FORAGE SORGHUM: *Sorghum bicolor* (L.) Monench 'SiloMilo'

THE EFFECTS OF FLUPYRADIFURONE APPLICATION METHOD ON SUGARCANE APHID, YIELD AND FEED QUALITY OF FORAGE SORGHUM IN CALIFORNIA, 2018

Nicholas Clark
UCCE, Kings, Tulare, and Fresno Counties
680 N. Campus Dr. Ste. A
Hanford, CA 93230
Phone: (559) 852-2788
Fax: (559) 582-5166
Email: neclark@ucdavis.edu

David Haviland
UCCE, Kern County
1031 S. Mt. Vernon Ave.
Bakersfield, CA 93307
Phone: (661) 862-6200
Fax: (661) 862-6208
E-mail: dhaviland@ucdavis.edu

Jeffrey A. Dahlberg
Kearney Agricultural Research & Extension Center
9240 S. Riverbend Ave.
Parlier, CA 93648
Phone: (559) 646-6060
Fax: (559) 646-6015
Email: jadahlberg@ucanr.edu

Brian Marsh
UCCE, Kern County
1031 S. Mount Vernon Ave.
Bakersfield, CA 93307
Phone: (661) 868-6210
E-mail: bmarsh@ucanr.edu

Bob Hutmacher
West Side Research and Extension Center
17353 W Oakland Ave.
Five Points, CA 93624
Phone: (559) 884-2412
Email: rbhutmacher@ucdavis.edu

Jennifer Heguy
UCCE Stanislaus, San Joaquin, and Merced Counties
3800 Cornucopia Way, A
Modesto, CA 95358
Phone: (209) 525-6800
Email: jmheguy@ucdavis.edu

Stephanie Rill
UCCE, Kern County
E-mail: smrill@ucanr.edu

Jorge Angeles
UCCE, Tulare County
E-mail: jaangeles@ucanr.edu

Pest: Sugarcane Aphid (SCA): *Melanophis sacchari (*Zehntner)

Introduction

During 2018, we conducted a trial in Five Points, California (CA), to evaluate the impact of flupyradifurone (Sivanto HL) application rate and method on the density of Sugarcane Aphid

(SCA) in forage sorghum. The field site was planted on 26 Jun, to the sorghum cultivar SiloMilo at 100,000 clothianidin (NipsIt Inside) and fluxofenim (Concep III) commercially treated seeds/acre to moisture on 30” beds. Plots were eight beds wide and approximately 40 feet long and were organized into a randomized complete block design with four replications. Fertilizer, irrigation, and weed management programs were executed according to industry standard practices for the region. Statistics were performed using Microsoft Excel 2016 for correlation and regression analyses and SPSS version 25 to perform ANOVA on yield, % dry matter at harvest, aphids/leaf, and aphid-days. Aphids/leaf were square root transformed before ANOVA.

We evaluated five combinations of application type and product rate (Table 1). At planting, the in-furrow flupyradifurone soil treatments were applied as a spray on seeds before the furrow was closed by the planter. On 30 Jul, side-dress flupyradifurone soil treatments were applied during furrow cultivation and nitrogen (N) fertilizer injection at layby. On 16 Aug, SCA were collected from commercial fields in Tulare County, CA, transported to the research plots, and distributed onto the sorghum leaves. SCA populations were allowed to establish in the field and increase naturally for fifteen days before foliar flupyradifurone treatment was applied. Foliar insecticides were applied in 30 GPA of water just prior to initiation of sorghum heading on 31 Aug using a high clearance spray rig with an 8-row boom.

Aphid populations were monitored approximately once weekly from introduction to the plots through harvest by counting the number of aphids on 20 mid-canopy leaves per plot. The numbers of cumulative aphid-days for each plot were calculated by multiplying the number of SCA at 4 DAI (days after introduction) by 4 days, then for the other evaluation dates calculating the average SCA per leaf for the current and previous sample date and multiplying by the number of days between evaluations, and then calculating the sum of the aphid-days from all evaluation dates.

The middle two rows of each plot were harvested on 17 Oct. Plot weights and lengths were measured to estimate yield (Table 2), and sub-samples for calculating percent dry matter and determining forage feed quality were obtained. Dried sub-samples were sent to a feed quality analytical lab for wet chemistry analyses of several critical factors (Table 3).

Results and discussion

Sugarcane Aphid Control Efficacy

There were significant differences in SCA density 4DAI and 11DAI (Table 1 & Figures 1-2). Plots receiving in-furrow or side-dress treatment treatments of Sivanto had lower aphid densities than plots that had not received treatment (Check and Sivanto foliar). After foliar treatment the lowest SCA densities were in plots treated by foliar and soil application with the in-furrow 4 fl oz rate significantly better than all other treatments and the side-dress 4 fl oz rate similar to the check. Between 7DAT and 21DAT, the foliar and in-furrow treatments had the least aphids with the check still significantly higher than all other treatments. At 28DAT, only the foliar and in-furrow treatments controlled aphids whereas the side-dress and check treatments were statistically similar and all above the aphid treatment threshold of 50 aphids/leaf. The lowest SCA cumulative aphid-days were in plots treated with flupyradifurone in-furrow at 4 fl oz and was significantly lower than the check, but not any other treatment. In summary, the in-furrow treatments resulted in the longest reduction in aphid numbers, yet the foliar treatment controlled aphid numbers throughout the duration of the trial. Side-dress treatments provided short-term control of aphids with numbers beginning to increase from other treatments between 14DAT and 21DAT.

