EXHIBIT C
Cover Sheet

Final Report
for
Texas Grain Sorghum Board (TGSB)

Project Title:	Grant Title: Development of a Decision Aid for Control of the Sugarcane Aphid in Grain Sorghum after the Initial Insecticide Application
Institution or Organization:	Texas A&M AgriLife Extension
Principal Investigator(s):	Pat Porter, Extension Entomologist
Other Investigator(s):	Blayne Reed, Kerry Siders, Tommy Doederlein and Katelyn Kesheimer, Extension Agents IPM
Cooperator(s):	Ed Bynum, Extension Entomologist

List of All Project Expenditures: Total award = $6,468. Total used = $5,128. Total available for refund = $1,340.

Because the sugarcane aphid arrived too late in the field we dedicated to this experiment, we were unable to compare aphid numbers and yield loss on resistant vs. susceptible hybrids. Therefore the cost of producing the crop was not charged to the grant. We incurred approximately $128 in Extension vehicle mileage in travel to collect aphids for artificial infestation in this field (2 attempts), and wish to be reimbursed for this from the $468 mileage allocation to Katelyn Kesheimer and Pat Porter explained below.

All other expenditures on this project were for labor or travel through funds deposited at TPMA. Labor included the use of Blayne Reed's field crew for establishing the first experimental field, hoeing, irrigating and weekly aphid scouting. Once we moved the experiment to the second field, costs were for labor involved with irrigation, insecticide application, harvest and threshing for yield determination. Travel costs were for Blayne Reed and his field scouts to come from Plainview for all field activities. Blayne Reed's total allocation was $4,750.

In addition to the experiment funded at Lubbock by this grant, we rated and harvested two insecticide trials because they could provide supporting data for the work at Lubbock. None of the costs associated with travel to Halfway or Bushland, or costs associated with harvesting and threshing were charged to this grant.

The following figures are estimates of funds we did not use and could turn back.

(1. The original grant request had Kerry Siders doing a replicate of the field experiment on farm in Hockley county. However, we never invoiced this work to the grant because Kerry decided he could not participate.)

2. $1,250 was allocated to Tommy Doederlein in Dawson/Lynn counties for the on-farm part of this research. Tommy was unable to find a suitable field for this part of the experiment, but he did have mileage costs associated with looking for the field. We expect to rebate approximately $1,000, but I need a week to ask Tommy to pull up his mileage records associated with travel for his part of this grant.

3. Katelyn Kesheimer and Pat Porter were awarded $468 to travel to Dawson County for the on-farm part of this research. Since Tommy Doederlein could not find a suitable field, Katelyn and Pat will refund $340 (holding back $128 for the travel associated with artificial infestation attempts at Lubbock).

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Executive Summary

If sugarcane aphid exceeds treatment thresholds and is left uncontrolled, or if the initial control does not work, there will be significant yield loss. In three locations we altered the number of sugarcane aphids in plots and determined yield as related to leaf damage on a 1-10 scale. Sorghum hybrids that were susceptible to sugarcane aphid lost 317 or 409 lbs. of yield for each additional level of leaf damage. When the least damaged plots were compared to the most damaged plots, yield losses of approximately 2,900 or 4,000 lbs. per acre were seen. However, a sorghum hybrid known to be resistant to sugarcane aphid only lost 155 lbs. of yield for each additional level of leaf damage, or approximately 1,230 pounds under the most severe damage. Originally this replicated trial was to be conducted at Lubbock only, but we added additional work to collect data from other locations. Together these locations suggest that yield loss to sugarcane aphid is affected either by the level of irrigation the crop receives or the aphid resistance in the hybrid or both. Our data suggest that insecticide applications should be used to protect the top 50 – 60% of the canopy if severe yield loss is to be avoided, and, due to rapid aphid population increases, we estimate that those applications need to be made no later than when the lower 20% of the canopy has leaf damage.

(At the request of Sorghum Checkoff, we include data on the effects sugarcane aphid damage has on the relative feed value of sorghum stalks but do not address this in the discussion.)

