Texas Grain Sorghum Board Final 2019 Report

Title: Sugarcane Aphid Damage to Forage Sorghum Silage Yield and Quality induced by different Infestation Levels for the Texas High Plains

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Summary

Forage sorghums grown across the High Plains for silage can be infested by the sugarcane aphid (*Melanaphis sacchari* Zehntner; Hemiptera: Aphididae). Management recommendations have been previously established for infestation of the sugarcane aphid (SCA) in grain sorghum but not forage sorghum. Therefore, a field study was conducted in 2017 and 2019 at the Texas A&M AgriLife Research facilities at Bushland, TX to evaluate the damage potential of the SCA to yield and quality of forage sorghum as fresh forage (0 days ensiled) and as silage (60 days ensiled). A commonly grown commercial forage sorghum silage hybrid with known SCA susceptibility (Pioneer 841F) was utilized for this trial. Untreated control treatments and different insecticide treatments were used to create different levels of SCA infestation and damage. In 2017, SCAs began to infest sorghum plots during the flowering stage and populations continued building to harvest at the soft dough growth stage. At the beginning milk stage, a strong linear relationship ($R^2 = 0.81$) between SCA damage and yield loss occurred. Every unit increase in damage, based on a 1 to 10 rating scale, demonstrated a 2.28 ton/A loss in yield when ratings ranged from 1 to 8. In 2019, initial SCA infestations began at the late whorl growth stage and populations increased exponentially until peaking at the early milk stage before suddenly crashing. There was little change in damage levels from the beginning milk stage to the soft dough stage when plots were harvested. Therefore, the linear relationships between damage and yield loss from the beginning milk stage ($R^2 = 0.42$) to soft dough ($R^2 = 0.48$) were very similar with 0.84 to 0.80 ton/A loss in yield for each increase in damage rating, respectively. Although yield reductions were lower in 2019, there were significant losses in economic return in both years when SCA damage levels were ≥ 5 during the early milk developmental stage. Reductions in quality with increased SCA damage mirror reductions in yield. Forage quality parameters were negatively impacted by increased SCA damage. Evaluation of forage quality data for both ensiling periods indicates that ensiling does not improve forage quality; however, silage stability as determined by silage pH was not negatively impacted by SCA damage. Consequently, to optimize silage quality, the quality of the fresh forage must be preserved through timely control of SCAs. Understanding the relationship between SCA damage and forage quality will help producers minimize reductions in forage yield and silage quality. Results also indicate that current action thresholds used for forage sorghum on the High Plains, which are based on grain sorghum growth stages, should be modified according to forage sorghum data.

Revised Action Thresholds for Forage Sorghum

Growth stage	Action threshold
Preboot	20% of plants infested with 50 or more aphids
Boot	20% of plants infested with 50 or more aphids
Flowering–milk	30% of plants infested with 50 or more aphids
Soft dough	Heavy honeydew and established aphid colonies. Treat only to prevent harvest problems. Observe preharvest intervals for insecticides.

Introduction

Dairy and feedlot beef cattle operations across the Texas High Plains and into Kansas have a high demand for large quantities of quality of silage. Historically, corn has been the predominant silage crop, but due to declining well capacities and pumping restrictions, there are increased opportunities for forage sorghum to take a greater share of the silage acres. Unfortunately, the sugarcane aphid (SCA) has become a severe pest of forage and grain sorghums since 2014. Previous research studies have primarily concentrated efforts on understanding the damage potential of SCAs and how to manage them on grain sorghum. However, SCA infestations in forage sorghum have been extremely heavy causing problems when cutting, but research data evaluating the damage to yield and quality of the ensiled forage from SCA infestations is nonexistent. Consequently, researchers often apply relationships between SCA damage and yield reductions in grain sorghum to forage sorghum. However, with forage sorghum, it is important to consider the impact SCAs have on forage tonnage as well as the forage quality at harvest and after ensiling.

We expect SCA damage to adversely impact forage tonnage, but it is unknown if the silage quality will be affected. A study on the impact of spider mite damage to corn grown for silage showed that as spider mite infestations increase, plant damage also increases resulting in declining biomass yields, but the spider mite infestation levels did not detrimentally affect the nutritional quality of the corn for silage (Bynum et al. 2015). Research addressing these questions and concerns about SCA damage to forage sorghums will end the speculations that currently exists. Our **primary goal** is to understand the relationship between SCA infestation levels and the damage potential for forage yield loss and silage quality. The **objective** was to create different levels of SCA infestations and correlate the subsequent level of damage to forage sorghum yields and silage quality.

Relevance to Sorghum Producers

Knowledge of the impact SCA feeding damage to forage yields and silage quality will provide growers and end-users needed information for better management options for SCAs. Understanding the potential for SCA damage to forage sorghum should mitigate unsubstantiated concerns for using forage sorghums for silage.

Methods and Materials

Trials were conducted at the Texas A&M AgriLife Research and Extension Bush Farm, Bushland, TX in 2017 and 2019. The trial was planted in 2018 but on August 1, the field was severely damaged from a hailstorm. Leaves were stripped to the mid-rib and prevented our ability to count SCA or to evaluate damage. Each year the trial area was planted to Pioneer 841F forage sorghum hybrid at a planting rate of 60,000 seeds per acre. Pioneer 841F was used because it was a popular hybrid known to be susceptible to SCAs. Prior to sugarcane aphid infestations field plots (six, 30 in. rows by 40 ft. long) were arranged in a randomized complete block design with 4 replications, and the center four rows of the six-row plot was sprayed. Since the objective of this trial was to evaluate the damage potential of SCA infestations, insecticides with different levels of efficacy against sugarcane aphids and untreated checks were used to create different sugarcane aphid infestations (Table 1).

Four insecticides representing different chemistries were used in 2017; Warrior II with Zeon technology (lambda-cyhalothrin), Lorsban Advance (chlorpyrifos), Intruder (acetamiprid), and

Sivanto Prime (flupyradifurone). Warrior II, a pyrethroid insecticide, does not control SCAs, but does kill beneficial insects and is known to flare aphid infestations. Previous insecticide trials with Lorsban Advanced, an organophosphate insecticide, have been shown to provide short residual activity and approximately 50% control of the SCA. Intruder, a neonicotinoid, is a broad-spectrum insecticide that provides short residual activity against SCAs as well as killing beneficial insects which allows surviving SCAs to build up to damaging infestations. Sivanto Prime was used at different application rates to provide plots with little to no damage from SCAs. In 2019, Warrior II with Zeon technology (lambda-cyhalothrin), Malathion (malathion), and Sivanto Prime (flupyradifurone) were used. Malathion, an organophosphate insecticide, was used rather than Lorsban and Intruder. Malathion is a broad-spectrum insecticide that only provides control of SCA for 5 days and kills beneficial insects, which will cause SCAs to flare.

Table 1. Insecticides and rates

Insecticide	Active	2017 Rate	2019 Rate
		(fl. oz/ac)	
Warrior II Zeon Technology	lambda-cyhalothrin	1.92	1.92
Lorsban Advance	chlorpyrifos	16.0	-----
Intruder	acetamiprid	1.0	-----
Sivanto Prime	flupyradifurone	5.0, 7.0, and 10.0	2.5 and 10.0
Malathion	malathion	-----	48.0

All insecticide applications were sprayed using a 5 nozzle, CO_2 hand carried boom with XR8002 VS nozzles calibrated at 3 mph and 42 psi to deliver 11.26 gpa and mixed with 0.25% v/v NIS. Plots were closely monitored for natural infestations, and plots with different infestation levels were assigned to specific insecticide treatments prior to insecticide application to ensure randomization across natural levels. SCAs were monitored weekly until plots were harvested at the soft dough stage. SCA counts were conducted by sampling two leaves per plant from 5 randomly selected plants per plot within the center two rows of a plot. The upper leaf was the 1st leaf below the flag leaf and the lower leaf was the 6th or 7th leaf below the flag leaf until SCAs damaged the lower leaves. When this occurred, the lower leaf became the leaf that had at least 70% green leaf material. Plots were rated for SCA infestation/damage using the Texas A&M AgriLife High Plains rating scale at each of the SCA count dates and at harvest (Table 2). Plots were rated for damage and lodging.

Plots were hand harvested at soft dough. Yield was determined from a 25 ft^2 area (1 row by 10 ft) within the center of each plot. Plant height was determined at harvest. Samples were chopped with a Cub Cadet CS3310 chipper shredder resulting in a forage chop length of 0.8 ± 0.2-in. and a sub-sample was collected for dry weight. Three 600 g samples of chopped forage were collected to simulate ensiling periods of 0, 30, and 60 days after harvest. Each 600 g sample was vacuum sealed in polyethylene bags (FoodSaver, series v4840, Sunbeam Products, Inc., Boca

Raton, FL) and held in a sealed mini-silo throughout the designated ensiling period. Silage pH was evaluated post-ensiling to ensure silage preservation and quality. Ensiled forage was shipped to Dairyland Laboratories, Arcadia, WI for forage analysis using near infrared reflectance spectroscopy (NIR) for all samples. Forage constituents are reported on a dry matter (DM) basis (Table 3).

Table 2. Texas A&M AgriLife High Plains Sugarcane Aphid/Damage Rating Scale

0: no aphids or honey dew found
1: ≤10% of leaf area infested or damaged, colonies establishing on lower leaves or some honey dew visible on 2 or less leaves
2: 11-20% of leaf area infested or damaged
3: 21-30% of leaf area infested, damaged or dead
4: 31-40% of leaf area infested, damaged or dead
5: 41-50% of leaf area infested, damaged or dead
6: 51-60% of leaf area infested, damaged or dead
7: 61-70% of leaf area infested, damaged or dead
8: 71-80% of leaf area infested, damaged or dead
9: 81-90% of leaf area infested, damaged or dead
10: 91% of leaf area damaged to dead

Table 3. Forage Analyses definitions

CP:	Crude Protein
ADF:	Acid Detergent Fiber; a fraction of the cell wall includes cellulose and lignin, which is inversely related to energy availability.
Lignin:	An indigestible fiber that has no energy value and restricts digestibility of other fiber components.
Starch:	A source of energy in silage and is a function of the proportion of grain in the silage. Digestibility can decrease as grain becomes hard and dryer.
aNDF:	Neutral Detergent Fiber; cell wall fraction of the forage.
IVTDMD:	In Vitro Dry Matter Digestibility; estimate of forage disappearance in the digestive tract.
NDFD:	NDF digestibility; estimated fiber digestibility after the specified length of time (48 hrs.).
uNDFom:	Undigested NDF after fermentation for the specified length of time (240 hrs.) expressed on an organic matter basis (om) in order to account for the ash.
TDN:	Total Digestible Nutrients (by Weiss equation) an index of energy concentration.
Milk/ton:	An index based on several variables that influence intake and nutritive value including ADF and NDF. These are applied to a standard dairy cow to project milk produced per ton of forage (pounds of milk per ton of forage/silage),
RFQ:	Relative Forage Quality - an index for comparing forages, not just alfalfa. RFQ is based on the same scoring system as RFV with an average score of 100; higher scores indicate better feeding value.
pH:	A measure of silage acidity, high or low levels can affect fermentation.

