Assessment of Consensus-Based Scouting for Management of Sugarcane Aphid (Heteroptera: Aphididae) in Georgia[1]

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Abstract The sugarcane aphid, *Melanaphis sacchari* (Zehntner) (Heteroptera: Aphididae), was recently recognized as a pest of grain sorghum, *Sorghum bicolor* (L.) Moench, in the southeastern United States. The objectives of the study reported herein were to evaluate the suitability of using a consensus-based scouting network and determine the timing of insecticide applications for management of sugarcane aphid in grain sorghum. The timing of insecticide applications was (1) application at 25 aphids per leaf, (2) application at 50 aphids per leaf, (3) a delayed application 1 week after occurrence of 50 aphids per leaf, or (4) not treated. Results showed that a single application of flupyradifurone at 15.4 g(AI)/ha consistently reduced populations to nearly zero for the remainder of the season, while aphid populations in the nontreated plots reached a peak of 300–400 aphids per leaf. Aphid populations on the upper leaves reached 50 aphids per leaf in nontreated plots 1 week after reaching the treatment threshold on the lower leaves. All plots receiving insecticide applications had similar estimated yields, which were >5 times greater than yields in nontreated plots. Results from the consensus-based scouting network showed that first detections and reported first commercial applications generally occurred within 1 week (range of 3–11 d) of the actual populations quantified in the research trials. These data suggest that initiating scouting for sugarcane aphid populations following notification of activity in the area through consensus reporting would provide adequate warning for preventing economic losses to sugarcane aphid.

Key Words pest management, insecticide application, scouting, *Melanaphis sacchari*, *Sorghum bicolor*

Sugarcane aphid, *Melanaphis sacchari* (Zehntner) (Heteroptera: Aphididae), is a recently discovered invasive insect pest that feeds on the phloem of grain sorghum, *Sorghum bicolor* (L.) Moench. This crop is commonly used for animal feed or ethanol production in the United States. The top grain sorghum–producing states in 2016 included Kansas, Texas, Colorado, Oklahoma, and South Dakota (USDA 2017a). Area planted to grain sorghum in the United States totaled 2,184,898 ha as of June 2017, and Georgia harvested 4,047 ha in 2016 (USDA 2017b). Populations

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of sugarcane aphid within the southeastern United States have greatly increased in the past 3 yr and have been a cause of significant decreases in yield. This invasive insect pest was a sporadic pest of sugarcane (*Saccharum officinarum* L.) in Louisiana since 1999; in 2013, sugarcane aphid was discovered near Beaumont, TX, on grain sorghum and the infestation eventually spread to Louisiana, Oklahoma, and Mississippi (Brown et al. 2015). In 2014, the pest spread north from Texas into Kansas and east into Georgia and Florida (Catchot et al. 2015). The insect has a high intrinsic rate of population increase. Reproduction in the United States is asexual; all aphids born are pregnant females and give birth to 1–3 nymphs per day (Bowling et al. 2016, Brown et al. 2015). However, sexual forms of the aphid have been reported in Asia and Mexico (David and Sandhu 1976, Peña-Martinez et al. 2016). Developmental time from first instar through the adult molt is only 5 d, and the life span is approximately 28 d. Sugarcane aphids can be dispersed by wind, so there is the potential to move large distances in a short period of time. Although these aphids have been recovered from many other agronomic crops including millet [*Cenchrus americanus* (L.)], corn (*Zea mays* L.), cotton (*Gossypium hirsutum* L.) and soybean [*Glycine max* (L.)], the sugarcane aphid is not an economic pest of these crops (Knutson et al. 2016).

Sugarcane aphid is easy to identify and is closely associated with grain and feed sorghum in the southeastern United States. It is distinguishable from other aphids by a pair of black cornicles, black tarsi, and light-colored head and body, while all other commonly occurring aphids of grain sorghum have clear cornicles and tarsi or a dark-colored body (Villanueva et al. 2014). Colonies are often found along the midrib of the underside of grain sorghum leaves; the bottom of the plant is often colonized first and aphids move upward as host quality deteriorates (Brown et al. 2015, Singh et al. 2004). Sugarcane aphids have piercing–sucking mouthparts and feed in the phloem. Because phloem is a relatively poor protein source, much of the liquid passes though the gut and is excreted as honeydew. The production of large quantities of honeydew creates an optimum environment for sooty mold; the loss of plant sap due to aphid feeding diverts nutrients that would otherwise be used within the plant for sustaining healthy tissues. This loss of nutrition can directly affect plant development, maturity, and grain yield. Heavy honeydew accumulations can clog harvesting machinery, further decreasing yield (Thomas 2017).

