

## SUSCEPTIBILITY OF STAGE IV CANAL POINT (CP) SUGARCANE CLONES TO YELLOW SUGARCANE APHID (*SIPHA FLAVA* (FORBES)) FEEDING DAMAGE

Gregg S. Nuessly<sup>1\*</sup>, Matthew G. Hentz<sup>2</sup>, and Robert A. Gilbert<sup>1</sup>

<sup>1</sup>Everglades Research and Education Center, University of Florida, IFAS, 3200 E. Palm Beach Rd., Belle Glade, FL 33430

<sup>2</sup>USDA, ARS, United States Horticultural Research Laboratory, 2001 South Rock Road, Ft. Pierce, FL 34945

\*Corresponding author: [gnessly@ufl.edu](mailto:gnessly@ufl.edu)

### ABSTRACT

Yellow sugarcane aphid, *Sipha flava* (Forbes) (Homoptera: Aphididae), causes damage to sugarcane (*Saccharum* spp. hybrids) plants by feeding. Based on field surveys, sugarcane response to *S. flava* feeding appeared to be variety dependent, with some varieties exhibiting severe chlorosis, reddening and necrosis in response to leaf feeding. In this study we compared the susceptibility of 16 CP 98 and 16 CP 99 series stage IV clones and two commercial standards to yellow sugarcane aphid feeding using a greenhouse bioassay. Alate aphids were allowed to naturally leave stressed sorghum sudan plants (*Sorghum bicolor* (L.) Moench) from a greenhouse colony and settle on test plants within a greenhouse. Aphid populations were allowed to develop on the plants for 22 days before they were evaluated for feeding damage and plant height. Feeding damage by *S. flava* varied widely among the tested varieties. Chlorosis and reddening were not good indicators of resulting high leaf necrosis. CP 98-1107 and CP 99-1896 were tolerant to *S. flava* showing relatively high levels of chlorosis and reddening, but little necrosis. Clones CP 98-1513, CP 98-1569, CP 98-1725, CP 98-2047 and CP 99-1540, CP 99-1686, CP 99-1865, and CP 99-3027 were the most susceptible to damage by the aphids. Clones showing the highest levels of resistance were CP 98-1417, CP 98-1481, CP 98-1497, CP 99-1542, CP 99-1893, CP 99-1894 and CP 99-1896. The results of this study indicates that CP genotypes exhibit a wide range of resistance to yellow sugarcane aphids and that YSA screening would be a useful addition to the CP breeding program.

### INTRODUCTION

Yellow sugarcane aphid, *Sipha flava* (Forbes) (Hemiptera: Aphididae), is a pest of sugarcane (*Saccharum* spp. hybrids), sorghum (*Sorghum bicolor* (L.) Moench), wheat (*Triticum* spp.), barley (*Hordeum* spp.), rye (*Secale cereale* L.), as well as many pasture grasses throughout Central, North, and South Americas, including the Caribbean islands, Puerto Rico, and Hawaii (Medina-Gaud et al. 1965; Kindler and Dalrymple 1990; Blackman and Eastop 2000). Yellow sugarcane aphid feeding damage to sugarcane is evidenced by a general chlorosis around feeding sites. Chlorosis spreads across the leaves as populations increase, followed by red to purple leaf discoloration and premature leaf necrosis. Prolonged feeding can lead to reduced tillering (Hall 2001) and death of entire sugarcane stools. Populations that increase to eventually damage all mature leaves on plants < 6 months old can reduce sugarcane yield at harvest time by 20% (Nuessly and Hentz 2002). Many species of natural predators exist in sugarcane that can reduce yellow sugarcane aphid population pressure (Hall 1988, 2001; Hall and Bennett 1994; Hentz and

Nuessly 2002). Insecticides can quickly control yellow sugarcane aphids (Nuessly and Hentz 2002) if natural enemies or rainfall (Miskimen 1970) fail to keep them below damaging levels.

Host plant resistance is an IPM strategy frequently compatible with biological and chemical controls. The strategy is particularly well suited to crops on which regular applications of insecticides are not economically feasible, including grasses. Antibiotic and antixenotic resistance traits have been found against yellow sugarcane aphids in various grains (Webster 1990; Webster et al. 1994), pasture and turf grasses (Starks and Mirkes 1979; Breen 1993; Kindler and Dalrymple 1999; Miyasaka et al. 2007), and sugarcane (White 1990).

Outbreaks of yellow sugarcane aphid became much more common in the Florida sugarcane growing region around the southern half of Lake Okeechobee beginning in 1999 (pers. observ.). Several short- and long-term projects were begun at that time to improve *S. flava* control, including an evaluation of the susceptibility of currently grown sugarcane varieties to yellow sugarcane aphid feeding damage. We found considerable variability in their susceptibility to *S. flava* colonization and feeding damage (G.S. Nuessly, unpublished data). CP 80-1824 and CP 89-2143 were readily colonized and quickly suffered damage to leaves and stalks while most other cultivars were not strongly colonized by this aphid in field situations. CP 89-2143 has a high sucrose content (Gilbert et al. 2006) that led to widespread adoption before its susceptibility to yellow sugarcane aphid was realized. The lengthy CP sugarcane variety development program allows for evaluation of many factors prior to their increase and commercial release, including horticultural characteristics and disease resistance, however YSA resistance is not routinely monitored. Information on susceptibility to insect damage would further aid sugarcane breeders and the Sugarcane Variety Release Committee in choosing the most suitable clones for south Florida conditions. The purpose of this study was to evaluate a greenhouse bioassay program for determining the susceptibility to *S. flava* feeding of sugarcane clones advancing from the stage III to stage IV CP breeding program.