2017 Field Plots

The field was a Pantex silty clay loam soil with a pH 7.8. It was previously planted to wheat in 2016. One week prior to planting, the field was sprayed with Brawl II ATZ®, a mixture of atrazine and s-metolachlor, for weed control. The field was fertilized with 178 lb N/A, 62 lb P_2O_5/A, and 28 lb S/A. On June 9, 2017 Pioneer 841F forage sorghum hybrid was planted at 60,000 seeds per acre on 30-inch rows. The test area was spot sprayed with Facet L at 32 fl oz/A using a SOLO backpack sprayer for bind weed control on June 30 and July 13. The field was furrow irrigated on June 13, July 18, and September 12 with approximately 5 to 6 acre-inches of water. In season precipitation totaled 19.51 inches between May 1 to Sept. 20. On July 2, the field was lightly damaged by hail, but plants grew out of the damage before SCAs began to infest the field.

Plots were inspected on July 21 and July 26, but SCAs were not found. However, SCAs had been found in a producer's forage sorghum trial that was approximately 1 mile east of the forage sorghum field trial. Since SCAs were close, a decision was made to initiate treatments. On July 28, the 10 fl oz/A treatment of Sivanto Prime was sprayed to prevent establishment of SCAs. Sorghum was in a vegetative stage and 4 ft. tall to the whorl. Weather conditions at application were 87.5° F, 45% RH, with a 3.1 mph wind from the SSW. Initial infestation of alate SCAs were not found until August 4, but infestations were sporadic across plants. On August 16 at the boot and head exertion growth stages, plots were counted for SCA numbers, but infestations were mostly alate females with 1st instar nymphs with no visible damage. On August 24, counts showed that 100% of the plants were infested with SCAs beginning to colonize the lower sampled leaf. The plant growth stage was at 50% bloom. The other insecticide treatments were sprayed August 26. Weather conditions at application were 77.5° F, 75% RH, with a 3.6 mph wind from the SSW. Plots were sampled on September 1, 8, and 15 for SCA densities and damage. On Sept. 20, plots were rated for SCA damage, hand harvested for yield and processed for ensiling comparisons.

2019 Field Plots

The 2019 field was a Pantex silty clay loam soil with a pH 7.8. It was previously planted to corn in 2018. The field was shredded then disk tilled to uniformly incorporate corn stalk residue. A preplant application of Cinch (s-metolachlor) at 1.5 pt/ac and Buccaneer (glyphosate) at 1 qt/ac was sprayed on April 28, 2019. The field was fertilized with 160 lb N/A and 80 lb P_2O_5/A preplant according to soil test results on April 12, 2019. On June 11, 2019, Pioneer 841F forage sorghum hybrid was planted at 60,000 seeds per acre on 30-inch rows. In-season precipitation was 6.17 inches from planting (June 11) to harvest (Sept. 16), and cumulative in-season irrigation was 24.4 inches and applied via drip irrigation on 30-inch spacings from June 24 to August 6, 2019. The test area was spot sprayed with Facet L at 32 fl oz/A using a SOLO backpack sprayer for bind weed control on July 10 and August 2, 2019.

In 2019, two untreated control treatments (UTC1 and UTC 2) were utilized due variability of natural aphid infestations and subsequent damage. On July 9 and July 16, plots were inspected but SCAs were not found. On July 17, the treatment for Sivanto Prime at 10 fl oz/A was sprayed when sorghum was in a vegetative stage and plants were approximately 4 ft. tall to the whorl. Weather conditions at application were 77.5° F, 63% RH, with a 7.6 mph wind from the SSW. The boom treated the center four rows of the six-row plot. Initial infestations of SCA were not found until August 13 at which time there were mostly alate aphids and 1st instar nymphs on 100% of the plants, but no visible feeding damage. On August 20, to assist in creating different infestation levels, treatments were assigned within each replicated block to specific treatments. Plots with the highest number of SCAs in each block were assigned to the Warrior treatment. Plots with the next highest number of SCAs were assigned to the UTC1 treatment, and plots with the lowest number of SCAs were assigned to the UTC 2 treatment. On August 21, the other insecticide treatments were sprayed. At application, the climatic conditions were x 79°F, 51% RH, with a 3 to 4 mph wind from the SSW. All plots were sampled on August 20, August 27, Sept. 3, and Sept. 10 for SCA densities and damage. On Sept. 16, plots were rated for SCA damage, hand harvested, and processed for yield and nutritional comparisons.

Data Analysis

SCA weekly counts and damage ratings among treatments were analyzed with JMP version 12 using a one-way randomized block design. Depending on the probability of significance mean separations were conducted using a student's t test or Tukey-Kramer test at P>0.05. Treatment effects on silage yield and quality measurements were analyzed using the general linear procedure (SAS, 2019). Confidence intervals and adjusted least significant differences for multiple comparisons were determined using Tukey's HSD.

Results and Discussion

2017 Sugarcane Aphid Infestations and Damage

In 2017, SCA populations were started building by August 24 (Table 4). In 2017, SCA numbers were statistically different for Warrior treatment compared to the other treatments on August 24. The Sivanto application at 10 fl oz/A on July 28 provided effective control of SCAs up to harvest. Also, both applications of Sivanto at 5 fl oz/A and 7 fl oz/A on August 26 provided effective control of SCA populations. The Sivanto treatments prevented SCAs from surviving and developing colonies on both the upper and lower leaves. By Sept. 15, the early application of Sivanto at 10 fl oz/A was starting to have a few aphid colonies with all life stages. All the Sivanto treatments equally prevented SCA densities from causing significant damage to the forage sorghum (Table 5). Following the insecticide applications on August 24 SCA densities in the Warrior treatment were statistically similar to the SCA densities in the untreated plots. SCA infestations in the Untreated and Warrior treatments increased rapidly from the 50% bloom stage to the soft dough stage. These infestations began earlier and resulted in more severe levels of damage throughout the head developmental stages than in the Intruder and Lorsban Advanced treatments (Table 5).

The single application of Intruder and Lorsban Advanced caused an initial reduction of SCA for one week. This delayed comparably SCA development and damage in both treatments throughout the head development period. Although SCA densities in the Intruder and Lorsban Advanced treatments were statistically similar to the Sivanto treatments during the beginning milk and milk growth stage, damage levels were increasing and becoming statistically different through milk to the soft dough stages. As intended, the insecticide treatments and the untreated check created different levels of damage among the test plots over time that affected forage yields (Table 6 and Fig. 1).

The heavy infestation and damage from SCAs in the untreated and the Warrior treatment were the only treatments that had a significant reduction in yield and percentage of plants lodged when compared among all treatments (Table 6). As observed in grain sorghum, honey dew built and sooty mold built under heavy SCA levels reducing plant photosynthetic activity and caused lodging. Although there was observable damage between treatments, damage did not affect moisture at harvest as reflected by % dry matter. There were no statistical differences in yield and lodging within the three Sivanto treatments as a result of low infestation and damage levels. Although SCA infestations and damage levels were significantly higher in the Intruder and Lorsban treatments during the milk and soft dough growth stages, these infestations and damage levels may not have occurred long enough to effect yield prior to harvesting on Sept. 20. SCA infestations did not significantly affect plant height likely because of the late infestation (p=0.4508).

Table 4. Average number of sugarcane aphids per leaf - 2017.

	Boot	50% Bloom	Beginning Milk	Milk	Soft Dough
Treatment and Rate/A	Aug 16	Aug 24	Sept 1	Sept 8	Sept 15
Intruder 1.0 oz	3.4 a	28.9 b	45.5 b	179.3 b	548.4 b
Lorsban Advanced 16 fl oz	3.5 a	51.5 b	9.1 b	214.4 b	481.2 b
Sivanto 10 fl oz	0.1 a	10.3 b	2.2 b	17.9 b	21.2 c
Sivanto 5 fl oz	8.3 a	35.6 b	11.6 b	3.7 b	11.3 c
Sivanto 7 fl oz	4.1 a	30.6 b	4.8 b	0.9 b	9.2 c
Untreated	30.9 a	23.6 b	693.9 a	1032.8 a	1136.6 a
Warrior II 1.92 fl oz	62.2 a	166.6 a	435.2 a	1280.1 a	1295.8 a
Treatment P>F	0.3807	0.0046	<.0001	<0.0001	<0.0001

Means within a column followed by the same letter are not significantly different. Tukey-Kramer HSD (*P*>0.05).

Table 5. Average High Plains sugarcane aphid damage rating - 2017.

	Boot	50% Bloom	Beginning Milk	Milk	Soft Dough	Soft Dough
Treatment and Rate/A	Aug 16	Aug 24	Sept 1	Sept 8	Sept 15	Sept 20
Intruder 1.0 oz	1.00 a	1.00 a	1.50 b	4.50 b	6.25 b	6.25 b
Lorsban Advanced 16 fl oz	1.00 a	1.25 a	1.00 b	3.25 bc	5.75 b	5.75 b
Sivanto 10 fl oz	0.25 b	1.00 a	1.00 b	1.00 c	1.00 c	1.00 c
Sivanto 5 fl oz	1.00 a	1.25 a	1.25 b	1.00 c	1.25 c	1.25 c
Sivanto 7 fl oz	1.00 a	1.25 a	1.00 b	1.00 c	1.00 c	1.00 c
Untreated	1.00 a	1.25 a	5.75 a	8.00 a	9.00 a	9.25 a
Warrior II 1.92 fl oz	1.00 a	1.75 a	4.50 a	8.50 a	8.75 a	8.75 a
Treatment P>F	0.0001	0.2001	<0.0001	<0.0001	<0.0001	<0.0001

Means within a column followed by the same letter are not significantly different. Tukey-Kramer HSD (*P*>0.05).

Table 6. Yield at 65% moisture, % dry matter, plant height, and % lodged plants infested with sugarcane aphids on September 20, 2017.

Treatment and Rate/A	Yield (tons/A) 65% Moisture	% Dry Matter	Plant Height (in)	% Lodged Plants
Intruder 1.0 oz	27.03 a	27.56 a	68.00 a	0 b
Lorsban Advanced 16 fl oz	27.75 a	26.05 a	72.75 a	0 b
Sivanto 10 fl oz	26.48 a	29.08 a	68.75 a	0 b
Sivanto 5 fl oz	27.11 a	29.15 a	69.50 a	0 b
Sivanto 7 fl oz	27.37 a	27.24 a	66.25 a	0 b
Untreated	15.17 b	31.38 a	68.50 a	38.8 a
Warrior II 1.92 fl oz	18.94 b	28.98 a	70.50 a	6.3 ab
Treatment P>F	<0.0001	0.7091	0.4508	0.0316

In the early stages of boot and 50% bloom, SCA infestations were becoming established but damage levels were below 2. At low infestations there was no relationship between SCA numbers and damage. By the beginning milk stage there was a strong linear relationship $R^2 = 0.906$) in damage level to the avg. number of SCA per leaf (Fig. 1). For each increase in 100 aphids, the damage level increased 0.007. If there were 500 aphid per leaf, the damage rating would have been 5.4. By Sept 8, at the milk growth stage a greater number of plots were averaging more than 500 aphids per leaf, but the relationship to damage was no longer linear. By this date SCAs were continuing to build in the untreated and Warrior treatments causing severe damage. SCAs were recovering from the Lorsban Advanced and Intruder treatments and beginning to cause more damage. The Sivanto treatments controlled SCAs and prevented damage from increasing at later growth stages.