Effective management of new invasive pests requires knowledge of pest biology, phenology, and application timing. Recently developed integrated management practices for this pest include use of resistant cultivars, insecticide seed treatments, and foliar-applied insecticides (Bowling et al. 2016). At present, integrated control tactics, including resistant cultivars and insecticides, are required to manage populations for economical production in Georgia. Although effective insecticide options are available, the timing of applications needs to be optimized. Grain sorghum is a relatively low-value crop (generally used for animal feed) and there is little incentive for investing in a commercial field scout. Therefore, the authors were interested in comparing actual populations of sugarcane aphids in research trials with results from a consensus-based scouting network. Consensus scouting is simply qualitative reporting on the general level of insect activity (i.e., low, medium, high) in a specified area.

Objectives of this project were to evaluate the suitability of using a consensus-based scouting network and to determine the timing of insecticide applications for

Table 1. Planting dates, timing of scouting, and harvest dates for insecticide trials in Georgia.

Year	Location	Planting Date	Begin Scouting	End Scouting	Harvest
2016	Plains	13 June	14 July	16 September	—
2017	Attapulgus	1 June	5 July	28 August	5 September
	Plains	15 June	10 July	6 September	18 September

management of sugarcane aphid in grain sorghum. In 2016, insecticide applications coincided with 50 aphids per leaf, delayed 1 week after reaching that threshold, or not treated. In 2017, the treatments were the same except that a fourth application was included when the aphids reached a threshold of 25 aphids per leaf.

Materials and Methods

Consensus scouting. EDDMapS IPM (www.eddmaps.org) is an example of a consensus-based scouting network that utilizes a smartphone app to record real-time data. Because Georgia growers generally do not hire scouts for grain sorghum production, we trained Agriculture and Natural Resource county agents in the University of Georgia (UGA) Extension Service (hereafter called agents) in the spring of each year of the study to report on the presence and relative abundance of sugarcane aphids in their respective counties using a consensus reporting tool called EDDMapS IPM. This tool is produced by the UGA Center for Invasive Species and Ecosystem Health (LaForest et al. 2015a, 2015b). Agents were instructed to log qualitative estimates (i.e., not reported, not present, low levels, economic levels present) of sugarcane aphid activity in their respective counties on a weekly basis during the summer months. Those data were uploaded from a smartphone app to a server and then returned to the smartphone app or on a website as a color-coded map representing the intensity of infestations throughout the region. The information technology components in EDDMapS include smartphone data entry, data logging, data processing on a server, and customized real-time alerts, including the first time that the target pest is reported and the first time that applications are reported in an adjacent county.

Insecticide trials. Grain sorghum was planted and managed using standard agronomic practices as recommended by UGA Cooperative Extension (Bean and Noland 2018). Soil sampling suggested, and the investigators applied, 0.560 metric ton [MT]/ha of 5–10–15 (N–P–K) base fertilizer with a micronutrient package prior to planting. Four replicated plots (6 rows wide by 10.66 m long) per treatment were established at Plains, GA (N 32.0377, W −84.3707), in 2016, and at Plains and Attapulgus, GA (N 30.7627, W −84.4816), in 2017 (Table 1). Regardless of year or location, fluxofenin (Concep III, Syngenta Crop Protection, Greensboro, NC)–treated DKS 53-53 grain sorghum (Bayer CropScience, Rhein, Germany) was planted on 0.91-m centers at a rate of 247,105 seed/ha. All plots received *S*-metolachlor (Dual Magnum, Syngenta Crop Protection) at 1,322 g(AI)/ha behind the planter, followed by atrazine (AAtrex 4L, Syngenta Crop Protection) at 1,681 g(AI)/ha, 1 mo after planting for weed control.

Research trials were scouted weekly for the presence of sugarcane aphid and the general condition of the plants. On each scouting date, 10 lower leaves and 10 upper leaves were randomly examined from each plot, and sugarcane aphid adults and nymphs were enumerated together on each leaf. Condition of plants was characterized visually on a scale of 1 to 9 following the methods of Sharma et al. (2013). Briefly, plants receiving a 1 on the scale showed no symptoms of aphid infestation, whereas plants receiving a 9 were dead. Prior to grain maturity in 2016, heavy populations of blackbirds (*Turdus merula* L.) decimated the plots and confounded yield to the point that no yield estimates were available. In 2017 only, the number of heads per row was enumerated and yield was estimated by collecting 20 random heads per plot at grain maturity. Grain heads were pooled by plot and dried in a laboratory oven at 50°C for 14 d before threshing on a single plant thresher (SVPT Small Vogel Plot Thresher, Almaco, Nevada, ID). Grain yield was then extrapolated to metric ton of grain per hectare and adjusted to a common 10% moisture content.