All flupyradifurone treatments resulted in good control of SCA, albeit at different times throughout the season. From the observations within this trial and the data presented in this report it is apparent that a treatment recommendation to a grower should include consideration of the planting date, relative area-wide SCA pressure, and crop stage at which SCA infestation is estimated or observed to occur. Our results show that a grower may opt to treat the soil at planting and expect season-long control of the aphid. Otherwise, if planting early and seasonal SCA pressure is yet unknown, a grower may opt to wait until layby and decide whether or not to include a side-dress treatment with a UN-32 injection below the furrow. Since this side-dress treatment was observed to lose efficacy toward the end of the season under SCA pressure, a grower may then opt to continue observing SCA pressure within the field after a side-dress treatment and decide whether or not to follow-up with a foliar treatment. One secondary benefit to consider with the side-dress treatment is that flupyradifurone was observed to be compatible in a tank mix with UN-32, so growers may opt to take advantage of including this method of flupyradifurone application in their typical layby operations to fertilize, cultivate weeds, and prepare furrows for irrigation, as a means of saving fuel and labor costs. Finally, foliar treatment with flupyradifurone at the threshold of 50 aphids/leaf again was observed to control SCA well for at least 3-4 weeks after treatment.

Treatment and Aphid Population Impact on Yield

When analyzed as distinct treatments, no rate and application method combination of flupyradifurone had a statistically significant effect on corrected dry matter yield ($p = 0.06$) or percent dry matter of harvested material ($p = 0.61$) (Table 2 & Figures 3-4). The in-furrow (at planting) treatments, the foliar treatment, and the high rate of side-dress treatment did apparently impart average yield protection relative to the untreated control with mean differences ranging from 2.2 to 5.5 tons/acre at 30% dry matter.

Treatments were then grouped for analyses according to application mode (by soil at planting, by soil at side-dress, and by foliar application at the insect treatment threshold of 50 aphids/leaf) and relative rate (low versus high). There were no statistically significant differences of yield or harvested dry matter, neither as a main effect of application mode ($p = 0.08$, and 0.30, for yield and dry matter, respectively) nor of relative rate ($p = 0.98$, and 0.65, for yield and dry matter, respectively) (Figures 5-6). It did appear that rate of flupyradifurone did not matter so much as whether or not it was applied, where on average application of flupyradifurone did protect yield relative to the untreated control. Application mode did appear to impact yield protection. The order of least to greatest yield protection between application methods was side-dress, in-furrow, and foliar. No significant treatment interactions were detected.

Impacts of aphid population, measured as cumulative aphid-days, on yield and dry matter percent at harvest were estimated by performing correlation and linear regression analyses. Aphid-days significantly and directly correlated with harvested dry matter percentage ($R = 0.496$, $R^2 = 0.246$, $p = 0.014$) (Figure 7). Though correlation was low, it is estimated that for every cumulative 2,000 aphid-days, harvested dry matter percent will increase by 3%. This is something to consider since this is not from dry matter accumulation (increase in carbohydrates) but rather plant moisture loss and thus reflects a risk of negatively impacting the ability to build desirable quality silage structures. Correlation was even lower between aphid-days and yield and a linear regression was not statistically significant ($R = 0.318$, $R^2 = 0.101$, $p = 0.130$) (Figure 8). While it appeared that increasing aphid-days tended to relate to decreased yields, this observation was not supported by statistical significance.

Treatment and Aphid Population Impact on Forage Feed Quality

There were neither strong correlations nor statistically significant linear regression effects of cumulative aphid-days on any of the tested feed quality parameters (data not shown). One hypothesis is that cumulative aphid-days by nature obfuscates effects of aphid feeding synchronized with specific crop phenological stages when particular feed quality parameters are being determined. This study demonstrated that various methods of flupyradifurone application imparted control of SCA at different times relative to crop phenological development.

Flupyradifurone rate and treatment combinations did have significant impacts on several feed quality components (Table 3). Both in-furrow and the foliar treatments significantly lowered the ADF relative to the untreated control. The side-dress treatments had intermediate effects on ADF levels. The high rate of the in-furrow and the foliar treatment significantly lowered the aNDF relative to the untreated control. The low rate of the in-furrow and both side-dress treatments had intermediate effects on aNDF levels. Both side-dress treatments significantly increased tNDFD30 and tNDFD30om relative to the low rate of the in-furrow treatment. The untreated control, foliar, and high rate of the in-furrow treatments had intermediate effects on tNDFD30 and tNDFD30om levels. The high rate of the in-furrow, both side-dress, and the foliar treatments significantly lowered the uNDF30 relative to the untreated control. The high rate of the in-furrow and the foliar treatments significantly increased NFC relative to the untreated control. Both side-dress and the low rate in-furrow treatments had intermediate effects on NFC levels.