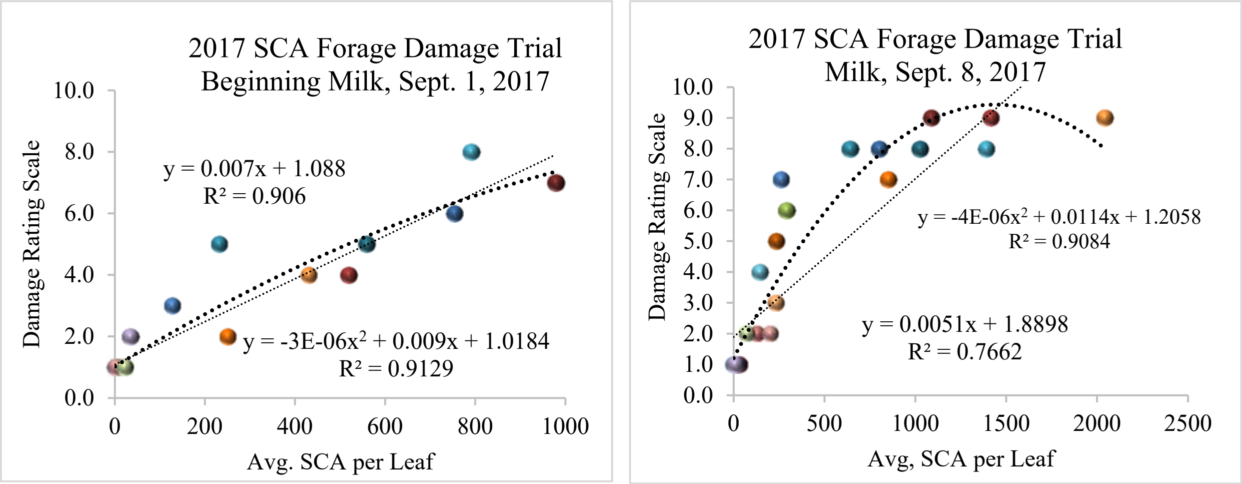

Figure 1. Relationship of avg. number of SCA per leaf to damage at the beginning milk and milk growth stages - 2017.

Prior to the milk stage, there was no correlation between the SCA infestation and damage levels (Fig. 2). However, the strongest linear relationship ($R^2 = 0.81$) between damage and yield loss occurred on Sept. 1 when the forage sorghum was at the beginning milk growth stage. Damage levels above 1 represent variability in damage from plots within the untreated and Warrior treatments. This was prior to infestations building up in the Intruder and Lorsban plots. The linear regression indicates there is a 2.28 ton/A loss in yield for each unit increase in damage when the forage sorghum was initiating the milk growth stage. From Sept. 1, SCA infestations continued to increase in the Intruder, Lorsban, untreated, and Warrior treatments causing an increase in damage throughout the milk, milk/soft dough, and soft dough growth stages. Because SCA infestation remained at high levels in the untreated and Warrior plots throughout the evaluation period, SCAs caused severe feeding injury to the forage plants. Within the Intruder and Lorsban treatment plots, the SCA infestations and damage increased, but did not reach levels as severe as those in the untreated and Warrior plots. Plots with the lower damage levels within the Lorsban and Intruder treatments shifted to higher damage levels each week from Sept. 1 to Sept. 20, but the later damage did not further affect the yield. This may explain why there were not strong linear relationships on Sept. 8, Sept. 15, and Sept. 20 sample dates. While data demonstrates negligible yield losses at damage ratings < 5, yield losses were significant at higher damage ratings. Yield losses could have been greater if the forage harvest occurred at a later growth stage (hard dough to physiological maturity) because SCAs would have continued to damage the forage.

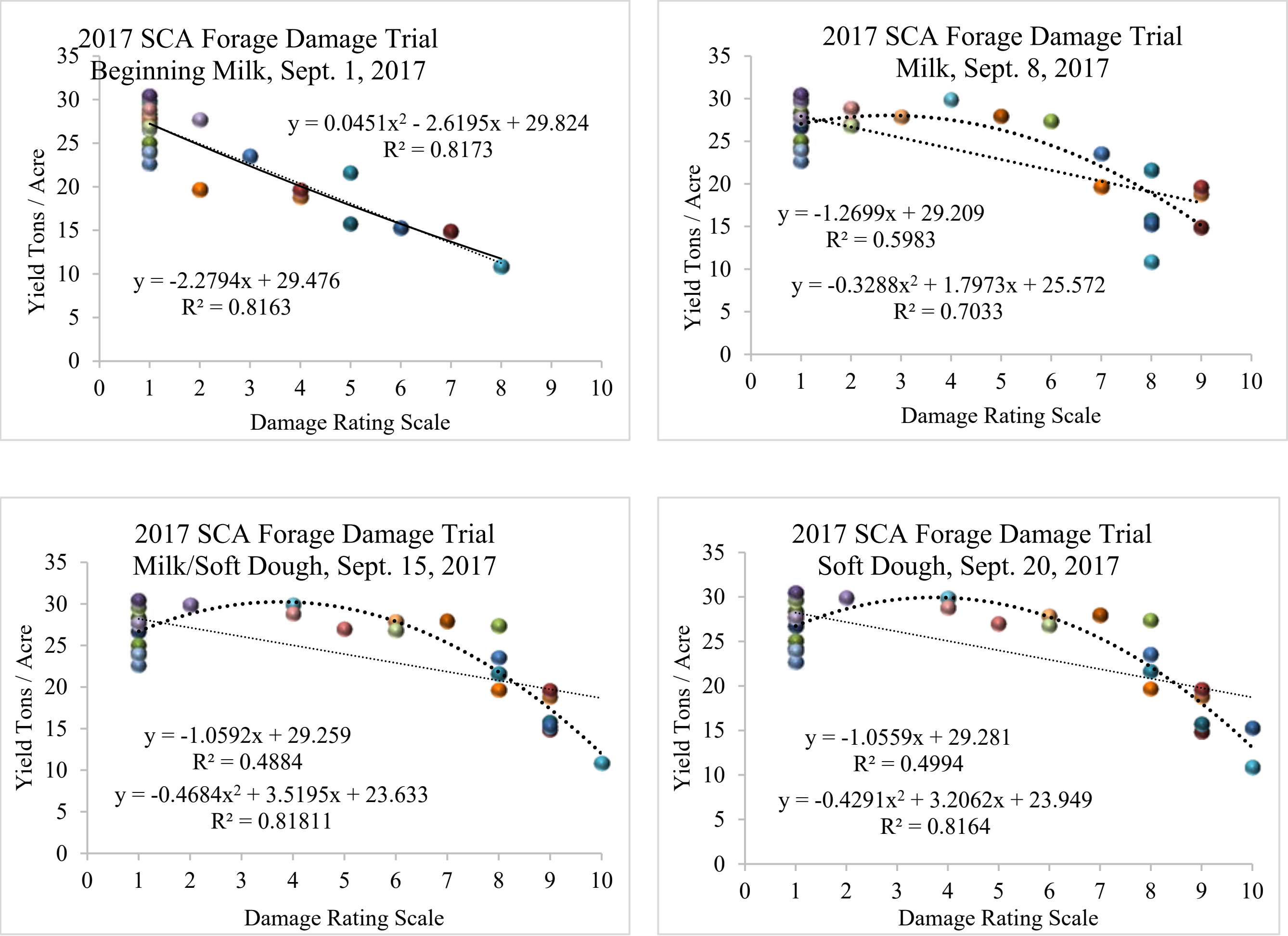

Figure 2. Relationship of SCA damage levels to yield over time from beginning milk to the soft dough stage at harvest - 2017.

Results indicate that SCA infestations should be controlled before damage reaches levels ≥ 5 at the beginning milk stage. The non-linear regression formula representing sorghum damage ratings to yield (tons/ac) at soft dough ($y=-0.429x^2+3.2062x+23.949$; Fig. 2) was used to calculate an estimate of gross economic gain or loss per acre (Table 7). These calculations show a progressive loss in yield when damage increased to rating levels between 7 to 10. At these levels, the loss in yield caused a significant loss in the economic return per acre when compared to the yield at damage level 1 (Table 8). Economic losses were between $40.70 to $480.75 per acre at a price of $30 per ton, $47.50 to $476.88 per ton at a price of $35 per ton, $54.38 to $545.00 per ton at a price of $40 per ton, and $61.18 to $$613.13 per ton at a price of $45 per ton (Table 8). When compared to the cost to apply an insecticide to prevent SCA damage, it would have been economical to apply an insecticide when the economic loss exceeded $45.00; assuming the insecticide cost at $35 per acre and an application cost of $10 per acre. This application would have been to prevent damage from reaching levels above 7 at purchase a price of $30 per ton and levels above 6 when purchase prices were ≥ $35 per ton.

Table 7. Economic estimate of gross return based on silage yield per level of SCA damage at harvest, September 20, 2017.

Silage Price = 10.5 * December 2017 corn board price ($38/ton delivered)

		Price per Ton			
Damage	Yield (ton/A)	$30.00	$35.00	$40.00	$45.00
1	26.73	$801.78	$935.41	$1,069.04	$1,202.67
2	28.65	$859.35	$1,002.58	$1,145.80	$1,289.03
3	29.71	$891.17	$1,039.70	$1,188.23	$1,336.76
4	29.91	$897.25	$1,046.79	$1,196.33	$1,345.87
5	29.25	$877.58	$1,023.84	$1,170.10	$1,316.36
6	27.74	$832.16	$970.85	$1,109.54	$1,248.24
7	25.37	$761.00	$887.83	$1,014.66	$1,141.49
8	22.14	$664.09	$774.77	$885.45	$996.13
9	18.05	$541.43	$631.67	$721.91	$812.15
10	13.10	$393.03	$458.54	$524.04	$589.55

The sale price of silage paid to a local farmer was based on a 10.5 factor * the December 2017 corn board price or $38 per ton deliver. We used this value to obtain a range of prices for silage ($30.00 to $45.00 per ton) for our estimates of dollar return based on yield / damage level

Table 8. Estimated economic loss based on silage yield per level of SCA damage at harvest, September 20, 2017.

		Price per Ton			
Damage	Yield Gain or Loss (ton/A)	$30.00	$35.00	$40.00	$45.00
2	1.92	$57.57	$67.16	$76.76	$86.35
3	2.98	$89.39	$104.29	$119.18	$134.08
4	3.18	$95.46	$111.37	$127.28	$143.19
5	2.53	$75.79	$88.42	$101.06	$113.69
6	1.01	$30.38	$35.44	$40.50	$45.56
7	-1.36	-$40.79	-$47.59	-$54.38	-$61.18
8	-4.59	-$137.70	-$160.65	-$183.60	-$206.55
9	-8.68	-$260.35	-$303.74	-$347.14	-$390.53
10	-13.63	-$408.75	-$476.88	-$545.00	-$613.13

[1] All plots had a minimum damage rating of 1; therefore, yield losses for damage level 2 through 10 were subtracted from damage level 1 (26.73 ton/A) in Table 6.

[2] The values in red indicate where insecticide applications would have been economical to apply based on the damage level and price per ton when using an insecticide cost of $35.00/A plus $10.00/A application cost.