## MATERIALS AND METHODS

Sugarcane clones advanced from Stage III to Stage IV in 2001 and 2002 were chosen for the trial. Twenty-eight clones, 14 from the CP 98 series and another 14 from the CP 99 series, were harvested from field plantings at the Everglades Research and Education Center, Belle Glade and from Sugar Farm Cooperative West Division, Pahokee, Florida (Table 1). Based on previous studies, susceptible (CP 80-1827) and resistant (CP 84-1198) clones were added to the Stage IV clones as controls. Single eye setts were cut from the stalks and submitted to 30-min hot water treatment to increase germination and reduce incidence of soil-borne diseases. At least 50 seed pieces of each clone were planted bud side up in 38 x 56 x 10 cm (width x length x depth) trays of Palm Beach soil mix (50% compost, 25% clean sand, 25% bark, Odum's, Loxahatchee, FL) and maintained in a greenhouse until they germinated. Susceptibility tests were conducted using plants selected for uniform size and transplanted into 56 x 77 x 20 cm trays of Palm Beach soil mix. Trays were planted with either all of the CP 98, or all of the CP 99 clones plus the two check clones for 16 clones per tray. One plant of each clone was randomly selected for planting in each tray with a final arrangement of four rows of four clones. Each series (CP 98 or CP 99) was replicated 12 times. Plants were allowed to grow in the test trays until they had at least three fully expanded leaves  $\geq$  25 cm long before exposing them to the

aphids. Trials were conducted within a 7.6 by 10.2 m greenhouse cooled with a fan and pad system. Trays were placed on greenhouse benches elevated 51 cm above the concrete-floored greenhouse.

Yellow sugarcane aphids for the trial were from a colony originally collected on sugarcane in the field and then maintained for 15 months in a glasshouse on a sorghum-sudangrass (*Sorghum bicolor* (L.) hybrid (cv. 'Cow Chow'). Earlier attempts to cage *S. flava* on sugarcane leaves to start colonies and to conduct experiments were unsuccessful in establishing the aphids on sugarcane plants. Placing aphids on plants and allowing them to settle and feed on their own was the only method we found to ensure establishment. Expanding on this idea, we chose a technique for this trial that would simulate colonization of plants in the field by winged aphids. Stressed sorghum-sudan plants infested with an *S. flava* colony that was actively producing alate (i.e., winged) forms were placed on greenhouse benches across the entire width of the greenhouse within 2 m of the cooling pads at the same elevation as the trays of sugarcane plants. Aphids that flew from the sorghum-sudan were drawn through the rows of test plants by the fans at the opposite end of the greenhouse from the cooling pads. Aphids were allowed to naturally settle on the sugarcane plants.

Damage ratings and plant height were used to evaluate sugarcane clone response to *S. flava* feeding. Leaf discoloration (chlorosis and reddening) and necrosis was rated on an increasing severity scale of 0 to 4 in 0.5 increments in 2002. In 2003, necrosis ratings were replaced with estimates of proportions of leaf necrosis. Proportions of leaves with necrotic tissue were summed and then divided by the number of leaves per plant to yield percentage necrotic tissue per plant. An overall damage rank was calculated for the CP 98 and the CP 99 series for use in ranking and comparing clones using a composite of the three damage ratings. Ranks of 1 to 16 (lowest damage to highest damage) were first assigned to the mean chlorosis, reddening and necrosis ratings for each clone. Ties among ratings were settled by giving the lowest ranking to the clone with the lowest necrosis rating in 2002 (CP 98) or lowest percentage necrosis in 2003 (CP 99). The next step was to compare the chlorosis and reddening values for each clone. The higher of the ranks between chlorosis and reddening was then added to twice the necrosis rank. The resulting values were ranked again to produce the overall damage rank for each clone. Chlorosis and reddening are both symptoms of the break down of chlorophyll. Feeding damage to sugarcane clones can be predominantly expressed as one or the other of these symptoms. Therefore, the symptom with the highest ranking was used in the equation to capture the greatest effect. Necrosis was given a greater proportional value in the equation because dead tissue provides no benefit to the plant. Spearman's rank correlation coefficient ( $r_s$ ) was used to determine if clone damage rankings were correlated across years for the CP 98 clones tested in 2002 and 2003 (Proc Corr Spearman option, SAS Institute 2008).