When treatments were grouped by application mode or relative rate of flupyradifurone and analyzed for their effect on feed quality, several feed quality parameters were significantly impacted by application mode (Table 4). Insecticide rate had no significant effect on any feed quality parameter (data not shown). Grouping treatments in this manner demonstrated the underlying effect of flupyradifurone treatment on feed quality parameters was likely due to the time at which aphid control was achieved relative to crop growth stages.

Summary

Aphid pressures achieved in the 2018 season were low-moderate as the season progressed. All flupyradifurone treatments significantly lowered the number of SCA in plots, though the side-dress treatments tended to lose efficacy earlier than the in-furrow treatments and the foliar treatments. Though there were no significant effects of treatment on crop yield or percent dry matter at harvest, there were nominal differences between treatments. The tendency was that use of flupyradifurone on average protected yield relative to the untreated control. The persistent control treatments (in-furrow and foliar) tended to keep harvested percent dry matter lower than the untreated control as well as the side-dress treatments which demonstrated good control but lost efficacy later in the season. Cumulative aphid-days was significantly, positively correlated with harvested percent dry matter (really a lack of moisture) and should be considered as the primary concern when considering control methods of SCA in forage sorghum if the crop will be put up in silage. It's also apparent that control of aphids at critical stages of crop development has significant effects on various, important feed quality factors. This last point is particularly important as many growers in the San Joaquin Valley of CA will increase their sorghum acreage when irrigation water availability is low or soil quality is too marginal for high corn production. Replacement of corn with forage sorghum when SCA can significantly, negatively impact forage feed quality is a critical issue and under these conditions probably poses the most important economic consideration for dairy operators, forage growers, and animal nutritionists when they are coordinating plans to produce quality feed for dairy animals' health and productivity.

Acknowledgments

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Tables and Figures

Table 1. The effects of insecticide treatments on aphid density

Treatment	Rate form prod/acre	Mean SCA per leaf							
		4DAI[1] 8/20/18	11DAI 8/27/18	4DAT[2] 9/4/18	7DAT 9/7/18	14DAT 9/14/18	21DAT 9/21/18	28DAT 9/28/18	Cum. Aphid-Days
Check	-	32.5	38.9b	29.7c	38.7c	64.1d	336.4d	120.8b	4118.7b
Sivanto HL in-furrow	4.0 fl oz	0.0	0.8a	0.9a	2.0a	2.2a	14.9a	29.5a	243.9a
Sivanto HL in-furrow	5.0 fl oz	2.5	18.8a	16.9b	6.5a	9.4b	45.0b	40.1a	806.4ab
Sivanto HL foliar[3]	3.5 fl oz	27.5	86.3b	7.5b	3.4a	4.5a	13.9ab	25.3a	1129.1ab
Sivanto HL side-dress[4]	2.5 fl oz	1.5	3.7a	11.7b	16.5b	17.0bc	173.6c	90.1b	1835.5ab
Sivanto HL side-dress[4]	4.0 fl oz	6.3	2.0a	18.9bc	18.4b	19.7c	138.5c	76.8b	1634.4ab
	F	3.3	10.3	11.9	37.3	50.4	96.4	30.8	3.4
	P	0.034	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.026

Means in a column followed by the same letter are not significantly different; P =0.05, Tukey's HSD.

[1] "Days after introduction" of SCA to plots

[2] "Days after treatment" with foliar spray

[3] Included 8 fl oz/ac of R-11 as a surfactant

[4] Included 100 lbs N/ac as UN32 fertilizer

Table 2.

Treatment	Rate form prod/acre	30% DM Yield ± SD (tons/acre)	Harvested % DM ± SD
Check	-	21.9 ± 1.5	34.8 ± 4.7
Sivanto HL in-furrow	4.0 fl oz	25.6 ± 2.4	29.9 ± 2.4
Sivanto HL in-furrow	5.0 fl oz	24.6 ± 2.1	31.5 ± 5.0
Sivanto HL foliar[1]	3.5 fl oz	27.4 ± 2.8	31.6 ± 3.4
Sivanto HL side-dress[2]	2.5 fl oz	23.2 ± 2.6	34.4 ± 7.8
Sivanto HL side-dress[2]	4.0 fl oz	24.1 ± 4.3	35.1 ± 5.5
	Statistical sig. (α=0.05)	N.S.	N.S.

