2025 WESTERN KANSAS AGRICULTURAL RESEARCH REPORT

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Research and Extension

KANSAS STATE UNIVERSITY AGRICULTURAL EXPERIMENT STATION AND COOPERATIVE EXTENSION SERVICE

2025 WESTERN KANSAS AGRICULTURAL RESEARCH

Contents

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Weather Information, Tribune, KS 2024

Amanda Burnett

In 2024, annual precipitation of 20.87 inches was recorded, which is 2.43 inches above normal. Five months had above-normal precipitation. May (4.87 inches) was the wettest month. The largest single amount of precipitation was 1.63 inches on August 23. December, the driest month, recorded 0.00 inch of precipitation.

Snowfall for the year totaled 12.8 inches (8.9 inches below normal); January, February, and March had 9.1, 3.1, and 0.6 inches, respectively. There was a total of 22 days of snow cover, which is three days below normal. The longest consecutive period of snow cover, 18 days, occurred January 5 to January 22.

Record-high temperatures were recorded on two days: March 3 (80°F), and October 6 (97°F). Historical record-high temperatures were tied on one day: October 11 (90°F). Record-low temperatures were recorded on two days: January 14 (-17°F), and August 9 (50°F). Historical record-low temperatures were tied on one day: August 10 (49°F). June was the warmest month with a mean temperature of 73.2°F. The hottest day of the year (105°F) occurred on July 14. The coldest day of the year (-18°F) occurred on January 16. January was the coldest month with a mean temperature of 23.7°F.

Mean air temperature was below normal for six months. February had the greatest departure above normal (4.6°F), and January had the greatest departure below normal (-6.5°F). Temperatures were 100°F or higher on nine days, which is four days below normal. Temperatures were 90°F or higher on 62 days, which is four days below normal. The latest spring freeze was April 22, which is 12 days earlier than normal; the earliest fall freeze fell on October 14, which is seven days later than normal. This produced a frost-free period of 175 days, which is 19 days greater than the normal 156 days.

Open-pan evaporation from April through September totaled 67.81 inches, which is 2.46 inches below normal. Wind speed for this period averaged 4.1 mph, which is 0.9 mph less than normal.

Table 1. Weather data, Southwest Research-Extension Center, Tribune, KS, 2024.

	Precipitation		Temperature: 2024 Average		Temperature: Normal		Temperature: 2024 Extreme		Wind		Evaporation	
Month	**2024**	**Normal**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**2024**	**Normal**	**2024**	**Normal**
	--------- in. ---------		---------------------------- °F ----------------------------						-------- mph -------		--------- in. ---------	
January	0.98	0.43	37.9	9.5	44.2	16.1	65	-18	---	---	---	---
February	0.61	0.54	54.1	21.2	47.2	18.7	74	5	---	---	---	---
March	0.10	0.99	58.9	20.8	56.9	26.5	80	8	---	---	---	---
April	0.88	1.66	69.7	32.3	64.9	34.6	89	20	4.4	5.6	9.55	8.06
May	4.87	2.23	75.2	42.6	74.6	46.0	88	33	4.3	5.2	11.77	11.73
June	2.28	2.77	89.3	57.0	86.2	56.6	101	47	4.9	5.2	13.51	14.27
July	2.79	3.14	87.2	56.8	91.4	61.7	105	50	3.2	4.8	12.14	15.11
August	3.51	2.87	88.8	56.9	88.2	59.8	103	48	3.5	4.3	10.53	11.67
September	0.60	1.13	85.2	48.1	81.4	50.8	95	38	4.0	4.7	10.31	9.43
October	1.09	1.59	76.6	35.2	68.3	36.7	97	10	4.2*	4.2*	7.84*	6.01*
November	3.16	0.53	54.8	23.9	54.7	25.6	70	8	---	---	---	---
December	0.00	0.56	52.5	16.5	44.8	17.2	68	5	---	---	---	---
ANNUAL	20.87	18.44	69.2	35.1	66.9	37.5	105	-18	4.1	5.0	67.81	70.27

Normal latest freeze (32°F) in spring:	May 4	2024	April 22
Normal earliest freeze (32°F) in fall:	October 7	2024	October 14
Normal frost-free (>32 °F) period:	156 days	2024	175 days

Normal for precipitation, snowfall, and temperature is 30-year average (1991-2020) from National Weather Service.
Normal for latest freeze, earliest freeze, wind, and evaporation is 30-year average (1991-2020) from Tribune weather data.
* Normal for October wind and evaporation is 20-year average (2001-2020) from Tribune weather data; October **NOT** included in annual totals.

Weather Information for Garden City, 2024

Colt McElroy

Precipitation in Garden City, KS, for 2024 totaled 23.49 inches. This was 3.96 inches above the 30-year average of 19.53 inches. From January through the end of June, the station received 8.3 inches, which was 1.42 inches below normal for that point in the year. No significant hail was witnessed on the station in 2024. The largest precipitation amounts recorded were 3.94 inches in June, 6.09 inches in July, 3.43 inches in August, and 4.24 inches in November, Measurable snowfall for the year totaled 14.30 inches; January, February, and March had 9.3, 3.0 and 2.0 inches respectively.

Average daily wind speed was 5.16 mph compared to the 30-year average of 4.95 mph. Open pan evaporation was measured daily from April through October and totaled 83.49 inches. This was 9.48 inches above the 30-year average of 74.01 inches.