The trials for the CP 98 and CP 99 Stage IV clones were conducted over two seasons. In 2002, only the CP 98 series of varieties were evaluated since the CP 99 Stage IV clones were not yet identified. Aphid-infested sorghum-sudan plants were placed in the greenhouse on 20 March and removed 1 April in 2002. One tray of the 16 CP 98 clones tested were placed randomly on each of 4 benches in 3 rows across the greenhouse for passive infestation by winged aphids as described above. Winged (alate) and nymphal aphids on sugarcane clones were counted on 29 March 2002. Damage ratings were recorded on 20 April and plant heights were measured on 5

May. In 2003, both the CP 98 and CP 99 Stage IV clones were evaluated at the same time. Aphid-infested plants were placed in the greenhouse on 5 March and removed 8 March 2003. One tray of each series was placed randomly on each of 4 benches arranged to produce 3 tiers of benches across the width of the greenhouse for passive infestation by winged aphids. Damage ratings were recorded on 20 and 27 March and plant heights were measured on 7 April. Aphid densities were not recorded in 2003 due to time constraints associated with the extra time required to manage and rate twice as many clones as in 2002.

Analysis of variance tests (Proc GLM, SAS Institute 2008) were conducted to evaluate whether clones were a significant source of variation for damage ratings, percentage necrosis and overall damage rankings. Post hoc mean separation (Fisher's LSD,  $p = 0.05$ ) was performed for measurements where the probability of greater  $F$  values were  $\leq 0.10$ .

## RESULTS

### CP 98 Series – 2002

Winged aphids appeared to exhibit preferences for certain clones and there were significant differences among clones in numbers of nymphs and winged adults (Table 1). The greatest number of alates was found on the susceptible check CP 80-1827 at 12.6 per plant with four other clones with  $> 9$  alates per plant. CP 98-1107, CP 98-1118, CP 98-1569, CP 98-2047 and CP 80-1827 had the greatest numbers of nymphs on the 29 March sample date. Nymph production approached 80 per plant on CP 80-1827 and was  $> 70$  per plant on three additional clones. The least number of alates settled and the least number of nymphs were produced on CP 98-1139 and CP 98-1481.

The plant response to yellow sugarcane aphid feeding varied significantly ( $p < 0.0001$ ) among the clones (Table 1). While some quickly became chlorotic, others displayed much more reddening of leaves and necrosis than other clones. Some clones exhibited high chlorosis, but only moderate reddening and necrosis (e.g., CP 98-1457), while others presented the opposite situation with low or moderate chlorosis and high reddening and necrosis (e.g., CP 98-1513 and CP 98-2047). Although CP 98-1325 had greater reddening from aphid feeding, its chlorosis and necrosis ratings were among the three lowest in each category. This was the reason the overall damage rank was based on the greatest of either chlorosis or reddening rankings. Both color symptoms suggest a breakdown of chlorophyll within cells similar to that expressed in senescing leaves (Thimann 1983). Based on necrosis ratings, it appeared that clones CP 98-1335, CP 98-2047 and particularly CP 98-1513 were notably more sensitive to yellow sugarcane aphid feeding than others. Some clones exhibited little affect from feeding, such as CP 98-1029, CP 98-1325, CP 98-1417, -CP 981481, CP 98-1497 and CP 98-1725 as indicated by their low overall damage rank. CP 98-1481 was unique in having one of the three lowest damage ratings in each of the three categories.

The top six ranked clones had at least two of three damage ratings below a value of 2 (Table 1). CP 98-1481 displayed the least amount of damage among the clones tested and also had the lowest aphid density. The clone with the next lowest overall rank, CP 98-1513, displayed the highest reddening and necrosis ratings, followed closely by CP 98-2047. Interestingly, the clone with the second lowest aphid density (i.e., CP 98-1139) appeared to be

more sensitive to feeding than others with higher aphid densities. For example, CP 98-1107 had a slightly lower overall rank than CP 98-1139 (7 and 8, respectively) despite having nearly 3x as many aphids. Therefore, mean damage ratings were not directly tied to aphid density in all clones. These differences indicate the aphids have varying degrees of success altering plants processes among clones.

### **CP 98 Series – 2003**

The CP 98 stage IV clones again varied significantly in their responses to *S. flava* feeding in 2003 (Table 2). Differences among clones were noted on 20 March within 15 days of exposure. CP 98-1481 and CP 98-2047 had the lowest and CP 98-1457, CP 98-1569, and CP 80-1827 had some of the greatest chlorosis ratings at the first reading. CP 98-1139, CP 98-1481, and CP 98-1497 had the lowest reddening ratings while CP 98-1569, and CP 98-2047 had the highest reddening ratings. Percentage necrosis had already risen to > 20% in CP 98-1513 and CP 98-2047 within 15 days of aphid exposure, while four clones had much lower necrosis values of  $\leq 5.1\%$ .

Damage ratings generally increased over the seven days following the first observations. Chlorosis on CP 98-2047 had decreased from 1.3 to 0.9, while its reddening rating had increased from 3.3 to 3.9 in seven days. Low chlorosis and high reddening for this clone was also observed in 2002. Chlorosis ratings were greater after 22 days exposure in 2003 than after 31 days in 2002. CP 98-2047 had the lowest chlorosis rating again in 2003, while many clones shared the greatest values  $\geq 2.7$ . Five clones had reddening values  $\geq 3.3$ . Five CP 98 clones had greater than 25% of their leaf surface area killed as a result of *S. flava* feeding in 2003. Three clones, CP 98-1417, CP 98-1481, and CP 98-1497 had < 8% necrotic tissue.