[1] Included 8 fl oz/ac of R-11 as a surfactant

[2] Included 100 lbs N/ac as UN32 fertilizer

Table 3. Proximal analyses of select forage sorghum feed quality parameters as affected by flupyradifurone treatment expressed as mean percent of sample dry matter

Treatment	Rate form prod/acre	CP	Ash	ADF	aNDF	Lignin	Starch	Fat	tNDFD 30[1]	tNDFD 30 om[1]	uNDF 30[1, 2]	NFC
Check	-	6.4	12.3	41.6 a	58.7 a	5.7	6.0 b	1.8	48.7 ab	53.6 ab	30.1 a	22.0 b
Sivanto HL in-furrow	4.0 fl oz	6.9	11.9	36.2 b	52.3 ab	5.3	13.7 ab	2.0	44.5 b	47.9 b	29.0 ab	28.1 ab
Sivanto HL in-furrow	5.0 fl oz	7.1	11.0	33.9 b	47.6 b	5.2	19.5 a	2.1	46.2 ab	50.7 ab	25.6 c	33.2 a
Sivanto HL foliar[c]	3.5 fl oz	7.1	10.9	34.8 b	48.9 b	5.4	19.0 a	1.8	45.4 ab	49.5 ab	26.2 bc	32.3 a
Sivanto HL side-dress[d]	2.5 fl oz	6.8	11.4	37.6 ab	54.2 ab	5.4	12.0 ab	2.1	50.4 a	54.9 a	26.9 bc	26.6 ab
Sivanto HL side-dress[d]	4.0 fl oz	6.6	12.1	38.4 ab	54.8 ab	5.3	9.8 ab	2.1	50.5 a	54.7 a	27.0 bc	25.5 ab
	F	0.808	1.063	6.665	6.094	0.206	3.314	1.032	4.132	4.301	2.815	4.562
	P	0.559	0.413	0.002	0.002	0.956	0.027	0.429	0.011	0.009	0.048	0.007

[1] Percent of NDF

[2] Post hoc means separation test was Fisher's LSD due to failure of Tukey HSD to find a significant difference.

Means within a column followed by the same lowercase letters are not significantly different at α = 0.05 according to Tukey HSD.

Table 4. Proximal analyses of select forage sorghum feed quality parameters as affected by mode of flupyradifurone application expressed as mean percent of sample dry matter

Treatment	Rate form prod/acre	CP	Ash	ADF	aNDF	Lignin	Starch	Fat	tNDFD 30[1]	tNDFD 30 om[1]	uNDF 30[1]	NFC
Check	-	6.4	12.3	41.6 a	58.7 a	5.7	6.0 b	1.8	48.7 ab	53.6 ab	30.1	22.0 b
In-furrow	4 fl oz	7.0	11.5	35.1 b	49.9 b	5.2	16.6 a	2.0	45.3 b	49.3 b	27.3	30.7 a
Side-dress	5 fl oz	6.7	11.8	38.0 ab	54.5 ab	5.4	10.9 ab	2.1	50.4 a	54.8 a	27.0	26.0 ab
Foliar	3.5 fl oz	7.1	10.9	34.8 b	48.9 b	5.4	19.0 a	1.8	45.4 b	49.5 b	26.2	32.3 a
	F	0.824	0.795	5.049	6.104	0.093	4.125	0.759	8.764	8.157	1.019	4.788
	P	0.455	0.468	0.021	0.009	0.911	0.035	0.483	0.002	0.003	0.381	0.022

[1] Percent of NDF

Means within a column followed by the same lowercase letters are not significantly different at α = 0.05 according to Tukey HSD.