2017 Silage Quality Analysis

In 2017, sugarcane aphid feeding damage to the forage negatively impacted quality. There were no statistical differences in forage quality between ensiling periods (freshly harvested; 0 days ensiled and silage; 60 days ensiled), so data was combined across all treatments for both ensiling periods. The forage quality in the untreated and Warrior treatments was significant reduced for all the ensiled components, except crude protein, when compared to the other insecticide treatments (Table 14). Heavy SCA pressure negatively affected grain development resulting in reduced starch levels as indicated by the reduced starch levels at high SCA levels, which represented the Warrior and UTC treatments (Fig. 3). Of significance, starch was < 15% for Warrior and the untreated check compared to other treatments where starch levels were > 20%. Lignin was positively correlated to SCA damage indicating that under increased SCA pressure, plants became lignified decreasing forage quality. Acid detergent fiber (ADF), a measure of the undigestible plant components (cellulose and lignin) was also positively correlated to SCA damage demonstrating that as SCA damage increases, forage digestibility decreases (Fig. 3); however, there was no difference in ADF levels between ensiling periods indicating that the ensiling process does not improve the forage digestibility. When comparing forage quality differences between the two ensiling periods, there was a statistical difference between pH and CP levels for the two periods; however, this is not related to SCA pressure. A decrease in silage pH is an indication of preservation not SCA damage. Additionally, CP levels naturally decrease during the ensiling process as a result of ammonia volatilization. Because Milk/Ton and RFQ provide an overall measure of the feed value based on starch and digestibility, the negative correlation between these parameters and SCA damage further indicates that silage quality is negatively impacted by SCAs and ensiling does not reverse the damage (Fig. 3). Therefore, 2017 data indicates that damage caused SCAs during the milk developmental stages impacts the quality of the forage sorghum at harvest.

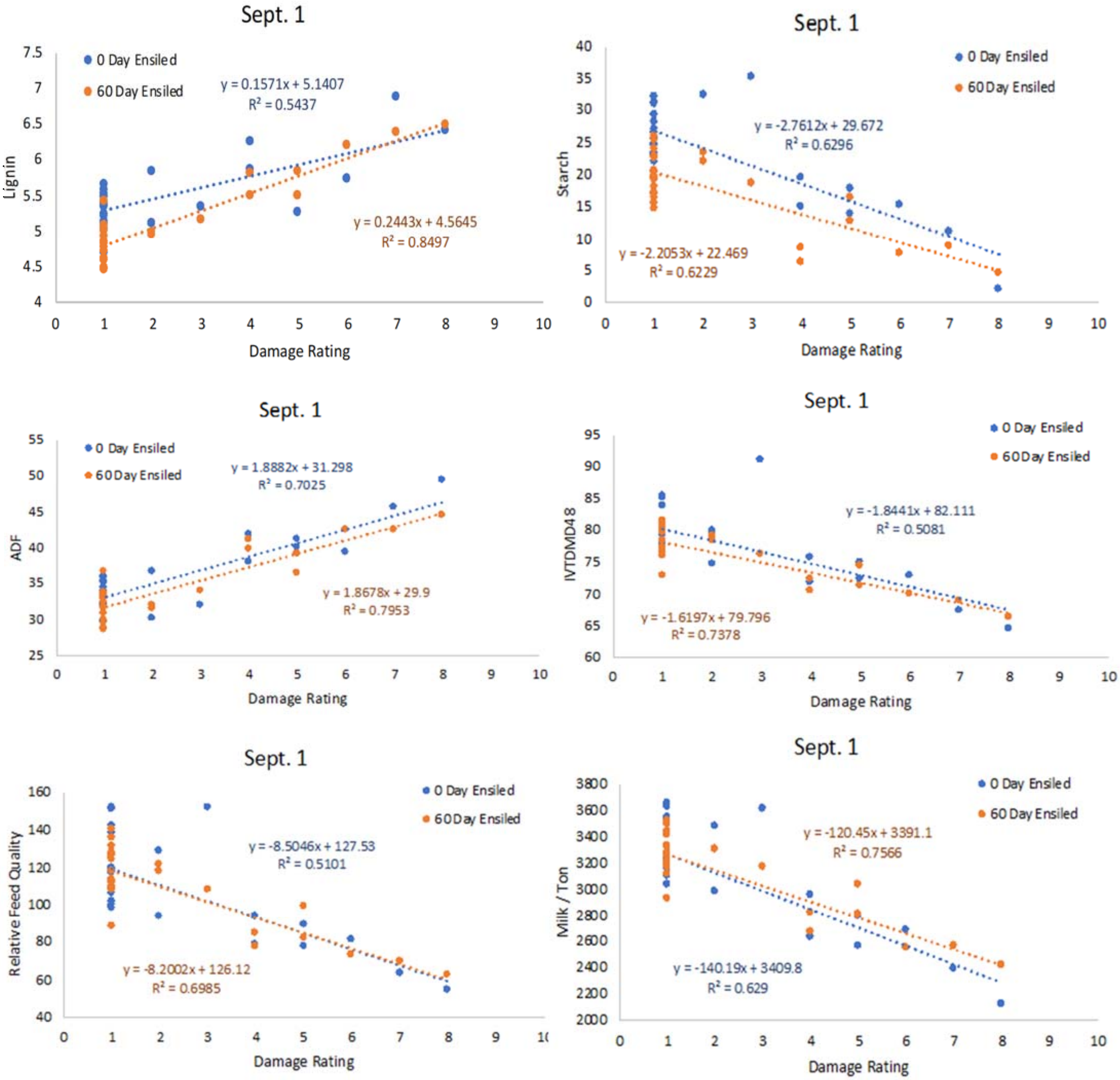

Figure 3. Relationship of silage quality components at 0 Day Ensiled and 60 Days Ensiled to sugarcane aphid damage ratings at beginning milk stage on September 1, 2017. Silage quality components based on % dry matter are starch, ADF (acid detergent fiber), Lignin, IVTDMD48 (In vitro dry matter digestibility at 48 hours). Other silage quality components are milk per ton (pounds of milk per ton of silage) and relative feed quality (RFQ).

2019 Sugarcane Aphid Infestations and Damage

In 2019, SCA counts initiated on August 13 showed no statistical differences in SCA infestations among the insecticide treatments and either of the Untreated Checks (UTC1 and UTC2) (Table 9). On August 20, SCA numbers in the Warrior treatment were statistically higher from the other designated treatments, except for the UTC1. However, there were not any statistical differences in damage levels among the treatments (Table 10). After applying the insecticide treatments on August 21 to all treatments except the previously applied Sivanto 10 fl oz/A treatment, both SCA densities and damage increased by August 27. SCA densities were statistically highest in the Warrior treatment compared to the other treatments, and SCA densities were statistically similar for Malathion, Sivanto 2.5 fl oz/A, UTC1 and UTC2 treatments. There was no statistical separation in aphid densities among the Malathion, Sivanto 2.5 fl oz/A, and Sivanto 10 fl oz/A treatments. However, by Sept. 3, damage levels increased proportionally to the SCA density levels of the treatments. Damage levels were highest in the Warrior treatment, although statistically similar to the UTC1 and UTC2 treatments. Damage levels were statistically similar among Malathion treatment and the two UTC treatments; however, damage levels for Malathion and the two Sivanto treatments were also not statistically different.

The highest level of SCA densities among the treatments peaked on Sept. 3 and aphid populations steadily declined until the trial was harvested on Sept. 16 at the soft dough stage. Both Sivanto treatments maintained SCA densities at very low levels and prevented any significant damage. Ratings for damage levels in both Sivanto treatments were less than 2 from Sept. 3 to Sept. 16 (Table 10). Although the application of Malathion slowed the increase in SCA densities and damage when compared to Warrior and the two UTC, SCA densities were still higher than in both Sivanto treatments. The SCA density in the Malathion treatment was statistically similar to each of the Sivanto treatments, but damage levels in the Malathion treatment on Sept. 3 and to Sept. 16 were statistical different from the Sivanto treatments due to greater damage in the Malathion treatment. Both SCA densities and/or damage levels in the UTC treatments and the Warrior treatment were statistically similar each week from Sept. 3 to Sept. 16. Damage levels were only recorded on Sept. 16 because SCA infestations had completely collapsed and aphids could not be found on the designated sample leaves. The exact cause for the aphid populations to collapse is not known.

When the population collapsed from Sept. 3 to Sept. 16, very little damage continued to accumulate among any of the treatments by the harvest date. This may explain why there were minimal differences among the treatment yields (Table 11). The yield in the Sivanto 10 fl oz/A treatment, with the lowest SCA densities and damage, was statistically higher than the yields in the Warrior and both UTC treatments which had the highest levels of SCA densities and damage. In 2019, there was less in-season precipitation than during the 2017 cropping year. It was observed that plant dry-down was quicker in damaged plots resulting in lower dry matter yields in the Warrior and UTC plots. The percentage of plants lodging as a result of SCA infestation and damage was very low, except for the Warrior treatment (Table 11).

Table 9. Average number of sugarcane aphids per leaf - 2019.

	Boot	Boot - Heading	50% Bloom	Beginning Milk	Milk-SD
Treatment and Rate/A	Aug 13	Aug 20	Aug 27	Sept 3	Sept 10
Malathion 1.5 pt	5.9 a	30.4 b	96.8 bc	291.8 bc	153.3 bc
Sivanto 10 fl oz	5.5 a	14.8 b	1.02 c	2.0 c	1.5 c
Sivanto 2.5 fl oz	12.5 a	43.9 b	56.3 bc	39.3 c	10.6 c
UTC1	7.9 a	48.1 ab	163.6 b	698.3 a	245.4 ab
UTC2	4.5 a	24.4 b	183.3 b	476.0 ab	248.5 ab
Warrior II 1.92 fl oz	11.4 a	80.9 a	398.6 a	717.4 a	386.6 a
Treatment P>F	0.5117 Tukey-Kramer	0.0003 Tukey-Kramer	0.0003 Student's t	<.0001 Tukey-Kramer	0.0048 Student's t

Means within a column followed by the same letter are not significantly different. Tukey-Kramer HSD or Student's t test (*P*>0.05).

Table 10. Average High Plains SCA damage rating - 2019.

	Boot	Boot - Heading	50% Bloom	Beginning Milk	Milk-SD	Soft Dough
Treatment and Rate/A	Aug 13	Aug 20	Aug 27	Sept 3	Sept 10	Aug 13
Malathion 1.5 pt	1.0	1.0 a	2.3 bcd	4.0 b	4.5 b	4.8 b
Sivanto 10 fl oz	1.0	1.0 a	1.0 d	1.0 c	1.0 c	1.0 c
Sivanto 2.5 fl oz	1.0	1.0 a	1.5 cd	1.5 c	1.5 c	1.8 c
UTC1	1.0	1.0 a	3.0 ab	7.3 a	7.3 a	7.5 a
UTC2	1.0	1.0 a	2.8 abc	6.0 ab	6.3 ab	6.8 a
Warrior II 1.92 fl oz	1.0	1.3 a	4.0 a	6.0 ab	6.8 ab	7.4 a
Treatment P>F	NS	0.4509	<.0001	<.0001	<.0001	<.0001
		Student's t	Tukey-Kramer	Tukey-Kramer	Tukey-Kramer	Student's t

Means within a column followed by the same letter are not significantly different. Tukey-Kramer HSD or Student's t test (*P*>0.05).