Overall damage rankings for CP 98 clones were well correlated between the two years ( $r_s = 0.6329$ ,  $p = 0.0082$ ), with 12 of the 16 tested clones in 2003 maintaining ranks within three places of their 2002 rankings. CP 98-1481 again had the best ranking. The other clones in the top five were CP 98-1107, CP 98-1335, CP 98-1417, and CP 98-1497.

### **CP99 Series - 2003**

The CP 99 clones also varied significantly in their responses to *S. flava* feeding (Table 3). Two of the clones, CP 99-1893 and CP 99-2099 responded quickly to aphid feeding and became chlorotic. In addition to these two clones, CP 99-1541 had joined the group of clones with the highest chlorosis at the second reading 7 days later.

Clones in the CP 99 series were not as quick to turn red in response to aphid feeding as the CP 98 series with all values  $\leq 2.8$  at the first reading. However, one week later five of the clones had reddening ratings  $\geq 3.4$ . The response of CP 99-1896 was very similar to that observed for CP 98-2047 in both 2002 and 2003 where both clones expressed limited chlorosis but elevated reddening ratings compared to other clones tested.

A wider range of percentage necrosis was observed for the CP 99 (3.4 to 41.5%) than CP 98 (6.1 to 30.6%) series in 2003. CP 99-1686 appeared to be very sensitive to aphid feeding with 35% necrosis after only 15 days and 41% after 22 days of aphid feeding. The next most

sensitive clone to leaf necrosis was CP 99-3027. Only one clone had < 5% necrosis (CP 99-1896), but three additional clones displayed < 10% necrosis.

Three CP 99 series had very similar damage ratings and finished with the lowest overall damage rankings, namely CP 99-1894, CP 99-1986 and CP 99-1542. Two clones appeared to be particularly sensitive to *S. flava* feeding (i.e., CP 99-1686 and CP 99-3027) with each having the greatest reddening and necrosis ratings and finishing with the worst two overall rankings.

The CP 99 clones were considerably shorter than the CP 98 clones in 2002 with only one clone reaching 20 cm in height. No apparent relationship was observed between plant height and any of the measured parameters.

## DISCUSSION

Chlorosis and reddening, the initial plant responses to yellow sugarcane aphid feeding, were not necessarily good indicators of resulting high leaf necrosis in the CP 98 or CP 99 series clones. CP 98-2047 and CP 99-1889 exhibited low chlorosis, but among the highest reddening and necrosis ratings. CP 98-1107 exhibited middle to upper levels of chlorosis and reddening, but had one of the lowest necrosis levels, showing fairly high tolerance to feeding. CP 99-1893 and CP 99-1896 had the greatest reddening values, but among the lowest necrosis values. Finally, CP 98-1725 had middle to high chlorosis and the lowest reddening ratings, but ended with one of the highest levels of necrosis. However, using chlorosis or reddening together with necrosis to determine an overall damage ranking for each clone provides one method for comparing sugarcane clones for susceptibility to *S. flava* feeding damage. Early season chlorosis and necrosis in response to yellow sugarcane aphid feeding were found to be good indicators of future yield loss in CP 80-1824 (Nuessly and Hentz 2002). Clones with the best ranks had low necrosis ratings together with the lowest chlorosis and reddening rates. Clones CP 98-1513, CP 98-1569, CP 98-1725, CP 98-2047 and CP99-1540, CP 99-1686, CP 99-1865, and CP 9-3027 were the most susceptible to damage by yellow sugarcane aphid feeding. Clones showing the highest levels of resistance were CP 98-1417, CP 98-1481, CP 98-1497 and CP 99-1542, CP 99-1894, CP 99-1896 and CP 99-1944.

Results from both years on CP 98 and CP 99 clones demonstrate the wide range in sensitivity to *S. flava* feeding possible in the material emerging from the sugarcane breeding program. Yellow sugarcane aphid also does not reach damaging populations most years in southern Florida. Outbreaks tend to be associated with relatively dry summer and fall seasons, because heavy rains normally play an important role in dislodging aphids from plants where many die in the surface water, are covered and trapped by wet soil, or are preyed upon by numerous predators on the soil surface and plant stalks. This study demonstrates that greenhouse bioassays of aphid susceptibility can be performed within a short period of time and can be used in conjunction with agronomic and disease data in making decisions to advance stage IV clones into commercial increase programs. While susceptibility to *S. flava* feeding is not routinely used in the selection process, the value of these rankings has since been proven useful by the Sugarcane Variety Release Committee in Florida to remove clones with greater than average susceptibility to *S. flava* feeding from further consideration that were already in question due to concerns with cold tolerance, disease, or stubble cane yields.

## ACKNOWLEDGEMENT

Stalk harvests, plant propagation and aphid colony maintenance was assisted by R. Innocent. This work was made possible by support from the Sugar Cane Grower's Cooperative of Florida.