Treatments related to the timing of insecticide application varied. Previously, Knutson et al. (2016) published an insecticide treatment threshold of 50 sugarcane aphids per leaf. In 2016, we initiated treatment of plots when the mean density of aphids in those representative plots exceeded 50 aphids per leaf ("on-time"). A second set of plots received a "delayed" treatment 1 week later. Finally, a third set of plots did not receive any insecticides. During the second year of our study (2017), an "early" threshold treatment of 25 aphids per leaf was added to the treatment structure. Regardless of year, treatment always consisted of a single application of flupyradifurone (Sivanto Prime, Bayer CropScience) at 15.4 g(AI)/ha. Insecticide applications were made at 138 kPa with a 2-row handheld sprayer unit (model D, R&D Sprayers, Opelousas, LA) equipped with four 8002E sprayer tips (TeeJet Technologies, Spraying Systems Co., Glendale Heights, IL) calibrated to deliver 112 liter/ha.

Treatments at each location were arranged in a randomized complete block design and each treatment was replicated four times. Count data were first subjected to a square root transformation (Zar 1999) to normalize variances before conducting an analysis of variance (ANOVA) using PROC GLIMMIX (SAS Institute 2008). All count data were analyzed separately by trial because aphid infestations occurred at different times at each location. Interactions between the fixed effects, date of sample and treatment, were further analyzed using the SLICE and SLICEDIFF options (SAS Institute 2008) to detect treatment differences within week of sample. Yield data were not transformed prior to analyses. In 2017, yields across locations were combined for analyses by modeling trial location and block as random effects. Representative data were back-transformed and plotted using SigmaPlot 14.0 (Systat Software, Inc., San Jose, CA).

Results

Insecticide trials. In 2016, sugarcane aphid populations began increasing in the plots located at Plains in mid-July but did not reach a season-long maximum density until late August. Sugarcane aphid populations exceeded the treatment threshold of 50 aphids per bottom leaf on 10 August (Fig. 1). Immediate application of flupyradifurone to plants in the on-time treated plots resulted in elimination of the aphid population by the next week. The application that was delayed by 1 week also eliminated aphid populations and they did not rebound. Conversely, aphid populations in the nontreated plots continued to increase over the season and reached nearly 300 aphids per bottom leaf and approximately 250 aphids per top leaf. In general, increased aphid populations on the upper leaves were delayed by approximately 1 week after increased populations on the lower leaves. The season-long maximum aphid populations on upper leaves also were delayed by approximately 1 week compared with lower leaves. Regardless of location on individual plants, insecticide application completely eliminated the aphids.

In addition to aphid counts, visual damage ratings were performed in each plot weekly. Visual damage was not apparent until late July (Fig. 2). The rate of increasing damage decreased following insecticide application, when comparing plots receiving insecticides with those not receiving insecticides. By the end of the summer, plots that received insecticides were rated similarly, whereas the plots that did not receive insecticides received a higher damage rating (Fig. 2).

In 2017, populations of sugarcane aphids started building earlier in the summer and ultimately exceeded the maximum counts observed in 2016. At Attapulgus, the early threshold on lower leaves was exceeded during the second week of July, whereas the on-time threshold was exceeded 1 week later on 19 July. Per the protocol, the delayed treatment was applied 1 week after the on-time threshold was reached; sugarcane aphid populations reached nearly 300 aphids per lower leaf before the delayed treatment was applied (Fig. 3). Populations increased to almost 400 aphids per leaf in the nontreated plots. Similar to the 2016 result, application of flupyradifurone decreased populations to nearly zero by the next sampling interval, regardless of aphid abundance. Populations on the upper leaves were delayed by approximately 1 week compared with populations on the lower leaves. Insecticide applications always provided lasting suppression of aphid populations and any population rebound was minimal.

At Plains in 2017, populations of sugarcane aphids were virtually nonexistent on 17 July, but all plots exceeded the 50 aphids per leaf threshold only 1 week later. Therefore, both the early and the on-time treatments received insecticide applications on the same date (Fig. 4). Following the protocol, the delayed treatments were treated 1 week later on 3 August when mean populations had reached almost 250 aphids per lower leaf. Interestingly, that insecticide application did not completely eliminate aphids in 1 week; however, within 2 weeks the population was less than the treatment threshold. Populations on the nontreated plants reached 400 aphids per leaf on the bottom leaves and $>$200 aphids per leaf on the upper leaves.

Across locations in 2017, visual damage ratings suggested that plants began exhibiting symptoms of aphid infestation and damage in late July. Although there were 2 weeks' difference between the early and delayed threshold treatments at Attapulgus, all plots receiving insecticide applications generally showed similar ratings for the remainder of the year (Fig. 5). Conversely, plots that did not receive insecticides scored appreciably worse on the visual rating scale. Although few aphids were observed on the plants in the weeks following insecticide application, plots continued to receive relatively higher scores as a result of sooty mold colonization on the leaves covered by aphid honeydew.