Table 11. Yield at 65% moisture, % dry matter, plant height, and % lodged plants infested with sugarcane aphids on September 16, 2019.

Treatment and Rate/A	Yield (tons/A) 65% Moist.	% Dry Matter	Plant Height (in.)	% Lodged Plants
Malathion 1.5 pt	22.01 ab	30.7 a	72.75 a	0 b
Sivanto 10 fl oz	24.35 a	33.3 a	71.50 a	1.3 ab
Sivanto 2.5 fl oz	21.07 ab	32.0 a	70.00 a	0 b
Untreated 1	16.44 c	28.8 a	70.25 a	0 b
Untreated 2	20.11 bc	28.1 a	73.75 a	2.5 ab
Warrior II 1.92 fl oz	19.19 bc	27.5 a	70.75 a	11.3 a
Treatment P>F	0.0169	0.4024	0.2185	0.0138
	Student's t	Student's t	Tukey-Kramer	Tukey-Kramer

Means within a column followed by the same letter are not significantly different. Tukey-Kramer HSD or Student's t test (*P*>0.05).

In 2019, SCA infestations were heavier during blooming compared to the same period in 2017. A strong linear relationship ($R^2 = 0.8291$) was starting between SCAs per leaf and damage at the 50% blooming growth stage (Fig. 4). This linear relationship showed there was a 0.0069 increase in damage for each 100 aphid increase per leaf. This relationship was compares to the SCA/damage relationship (0.007 increase for each 100 aphid increase per leaf) at the beginning milk stage in 2017. At bloom and beginning milk, populations were fewer than 1000 aphids per leaf although SCA populations peaked on Sept. 3 at the beginning milk growth stage. At this time, there was a strong linear relationship ($R^2 = 0.8629$) between SCAs per leaf and damage with a 0.0074 increase in damage for each 100 aphid increase per leaf. When there were 500 aphids per leaf at 50% bloom compared to beginning milk stage, the damage levels were 4.8 and 5.2, respectively.

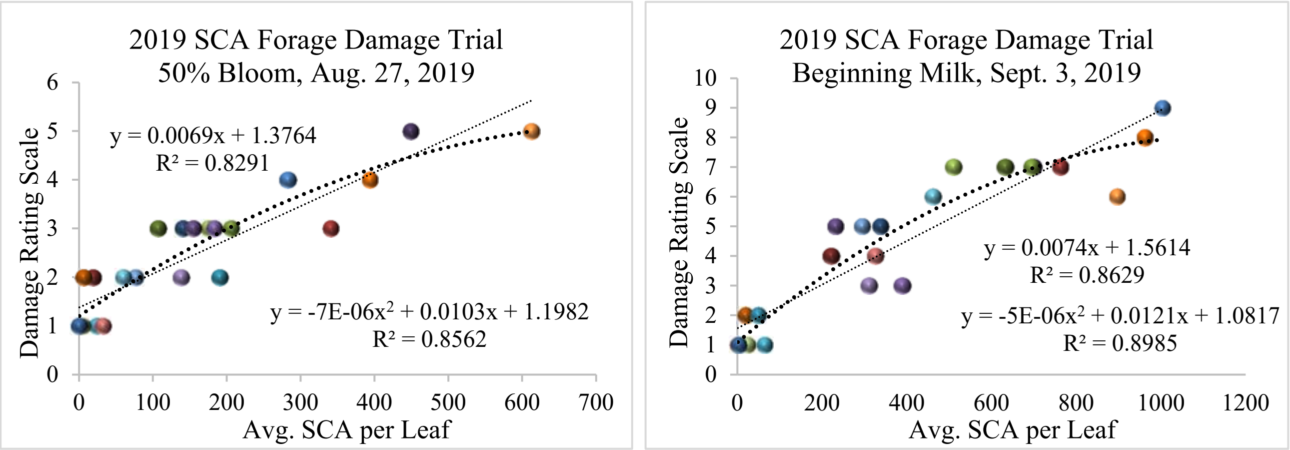

Figure 4. Relationship of avg. number of SCA per leaf to damage at 50% bloom and beginning milk growth stages - 2019.

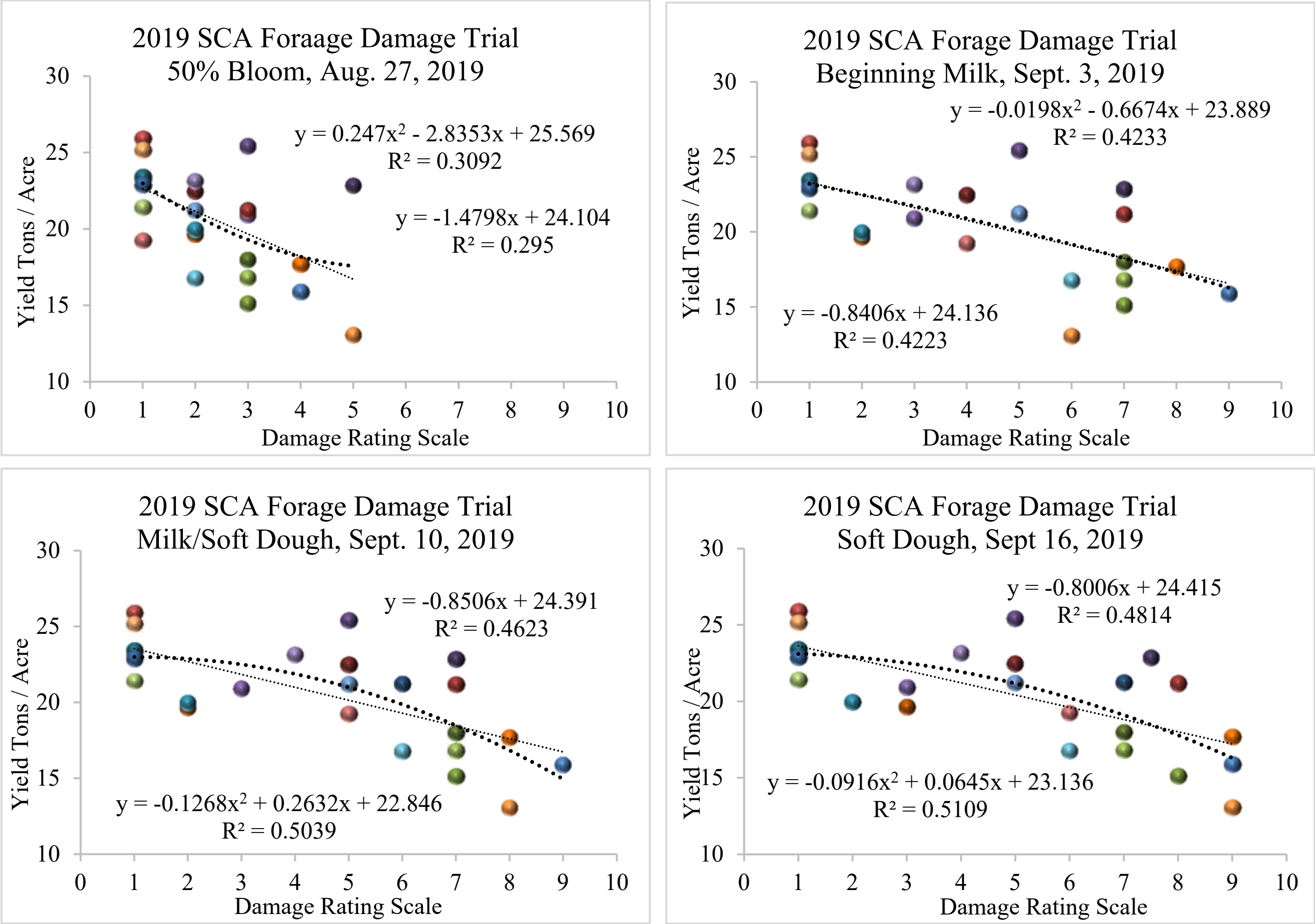

Figure 5. Relationship between SCA damage levels to yield over time from 50% bloom to the soft dough stage at harvest - 2019.

Low SCA damage levels prior to August 27 did not correlate to yield (Fig. 5). There was a slight linear relationship between damage to yield ($R^2 = 0.295$) on August 27 when forage sorghum was at 50% bloom. At this date damage was still relatively low among plots. At the Sept. 3 date, when sorghum kernels were in early milk, damage in some plots was becoming more severe (> 5). The linear relationship between damage levels to yield was becoming stronger ($R^2 = 0.4233$) with 0.84 tons yield loss for each change in damage rating (Fig. 5). After Sept. 3, the slight changes in damage levels among the plots each week only caused minimal changes to the linear relationship between damage levels and yield on Sept. 10 and Sept. 16 ($R^2 = 0.4623$ and $R^2 = 0.4814$, respectively). These minimal changes could be associated with SCA populations crashing after peaking on Sept. 3.

As in 2017, the non-linear regression formula for damage rating to yield (tons/ac) at soft dough ($y=-0.0916x^2+0.0645x+23.136$) was used to calculate silage yield for each level of SCA damage from 1 to 10 (Fig. 4) and estimate the gross economic loss per acre (Table 12). The calculations show a steady decline in yield as damage increased from 1 to 10. Likewise, the gross returns for each of the prices per ton declines for each yield loss per damage increase. Since yields decreased for each damage level ≥1, there were negative economic losses per damage level associated with each of the four prices per ton categories (Table 13). When the purchase price for silage was $30 per ton, there was an economic loss of $6.30 to $252.90 per ton when damage increased from level 2 to 10. The economic loss was $7.35 to $295.05, $8.40 to $337.20, and $9.45 to $379.35 at purchase prices of $35, $40, $45 per ton, respectively. When using the same estimated cost of applying an insecticide ($35.00/A for insecticide and $10.00/A for application), it would have been economical to apply an insecticide to prevent damage from reaching levels above 4 at silage purchase prices of $30 and $35 per ton and damage levels above 3 at purchase prices of $40 to $45 per ton. These values demonstrate the potential economic losses that are associated with different damage levels caused from SCA infestations, even when SCA infestations collapse during head developmental growth stages.

Table 12. Economic estimate of gross return based on silage yield per level of SCA damage at harvest, September 16, 2019.

Silage Price = 10.5 * December 2017 corn board price ($38/ton delivered)[1]

		Price per Ton			
Damage	Yield (ton /A)	$30.00	$35.00	$40.00	$45.00
1	23.11	$693.30	$808.85	$924.40	$1,039.95
2	22.90	$687.00	$801.50	$916.00	$1,030.50
3	22.51	$675.30	$787.85	$900.40	$1,012.95
4	21.93	$658.20	$767.90	$877.60	$987.30
5	21.18	$635.40	$741.30	$847.20	$953.10
6	20.25	$607.50	$708.75	$810.00	$911.25
7	19.13	$573.90	$669.55	$765.20	$860.85
8	17.83	$534.60	$623.70	$712.80	$801.90
9	16.35	$490.50	$572.25	$654.00	$735.75
10	14.68	$440.40	$513.80	$587.20	$660.60

[1] The sale price of silage paid to a local farmer was based on a 10.5 factor * the December 2017 corn board price or $38 per ton deliver. We used this value to obtain a range of prices for silage ($30.00 to $45.00 per ton) for our estimates of dollar return based on yield / damage level.