## REFERENCES

- Blackman, R.L., and V.F. Eastop. 2000. Aphids on the Worlds Crops: An Identification and Information Guide, 2<sup>nd</sup> Ed. Wiley, Chichester, UK.
- Breen, J.P. 1993. Enhanced resistance to three species of aphids (Homoptera: Aphididae) in *Acremonium* endophyte-infected turfgrasses. *J. Econ. Entomol.* 86: 1279-1286.
- Gilbert, R.A., J.M Shine Jr., J.D. Miller, R.W. Rice, and C.R. Rainbolt. 2006. The effect of genotype, environment and time of harvest on sugarcane yields in Florida, USA. *Field Crops Res.* 95: 156-170.
- Hall, D.G. 1988. Insects and mites associated with sugarcane in Florida. *Florida Entomol.* 71: 138-150.
- Hall, D.G. 2001. Notes on the yellow sugarcane aphid *Sipha flava* (Homoptera: aphididae) and the lady beetle *Diomus terminatus* (Coleoptera: Coccinellidae) in Florida. *J. Am. Soc. Sugar Cane Technol.* 21: 21-29.
- Hall, D.G., and F. Bennett. 1994. Biological control and IPM of sugarcane pests in Florida. Pages 297-325. *In Pest Management in the Subtropics, Biological Control - A Florida Perspective.* D. Rosen, F.D. Bennett and J.L. Capinera [eds.]. Intercept Ltd., Andover, UK.
- Hentz, M.G., and G.S. Nuessly. 2002. Morphology and biology of *Diomus terminatus* (Coleoptera: Coccinellidae), a predator of the yellow sugarcane aphid, *Sipha flava* (Homoptera: Aphidae). *Florida Entomologist* 85: 276-278.
- Kindler, S.D., and R.L. Dalrymple. 1999. Relative susceptibility of cereals and pasture grasses to the yellow sugarcane aphid (Homoptera: Aphididae). *J. Agric. Urban Entomol.* 16: 113-122.
- Medina-Gaud, S., L.F. Martorell, and R.B. Robles. 1965. Notes on the biology and control of the yellow aphid of sugarcane, *Sipha flava* (Forbes) in Puerto Rico. *Proc. 12<sup>th</sup> Congress of the International Society of Sugarcane Technologists, San Juan, Puerto Rico, March 28-April 10:* 1307-1320.
- Miskimen, G.W. 1970. Population dynamics of the yellow sugarcane aphid, *Sipha flava*, in Puerto Rico, as affected by heavy rains. *Ann. Ent. Soc. Am.* 63: 642-645.

- Miyasaka, S.C., J.D. Hansen, and G.K. Fukumoto. 2007. Resistance to yellow sugarcane aphid: screening kikuyu and other grasses. *Crop. Protection* 26: 503-510.
- Nuessly, G.S. 2002. Feeding effects of yellow sugarcane aphid on sugarcane. *J. Amer. Soc. Sugar Cane Technol.* (abstract) 22: 126-127.
- Nuessly, G.S., and M.G. Hentz. 2002. Evaluation of insecticides for control of yellow sugarcane aphid on sugarcane, 2000. 2 pp. *Arthropod Management Tests* 27: F113, Entomological Society of America, Lanham, MD.
- SAS Institute. 2008. PROC user's manual, version 9th ed. SAS Institute, Cary, NC.
- Starks, K.J. and K.A. Mirkes. 1979. Yellow sugarcane aphid: plant resistance in cereal crops. *J. Econ. Entomol.* 72: 486-488.
- Thimann, K.V. 1983. The senescence of leaves, pp. 85-115, *In*: Thimann, K.V., R.C. Adelman, and G.S. Roth (eds.), *Senescence in Plants*. CRC Press, Boca Raton, Florida.
- Webster, J.A. 1990. Yellow sugarcane aphid (Homoptera: Aphididae): detection and mechanisms of resistance among Ethiopian sorghum lines. *J. Econ. Entomol.* 83: 1053-1057.
- Webster, J.A., C. Inayatullah, M. Hamissou, and K.A. Mirkes. 1994. Leaf pubescence effects in wheat on yellow sugarcane aphids and greenbugs (Homoptera: Aphididae). *J. Econ. Entomol.* 87: 231-240.
- White, W.H. 1990. Yellow sugarcane aphid (Homoptera: Aphididae) resistance mechanisms in selected sugarcane cultivars. *J. Econ. Entomol.* 83: 2111-2114.