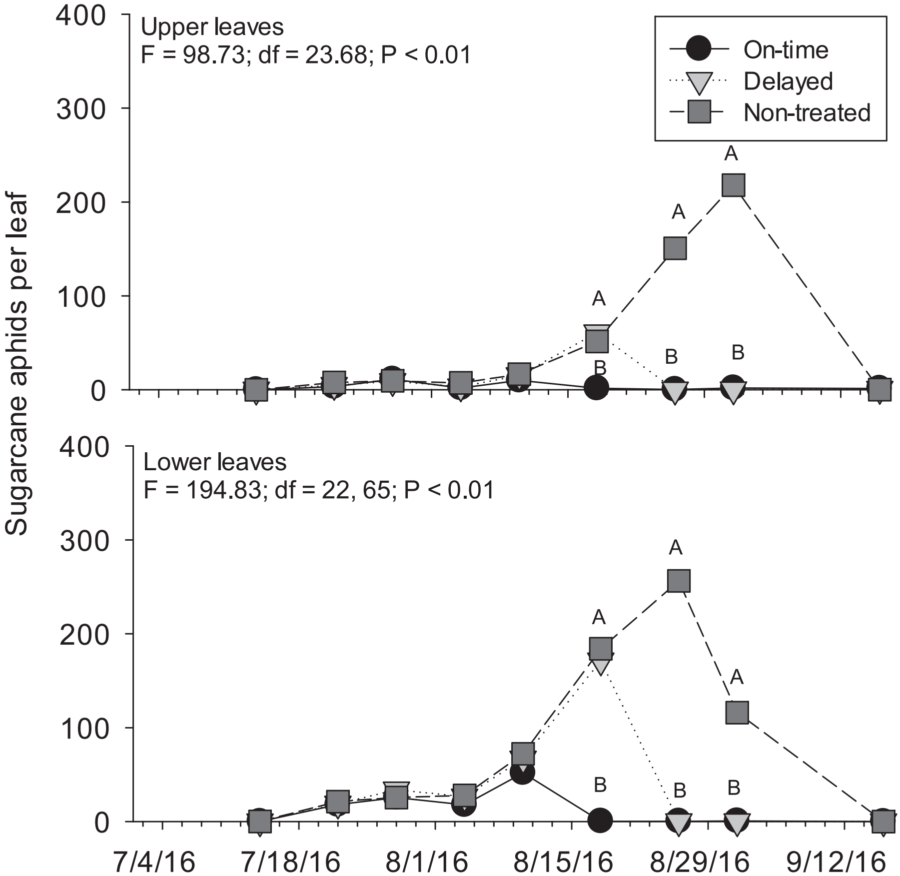

Fig. 1. Mean sugarcane aphid counts per upper leaf (top) or lower leaf (bottom) by treatment at Plains, GA, in 2016. Insecticide treatments were applied to the on-time treated plots on 11 August, and the delayed plots on 20 August. Different letters within weeks indicate the presence of statistically significant treatment differences.

In 2017, there were significant differences among treatments in the number of mature grain heads per hectare ($F = 57.63$; df $=3$, 27; $P < 0.01$). Range of responses was 35,111 ($\pm$ 12,243) in the nontreated to 161,458 ($\pm$ 11,794) heads/ha in the early threshold plots. Similarly, estimated yield, pooled across locations, showed profound differences in treated versus nontreated plots (Fig. 6). However, insecticide application timing had minimal effect on final yield. Yield in treated plots produced between 5.84 and 5.93 MT/ha, whereas the nontreated plots yielded 82% less. Assuming a conservative market price of US$3.00 per 25.4 kg of grain sorghum, the monetary value of the harvested grain in this study ranged from $129 (nontreated) to $700 (early threshold) per hectare. UGA enterprise farm budgets estimate that the 15.4 g(AI)/ha application of flupyradifurone insecticide will cost