The mean annual air temperature was 56.8°F compared to the 30-year average of 54.3°F. Triple-digit temperatures were observed in June, July and August. The longest consecutive run of triple-digit days was observed from July 28 through August 1 with an average temperature of 103.6°F. August 19 exhibited the highest temperature of 110°F. The lowest temperature was observed on January 16 and 17 at -13°F.

The 2024 climate information for Garden City is summarized in Table 1.

			Monthly temperatures						Wind		Evaporation	
	Precipitation		2024 avg.			Mean	2024 extreme					
Month	2024	Avg.	Max	Min	Mean	30-year avg.	Max	Min	2024	30-year avg.	2024	30-year avg.
	------- in. -------		----------------------------- °F -----------------------------						------ mph ------		-------- in. --------	
January	0.71	0.47	37.3	14.0	25.6	31.1	67	-13	5.52	4.19	---	---
February	0.47	0.59	59.7	26.0	42.8	34.2	82	10	4.09	4.99	---	---
March	0.76	1.14	61.7	27.0	44.4	43.6	80	14	6.39	5.82	---	---
April	0.17	1.64	72.1	39.6	55.8	52.3	91	25	6.12	6.24	10.11	8.19
May	2.25	2.79	80.3	48.8	64.5	63.1	94	34	5.65	5.50	12.59	10.55
June	3.94	3.09	92.2	64.1	78.2	74.1	104	57	6.52	5.46	14.92	13.28
July	6.09	3.16	92.3	62.7	77.5	78.8	108	56	4.42	4.58	12.56	13.86
August	3.43	2.80	92.6	63.9	78.3	76.6	110	54	5.03	4.18	12.92	11.67
September	1.29	1.33	87.9	55.1	71.5	68.6	99	41	5.17	4.81	11.16	9.78
October	0.11	1.32	79.9	42.9	61.4	55.2	98	27	5.02	4.82	9.23	6.68
November	4.24	0.49	57.8	30.3	44.1	42.0	74	15	4.22	4.67	---	---
December	0.03	0.71	54.0	20.3	37.1	32.3	67	10	3.77	4.20	---	---
ANNUAL	23.49	19.53	72.3	41.2	56.8	54.3	110	-13	5.16	4.95	83.49	74.01

Normal latest spring freeze (32°F): April 29. In 2024: April 21
Normal earliest fall freeze (32°F): Oct. 13. In 2024: October 16
Normal frost-free period (>32°F): 168 days. In 2024: 178 days
30-year averages are for the period 1991-2020. All recordings were taken at 8:00 a.m.

Resistant Palmer Amaranth Seed Production and Retention in Kansas Soybean Production

Taylor Lambert and K.B. Jeremie Kouame

Summary
The effective management of Palmer amaranth (*Amaranthus palmeri*) seedbanks is a critical challenge in Kansas soybean production. This study investigates Palmer amaranth seed production and retention at the time of soybean harvest, providing insights into the weed's seed production in Kansas soybean fields and the potential effectiveness of harvest weed seed control tactics for its control. Data were collected from 12 counties in Kansas, where female Palmer amaranth plants were collected and seed and debris of the plant, fallen on the ground, were vacuumed. Results showed that female Palmer amaranth plants with an aboveground biomass of 0.3 and 0.4 lb produced on average 58,100 and 84,900 seeds, respectively. Moreover, approximately 97% of the seeds remained on the plant at harvest, suggesting that a Harvest Weed Seed Destruction (HWSD) strategy could be highly effective in reducing the number of Palmer amaranth viable seeds that return to the soil seedbank.

Introduction
Palmer amaranth is a highly invasive weed species that poses a significant threat to soybean production in Kansas. It has been reported to cause nearly 80% yield loss in Northeast Kansas (Bensch, et al., 2003). Also, Palmer amaranth in Kansas has developed resistance to WSSA Group 2 (chlorsulfuron, thifensulfuron, imazethapyr, and imazamox), Group 4 (2,4-D), Group 5 and 6 (atrazine and metribuzin), Group 9 (glyphosate), Group 14 (fomesafen and lactofen), and Group 27 (mesotrione and tembotrione) herbicides (Heap, 2024), leaving growers with very few postemergence options (Peterson and Jugulam, 2019). Its rapid growth and ability to produce large quantities of seed contribute to the development of persistent seedbanks, making it a challenge for farmers (Shaner and Beckie, 2014). In fact, a female Palmer amaranth plant can produce up to 600,000 seeds (Ward, 2013), with the majority of these seeds retained on the plant at the time of harvest and making seeds vulnerable to harvest weed seed control practices. Effective management strategies are necessary to control its spread and reduce its impact on crop yields. Harvest Weed Seed (HWSD) control is an emerging strategy that targets weed seeds during harvest, preventing them from entering the soil seedbank (Walsh and Powles, 2014). Various methods, such as mechanical harvest weed seed destructors, chaff lining, narrow windrow burning, and chaff carts have been explored and have shown promising results for long-term weed management (Schwartz-Lazaro et al., 2017; Walsh & Newman, 2007; Walsh et al., 2017; Walsh et al., 2017; Walsh et al., 2018; Walsh et al., 2018; Walsh et al., 2021). However, a critical step for their use is assessment of seed-retention of the most problematic weeds at crop maturity (Soni et al., 2020; Walsh et al., 2018; Walsh & Powles, 2014). This research aims to investigate the seed production and retention of Palmer amaranth at the time of soybean harvest, with the goal of evaluating the potential effectiveness of HWSD in Kansas soybean fields.