Technical Objectives

1. Determine what percentage canopy damage justifies a second insecticide application to protect remaining yield potential.
2. Quantify yield loss per each additional level of leaf damage using a 1-10 damage scale.

Background

Plots of DKS 44-20 (sugarcane aphid susceptible) and DK 37-07 (thought to be resistant) sorghum were planted on 26 May at the Texas A&M AgriLife Experiment Station in Lubbock, Texas. Individual plots were staked and hoed, alleys were constructed and the field received two furrow irrigations. However, sugarcane aphid was late in arriving in the Lubbock area and, after initiating the insecticide applications to create different levels of infestation in the plots at aphid arrival, the aphids failed to increase in number. We then twice brought in aphid-infested leaves from commercial sorghum fields and artificially infested the plots. These aphids also failed to increase quickly and we were forced to move the trial to a nearby field that was planted relatively late to Pioneer 85Y40 hybrid sorghum. This sorghum is not known to have sugarcane aphid resistance and is assumed to be relatively susceptible. Unfortunately, we no longer had the option to work with both a sugarcane aphid susceptible and sugarcane resistant hybrid as originally proposed. Plots in the new field were 15 feet long x 5 rows wide and were planted on 40-inch centers with furrow irrigation.

This field was made available to us on 30 August, well after aphids had established and were present in high numbers on lower leaves. The plants were completing pollination at this time. We immediately began a sequence of insecticide applications in order to create

different aphid populations in the plots. These applications continued through hard dough. In total there were four insecticide application dates. We attempted to create five levels of infestation by spraying different insecticides at different rates and timings.

Table 1. Insecticide treatments used to create different aphid populations and dates of application.

Treatment	30 August	2 Sept.	8 Sept.	14 Sept.
Sivanto 7.0 oz	Y		Y	Y
Sivanto 2.5 oz		Y	Y	
Transform 0.5 oz		Y	Y	
Unsprayed				
Asana 1.0 oz		Y	Y	Y

The Asana treatment was intended to kill the beneficial insects present and potentially create a higher aphid population than in the untreated plots. Plots were rated for aphid damage on a 1 – 10 scale (10 being all leaves damaged) on September 9th and 28th, and for a final time on October 1st.

Table 2. Plot rating by treatment and replication on 1 October.

Treatment	Rep 1	Rep 2	Rep 3	Rep 4	Trt Avg.
Sivanto 7.0 oz	1.5	1.5	3.0	2.0	2.0
Sivanto 2.5 oz	4.0	1.5	5.0	3.5	3.5
Transform 0.5 oz	3.0	3.5	3.5	3.5	3.4
Unsprayed	8.5	8.0	8.5	9.0	8.5
Asana 1.0 oz	9.0	9.0	8.5	8.0	8.6
Replication Avg.	5.2	4.7	5.7	5.2	

For each plot, two 10-foot sections of row were harvested. Samples were threshed and grain yield, percent moisture and bushel weight were determined. Additionally, four row feet of stalk material per plot at grain harvest was taken to Servi-Tech Laboratories in Amarillo for feed quality analysis. Given the level of variability between plots with the same insecticide regimes, linear regression was used to determine the relationship between leaf damage rating, grain yield and stalk quality. For example, yield and stalk ratings taken from the Sivanto 7.0 oz. treatment in Replication 1 were assigned a 1.5 damage rating for the sake of analysis. Similarly, yield and stalk quality data taken from the Asana treatment in Replication 1 were assigned a damage rating of 9.0.

Additionally, because we had insecticide efficacy trials near Halfway and Bushland that generated plots with different levels of leaf damage, we also correlated leaf damage vs. yield in these experiments.

Results

1. Sugarcane aphid damage affected yield and grain quality. Figure 1A correlates yield as affected by leaf damage, and the regression equation shows that each additional level of leaf damage resulted in an additional 317 lbs. (5.88%) of yield loss. In terms of market value, this equated to a loss of $16.58 per acre for each additional level of leaf damage (based on a value of $5.23/cwt) (Figure 1B). Additionally, sugarcane aphid damage resulted in a 0.3357 lb. (0.54%) reduction bushel weight (Figure 1C) per increment increase in leaf damage rating, and bushel weight was a significant contributor to yield (Figure 1D).