Table 13. Estimated economic loss based on silage yield per level of SCA damage at harvest, September 16, 2019.[1,2]

Damage	Yield Loss (ton /A)	Price per Ton			
		$30.00	$35.00	$40.00	$45.00
2	-0.21	-$6.30	-$7.35	-$8.40	-$9.45
3	-0.6	-$18.00	-$21.00	-$24.00	-$27.00
4	-1.17	-$35.10	-$40.95	-$46.80	-$52.65
5	-1.93	-$57.90	-$67.55	-$77.20	-$86.85
6	-2.86	-$85.80	-$100.10	-$114.40	-$128.70
7	-3.98	-$119.40	-$139.30	-$159.20	-$179.10
8	-5.29	-$158.70	-$185.15	-$211.60	-$238.05
9	-6.76	-$202.80	-$236.60	-$270.40	-$304.20
10	-8.43	-$252.90	-$295.05	-$337.20	-$379.35

[1] All plots had a minimum damage rating of 1: therefore, yield losses for damage level 2 through 10 were subtracted from damage level 1 (23.11 ton/A) in Table 11.

[2] The values in red indicate where insecticide applications would have been economical to apply based on the damage level and price per ton using an insecticide cost of $35.00/A plus $10.00/A application cost.

2019 Silage Quality Analysis

There was no difference in quality parameters as a result of the different SCA levels created by the insecticide treatments for both ensiling period (0 day and 60 days) in 2019; however, analysis of data by ensiling duration revealed differences in quality (Tables 14-17). While parameters were not statistically different, a regression analysis evaluating forage quality parameters and SCA damage at early milk stage (Sept. 3, 2019) when grain berries were watery to milky confirmed trends similar to those observed in 2017 (Figs. 6 and 7). Because SCA pressure was less in 2019, reductions in forage quality were not as great, but there were still observable impacts from SCA pressure on forage parameters. There was no difference in pH for either the fresh or the ensiled forage between treatments indicating that SCA damage and differences in DM at harvest did not negatively affect the preservation of the forage in 2019. There was also trends for SCA damage to reduce ADF, RFQ, and Milk/ton. The relative feed quality for the Sivanto 10.0 fl. oz/ac rate was 117% greater than for the Warrior and combined UTC average. As in 2017, starch levels dropped with SCA damage levels ≥5 (Fig. 7). Differences in CP between the two ensiling periods was a function of natural changes in protein during the ensiling process. In 2019, there was no significant difference in CP between different levels of damage like in 2017 even though there was a trend to have greater CP with better SCA control. Reductions in quality indicates that quality reductions are closely related to yield reductions. Timely control of SCAs will minimize reductions in yield and quality.

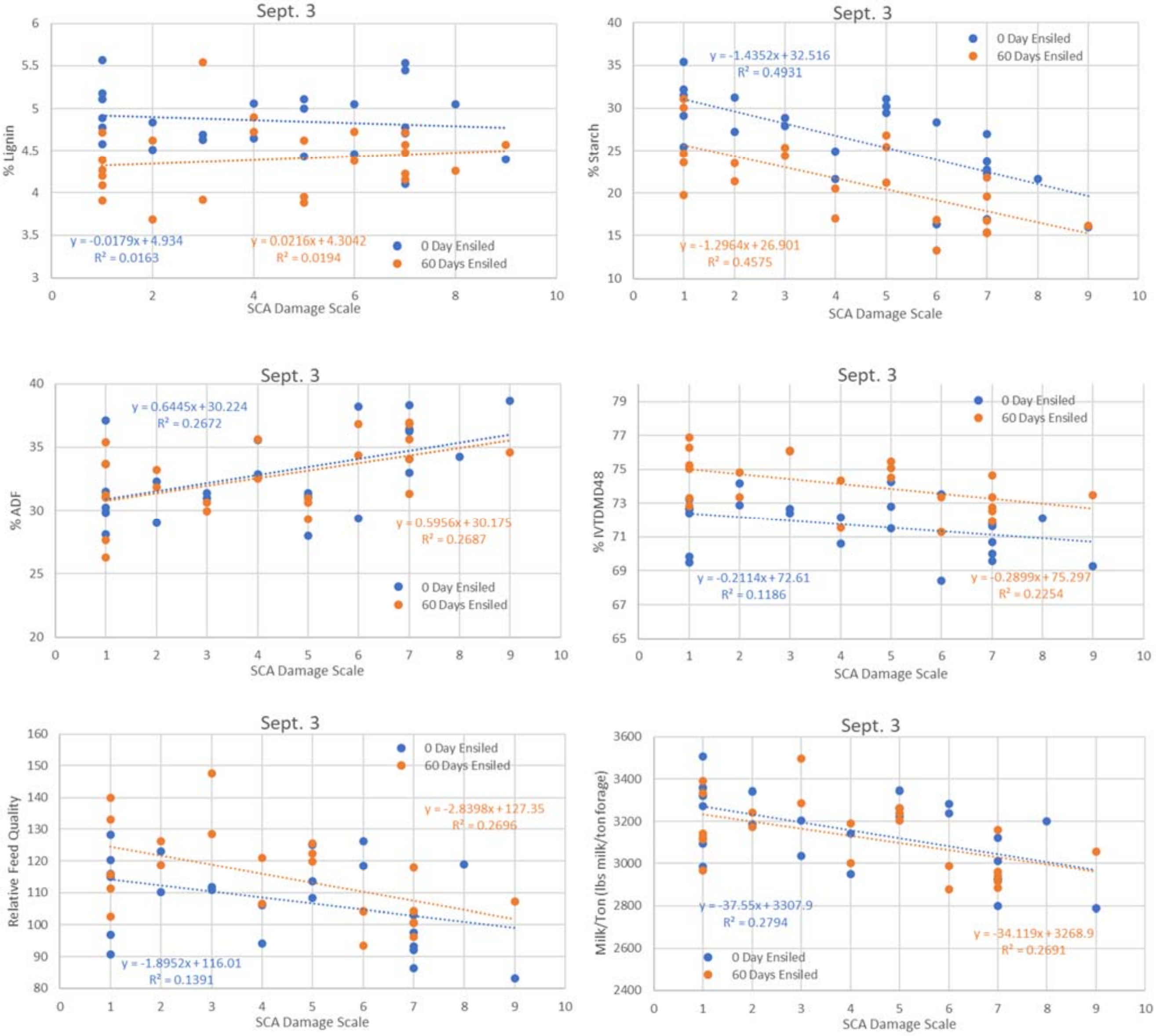

Figure 6. Relationship of silage quality components at 0 Day Ensiled and 60 Days Ensiled to sugarcane aphid damage ratings at beginning milk stage on September 3, 2019. Silage quality components based on % dry matter are starch, ADF (acid detergent fiber), Lignin, IVTDMD48 (In vitro dry matter digestibility at 48 hours). Other silage quality components are milk per ton (pounds of milk per ton of silage) and relative feed quality (RFQ).

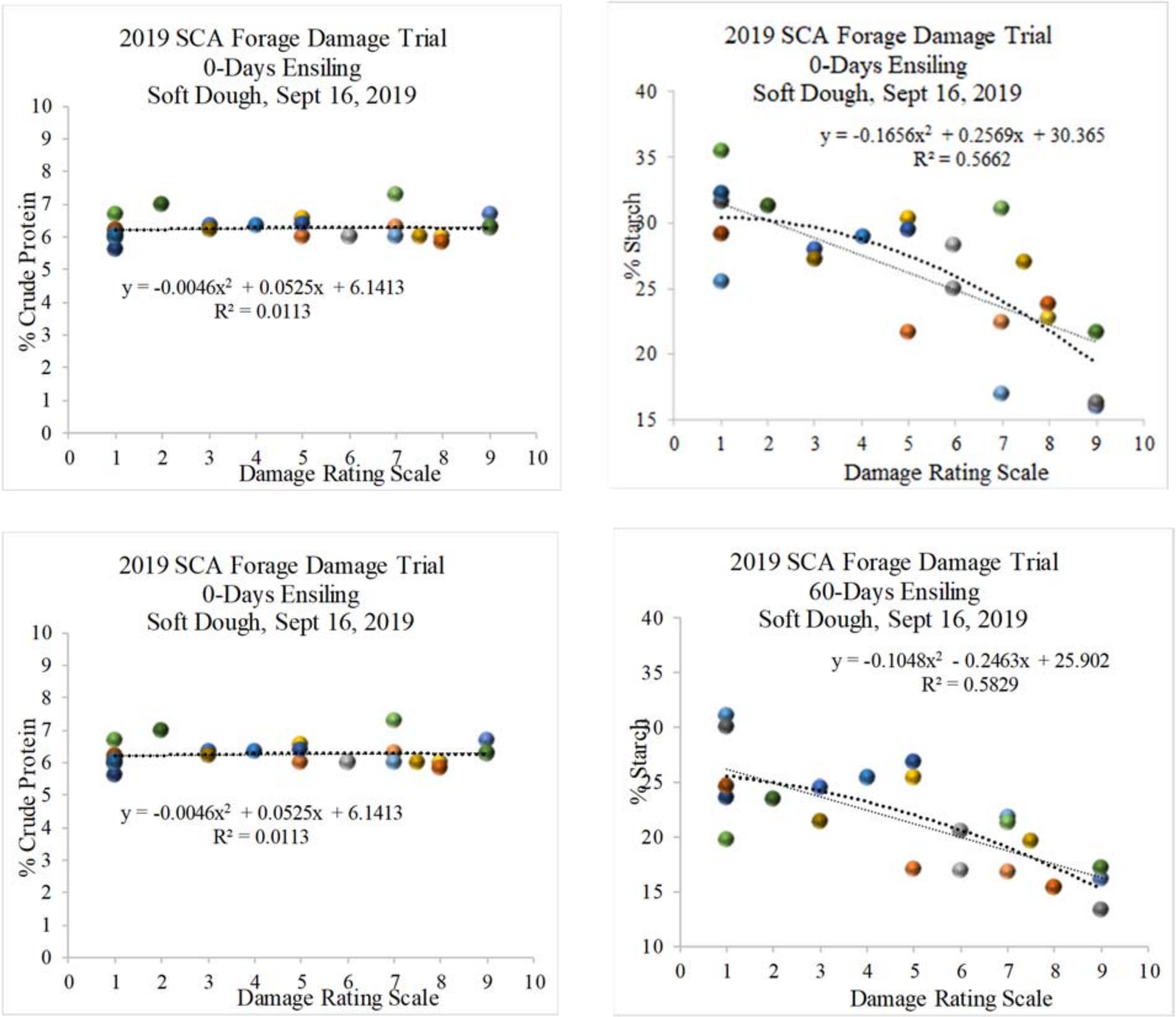

Figure 7. Relationship between the damage ratings on Sept. 16, 2019 with % crude protein and % starch

Conclusions

For this study there were distinctly different SCA infestations between 2017 and 2019. During 2017 alate, SCAs began infesting the forage sorghum in early August when the forage sorghum was in the late whorl stage. Populations continued increasing and were developing into small colonies by August 16 during the sorghum boot growth stage. Populations continued to increase at an exponential rate throughout the head developmental growth stages from flowering to soft dough. During this time plots were under heavy SCA infestation and feeding caused severe damage in the untreated and Warrior treatments. The insecticide application of Sivanto Prime provided excellent control of SCA when the 10 fl oz/A rate was applied before SCA began to infest the field. Sivanto Prime also provided good control when the 5 and 7 fl oz/A rates were applied at flowering before heavy aphid infestations. Both Lorsban Advance (16 fl oz/A) and Intruder (10 oz/A) delayed SCA populations from building for a week. This delayed SCA populations from flaring-up for two weeks and prevented damage from reaching levels as severe as damage in the Untreated and Warrior treatments during the milk to soft dough growth stage.