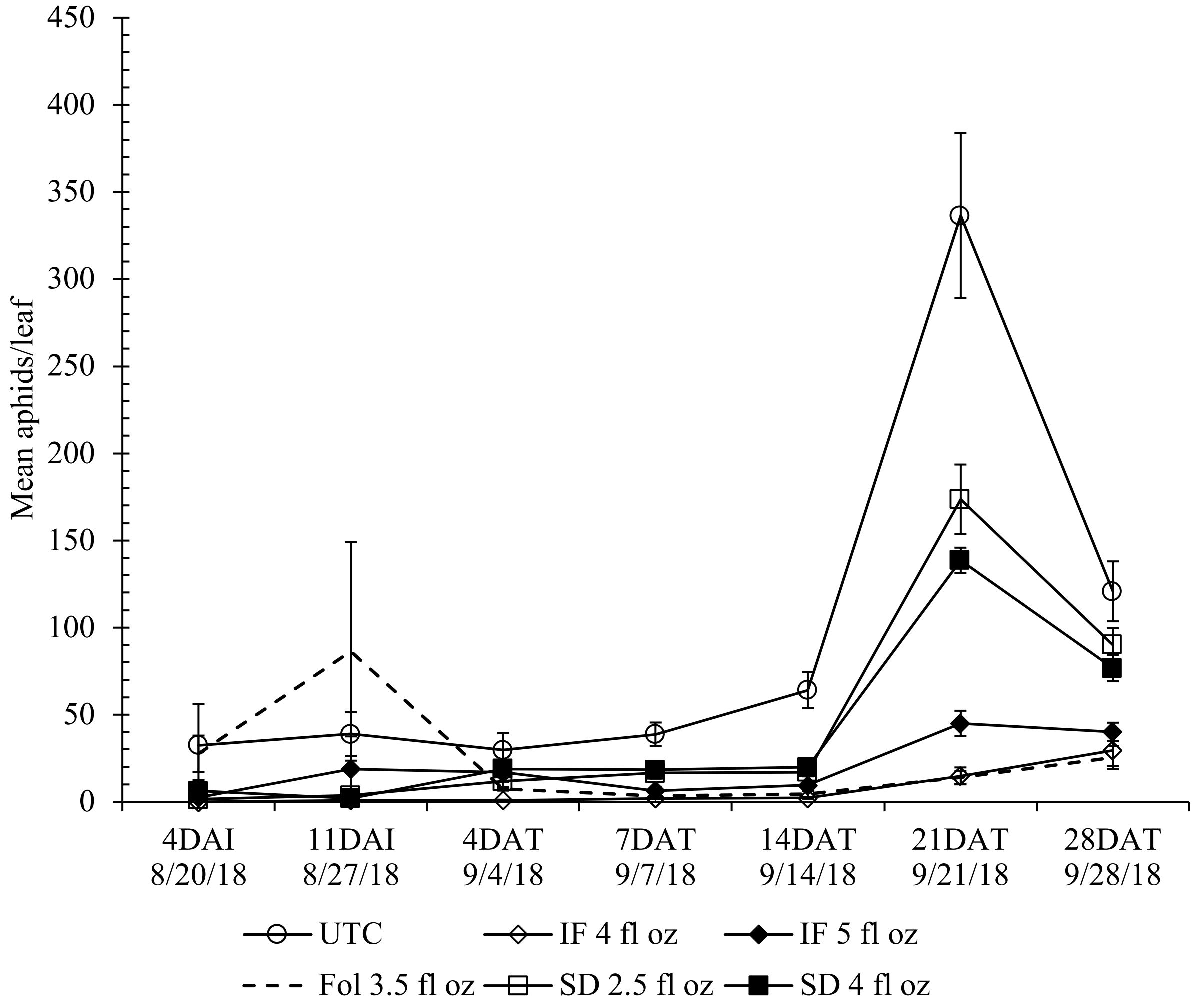

Figure 1. Flupyradifurone rate and application mode treatment effect on mean aphids/leaf over time. Bars represent the standard deviation.

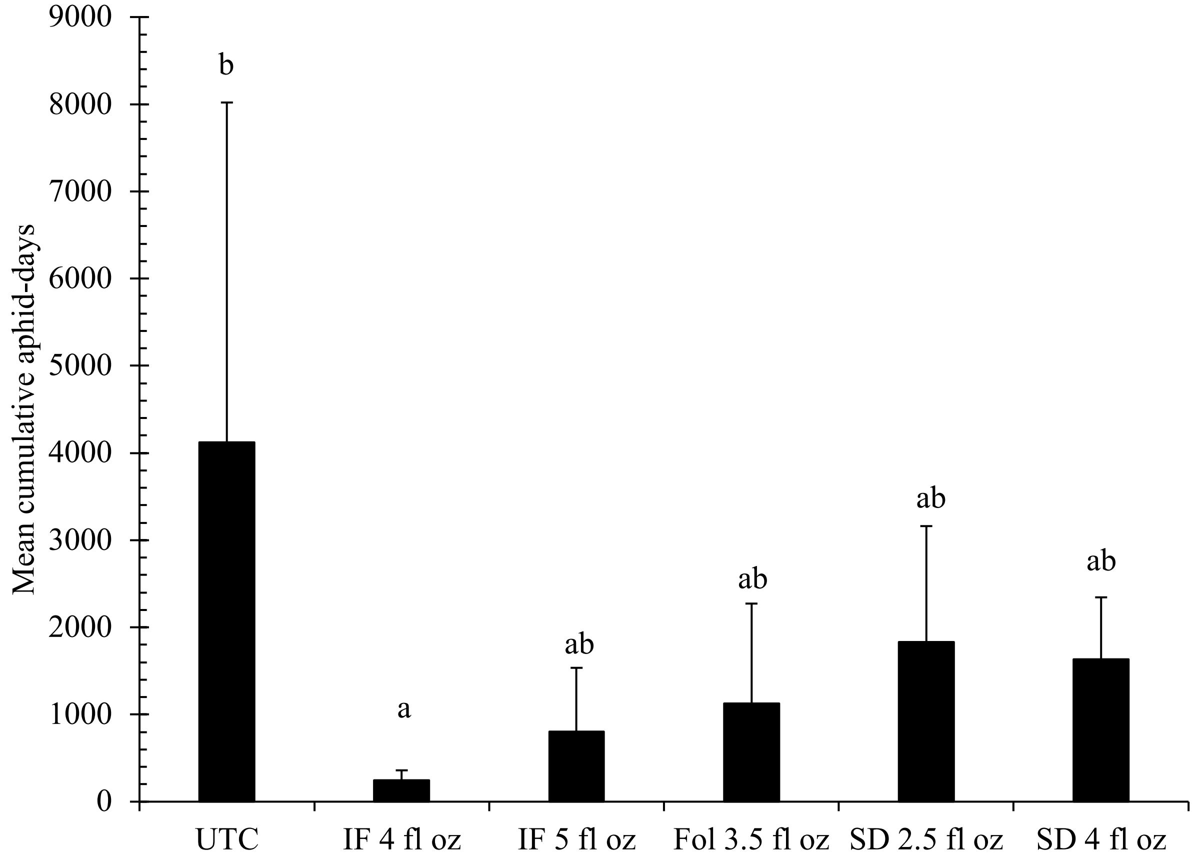

Figure 2. Flupyradifurone rate and application mode treatment effect on mean SCA cumulative aphid-days