Figure 1. Effects of leaf damage on yield, economic value and grain quality, Lubbock 2016.

Figure 1A. Yield at different damage ratings. (Pr> F <0.0001)

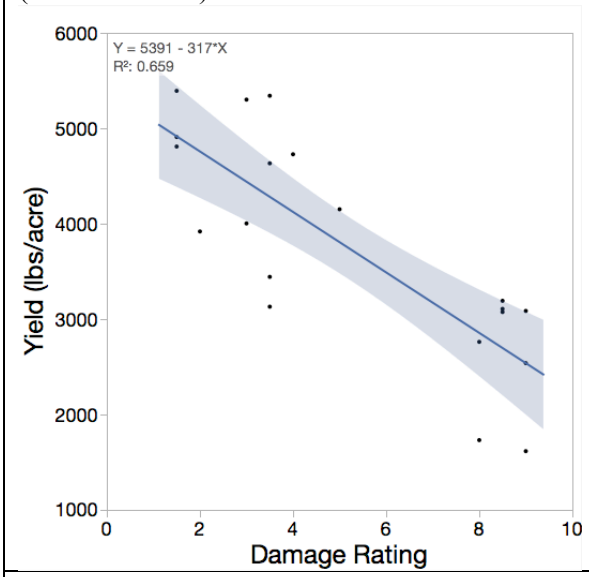


Figure 1B. Dollar value per acre at different damage ratings. (Pr> F <0.0001)

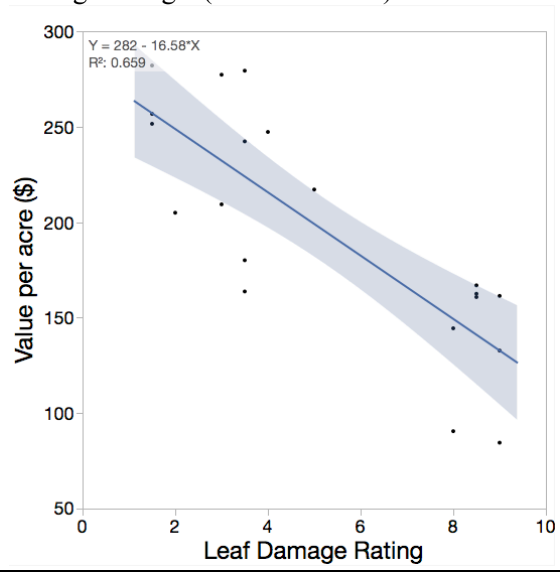


Figure 1C. Relationship between damage rating and bushel weight. (Pr> F < 0.0003)

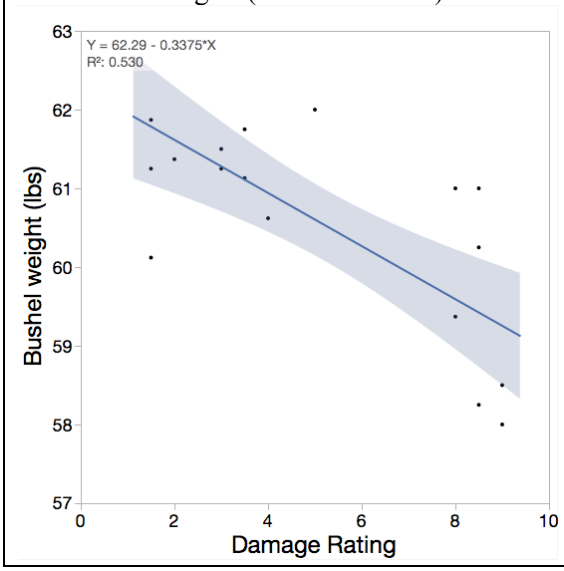
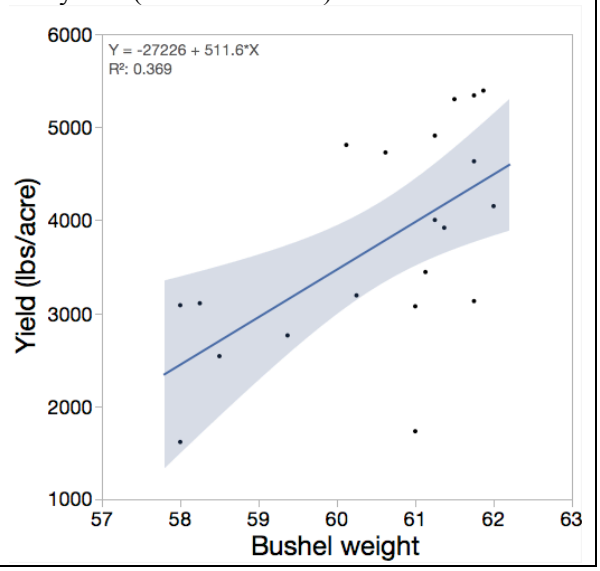