Procedures

Study area

Twelve thousand farmers plant soybeans on 4.5 million acres of Kansas production ground, averaging harvests of 40.5 bu/a. Some regions of Kansas are better suited for soybeans due to precipitation amounts in Kansas ranging from 6 to 38 inches a year. For the purposes of this study, 22 soybean fields were visited in 12 counties within one week of harvest (Figure 1).

Palmer amaranth biomass and seed collection processes

Two approaches are generally referred to in the scientific literature as ways to assess weed-seed retention: field surveys and periodic monitoring (Walsh et al, 2018). Our study used the field survey approach that involves randomly visiting fields at crop maturity, as it allows an estimation of seed retention as it typically occurs in commercial production environments (Walsh et al., 2018). Palmer amaranth plants were collected from 12 counties in Kansas where herbicide-resistant populations had been previously reported. In each county, one or two soybean fields were selected within one week of harvest. Three mature female Palmer amaranth plants were harvested from each field and bagged separately. For each plant, the surrounding ground, extending 1 ft beyond the plant's diameter, was vacuumed to collect any seed and debris that had fallen from the plant. These materials were also bagged separately. The plants were weighed to determine their biomass, and the seed was manually removed, cleaned, and weighed to determine the total amount of seed retained on the plant. The vacuumed debris samples were sifted and cleaned to collect seeds that had shattered off the plant before harvest. The weight of the collected seeds from both the plant and the vacuumed debris was recorded. On average, 100-seed weights were recorded on 36 subsamples and used to estimate the total number of seeds in each case.

Data analysis

The relationship between Palmer amaranth seed production and its aboveground biomass was evaluated by fitting the linear model to data across counties and fields with the lm function of the stats package in R software (v. 4.3.3; R Core Team 2024). A map of the visited fields and bar graphs of the percentage of Palmer amaranth seeds retained/shattered was also created using R software (v. 4.3.3; R Core Team 2024).

Results and Discussions

Palmer amaranth biomass and seed production in Kansas

Palmer amaranth seed production showed a strong relationship with the weed's aboveground biomass (Figure 2), with 78% of the variability in seed production explained by the linear regression ($R^2 = 0.78$). It could be predicted from the results that female Palmer amaranth plants with an aboveground biomass of 0.1, 0.2, 0.3, and 0.4 lb produced on average 4,600, 31,400, 58,100, and 84,900 seeds, respectively, in soybean fields in Kansas in 2023. Also, results revealed that we could expect an increase of 540 seeds for each increase in a female Palmer amaranth aboveground biomass (Figure 2).

Palmer amaranth's prolific seed production results in this study are consistent with previous research (Ward et al., 2013). Palmer amaranth plants that emerged between mid-June and late-July in 38-inch row-spacing soybean fields produced 19,618 seeds/sq. ft., while those in 7.5-inch row-spacing soybean fields produced 1,200.68 seeds/sq. ft.

(Jha et al., 2008). The relationship between Palmer amaranth biomass and seed production is not surprising. Previous research documented a strong relationship between the total amount of organic matter produced through photosynthesis (gross primary production) and grain yield of plants, with a well-defined relationship between plant productivity and the photosynthetically active radiation absorbed by the green portion of the vegetation (Gitelson et al., 2015).

Palmer amaranth seed retention in Kansas

Palmer amaranth seed retention varied between 90% and 100%, with an average of 97% of the seeds retained at harvest (Figure 3). The average number of seeds that remained on a single plant was 40,541 seeds, while 1471 seeds (3%) were lost to shattering. These findings suggest that Palmer amaranth seeds are largely retained on the plant and, if not effectively managed, are likely to enter the soybean combine, be mixed with the chaff and redistributed to the field with the potential of contributing to the increase of the soil seedbank.

Palmer amaranth biomass and seed production

The findings from this study demonstrate that Palmer amaranth retains the vast majority of its seed on the plant at harvest. Results are comparable to other data around the US. Previous research reported 98% seed retention at soybean maturity and 95% seed retention one month after soybean maturity (Norsworthy et al., 2014). Also, seed retention of Palmer amaranth in soybean fields was reported to range from 85% to 95% (Schwartz-Lazaro et al., 2017).

The high retention rate observed in this study makes it compelling for Kansas soybean farmers to integrate HWSC technologies into their harvest practices. The use of equipment such as the Seed Destructor or chaff carts can destroy or collect weed seeds during harvest and prevent them from contributing to the weed seedbank. By targeting the 97% of seeds that remain on the plant, HWSD offers an efficient and practical solution for managing multiple herbicide-resistant Palmer amaranth populations. While this study provides valuable insights into seed production and retention, it is limited to fields in Kansas and may not fully represent variability across different regions. Different management practices (herbicide programs, cover crops, etc.) will affect seed production in different ways. Future studies should explore the long-term effects of integrating HWSD strategies on Palmer amaranth seedbank dynamics and soybean yield.