**Table 1. Aphid density and damage assessments of CP 98 Stage IV clones in 2002 after exposure to yellow sugarcane aphid feeding in a greenhouse.**

Clone	Mean $\pm$ SEM no./plant (29 March)		Mean $\pm$ SEM damage rating (20 April)			Overall damage rank <sup>2</sup>
	Alates	Nymphs	Chlorosis <sup>1</sup>	Reddening <sup>1</sup>	Necrosis <sup>1</sup>	
CP 98-1029	6.7 $\pm$ 0.7 b-g	54.3 $\pm$ 8.6 abc	1.2 $\pm$ 0.1def	1.3 $\pm$ 0.2 fg	1.0 $\pm$ 0.2gh	3
CP 98-1107	9.8 $\pm$ 1.9 abc	63.6 $\pm$ 14.6 abc	1.6 $\pm$ 0.2cd	1.9 $\pm$ 0.2 cde	1.6 $\pm$ 0.3d-g	7
CP 98-1118	9.9 $\pm$ 0.9 ab	71.4 $\pm$ 6.6 ab	1.5 $\pm$ 0.2cd	1.6 $\pm$ 0.2 def	2.1 $\pm$ 0.3bcd	11
CP 98-1139	3.7 $\pm$ 0.9 gh	21.0 $\pm$ 4.8 de	1.6 $\pm$ 0.3cd	1.1 $\pm$ 0.2 fg	1.6 $\pm$ 0.2c-f	8
CP 98-1325	7.3 $\pm$ 1.3 b-f	47.1 $\pm$ 8.3 bcd	0.9 $\pm$ 0.1efg	2.0 $\pm$ 0.2 cd	0.9 $\pm$ 0.2h	4
CP 98-1335	8.4 $\pm$ 2.0 b-e	57.1 $\pm$ 8.6 abc	2.2 $\pm$ 0.2ab	1.5 $\pm$ 0.2 def	2.2 $\pm$ 0.3abc	14
CP98-1417	4.8 $\pm$ 0.6 fgh	38.7 $\pm$ 8.0 cde	1.3 $\pm$ 0.2de	1.5 $\pm$ 0.2 def	1.0 $\pm$ 0.2fgh	5
CP 98-1457	5.8 $\pm$ 1.3 d-h	43.3 $\pm$ 10.1 cde	2.1 $\pm$ 0.3ab	1.4 $\pm$ 0.2 ef	1.7 $\pm$ 0.3b-e	9
CP 98-1481	3.3 $\pm$ 1.0 h	18.0 $\pm$ 5.3 e	0.7 $\pm$ 0.1fg	0.9 $\pm$ 0.2 g	0.5 $\pm$ 0.2h	1
CP 98-1497	6.6 $\pm$ 1.1 c-g	38.5 $\pm$ 8.5 cde	1.4 $\pm$ 0.2d	1.3 $\pm$ 0.2 fg	0.9 $\pm$ 0.2h	2
CP 98-1513	8.5 $\pm$ 1.4 b-e	74.0 $\pm$ 17.7 ab	1.3 $\pm$ 0.2de	3.4 $\pm$ 0.3 a	2.8 $\pm$ 0.3a	16
CP 98-1569	9.1 $\pm$ 1.5 bcd	56.8 $\pm$ 9.2 abc	1.9 $\pm$ 0.2bc	2.7 $\pm$ 0.3 b	2.0 $\pm$ 0.3bcd	12
CP 98-1725	5.8 $\pm$ 0.9 e-h	39.6 $\pm$ 4.9 cde	1.3 $\pm$ 0.2de	0.8 $\pm$ 0.2 g	1.1 $\pm$ 0.2e-h	6
CP 98-2047	9.8 $\pm$ 1.4 abc	73.2 $\pm$ 13.8 ab	0.7 $\pm$ 0.1g	3.4 $\pm$ 0.2 a	2.3 $\pm$ 0.2ab	15
CP 80-1827	12.6 $\pm$ 1.9 a	79.9 $\pm$ 11.3 a	2.3 $\pm$ 0.1a	2.4 $\pm$ 0.2 bc	2.0 $\pm$ 0.3bcd	13
C P84-1198	6.0 $\pm$ 1.2 d-h	54.9 $\pm$ 10.1 abc	1.6 $\pm$ 0.2cd	2.3 $\pm$ 0.3 bc	1.8 $\pm$ 0.3bcd	10
<i>F</i> (df = 15, 164)	4.70 ***	3.59***	9.31***	16.02***	8.30***	

Means in the same column followed by different letters are significantly different at  $p = 0.05$  (LSD).

\*\*\*ANOVA *F* significant at  $p < 0.0001$ .

<sup>1</sup>Ratings from 0 to 4 scale (0.5 increments) with increasing severity 31 d after aphid exposure.

<sup>2</sup>Chlorosis, reddening and necrosis values assigned ranks 1 to 16 from least to greatest damage. Comparing the chlorosis and reddening values for each clone, the higher of the ranks was then added to twice the necrosis rank. The resulting values were ranked again to produce the overall damage rank for each clone.

**Table 2. Damage assessments of CP98 Stage IV clones in 2003 after exposure to yellow sugarcane aphid feeding in a greenhouse.**