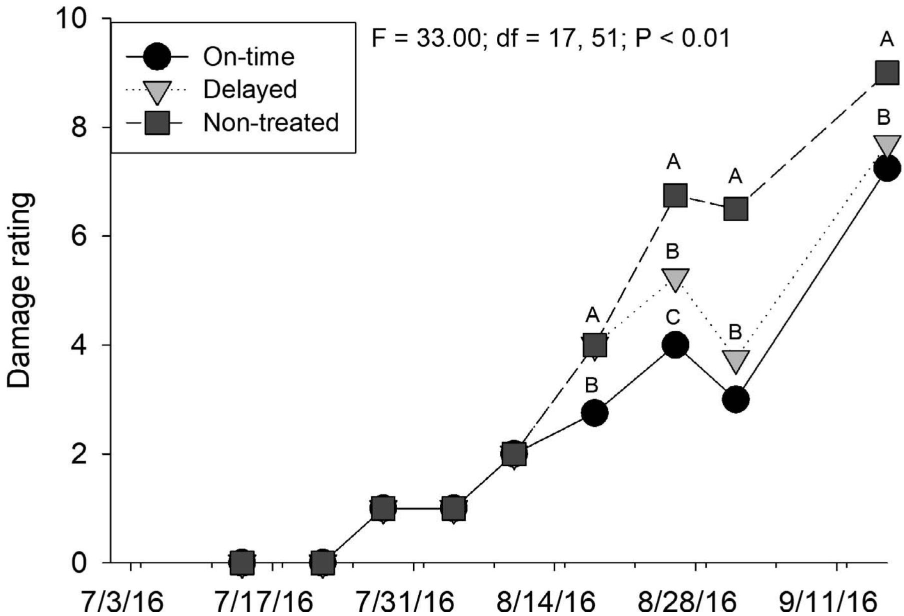

Fig. 2. Mean visual damage rating (1–9) by treatment at Plains, GA, in 2016. Insecticide treatments were applied to the on-time treated plots on 11 August, and the delayed plots on 20 August. Different letters within weeks indicate the presence of statistically significant treatment differences. Different letters within weeks indicate the presence of statistically significant treatment differences.

approximately $22.93/ha for product plus an estimated $5.73/ha (includes both variable and fixed costs) in application expenditures for a total cost of $28.66/ha (Smith and Rabinowitz 2019). Therefore, these data show that a properly timed insecticide application could increase grain value by $571/ha.

Consensus scouting. Fewer than expected observations of sugarcane aphid populations were recorded in the consensus-based scouting network. For example, only four observations near the research trial location were reported in 2016. However, the first reported observation of sugarcane aphid presence from the county where the research trial was conducted occurred 11 d before first detection in the research trials (Table 2). Conversely, aphids reached the treatment threshold in the research trial 7 d before the first report of any commercial insecticide applications in that county. In 2017, there were 16 consensus scouting observations recorded from the scouting network near the Plains location and 8 observations near the Attapulgus location. Date of first observation and first commercial treatment from contiguous counties in the scouting network occurred within 1 week of the actual first observation and first treatment in the research trials at Plains (Table 2). The first observation of sugarcane aphids from the consensus scouting records near Attapulgus was approximately 2 weeks after detection in the research trials; however, the date of first