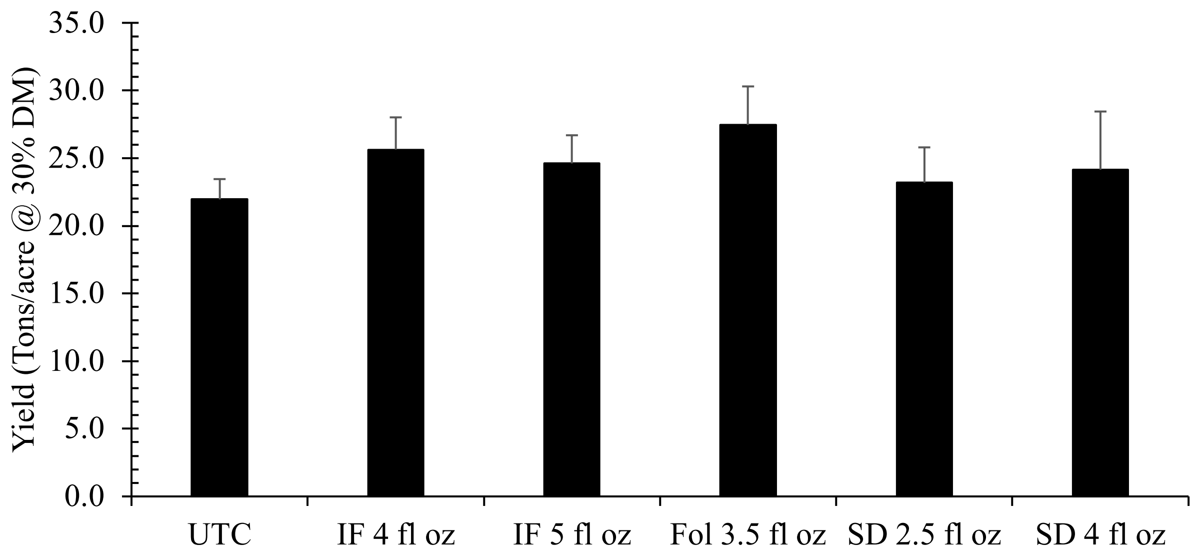

Figure 3. Effect of flupyradifurone rate and application mode treatment on yield

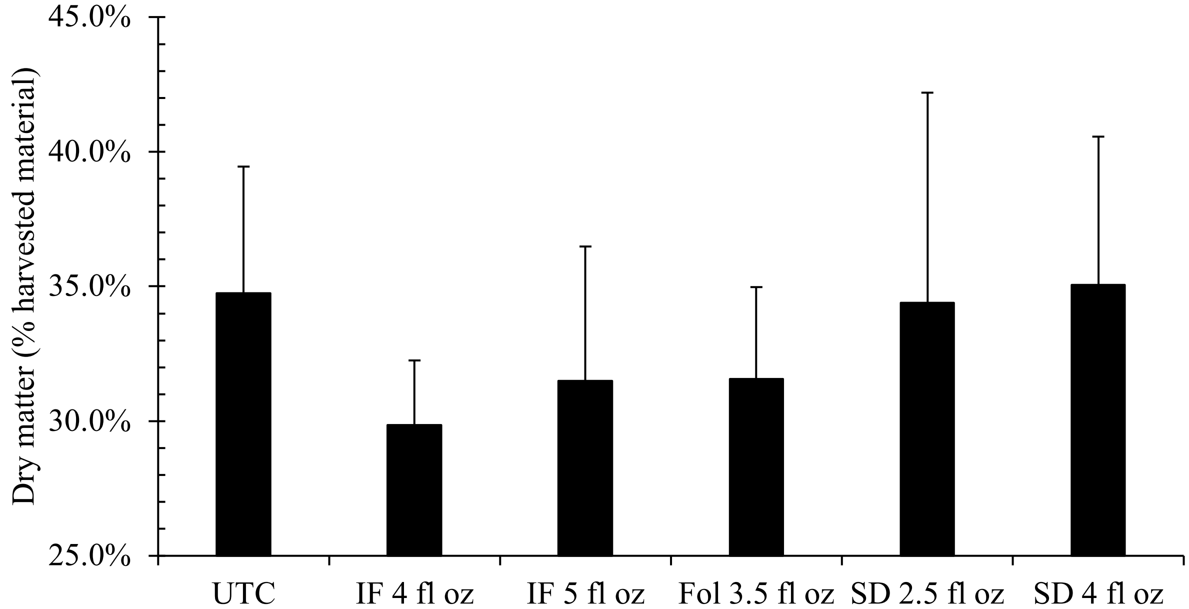

Figure 4. Effect of flupyradifurone rate and application mode treatment on harvested dry matter percent