Clone	Mean ± SEM						Overall damage rank <sup>3</sup>
	20 March			27 March			
	Chlorosis <sup>1</sup>	Reddening <sup>1</sup>	Necrosis (%) <sup>2</sup>	Chlorosis <sup>1</sup>	Reddening <sup>1</sup>	Necrosis (%) <sup>2</sup>	
CP 98-1029	1.9 ± 0.4bcd	1.8 ± 0.2cd	7.8 ± 0.2cd	3.1 ± 0.2ab	2.9 ± 0.3bc	13.1 ± 2.8 cde	8
CP 98-1107	1.8 ± 0.2bcd	2.3 ± 0.2bc	4.8 ± 2.3cd	2.8 ± 0.2abc	3.3 ± 0.1ab	9.3 ± 2.8 de	4
CP 98-1118	2.1 ± 0.2abc	2.3 ± 0.2bc	12.1 ± 4.3a-d	3.2 ± 0.2a	2.8 ± 0.4bcd	21.1 ± 5.0 a-d	10
CP 98-1139	2.0 ± 0.3a-d	1.3 ± 0.3d	9.9 ± 3.2bcd	2.8 ± 0.3abc	1.8 ± 0.4ef	13.0 ± 4.4 cde	6
CP 98-1325	1.9 ± 0.3bcd	2.1 ± 0.2bc	11.9 ± 3.5a-d	2.7 ± 0.2abc	2.4 ± 0.3cde	17.8 ± 4.9 b-e	7
CP 98-1335	1.8 ± 0.2cde	1.8 ± 0.4cd	14.9 ± 4.8abc	2.3 ± 0.2cd	2.2 ± 0.2de	14.6 ± 3.2 cde	5
CP 98-1417	2.0 ± 0.5a-d	2.7 ± 0.3ab	3.1 ± 1.0d	2.4 ± 0.3bcd	2.4 ± 0.2cde	6.9 ± 2.1 e	2
CP 98-1457	2.4 ± 0.2abc	2.1 ± 0.3bc	11.7 ± 3.1a-d	3.0 ± 0.2abc	2.4 ± 0.2cde	22.3 ± 4.2 abc	12
CP 98-1481	1.1 ± 0.2e	1.2 ± 0.2d	5.1 ± 3.2cd	2.3 ± 0.3cd	2.1 ± 0.3de	6.1 ± 2.7 e	1
CP 98-1497	1.7 ± 0.4cde	1.2 ± 0.3d	4.1 ± 2.1d	2.4 ± 0.3bcd	1.9 ± 0.3ef	7.9 ± 2.2 e	3
CP 98-1513	1.8 ± 0.2cd	2.6 ± 0.3ab	21.1 ± 4.1a	2.1 ± 0.3d	3.4 ± 0.2ab	27.2 ± 4.0 ab	13
CP 98-1569	2.7 ± 0.2a	3.1 ± 0.2a	12.6 ± 3.4a-d	2.7 ± 0.3a-d	3.7 ± 0.1a	28.2 ± 6.1 ab	15
CP 98-1725	2.3 ± 0.3abc	1.8 ± 0.2cd	19.8 ± 7.8ab	2.7 ± 0.3a-d	1.3 ± 0.2f	30.4 ± 8.5 a	14
CP 98-2047	1.3 ± 0.2de	3.3 ± 0.3a	21.2 ± 4.1a	0.9 ± 0.2e	3.9 ± 0.1a	30.6 ± 4.9 a	16
CP 80-1827	2.6 ± 0.3ab	2.6 ± 0.3ab	9.9 ± 2.8bcd	2.7 ± 0.2a-d	3.3 ± 0.2ab	13.7 ± 3.5 cde	9
CP 84-1198	2.3 ± 0.2abc	2.1 ± 0.4bc	18.6 ± 4.0ab	2.7 ± 0.2abc	2.5 ± 0.2cde	28.1 ± 4.5 ab	11
<i>F</i> (df = 15, 128)	2.53 <i>p</i> = 0.0026	5.72 <i>p</i> < 0.0001	2.51 <i>p</i> = 0.0028	4.78 <i>p</i> < 0.0001	8.65 <i>p</i> < 0.0001	3.96 <i>p</i> < 0.0001	

Means in the same column followed by different letters are significantly different at *p*=0.05 (LSD).

<sup>1</sup>Ratings from 0 to 4 scale (0.5 increments) with increasing severity 15 and 22 d after aphid exposure.

<sup>2</sup>Sum of percentage leaf necrosis from aphid feeding divided by the number of leaves 15 and 22 d after aphid exposure.

<sup>3</sup>Chlorosis, reddening and necrosis values assigned ranks 1 to 16 from least to greatest damage. Comparing the chlorosis and reddening values for each clone, the higher of the ranks was then added to twice the necrosis rank. The resulting values were ranked again to produce the overall damage rank for each clone.

**Table 3. Damage assessments of CP99 Stage IV clones in 2003 after exposure to yellow sugarcane aphid feeding in a greenhouse.**