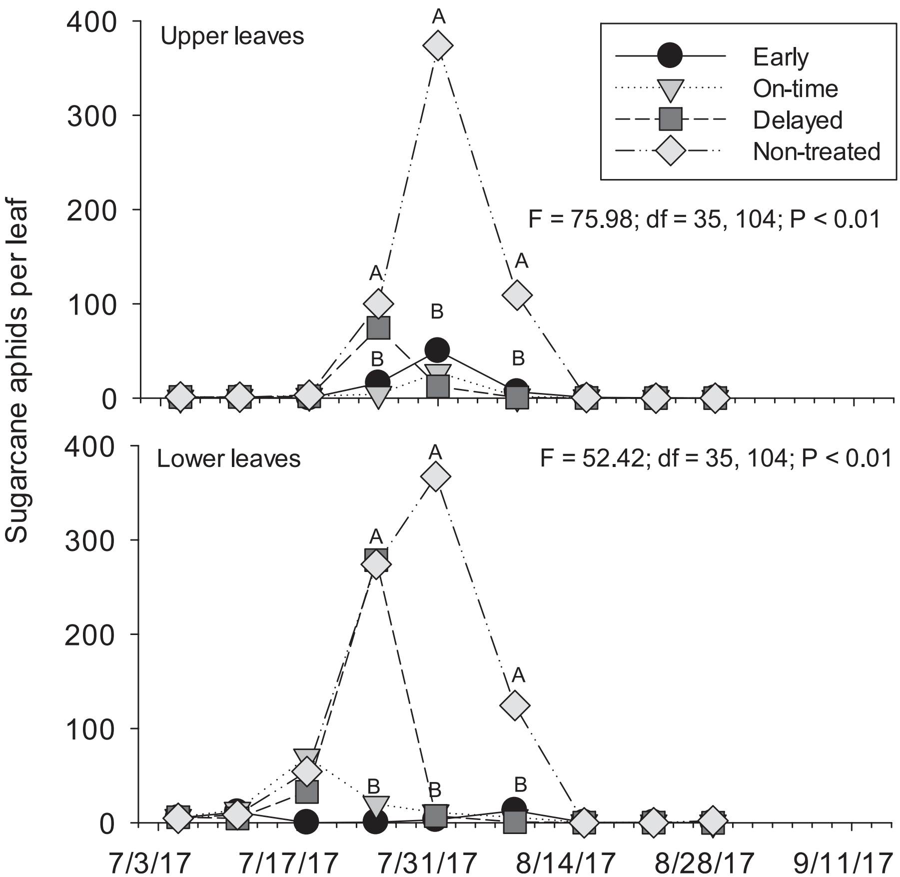

Fig. 3. Mean sugarcane aphid counts per upper leaf (top) or lower leaf (bottom) by treatment at Attapulgus, GA, in 2017. Insecticide treatments were applied to the early plots on 12 July, on-time treatments on 19 July, and the delayed treatments on 26 July. Different letters within weeks indicate the presence of statistically significant treatment differences.

insecticide application from the consensus-based scouting network was only 5 d earlier than the actual on-time application to the research trials.

Discussion

Our results show that sugarcane aphid heavily infested all plots at all trial locations in the study. As previously observed in the Mid-South, sugarcane aphid exhibits a propensity for rapid population increase. In this study, populations generally increased at a rate of 4 times per week. Although the aphids colonized the lower leaves prior to upper leaves on the same plant, the population increases on upper leaves were even

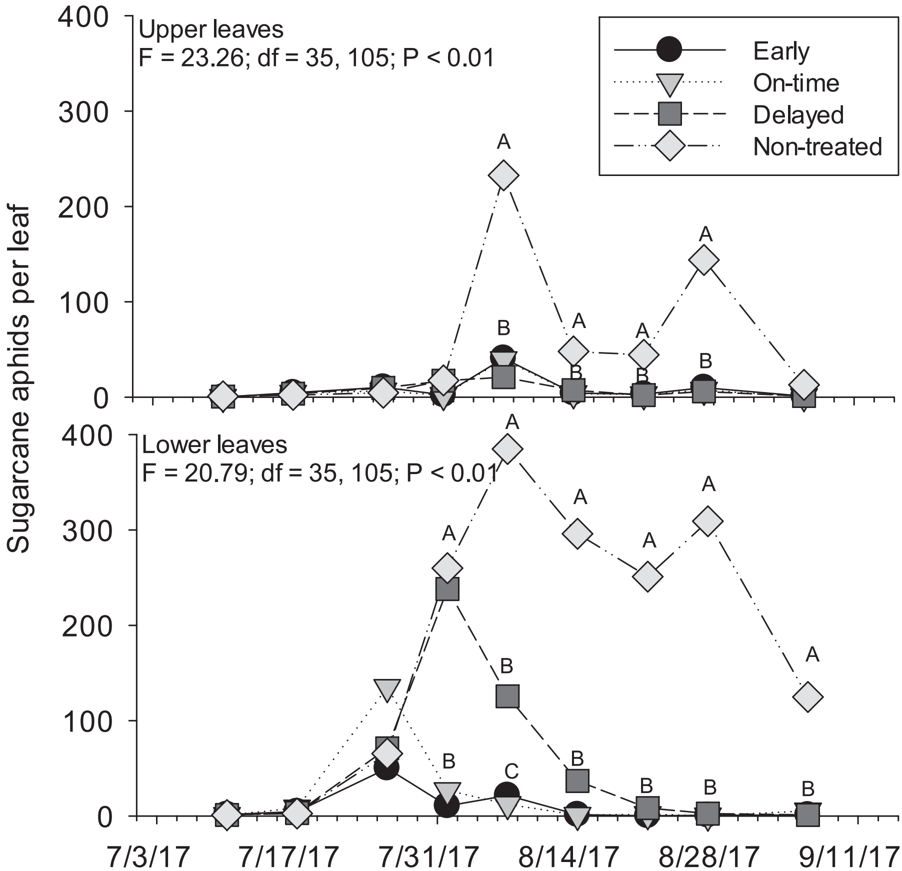

Fig. 4. Mean sugarcane aphid counts per leaf on upper leaves (top) or lower leaves (bottom) by treatment at Plains, GA, in 2017. Insecticide treatments were applied to both the early and on-time treatments on 26 July, and delayed plots on 3 August. Different letters within weeks indicate the presence of statistically significant treatment differences.

more dramatic. At Plains in 2017, populations on the top leaves increased from very low densities to >200 aphids per leaf in only 1 week. Growers must be aware of increasing populations and ready to act to prevent economic damage.