Acknowledgments

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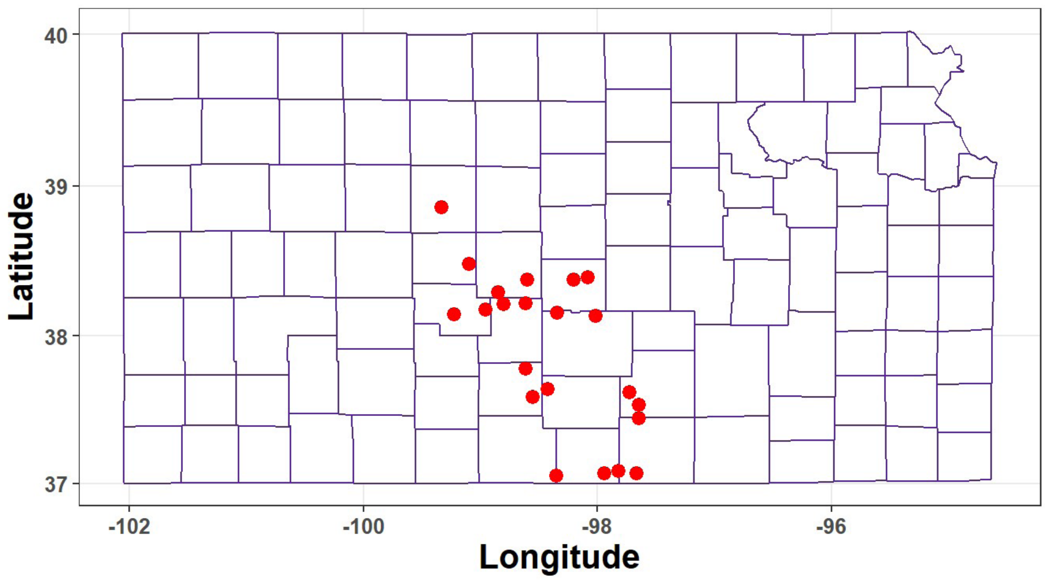

Figure 1. Distribution of soybean fields visited in 2023 for evaluating Palmer amaranth seed production and retention at harvest.

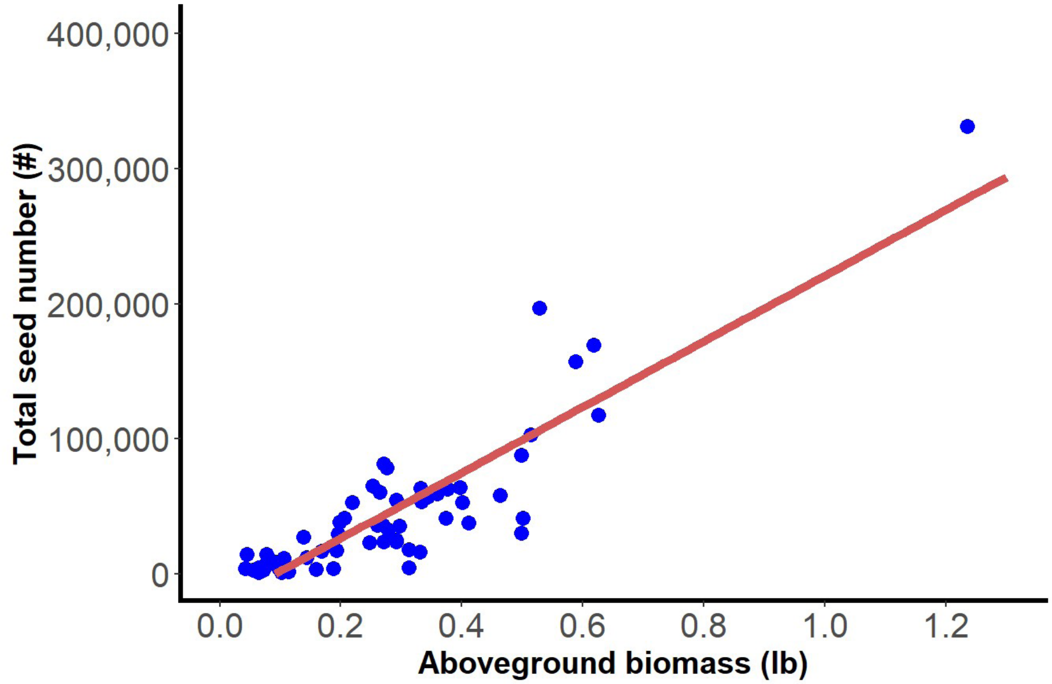

Figure 2. Relationship between Palmer amaranth seed production and aboveground biomass in Kansas in 2023.