This averted substantial yield losses when sorghum was harvested at the soft dough stage, but if the harvest date had been at a later growth stage, the yield losses may have been more substantial. When SCA infestations increased and caused damage from ratings of 4 to 8 at the beginning milk stage, damage continued to increase to soft dough growth resulting in significant losses in yield (tons/A), a higher percentage of plants lodging, and poorer quality of forage that would be ensiled. If damage levels were ≤ 6.0 by the soft dough growth stage, there was no losses in yield or economic return. However, when damage levels were between rating of 7 to 10 at harvest there was a progressive loss in yield and a substantial loss in the economic return.

In 2019, SCAs began infestation time and rate was similar to populations in 2017. Alate aphids were detected in early August at the late whorl growth stages and increased exponentially until populations peaked when kernels in the sorghum head were starting to form milk. By late-milk/early soft dough SCA populations began to decline and completely crashed by soft dough stage when plots were harvested. The reasons for the SCA population to crash is not known. For this study the actual reasons for the crash are not as important as how the crash in the population influenced the subsequent damage to the forage sorghum. When aphid populations began to decline from milk/soft dough to the soft dough growth stages damage levels only slightly increased. Sivanto Prime at 10 fl oz and 2.5 fl oz per A rates kept SCA infestations and damage at low levels. SCAs may have increased in the 2.5 fl oz treatment of Sivanto Prime if populations had not crashed. Malathion at 1.5 pt/A slowed the buildup of SCA and damage. On average, damage levels within both the untreated check and the Warrior treatments only reached levels between 6.8 to 7.5 by the soft dough growth stage, but a few plots within these treatments had damage levels of 8 to 9 during the beginning milk through to the soft dough growth stages. As in 2017, decreases in quality with increasing SCA damage indicates that timely control of SCAs is necessary to iwill minimize reductions in yield and quality.

Data from this research has provided valuable knowledge about SCA feeding damage in forage sorghum, and the necessary data to develop economic thresholds for farmers to make a more educated decision for insecticide application timing to forage sorghums grown for silage. In both study years, SCAs did not begin to infest the forage trials until late July or early August when plants were initiating head developmental growth stages. However, when SCAs begin to infest the field, a producer, crop advisor, or industry sales representative cannot predict how quickly SCA populations will increase, the severity of the damage, or if populations may naturally collapse. Based on the growth stages of the forage sorghum when SCAs began to infest the fields in 2017 and 2019, research demonstrated a strong linear relationship between SCA per leaf and damage as well as between damage and yield losses at the early milk developmental growth stage. The potential for yield loss was much higher in 2017 (2.28 tons/A for each increase in damage) compared to 2019 (0.84 tons/A per damage increase) because of the SCA populations collapsing in 2019. But in both years, once SCA damage levels were ≥ 5 during the early milk stage, significant losses in yield and economic return were incurred by harvest. Since SCA populations can develop rapidly, SCA should be closely monitored and quickly controlled to prevent damage and economic losses. However, determining when to spray is often a difficult decision for producers. Insecticides and the cost to apply them can be expensive. Farmers are often hesitant about making an insecticide application because there is a risk that they may need to spend more money for a second application. Farmers often delay the application until there are high numbers of SCAs infesting plants. As a result, SCAs may have already caused significant economic losses due to reduced yield and possibly in forage quality.

If alate SCAs are found just as they are beginning to infest the field there will be about 10 to 20 days before SCAs colonize 100% of the plants. Aphid densities have been reported to double on susceptible grain sorghum hybrids in 4 to 8 days resulting in yields reduced by 50% to nearly 100% when aphid densities peaked above 300 aphids per leaf (Brewer et al. 2017). Bowling et al. (2016) reported SCA populations can exceed 10,000 per plant on grain sorghum and it is difficult to control SCAs once densities exceed 500 aphids per leaf. For sorghum grown for grain production, there have been two types of thresholds published for when to apply insecticide applications to prevent significant yield loss. One threshold recommends treatment when aphid densities exceed 40 - 50 aphids per leaf (Gordy et al. 2019, Knutson et al. 2016, Knutson et al. 2018, and Szczepaniec 2018). The other threshold recommends treatment based on percentage of plants infested with or without SCA counts at different plant growth stages (Buntin D. and J. K. Brock 2016, Bynum et. al. 2016, Catchot 2015, Knutson et al. 2016, Knutson et al. 2018). Knutson (et al. 2018) stated the choice of one threshold over another threshold varies by geographic region, personal preference, degree of thoroughness and consideration of the weather and the ability to make timely, effective insecticide applications when using thresholds. Producers in the Texas High Plains adopted the more conservative threshold based on percentage of plants infested with 50 aphids at certain growth stages (Knutson et al., 2018) (Table 18). The action threshold is extended through the entire head developmental growth stages up to black layer when grain is physiologically mature and ready to harvest.

Table 18. Action thresholds for grain sorghum based on sorghum growth stages
(Source: revised from thresholds created by Louisiana State University) Knutson et al. 2018.

Growth stage	Action threshold
Preboot	20% of plants infested with 50 or more aphids
Boot	20% of plants infested with 50 or more aphids
Flowering–milk	30% of plants infested with 50 or more aphids
Soft dough	30% of plants infested with established aphid colonies and localized areas[1] with heavy honeydew
Dough	30% of plants infested with established aphid colonies and localized areas[1] with heavy honeydew
Black layer	Heavy honeydew and established aphid colonies. Treat only to prevent harvest problems. Observe preharvest intervals for insecticides.

[1] A single plant or group of adjacent plants with sugarcane aphid colonies

For grain sorghum, production the primary concern when controlling SCAs is to prevent excessive damage to the plant that would cause significant losses in grain yields. However, for forage sorghum production, the primary concern is that SCA damage will cause significant yield losses in the tonnage of forage, nutritional quality of the forage at harvest, and any nutritional deterioration during the time the forage is ensiled prior to feeding livestock and dairy animals. SCAs infestations in forage fields can be equally as bad or worse than infestations in grain sorghum fields. Controlling SCAs in forage sorghums is even more difficult because of high seeding rates under irrigation and tall plant canopies (6 to 14 feet) (Western Forage Production Guide, 2010). This causes the canopy to be denser than grain sorghum which restricts penetration of insecticide sprays to lower leaves infested with SCA. From our studies, the action threshold used for grain sorghum can be modified for forage sorghums. The primary modification is that forage sorghum is harvested at soft dough. Therefore, the dough and black layer growth stages are not needed and the protection for forage sorghum at soft dough would be critical to prevent heavy infestations and honeydew that would cause harvest problems. The revised action thresholds for controlling SCA infestations in forage sorghums will allow time for producers to have the field sprayed before SCA infestations could reach damage levels ≥5 (Table 19). Bell and Bynum have noted in forage sorghum variety trials that when SCA infest forage sorghums in the vegetative growth stage, forage sorghums will grow out of the SCA damage following an insecticide application.

Table 19. Action thresholds for forage sorghum based on sorghum growth stages (Source: revised from thresholds created by Louisiana State University.

Growth stage	Action threshold
Preboot	20% of plants infested with 50 or more aphids
Boot	20% of plants infested with 50 or more aphids
Flowering–milk	30% of plants infested with 50 or more aphids
Soft dough	Heavy honeydew and established aphid colonies. Treat only to prevent harvest problems. Observe preharvest intervals for insecticides.

Alternative Management Practices

A management practice that is recommended for grain sorghum on the Texas High Plains is to plant earlier or select an earlier maturing hybrid so plants can reach later head development growth stages before SCA reach damaging levels (Knutson et al. 2018). With forage sorghums, the recommended harvest date is at the soft dough stage. Planting earlier could be an option to avoid damaging SCA infestations, as SCAs do not overwinter on the Texas High Plains and must migrate from south Texas. It is not until mid-July in the southern High Plains and August in the Texas Panhandle that SCAs are reported to begin infesting both grain and forage sorghums (Bowling 2016). Planting earlier would allow the forage sorghums to be at later growth stages or may be harvested and damaging SCA infestations could be avoided at the most susceptible growth stages.

Following the initial outbreaks of SCAs in 2013 (Bowling et al. 2016), a primary emphasis by researchers was to look for previously identified resistant grain sorghum lines (Teetes et al. 1995), commercial varieties exhibiting resistance (Gonzales et al. 2019) and screen sorghum inbred lines for new resistance (Mbulwe et al. 2015, Limaje et al. 2018, Paudyal et. al. 2019). Emphasis towards screening for resistance in forage sorghums have increased within the last two years and there is one commercial forage sorghum by Pioneer Seed being sold as SCA tolerant. As more SCA resistant forage sorghums are developed, farmers will have another option to help manage SCA infestations, but populations could still develop to damaging levels.

Neonicotinoid insecticides applied as at-planting seed treatments (Cruiser 5FS, Poncho 600FS, Gaucho 600 FS,a Nipsit Inside 5FS) have shown to provide at least 40 days of protection from SCA infestations (Jones et. al. 2015). The use of these at-planting seed treatments may not provide long enough residual activity to protect forage sorghum during the head developmental growth stages on the Texas High Plains.

Currently, there are two labeled insecticides that will effectively control SCA when foliarly applied by ground or aerially. These are Sivanto® Prime (Flupyradifurone) and Transform® WG

(Sulfoxaflor). Studies with Sivanto® HL, a new formulation, have shown that in-furrow at-planting applications (IFAP) and side-dress applications 30 days after planting could provide SCA protection for up to 100 days after planting (IFAP) and 50 days after the side dress application. The usage of these application methods could be an option when Bayer Crop Science commercialize the HL formulation. However, the application methods are prophylactic measures intended to prevent SCA infestations without knowing whether SCA would develop into damaging infestations. Another management practice would be to apply Sivanto® Prime through a pivot irrigation system equipped with drop nozzles and splash plates to direct the spray up into the plant canopy. This method has provided very good control of SCA infestations in grain sorghum and could be a good alternative for forage sorghum. Further studies are needed to evaluate the use of other aphicides for SCA control with this application method. Sefina® (Afidopyropen) by BASF looks to be promising for SCA control, but it is not expected to be labeled for use in sorghum until 2020 or later.

Forage sorghum production in the Texas High Plains has been negatively impacted by the SCA. Without knowing anything about the damage potential of the SCA on forage sorghums grown for silage, farmers and crop advisors relied on past experiences of how they managed other aphid pests when making control decisions for SCA. Therefore, this study was designed to determine the relationship of SCA infestation levels to the damage potential for forage yield loss and silage quality so that management decisions could be based on results of actual SCA damage to forage sorghums.

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Table 14. Mean value for 2017 forage quality components when analyzed by a factorial design for treatment by ensiled days.