Damage caused by sugarcane aphid is attributed to phloem feeding in the stem and leaves of the plant. In addition to the stress caused by heavy aphid infestations, excess honeydew collects on the leaves below the feeding aphids and creates the ideal habitat for growth of sooty mold (Brown et al. 2015). Sooty mold decreases light interception, further stressing the plant and leading to desiccation (Thomas 2017). A single insecticide application reduced the aphid population to below threshold populations within 1 week, and a single insecticide application generally reduced sugarcane aphid populations for the duration of the growing season. The

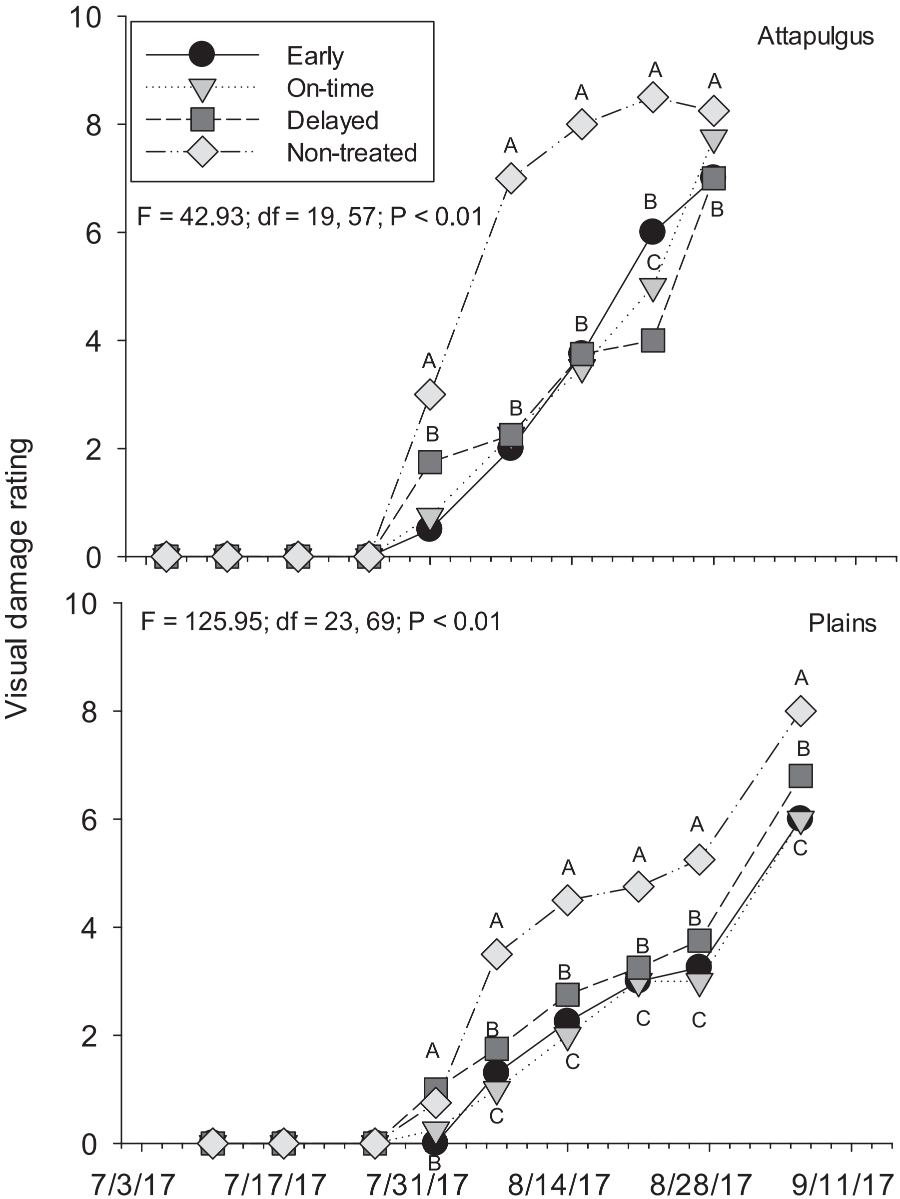

Fig. 5. Mean visual damage rating by treatment at Attapulgus (top) and Plains (bottom), GA, in 2017. At Attapulgus, insecticide treatments were applied to the early plots on 12 July, the on-time treatments on 19 July, and the delayed treatments on 26 July. At Plains, insecticide treatments were applied to both the early and on-time treatments on 26 July, and delayed plots on 3 August. Different letters within weeks indicate the presence of statistically significant treatment differences.

