5.2-fold ($F = 28.54; \text{df}= 1, 36; P < 0.0001$), and by 6.7-, 5.7-6, and 37-fold in late July on LCP 85-384, Ho 95-988, HoCP 96-540, and L 97-128, respectively ($F = 64.10; \text{df}= 1, 36; P < 0.0001$) (Table 1).

From early June 2008 onward, $S. \text{flava}$ were absent from Ho 95-988 and from LCP 85-384 early July onward. By early June, no $S. \text{flava}$ occurred on HoCP 96-540, and $M. \text{sacchari}$ populations were 2.7- and 14.3-fold more abundant than on $S. \text{flava}$ on LCP 85-384 and L 97-128, respectively ($F = 80.61; \text{df}= 1, 36; P < 0.0001$) (Table 1). The differences between $M. \text{sacchari}$ and $S. \text{flava}$ populations 2 wk later increased to 86-, 12.7-, 9.3-, and 22-fold on LCP 85-384, HoCP 91-555, HoCP 96-540, and L 97-128, respectively ($F = 92.79; \text{df}= 1, 36; P < 0.0001$). Early July populations of $M. \text{sacchari}$ were 29.6- and 38.8-fold greater than those of $S. \text{flava}$ on HoCP 96-540 and L 97-128, respectively ($F = 161.71; \text{df}= 1, 36; P < 0.0001$), and by the end of the month, $M. \text{sacchari}$ were 6- and 2.3-fold more numerous than $S. \text{flava}$ on HoCP 96-540 and L 97-128, respectively ($F = 59.69; \text{df}= 1, 36; P < 0.0001$) (Table 1).

**Discussion**

Host plant resistance to insect pests is a major component of integrated pest management (IPM) in Louisiana sugarcane (Reay-Jones et al. 2003, Posey et al. 2006). Because sugarcane is perennial and three to five crops are typically harvested from each planting, judicious cultivar selection can be crucial to long-term production (Posey et al. 2006). The major insect problem in Louisiana sugarcane is the sugarcane borer, *Diatraea saccharalis* (F.) (Lepidoptera: Crambidae), which has been the focus of varietal resistance efforts (Bessin et al. 1990, Reagan 2001), but aphid outbreaks have become increasingly common (McAllister et al. 2008). Most studies aimed at understanding host plant resistance against *M. \text{sacchari}*, however, have been conducted on sorghum, *Sorghum bicolor* (L.) Moench (Setokuchi 1988, Kawada 1995, Teetes et al. 1995). Although White (1990) conducted a greenhouse evaluation of *S. \text{flava}* resistance among selected sugarcane cultivars, our study confirmed that resistance against both aphid species exhibited by HoCP 91-555 in greenhouse studies (Akbar et al. 2010) was evident under season-long field conditions. Because our experiments were conducted on relatively small field plots, increasing the possibility of border effects that might mitigate observed resistance when adjacent to plots of susceptible cultivars, expressions of resistance by HoCP 91-555 and HoCP 96-540 in larger plantings might be even greater than those we observed. Levels of sugarcane resistance to some insects, such as the Mexican rice borer, *Eoreuma loftini* (Dyar) (Lepidoptera: Crambidae), however, can change according to insect pressure and environmental conditions (Reay-Jones et al. 2003, 2005; Showler and Castro 2010).

This work confirms previously reported observations that *M. \text{sacchari}* infestations start low in the spring, build over May and June, peak in July, followed by a population decline (Hall and Bennett 1994, McAllister et al. 2005). Rapid population buildup of *M. \text{sacchari}* on L97-125 and Ho 95-988 indicates enhanced colonization, reproductive potential, and substantial survival relative to the other three cultivars. Differences in aphid densities on different cultivars can be attributed to nutritional quality of the host plant in terms of limiting essential nutrients (Auchair 1989, Smith 2005) and other factors impacting overall biotic potential (Akbar et al. 2010). Absence of certain free essential amino acids in the phloem sap of HoCP 91-555 has been associated with resistance to aphids (Akbar 2010) and that also might explain relatively low infestations of another hemipteran, the sugarcane tingid *Leptodictya tabida* Herrich-Schaeffer on this cultivar in field surveys and plot studies conducted in the Lower Rio Grande Valley of Texas (Setamou et al. 2005). However, although LCP 85-384, HoCP 91-555, and HoCP 96-540 were comparatively resistant to both aphid species, the same cultivars are susceptible to the sugarcane borer and the Mexican rice borer (Reay-Jones et al. 2003, Posey et al. 2006). In a greenhouse experiment, lower intrinsic rates of increase for *M. \text{sacchari}* and *S. \text{flava}* (1.8–2.8-fold) and longer doubling time (1.7–3.1-fold) were found on HoCP 91-555 than on L 97-128 (Akbar et al. 2010).

Louisiana’s sugarcane industry has relied extensively on the early-maturing LCP 85-384 since its release in 1993 (Legendre and Gravois 2009) because of its desirable agronomic characteristics, including high stalk populations, stubbling ability, and relatively high sugar and cane yields (Milligan et al. 1994, LaBorde et al. 2008). In our study, LCP 85-384 showed moderate resistance to *M. \text{sacchari}*, in agreement with McAllister et al. (2008), who also reported moderate levels of resistance to *M. \text{sacchari}* in association with low incidence of ScYLV in LCP 85-384. But vulnerability to common brown rust in LCP 85-384 has forced farmers to adopt other cultivars (Hoy et al. 2000), and a survey in 2008 indicated a substantial shift in cultivar composition since 2004 (when LCP 85-384 constituted 91% of the sugarcane grown) such that the relative proportion of acreage of LCP 85-384, HoCP 91-555, Ho 95-988, HoCP 96-540, and L 97-128 was 22, 2, 5, 44, and 17%, respectively (Legendre and Gravois 2009). Both HoCP 91-555 and HoCP 96-540 are resistant to some diseases, but each is susceptible to the sugarcane borer and therefore not recommended where insecticides cannot be applied (Legendre et al. 2000, Tew et al. 2005a). The two cultivars, however, are resistant to both aphid species season-long, and HoCP 91-555, in particular, might be a good choice in areas with high aphid populations.

Reasons for the greater numbers of *M. \text{sacchari})* than *S. \text{flava}* are not clear, but observations on variations in the amount of honeydew excreted (Akbar 2010) by each aphid species and ant attendance suggest a possible role of the red imported fire ant, *Solenopsis invicta* Buren, in protecting *M. \text{sacchari}*, the more prolific
honeydew producer (Flatt and Weisser 2000. Yao and Akimoto 2001, Woodring et al. 2004). Numbers of parasitized aphid mummies were negligible (≤0.2 per plant) on each cultivar (Akbar 2010), and differences in numbers of predators were unlikely, unless they resulted from differences in aphid populations.

Although aphid biotype development presents a degree of risk when relying exclusively on aphid resis-
tant cultivars over a wide geographical range, we believe this situation is less likely to occur in Louisiana sugarcane because the crop is a highly heterozygous hybrid (Smith 2005). Furthermore, Louisiana’s current sugarcane acreage is planted to several cultivars exhibiting different degrees of resistance to aphids, reducing selection pressure toward new biotypes (Smith 2005).

With information generated from this study, resist-
tant cultivars can be incorporated as a tactic within Louisiana’s sugarcane IPM programs. Understanding of the mechanism(s) that imparts sugarcane resistance to aphids will probably be important for developing new sugarcane cultivars resistant to aphids, for avoiding the viruses they transmit, and for developing nonbiological assay screening approaches.

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