Figure 1D. Relationship between bushel weight and yield. (PR> F <0.0045)



2. Sugarcane aphid damage reduced the nutrient value in stalks (data supplied at the request of Sorghum Checkoff). With each increase in damage level, Crude Protein declined 2.12% and Digestible Energy declined 1.15% (Figure 2A and 2B). Total Digestible Nutrients declined by 1.16% with each increase in damage level, and Acid Detergent Fiber (indigestible fiber) increased by 2.47% per increase in damage level.

Figure 2. Effects of leaf damage on feed value of sorghum stalks.

Figure 2A. Crude protein at different leaf damage ratings. (Pr> F <0.0001)

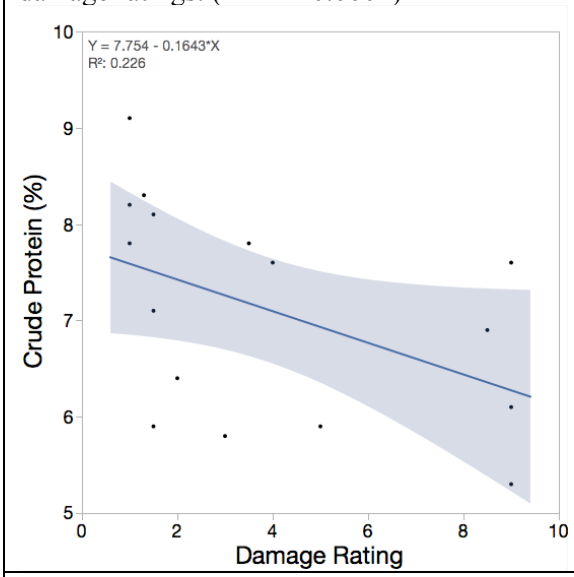


Figure 2B. Digestible energy at different leaf damage ratings. (Pr> F <0.0003)

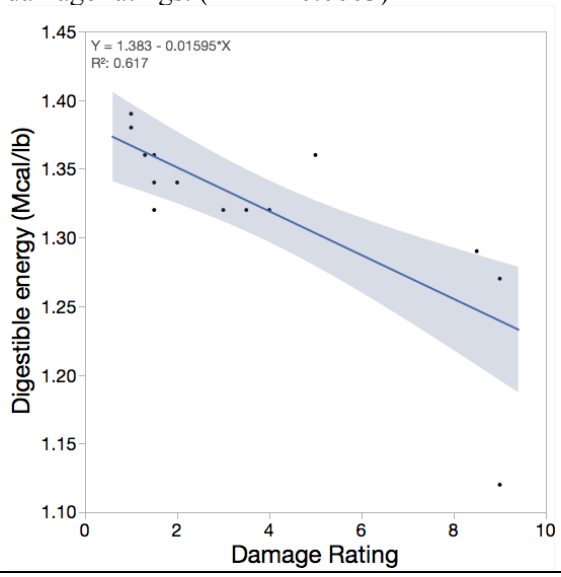


Figure 1C. Relationship between Total Digestible Nutrients and leaf damage rating. (Pr> F < 0.0002)