	% (Dry Matter Basis)							
Treatment	CP	Lignin	Starch	ADF	aNDF	uNDFom240	NDFD240	IVTDMD48
Untreated	8.4 c	6.10 a	11.6 b	41.4 a	59 a	19.9 a	67.7 ab	70.2 b
Warrior II 1.92 fl. oz	8.7 bc	5.72 a	13.6 b	39.6 a	56.9 a	19.1 ab	68.6 a	72.8 b
Lorsban Advanced 16 fl. oz	9.2 abc	5.11 b	22.7 a	33.5 b	49.7 b	18.2 bc	64.4 abc	77.9 a
Intruder 1.0 fl. oz	9.1 abc	5.10 b	25.0 a	32.6 b	47.6 b	18.3 bc	62.8 c	80.3 a
Sivanto 5 fl. oz	9.2 abc	5.10 b	25.2 a	31.8 b	46.9 b	17.4 c	63.6 bc	78.8 a
Sivanto 7 fl. oz	9.6 a	5.07 b	21.6 a	32.9 b	48.5 b	17.3 c	65.6 abc	79.3 a
Sivanto 10 fl. oz	9.4 ab	4.98 b	22.8 a	32.2 b	48.1 b	17.7 c	64.4 bc	79.7 a
LSD	0.8	0.5	6.9	4.6	6.0	1.4	4.3	4.8
Treatment P>F Values	0.0015	<.0001	<.0001	<.0001	<.0001	<.0001	0.006	<.0001

	% (Dry Matter Basis)							
Ensiled Days	CP	Lignin	Starch	ADF	aNDF	uNDFom240	NDFD240	IVTDMD48
0	9.4 a	5.5 a	23.3 a	35.6 a	52.4 a	19.8 a	63.7 b	77.9 a
60	8.7 b	5.1 b	17.4 b	34.1 a	49.5 b	16.8 b	66.8 a	76.1 b
LSD	0.3	0.2	2.4	1.6	2.1	0.5	1.5	1.7
Ensiled P>F Values	<.0001	0.0001	<.0001	0.0769	0.065	<.0001	0.0002	0.0374
TRT*Ensiled P>F Values	0.5061	0.6736	0.6184	0.9426	0.8255	0.344	0.7691	0.1862

[a] Means in each column for treatment and ensiled days with the same letter are not significantly different, Tukey-Kramer method for multiple mean separation (P>0.05).

Table 14. continued

TRT	TDN		Milk/Ton		RFQ		pH	
Untreated	48.5	b	2625	b	76.9	b	----	
Warrior II 1.92 fl. oz	51.0	b	2782	b	85.2	b	----	
Lorsban Advanced 16 fl. oz	57.4	a	3189	a	111.4	a	----	
Intruder 1.0 fl. oz	58.9	a	3278	a	121.7	a	----	
Sivanto 5 fl. oz	58.8	a	3274	a	118.5	a	----	
Sivanto 7 fl. oz	58.4	a	3243	a	118.1	a	----	
Sivanto 10 fl. oz	59.5	a	3327	a	122.4	a	----	
LSD	5.3		345		24.1		0.24	
Treatment P>F Values	<.0001		<.0001		<.0001		0.0227	

Ensiled Days	TDN		Milk/Ton		RFQ		pH	
0	55.9	a	3089	a	108.1	a	5.77	a
60	56.2	a	3116	a	107.4	a	3.62	b
LSD	1.86		120		8.406		0.08	
Ensiled P>F Values	0.7666		0.6603		0.8653		<.0001	
TRT*Ensiled P>F Values	0.6419		0.6775		0.4494		0.2376	

[a] Means in each column for treatment and ensiled days with the same letter are not significantly different, Tukey-Kramer method for multiple mean separation (P>0.05).

Table 15. Mean value for 2019 forage quality components when analyzed by a factorial design for treatment across both ensiling periods.

	% (Dry Matter Basis)							
Treatment	CP	Lignin	Starch	ADF	aNDF	uNDFom240	NDFD240	IVTDMD48
Untreated 1	6.7 a	4.8 a	19.3 b	35.3 a	49.9 a	21.5 a	55.1 a	70.2 a
Untreated 2	7.0 a	4.4 a	23.3 ab	32.5 a	46.7 a	20.7 a	54.0 a	72.8 a
Malathion 1.5 pt	6.9 a	4.5 a	24.0 ab	32.6 a	46.0 a	20.9 a	52.8 ab	77.9 a
Sivanto 2.5 fl. oz	7.1 a	4.5 a	26.8 a	31.2 a	43.5 a	20.7 a	50.4 b	80.3 a
Sivanto 10 fl. oz	7.1 a	4.7 a	25.9 ab	31.6 a	44.0 a	21.0 a	50.1 b	78.8 a
Warrior II 1.92 fl. oz	6.9 a	4.6 a	21.2 ab	34.1 a	48.9 a	21.2 a	54.8 a	79.3 a
LSD	NS	NS	4.95	NS	NS	NS	3.67	NS
Treatment P>F Values	0.4689	0.2372	0.0389	0.0946	0.0460	0.3902	0.0266	0.2911

	% (Dry Matter Basis)							
Ensiled Days	CP	Lignin	Starch	ADF	aNDF	uNDFom240	NDFD240	IVTDMD48
0	6.3 b	4.9 a	25.8 a	33.0 a	46.5 a	21.6 a	51.5 b	71.7 b
60	7.6 a	4.3 b	20.4 b	33.1 a	47.2 a	20.4 b	54.7 a	73.8 a
LSD	0.3	0.2	2.4	1.6	2.1	0.5	1.5	1.7
Ensiled P>F Values	<0.0001	<0.0001	0.0016	0.7914	0.9796	<0.0001	0.0127	<0.0001
TRT*Ensiled P>F Values	0.3736	0.4167	0.9185	0.8902	0.9324	0.5000	0.9998	0.7643

[a] Means in each column for treatment and ensiled days with the same letter are not significantly different, Tukey-Kramer method for multiple mean separation (P>0.05).

Table 15. continued

TRT	TDN	Milk/Ton	RFQ	pH
Untreated 1	54.3 a	2988 a	99.9 a	4.71 a
Untreated 2	56.4 a	3129 a	111.0 a	4.56 b
Malathion 1.5 pt	56.3 a	3120 a	109.2 a	4.69 ab
Sivanto 2.5 fl oz	57.9 a	3222 a	117.3 a	4.83 a
Sivanto 10 fl oz	57.7 a	3224 a	116.2 a	4.86 a
Warrior II 1.92 fl oz	55.0 a	3032 a	103.4 a	4.63 ab
LSD	NS	NS	NS	0.24
Treatment P>F Values	0.0723	0.0588	0.0862	0.0227

Ensiled Days	TDN	Milk/Ton	RFQ	pH
0	56.3 a	3141 a	105.7 a	5.21 a
60	56.0 a	3081 a	112.0 a	4.23 b
LSD	NS	NS	NS	0.1124
Ensiled P>F Values	0.9941	0.3959	0.0590	<.0001
TRT*Ensiled P>F Values	0.9648	0.9669	0.9047	0.1975

[a] Means in each column for treatment and ensiled days with the same letter are not significantly different, Tukey-Kramer method for multiple mean separation (P>0.05).

Table 16. Mean value for 2019 forage quality components for fresh, un-ensiled forage (Day 0).

	% (Dry Matter Basis)															
Treatment	CP		Lignin		Starch		ADF		aNDF		uNDFom240		NDFD240		IVTDMD48	
Untreated 1	6.2	a	5.1	a	22.3	a	35.2	a	49.8	a	22.1	a	53.4	a	70.9	a
Untreated 2	6.4	a	4.7	a	25.3	a	32.9	a	46.5	a	21.1	a	52.6	a	72.1	a
Malathion 1.5 pt	6.2	a	4.9	a	26.2	a	32.7	a	46.2	a	21.5	a	51.5	ab	71.7	a
Sivanto 2.5 fl oz	6.3	a	4.7	a	30.6	a	30.4	a	42.5	a	20.9	a	49.0	b	73.0	a
Sivanto 10 fl oz	6.1	a	5.2	a	27.0	a	32.6	a	45.5	a	22.1	a	49.0	b	71.3	a
Warrior II 1.92 fl oz	6.2	a	4.9	a	23.5	a	34.1	a	48.6	a	21.7	a	53.4	a	71.2	a
LSD	NS		NS		NS		NS		NS		NS		3.67		NS	
Treatment P>F Values	0.9620		0.2712		0.3617		0.4560		0.4008		0.3478		0.3808		0.5010	

Table 16. continued

TRT	TDN		Milk/Ton		RFQ		pH	
Untreated 1	54.2	a	3002	a	96.7	a	5.25	a
Untreated 2	56.2	a	3123	a	107.0	a	5.15	a
Malathion 1.5 pt	56.3	a	3140	a	104.9	a	5.16	a
Sivanto 2.5 fl oz	58.6	a	3290	a	117.1	a	5.24	a
Sivanto 10 fl oz	57.3	a	3226	a	108.0	a	5.30	a
Warrior II 1.92 fl oz	55.1	a	3067	a	100.7	a	5.20	a
LSD	NS		NS		NS		NS	
Treatment P>F Values	0.3697		0.3264		0.0862		0.6656	

Table 17. Mean value for 2019 forage quality components after 60 days of ensiling.

	% (Dry Matter Basis)															
Treatment	CP		Lignin		Starch		ADF		aNDF		uNDFom240		NDFD240		IVTDMD48	
Untreated 1	6.8	a	4.5	a	13.6	a	37.3	a	53.3	a	20.9	a	59.3	a	72.2	a
Untreated 2	7.7	a	4.3	a	20.2	a	32.8	a	47.9	a	20.2	a	56.4	a	74.1	a
Malathion 1.5 pt	7.6	a	4.2	a	21.8	a	32.5	a	45.9	a	20.3	a	54.0	a	74.1	a
Sivanto 2.5 fl oz	7.9	a	4.4	a	23.0	a	32.0	a	44.5	a	20.5	a	51.7	a	74.3	a
Sivanto 10 fl oz	8.0	a	4.2	a	24.8	a	30.5	a	42.5	a	19.9	a	51.2	a	75.1	a
Warrior II 1.92 fl oz	7.5	a	4.4	a	19.3	a	33.8	a	49.0	a	20.9	a	55.7	a	73.0	a
LSD	NS		NS		NS		NS		NS		NS		NS		NS	
Treatment P>F Values	0.2304		0.4770		0.1436		0.4560		0.1646		0.6221		0.1450		0.5035	

Table 17. continued

TRT	TDN		Milk/Ton		RFQ		pH	
Untreated 1	52.8	a	2860	a	98.0	a	4.21	ab
Untreated 2	56.3	a	3106	a	112.5	a	4.01	b
Malathion 1.5 pt	56.4	a	3100	a	113.6	a	4.22	ab
Sivanto 2.5 fl oz	57.2	a	3154	a	117.4	a	4.43	a
Sivanto 10 fl oz	58.2	a	3223	a	124.4	a	4.42	a
Warrior II 1.92 fl oz	55.3	a	3046	a	106.2	a	4.07	b
LSD	NS		NS		NS		0.2786	
Treatment P>F Values	0.3050		0.3050		0.3133		0.0160	

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