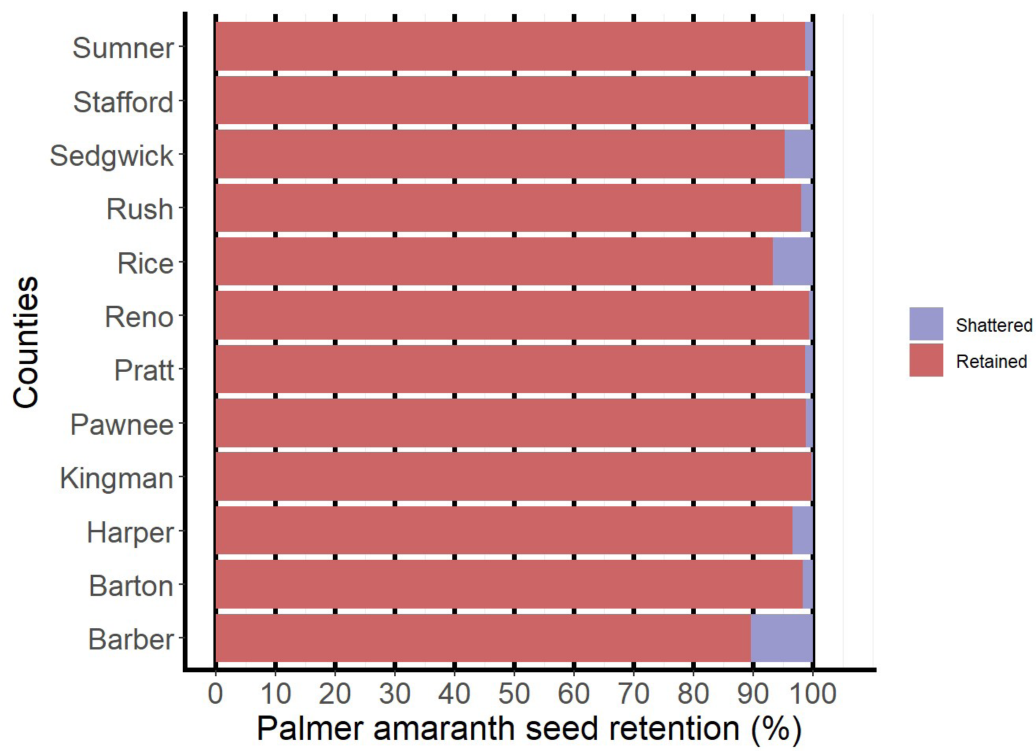

Figure 3. Palmer amaranth seed retention at harvest in 12 Kansas counties in 2023.

Productivity, Nutritive Value, and Profitability of Single and Multi-Species Cover Crops in Dryland Environments

Augustine K. Obour, John D. Holman, Logan M. Simon, and Yared Assefa

Summary

Replacing fallow with dual-purpose cover crops (CCs) can increase the profitability of dryland crop rotations in the semi-arid Great Plains. Little research information is available on CC mixtures that optimize productivity and profitability in dryland environments. Field experiments were conducted from 2015 to 2017 at the Kansas State University Hearting Beason (HB) Ranch near Brownell, KS, to quantify forage productivity, nutritive value, and profitability of spring-planted single or mixed species CCs in a winter wheat-grain sorghum-fallow (WSF) crop rotation. The CC treatments were implemented in the fallow phase ahead of winter wheat planting. Treatments were five spring-planted CC treatments: (1) spring oat; (2) spring triticale; (3) oat and triticale mixture (OT, two-species mixture); (3) oat, triticale, and pea (OTP, three-species mixture); and (5) oat, triticale, pea, radish, turnips, and buckwheat (cocktail, six-species mixture), and chemical fallow. Results showed that CC forage accumulation was 33% to 35% greater in sole triticale and OT mixture compared with sole spring oat or cocktail treatments. Multi-species mixtures, cocktail, and OTP had significantly greater available energy, digestibility, and dry matter intake based on measured CP, ADF, NDF, and *in vitro* dry matter digestibility (IVDMD) compared with single CC species (oat or triticale). Net return was directly proportional to CC forage accumulation. Averaged across years, net return was $40/a greater for the OT treatment compared with the multi-species mixtures. Our results suggest that simple CC mixtures with greater forage accumulation (for example, sole triticale and OT mixture) are better dual-purpose CC alternatives for the semi-arid Great Plains.

Introduction

Cropping system diversification with CCs can provide several benefits. These include improving soil quality, nutrient cycling, weed and pest suppression, as well as reduced wind erosion. The primary drawback of CCs in water-limited environments is the water use of CCs, which often affects subsequent cash crop yields. Utilizing CCs as forage can provide economic benefits and help offset loss in revenue associated with decreases in subsequent crop yields when CCs are grown in place of fallow. This approach could provide an opportunity for dryland producers to build soil health and produce forage for the region's livestock industry.

Information is limited regarding the best CC mixtures to optimize productivity, nutritive value, and profitability in water-limited dryland systems. Developing climate-specific CC management recommendations for dryland farmers will improve adoption in the semi-arid Great Plains. This research reports on the productivity and net returns of CCs in a dryland winter wheat-sorghum-fallow rotation. The research objective was to determine forage productivity and profitability of single and multi-species cover crops when used as a forage resource in dryland systems.

Procedures

This study is a component of a large CC field experiment initiated in spring 2015 at the Kansas State University experiment fields at HB Ranch near Brownell, KS. The overall goal of the CC trials was to develop climate-specific CC management options for integrating CCs into dryland crop production in western Kansas. The experimental design for the current study was a split-plot randomized complete block with four replications. The main plots were three crop phases of the WSF rotation (WSF, SFW, and FWS). The subplots were five spring-planted cover crop (CC) treatments: (1) spring oat; (2) spring triticale; (3) oat and triticale mixture (OT, two-species mixture); (3) oat, triticale, and pea (OTP, three-species mixture); and (5) oat, triticale, pea, radish, turnips, and buckwheat (cocktail, six-species mixture), and chemical fallow. The CCs were planted by March 15 in the fallow period between grain sorghum harvest and planting the next winter wheat crop in the rotation. Seeding rates were: 64 lb/a for spring oat; 76 lb/a for spring triticale; 32 lb/a of oat and 38 lb/a triticale (OT); 21 lb/a oat, 28 lb/a triticale, and 40 lb/a pea (OTP); and 15 lb/a oat, 15 lb/a triticale, 15 lb/a pea, 1 lb/a radish, 1 lb/a turnip and 4 lb/a for buckwheat (cocktail).