Clone	Mean $\pm$ SEM						Overall damage rank <sup>3</sup>
	20 March			27 March			
	Chlorosis <sup>1</sup>	Reddening <sup>1</sup>	Necrosis (%) <sup>2</sup>	Chlorosis <sup>1</sup>	Reddening <sup>1</sup>	Necrosis (%) <sup>2</sup>	
CP 99-1534	2.0 $\pm$ 0.2abc	1.9 $\pm$ 0.3bcd	9.3 $\pm$ 3.7e-h	2.5 $\pm$ 0.3a-d	2.1 $\pm$ 0.3e-h	22.9 $\pm$ 4.8 cde	8
CP 99-1540	2.0 $\pm$ 0.2abc	2.5 $\pm$ 0.3abc	16.5 $\pm$ 2.c-f	2.7 $\pm$ 0.2cde	2.9 $\pm$ 0.3bcd	24.4 $\pm$ 0.3 bcd	14
CP 99-1541	1.9 $\pm$ 0.3abc	1.0 $\pm$ 0.2ef	8.0 $\pm$ 1.3fge	3.0 $\pm$ 0.2ab	1.2 $\pm$ 0.1i	14.3 $\pm$ 1.8 ef	7
CP 99-1542	2.0 $\pm$ 0.3abc	0.9 $\pm$ 0.2f	3.9 $\pm$ 0.9gh	2.8 $\pm$ 0.2abc	1.5 $\pm$ 0.2hi	8.1 $\pm$ 1.6 fg	3
CP 99-1686	2.2 $\pm$ 0.2abc	2.5 $\pm$ 0.2abc	35.9 $\pm$ 4.6a	2.4 $\pm$ 0.3b-e	3.5 $\pm$ 0.3abc	41.5 $\pm$ 4.9 a	16
CP 99-1865	1.8 $\pm$ 0.3abc	2.5 $\pm$ 0.4abc	22.2 $\pm$ 3.0bcd	2.4 $\pm$ 0.3b-e	2.9 $\pm$ 0.2bcd	31.6 $\pm$ 2.1 abc	13
CP 99-1889	1.5 $\pm$ 0.3cd	2.8 $\pm$ 0.3a	23.1 $\pm$ 4.9bc	1.8 $\pm$ 0.3e	3.5 $\pm$ 0.2ab	29.9 $\pm$ 4.2 bc	11
CP 99-1893	2.5 $\pm$ 0.6ab	2.8 $\pm$ 0.3a	12.7 $\pm$ 2.7d-g	2.7 $\pm$ 0.2a-d	3.4 $\pm$ 0.1abc	16.7 $\pm$ 1.9 def	9
CP 99-1894	2.0 $\pm$ 0.6abc	1.0 $\pm$ 0.3ef	5.5 $\pm$ 2.8gh	2.7 $\pm$ 0.2a-d	1.6 $\pm$ 0.3ghi	7.3 $\pm$ 2.8 fg	1
CP 99-1896	0.6 $\pm$ 0.2d	2.5 $\pm$ 0.5abc	1.4 $\pm$ 0.5h	0.5 $\pm$ 0.0f	3.8 $\pm$ 0.1a	3.4 $\pm$ 0.9 g	2
CP 99-1944	1.9 $\pm$ 0.4abc	2.1 $\pm$ 0.3abc	5.0 $\pm$ 1.3gh	2.4 $\pm$ 0.3b-e	2.5 $\pm$ 0.3def	12.8 $\pm$ 3.7 fg	4
CP 99-2084	1.6 $\pm$ 0.2bc	1.7 $\pm$ 0.3cde	18.1 $\pm$ 4.9cde	2.1 $\pm$ 0.3de	1.8 $\pm$ 0.3f-i	23.1 $\pm$ 4.0 cde	5
CP 99-2099	2.6 $\pm$ 0.3a	1.3 $\pm$ 0.3def	28.1 $\pm$ 5.3ab	3.1 $\pm$ 0.2a	2.0 $\pm$ 0.3fgh	29.4 $\pm$ 4.3 bc	12
CP 99-3027	2.1 $\pm$ 0.3abc	2.7 $\pm$ 0.2ab	24.0 $\pm$ 4.0bc	2.3 $\pm$ 0.3b-e	3.4 $\pm$ 0.3abc	33.5 $\pm$ 4.1 ab	15
CP 80-1827	1.6 $\pm$ 0.3abc	2.0 $\pm$ 0.3bcd	5.6 $\pm$ 1.4gh	2.7 $\pm$ 0.2a-d	2.8 $\pm$ 0.3cde	9.0 $\pm$ 2.4 fg	6
CP 84-1198	1.9 $\pm$ 0.3abc	2.0 $\pm$ 0.3bcd	20.3 $\pm$ 4.1bcd	2.5 $\pm$ 0.3a-d	2.3 $\pm$ 0.3d-g	28.5 $\pm$ 4.1 bc	10
<i>F</i> (df = 15, 128)	1.65	5.01	8.73	6.4	11.01	9.82	
	<i>p</i> = 0.0672	<i>p</i> < 0.0001	<i>p</i> < 0.0001	<i>p</i> < 0.0001	<i>p</i> < 0.0001	<i>p</i> < 0.0001	

Means in the same column followed by different letters are significantly different at *p* = 0.05 (LSD).

<sup>1</sup>Ratings from 0 to 4 scale (0.5 increments) with increasing severity 15 and 22 d after aphid exposure.

<sup>2</sup>Sum of percentage leaf necrosis from aphid feeding divided by the number of leaves 15 and 22 d after aphid exposure.

<sup>3</sup>Chlorosis, reddening and necrosis values assigned ranks 1 to 16 from least to greatest damage. Comparing the chlorosis and reddening values for each clone, the higher of the ranks was then added to twice the necrosis rank. The resulting values were ranked again to produce the overall damage rank for each clone.