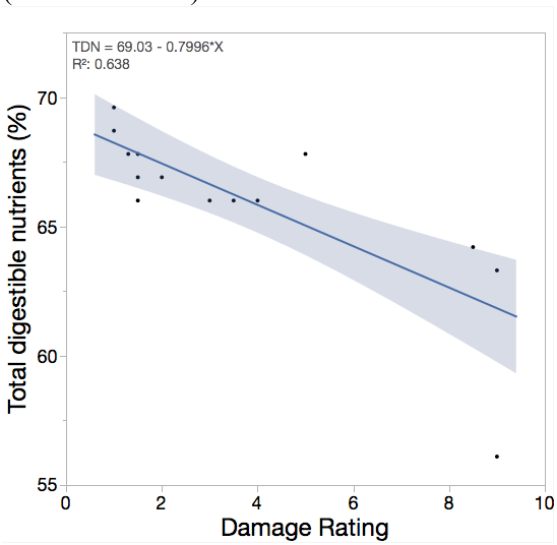
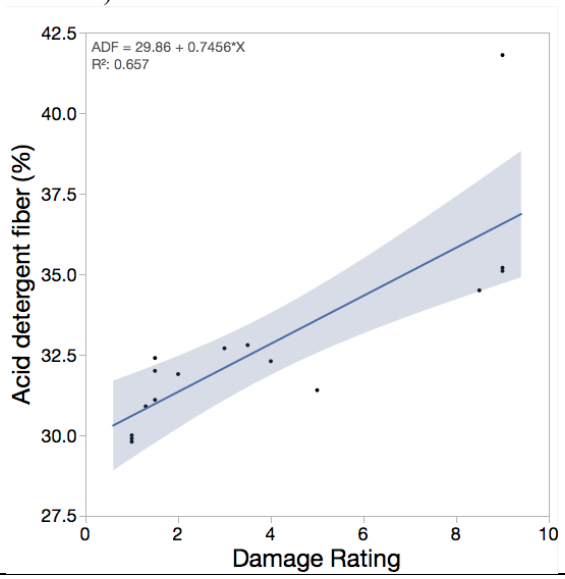


Figure 1D. Relationship between Acid Detergent Fiber and leaf damage rating. (PR> F <0.0001)

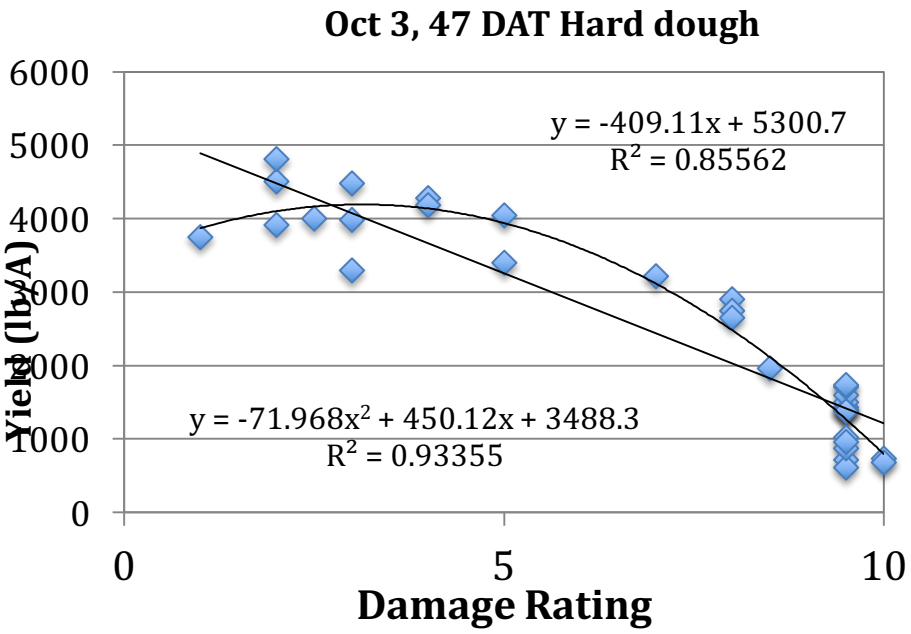


Supporting data from our other trials

In addition to this planned experiment at Lubbock, two insecticide efficacy trials yielded plots with various damage rating levels and we took yield on these plots to augment the conclusions from the Lubbock trial.