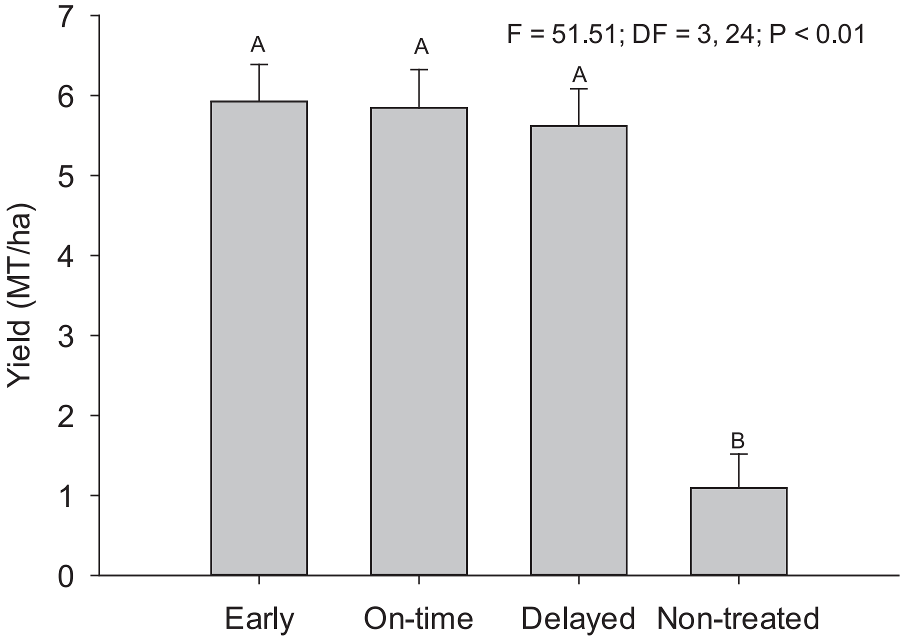

Fig. 6. Mean ± SE grain yield (metric ton [MT]/ha adjusted to a common 10% moisture content) across locations in 2017. Different letters indicate the presence of statistically significant treatment differences.

one exception to this was at Plains in 2017 on the lower leaves, where the initial density was >200 aphids per leaf and the population decreased by >60**%** by 1 week and was below the treatment threshold the following week. No additional applications were required to maintain the populations below threshold, with the population remaining close to zero for the remainder of the year. This was surprising, as the treated plots were randomly juxtaposed with the nontreated plots, which still harbored very large numbers of aphids.

This protocol was also intended to provide guidance as to appropriate treatment thresholds for management of this pest in Georgia. We expected that there would be a yield penalty if the sugarcane aphid populations exceeded 50 aphids per bottom leaf before treatment. However, the three different thresholds occurred within only 1 week of each other and, therefore, there was no separation in yield potential among treatment thresholds. These data suggest that a reasonable way to manage populations is simply to be aware of the date of first observation in that area (detection in a contiguous county) and then initiate sampling weekly until populations rapidly increase.

Limited use of the consensus-based scouting network by agents may have diminished the utility of the approach for this project, but the results suggested that this approach could be useful for this and potentially other insect pests. Barriers to adoption reported by agents included loss of interest, lack of personnel covering grain sorghum production, and lack of time (M.D.T. unpubl.). For example, in 2017,

Table 2. Dates of sugarcane aphid first detection and first time above 50 aphids per bottom leaf in research trials compared with consensus-reported populations in Georgia.

Year	Location	Consensus First Detection	Research Trial First Detection	Consensus First Application	Research Trial Application at 50 Aphids
2016	Plains	11 July	22 July	17 August	10 August
2017	Attapulgus	24 July	5 July	13 August	18 July
	Plains	20 July	17 July	20 July	26 July

there was no agent in the county where the Attapulgus field trial was conducted. Further, statewide area planted to grain sorghum decreased by nearly 60% from 2015 to 2017, due to severe infestations of sugarcane aphid that limited producer economic returns in the previous year. Given that research trials were only scouted weekly, the resolution for comparing between actual counts in the research trials and relative findings from the network should be measured in weeks. There was an agent in the county where the Plains research trial was conducted, and reported first detections and reported first commercial applications generally occurred within 1 week (range of 3–11 d) of the actual populations quantified in the research trials.

Due to the explosive nature of sugarcane aphid population growth, required frequency of scouting for sugarcane aphid is presently under debate. Because grain sorghum does not command a premium price in Georgia, growers are reticent to pay for a commercial scout, and scouting more than one time per week is not feasible. UGA Extension recommends scouting grain sorghum at least once per week. Texas Agrilife Extension recommended twice-weekly scouting if aphids were found on the lower leaves, but those guidelines were developed before flupyradifurone was labeled for this pest (Bowling et al. 2015). These data suggest that insecticide application anytime during a 2-week period will provide economic suppression of sugarcane aphid and resulting yield losses. These data support weekly scouting intervals without jeopardizing yield potential.

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