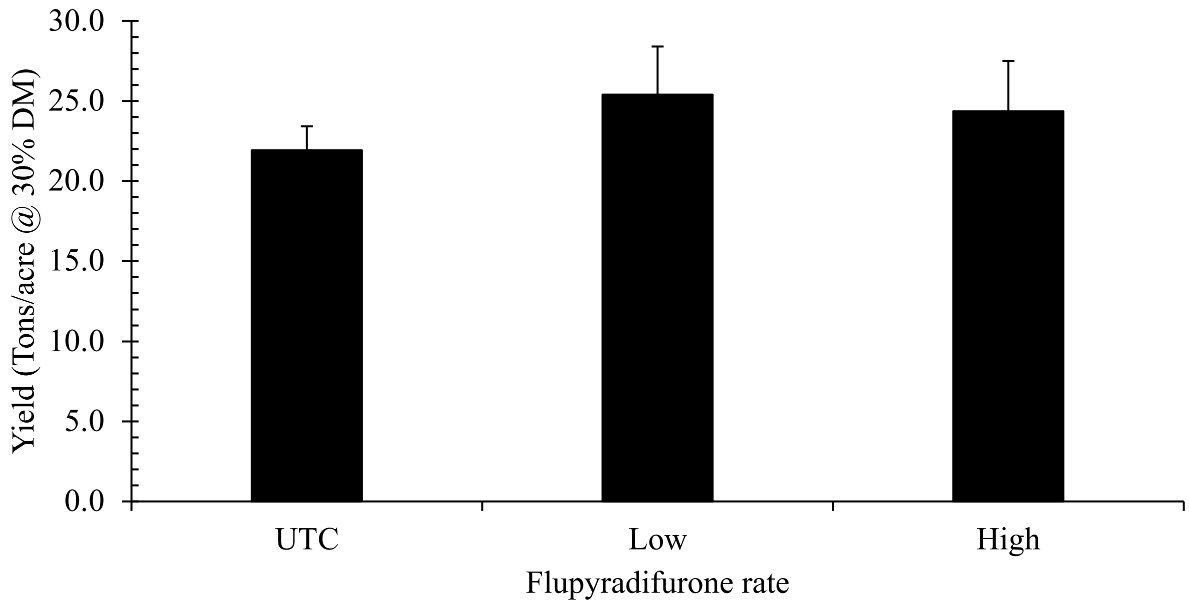

Figure 5. Effect of relative flupyradifurone rate on forage sorghum yield

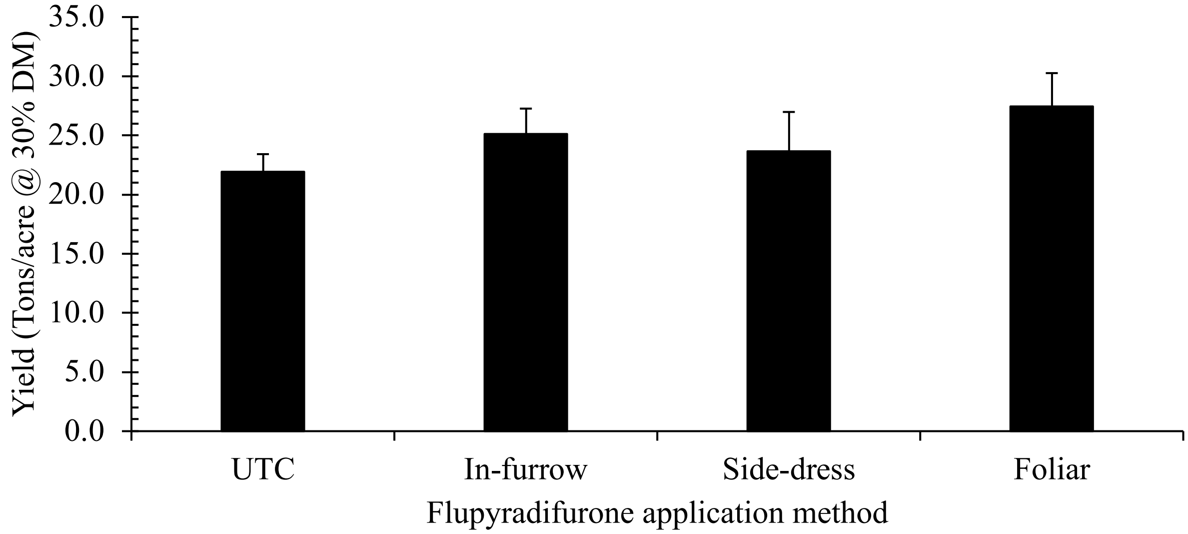

Figure 6. Effect of flupyradifurone application mode on forage sorghum yield