The CCs were harvested at heading to determine DM production and nutritive value. Forage harvests were performed in the last week in May 2015 and the first week in June 2016 and 2017. During each harvest, a 3-ft × 100-ft forage strip was harvested from each plot using a Carter plot forage harvester (Carter Manufacturing Company, Inc.) to a 6-inch stubble height. Whole plot sample weights were recorded, sub-samples were weighed, and oven dried for DM. Oven-dried samples were ground to pass through a 1-mm mesh screen in a Wiley Mill (Thomas Scientific, Swedesboro, NJ). The ground samples were then analyzed for forage nutritive value [crude protein (CP), acid detergent fiber (ADF), neutral detergent fiber (NDF), *in vitro* dry matter digestibility (IVDMD)], and tissue nutrient concentrations (Ward Laboratories, Inc., Kearney, NE) using Foss 6500 near infrared spectroscopy (NIRS).

Economic profitability (net return) was calculated as total revenue minus total costs for each treatment in each year. Total revenue was calculated as forage mass multiplied by price of hay. Field operations and input costs were estimated using 5-year average custom rate values published by Kansas State University Land Use Survey Program and the Kansas Department of Agriculture (AgManager, 2021). Cover crop hay prices were taken from the USDA Economic Research Service's market reports (USDA-ERS, 2021). Prices for hay were calculated on a per ton basis and averaged $130/ton over the study period. Total variable costs were calculated as the sum of the expenses for CC seed, planting, harvesting, hay swathing, and baling.

Results

Forage Mass, Nutritive Value, and Net Returns

Forage accumulation differed among CCs in 2015 and 2016 but not in 2017 (Table 1). In 2015, forage accumulation of the OT mixture was significantly greater than the cocktail treatment. There were no significant differences among other CC treatments. In 2016, triticale forage accumulation was greater than oat alone and the OTP mixture. Forage accumulation of the OTP and cocktail treatments were not significantly different in 2016 (Table 1). Across years, CC forage accumulation was 33% to 35% greater in triticale alone and the OT mixture compared with oat alone or the cocktail treatment. This result suggests triticale or triticale-dominated mixture productivity was greater compared with the oat alone or the cocktail and OTP treatments where the proportion of triticale in the mixture was less.

The multi-species mixtures (i.e., cocktail and OTP) had greater CP compared with oat alone in two of the three years, and IVDMD with these treatments was greater than triticale. Triticale had moderate concentrations of CP, the greatest ADF and NDF, and the least IVDMD compared with the cocktail, and OTP CC treatments (Table 2). Therefore, the cocktail and OTP treatments had greater available energy, digestibility, and greater dry matter intake compared to triticale alone or the OT treatment. Due to relatively higher ADF, NDF, and lower IVDMD concentrations, triticale intake and digestibility could be less than the other treatments. Complementarity from the component crops in multi-species mixtures often increased nutritive value.

Gross return was greatest for triticale alone and triticale-dominated mixtures compared with the cocktail and oat alone treatments (Table 1). Gross return was not significantly different over the three years. Net return was greatest for the OT treatment compared with the OTP and cocktail treatments (Table 1). There was a significant linear relationship between forage accumulation and net return for all treatments (Fig. 1). Net return increased by $0.05 for each lb/a increase in forage accumulation. Crude protein yield, a function of CP concentration and forage accumulation, was greater for triticale and OT treatments compared with oat or the cocktail treatment. Crude protein yield ranged from 274 lb/a for oat alone to 362 lb/a for the OT treatment.

Conclusions

Our results showed CC forage accumulation was greater in the triticale alone and OT mixture compared with the oat alone or cocktail treatments. Multi-species CCs mixtures (i.e., cocktail and OTP) had significantly greater available energy, digestibility, and greater dry matter intake compared with single species (i.e., oat or triticale alone). Net returns for the OT or triticale alone treatments were greater compared with the multi-species mixtures (i.e., cocktail and OTP). Our results suggest that simple CC mixtures with greater forage accumulation (e.g., triticale alone and OT mixture) are better dual-purpose CC alternatives for the semi-arid Great Plains.

Acknowledgements

This work was jointly supported by Kansas Agricultural Experiment Station, USDA National Institute of Food and Agriculture (Hatch Project 1019594); USDA Ogallala Aquifer Grant Program [Grant no. 58-3090-5-007]; and USDA North Central Sustainable Agricultural Research and Education Program [Grant no. LNC 18-411].

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Table 1. Cover crop forage accumulation for the years 2015-2017, average across years, net returns and type 3 test of fixed effects

	Forage accumulation				Gross	Net
	2015	2016	2017	Average	return	return
	------------------- lb/lbs./a -------------------				--------- $/a ---------	
Cover crop treatment						
Spring oat	32741ab[†]	1885b	2079	2235c	149b	55ab
Spring triticale	3952ab	3330a	2559	2980ab	199a	82ab
Spring oat-triticale mixture	357a	2575ab	2909	3013a	201a	87a
Spring oat-triticale-pea mixture	2521ab	2044b	2756	2440bc	163ab	48b
Cocktail	2241b	2364ab	2068	2225c	148b	46b
HSD	1232	1251	NS	573	49	36
Year						
2015				2822	188	75
2016				2439	163	57
2017				2474	165	59
HSD				NS	NS	NS
Type three test of fixed effects						
Treatment (T)	0.0429	0.0242	0.1715	0.0107		
Year (Y)	-	-	-	0.1735		
Y × T	-	-	-	0.3913		

†Means within a column followed by different letters indicate significant differences among cover crop treatments at $\alpha < 0.05$.