Dr. Ed Bynum's insecticide efficacy trial was conducted at Bushland on Dekalb DK44-20 sorghum that received pre-plant irrigation and was rain-fed thereafter. This hybrid is known to be susceptible to sugarcane aphid and infestations exceeded the economic threshold at flowering.

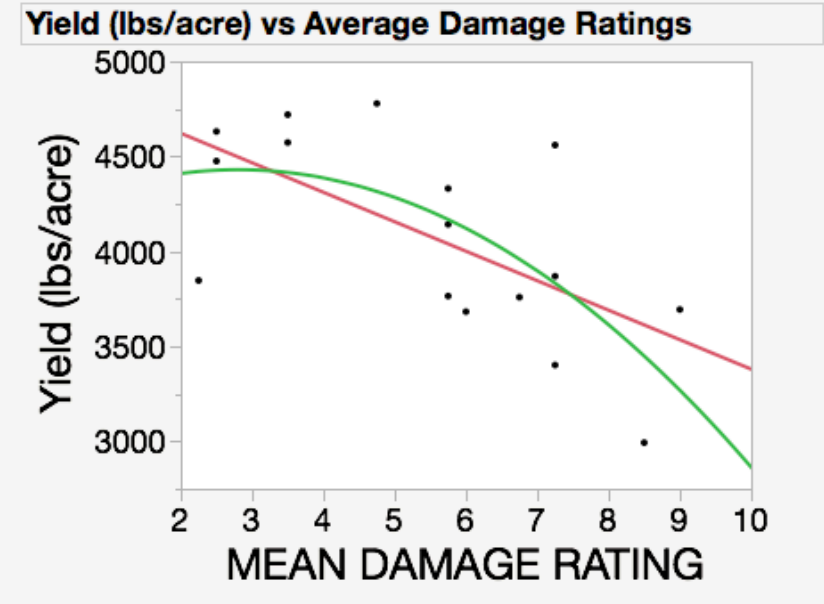
Figure 3. Yield vs. damage rating at harvest of DK44-20 sorghum grown under rain-fed conditions at Bushland, Texas 2016.



The yield loss at Bushland was 409 lbs. per additional level of leaf damage, or approximately 4,000 lbs. difference between undamaged plants and those with a leaf damage rating of 10.

Blayne Reed's insecticide efficacy trial at the Helms Farm near Halfway was conducted on DK 37-07 sorghum which is known to be resistant to sugarcane aphid to some extent. This sorghum was grown under drip irrigation and was well watered the entire season. Infestations exceeded the economic threshold at flowering.

Figure 4. Yield vs. damage rating at harvest of DK 37-07 sorghum grown under drip irrigation near Halfway, Texas 2016.



In this case, yield loss per additional level of leaf damage was only 155 lbs, which was approximately half of the yield loss observed for susceptible sorghum grown with less water at the other two locations.

From these combined data we cannot separate the effect of good irrigation and/or sugarcane aphid resistance on reduced yield loss from leaf damage, but there does appear to be some effect of either less drought stress or aphid resistance or both. (This is why our proposed research in 2017 is to address the irrigation effect on yield loss.)

Table 3. Summary information from the three yield loss vs. leaf damage rating experiments.