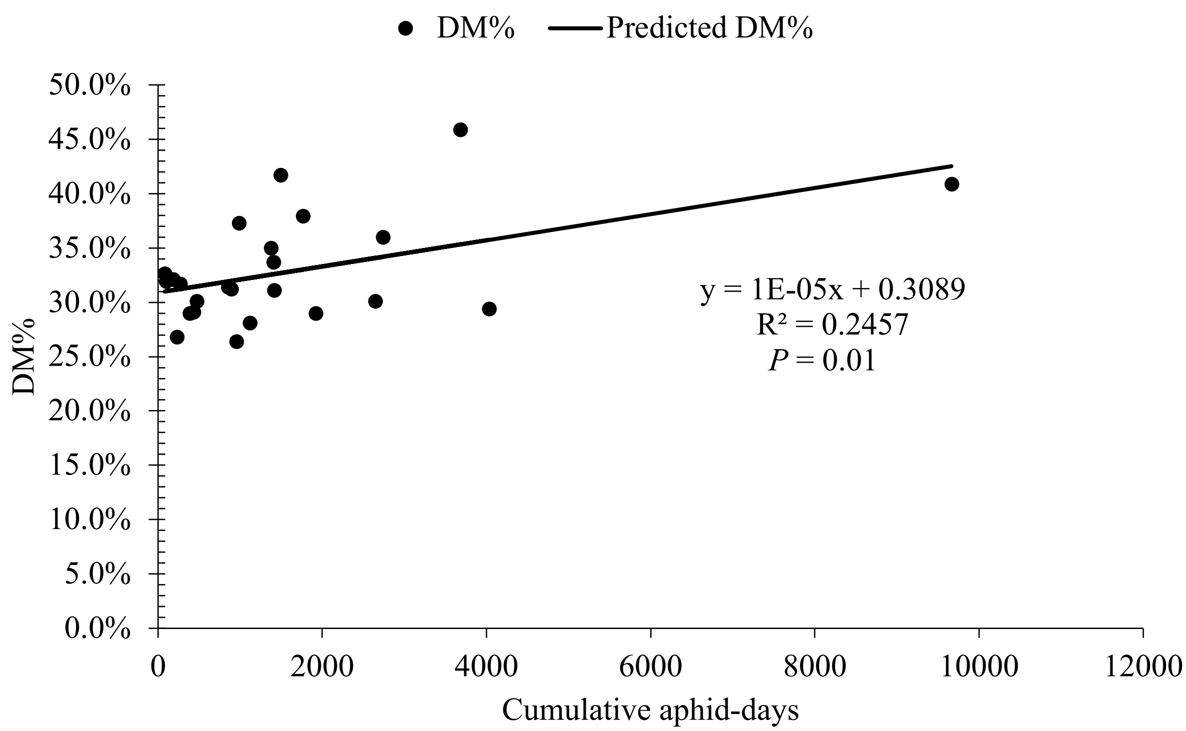

Figure 7. Cumulative aphid-days effect on harvest DM%

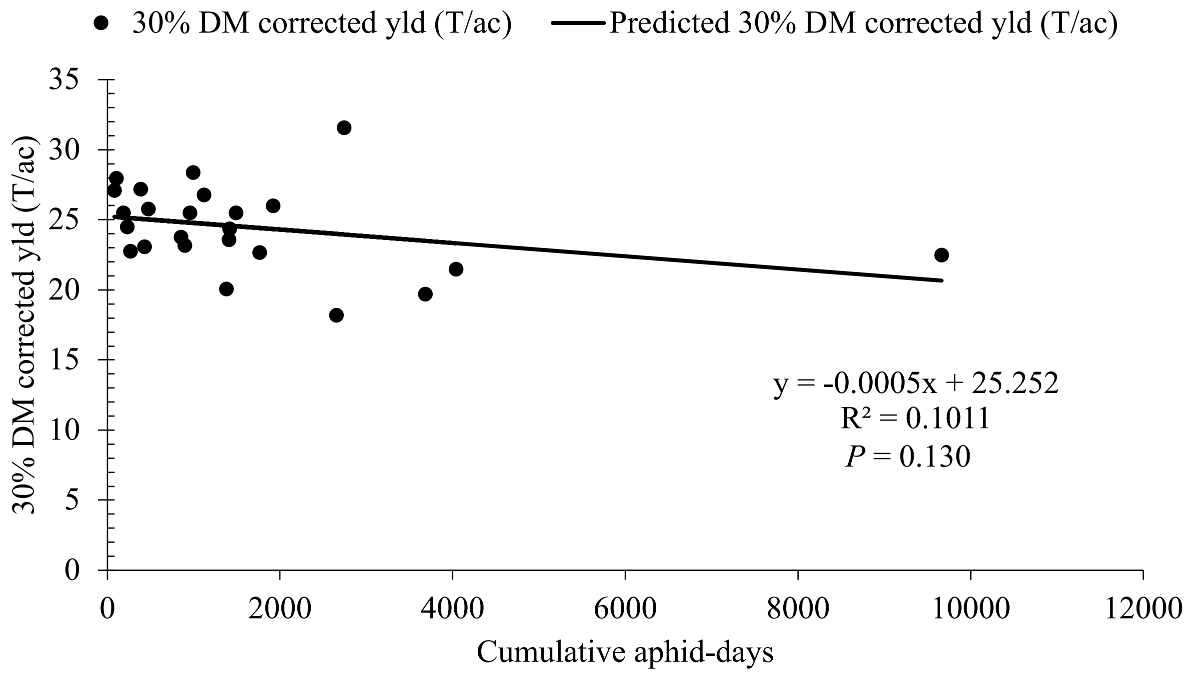

Figure 8. Cumulative aphid-days effect on yield