Table 2. Cover crop nutritive value, i.e., crude protein (CP), acid detergent fiber, neutral detergent fiber (NDF), in vitro dry matter (IVDMD) concentration by treatment and year, and type 3 test of fixed effects

	Concentration			
	CP	ADF	NDF	IVDMD
	----	----	% ----	----
Cover crop treatment				
Spring oat	11.9ab†	37.1b	62.1b	73.8a
Spring triticale	12.1ab	38.8a	65.3a	69.7b
Spring oat-triticale mixture	11.6b	37.1b	62.9ab	72.7a
Spring oat-triticale-pea mixture	13.4a	37.1b	61.5b	73.7a
Cocktail	13.0ab	37.2ab	61.8b	73.8a
HSD	1.5	1.6	3.1	2.7
Year				
2015	17.7a	36.6b	56.8c	82.4a
2016	9.1c	38.6a	64.1b	67.8b
2017	10.3b	37.1b	67.3a	68.1b
HSD	1.0	1.1	2.0	1.8
Type three test of fixed effects				
Treatment (T)	0.0046	0.0311	0.0065	0.0002
Year (Y)	<.0001	0.0003	<.0001	<.0001
Y × T	0.0117	0.5292	0.3388	0.4886

†Means within a column followed by different letters indicate significant differences among cover crop treatments or years at $\alpha < 0.05$.

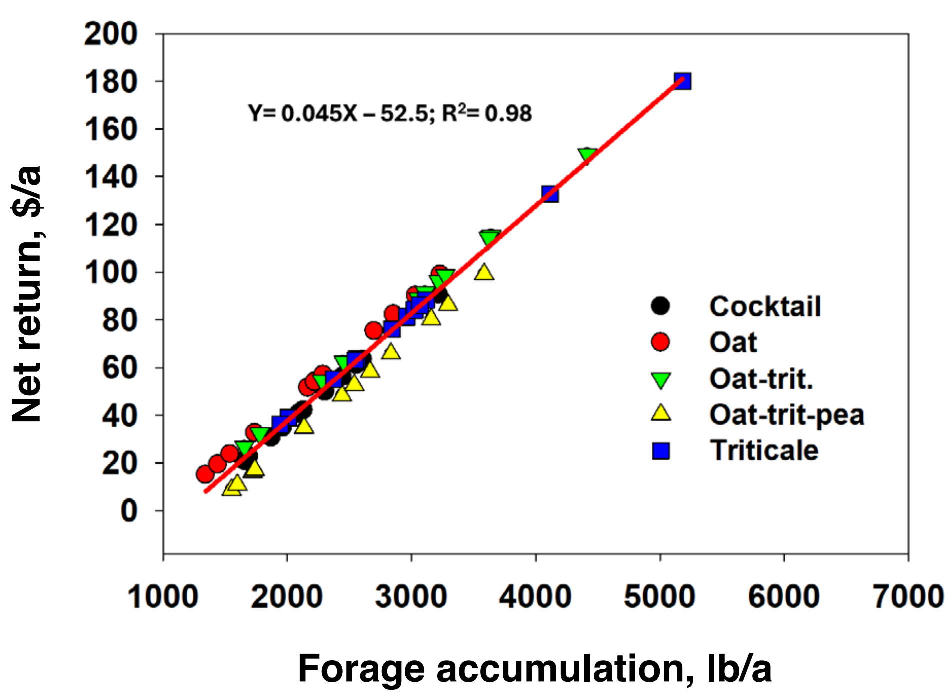

Figure 1. Forage accumulation and net revenue relations of spring cover crops from 2015 through 2017 at Hays, KS.

Production Practice Effects on Cotton Growth and Development in Thermally Limited Kansas

Logan M. Simon, Jonathan Aguilar, and Farzam Moghbel

Summary

Declining water well capacities across southwest Kansas and the High Plains have forced many producers to reassess crop selection for their irrigated acreage. One strategy that could stabilize irrigated acreage as well as on-farm economic returns and potentially reduce the rate of aquifer depletion is the incorporation of more drought-tolerant crops like cotton. However, in thermally-limited cotton-producing regions like southwest Kansas where the growing season is relatively short, regionally-focused management practices are essential to avoid yield and quality penalties due to the narrow production window between planting and physiological maturity. The objective of this study was to determine the impacts of planting date, seeding rate, variety, and irrigation level on cotton yield formation factors including square and boll initiation/position/retention as well as locks/boll, seeds/lock, and lint yield in the 2024 growing season at Garden City, KS. In this study, cotton yield components were most responsive to seeding rate followed by planting date and then variety maturity. Cotton yield components were least responsive to irrigation rate. Results showed stand density was slightly decreased under the high irrigation rate compared to the low irrigation rate and proportionally impacted by seeding rate in the order of 75,000 > 50,000 > 25,000 seeds/a. End of season bolls/plant were greater under the low seeding rate compared to the medium and high seeding rates. Locks/boll were unaffected by any treatments. Seeds/lock were greater with the early planting date than the late planting date. Cotton lint yield was greater with PHY 205 than PHY 332 and greater with the early planting date than with the late planting date. Lint yield was increased with increasing seeding rate in the order of 75,000 > 50,000 > 25,000 seeds/a. Plants/a was the only yield component significantly correlated with lint yield. Lint percent was greater with PHY 205 than PHY 332 and greater with the early planting date than the late planting date. Lint percent was greater with the highest seeding rate than the lowest seeding rate. These results underscore that successful stand establishment is essential to success with cotton in thermally-limited Kansas.