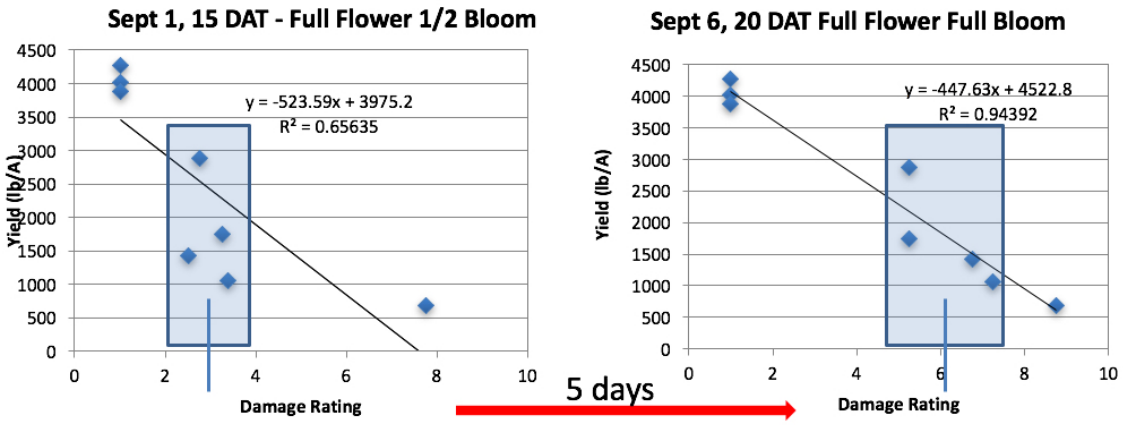
Location	Hybrid	Irrigation	Yield loss/additional level of leaf damage (lbs.) ($*)	Yield loss at highest level of damage (approximate)
Lubbock	Pioneer 85Y40 susceptible	Limited row water	317 ($16.16)	2,900
Bushland	DK 44-20 susceptible	Pre-watered then rain-fed	409 ($20.85)	4000
Halfway	DK 37-07 resistant	Abundant drip irrigation	155 ($7.90)	1,230

*Dollar values are at $5.10 per cwt.

Initial insecticide applications should be made when sugarcane aphid reaches the economic threshold, and in most cases a single application at a high rate of insecticide with good coverage will provide two or more weeks of control. It is also the case that beneficial insects will often prevent the need for a second application, provided the first application was effective. However, there are cases where either the first application was not effective or could not be made, and our data suggest there will be major yield losses if the aphids are not controlled.

Repeated insecticide applications are unreasonably expensive. Our data suggest that sorghum can lose the bottom 40 – 50% of the canopy before a second insecticide application is economically justified. However, if the top half of the canopy is to be protected, we estimate that insecticide applications must be applied when the field reaches a leaf damage rating of approximately 2 (the lower 20% of the canopy damaged). The Bushland insecticide efficacy trial tracked leaf damage ratings over time, and clearly showed that plots with an average leaf damage rating of 3 on September 1 had reached an average leaf damage rating of 6 just five days later (Figure 5).

Figure 5. Progression of leaf damage in plots at Bushland, 2016.



Conclusions

If left uncontrolled, or if the initial control attempt fails, sugarcane aphid has the potential to severely decrease yield. Our data suggest that follow-up insecticide applications should be timed to protect the upper 50-60% of the canopy. Given the rate of increase in sugarcane aphid populations, we estimate that the additional insecticide application should be made no later than when the lower 20% of the canopy has leaf damage and active, expanding aphid populations.

Impact

Economic Impact

•**Industry:** Our results suggest that resistant/tolerant hybrids may lose less yield per unit leaf damage than susceptible hybrids, but we encountered this possibility by chance and it was not part of the planned experiment. Perhaps irrigation can also be used to reduce yield losses, but this was also not a planned component of our experiment.

•**Producer:** Our results clearly show that grain sorghum that exceeds the first insecticide application threshold at flowering must be protected. If sugarcane aphid numbers go unchecked through ineffective control then yield losses will be severe. Our data show that the crop can still yield reasonably well under moderate damage, but it is essential to protect the top 50 – 60% of the canopy.

Economic Feasibility: The cost of not not making a insecticide application when necessary will be very high and depends in part on hybrid and irrigation.

Return on Investment:

Next Steps

We submitted a proposal for 2017 to examine the relationship between irrigation status, leaf damage and yield. Or proposal intended to use a sugarcane aphid susceptible hybrid but, give our findings from this year, we should probably use both a resistant and susceptible hybrid.

Appendices

List of Abbreviations