Introduction

Declining water well capacities across southwest Kansas and the High Plains have forced many producers to reassess crop selection for their irrigated acreage. One strategy that could stabilize irrigated acreage as well as on-farm economic returns and potentially reduce the rate of aquifer depletion is the incorporation of more drought-tolerant crops like cotton. Cotton production and ginning in Kansas have exceeded 2.4 million bales since 1996. Significant infrastructure investments have been made in Kansas cotton, including the establishment of four gins in Moscow, Pratt, Anthony, and Winfield. However, in thermally-limited cotton-producing regions like southwest Kansas, regionally-focused management practices are essential to avoid yield and quality penalties due to the narrow production window between planting and physiological maturity.

The objective of this study was to determine the impacts of planting date, seeding rate, variety, and irrigation level on cotton yield formation factors including square and boll initiation/position/retention as well as locks/boll, seeds/lock, and lint yield by boll position in the 2024 growing season at Garden City, KS.

Procedures

This study was initiated in 2020 at the Kansas State University Southwest Research-Extension Center near Garden City, KS to investigate the effects of seeding rate, planting date, variety maturity, and irrigation rate in a randomized complete block design with four replications. Plots were 45 ft wide and 90 ft long. The study site averages 18 inches of annual precipitation with an elevation of 2,828 ft above sea level. The soil type was a Ulysses silt loam (fine-silty, mixed, superactive, mesic Torriothentic Haplustolls). Treatment levels included:

1. Three seeding rates targeting plant populations of 25,000, 50,000, and 75,000 plants/a.
2. Two target planting dates of May 1 (early) and May 15 (late).
3. Two varieties that were selected to represent early (PHY 332) and very early (PHY 205) maturity.
4. Two irrigation levels to represent full irrigation (300 gal/minute) and deficit irrigation (150 gal/minute).

In 2024, cotton was planted on May 9, 2024 (Early) and May 23, 2024 (Late). Plots were over-seeded and thinned to achieve targeted seeding rates. Fertilizer, pesticide, plant growth regulator, and harvest aid applications were consistent across all treatments and followed typical recommendations for the High Plains region of southwest Kansas and the Oklahoma/Texas Panhandles. To monitor growth and physiological development/yield formation, three cotton plants per plot were monitored weekly through the growing season with data regarding square and boll initiation/position/retention including measurements of plant height, node number, first position squares above white flower, first position bolls below white flower, and nodes above cracked boll. At harvest maturity and following harvest aid application, three whole plants were collected and partitioned by hand to determine yield components of bolls/plant, locks/boll, and seeds/lock. Lint yield samples were also collected by hand from a 10-ft length of two rows in each plot and ginned at the Texas A&M AgriLife Research gin at Lubbock, Texas. Statistical analyses were conducted using the PROC GLIMMIX procedure in SAS. Interactions and main effects were considered significant at $\alpha = 0.05$. Correlation analysis of cotton yield components and lint yield was conducted using the PROC CORR procedure in SAS.

Results

For the purposes of this proceedings paper, and based on limited significant interaction effects, focus was placed on the main effects of variety maturity, seeding rate, planting date, and irrigation rate. Results showed stand density was unaffected by variety or planting date (Figure 1a;c), but was slightly decreased under the high irrigation rate than the low irrigation rate (Fig 1d). Seeding rate had a proportional impact on final stand density in the order of 75,000 > 50,000 > 25,000 seeds/a (Fig. 1b). There was no substantial impact of treatments on nodes to first fruiting branch (data not shown). Plant height was not strongly affected by irrigation rate, but variety, seeding rate, and planting date each influenced height. Early planted cotton maintained greater height compared to late planted cotton until mid-August, which was 98 and 84 days after planting (DAP) for the early and late dates, respectively. Varieties were similar in height until early August (84 and 70 DAP), after which PHY 332 maintained greater height than PHY 205, at 36 and 30 inches at end of season, respectively. Both varieties stabilized in height by early September (119 and 105 DAP). Increasing seeding rates resulted in small but consistent increases in plant height over lower seeding rates (75,000 > 50,0000 > 25,000 plants/a), which was maintained throughout the growing season, at 34, 33, and 32 inches, respectively.

Number of nodes/plant was unaffected by treatments (data not shown), and total fruiting branches/plant was not substantially impacted by variety, seeding rate, or irrigation level. However, early planted cotton maintained more total fruiting branches/plant than the late planted cotton until mid-September (126 and 112 DAP). White flowers appeared in early planted cotton in early August (84 DAP). One week later (77 DAP), white flowers appeared in late planted cotton. Early planted cotton maintained one more first position square above white flower than late planted cotton until the end of flowering. First position squares above white flower were unaffected by seeding rate, variety, or irrigation level. Similar observations were made for nodes above white flower. First position bolls below white flower were unaffected by seeding rate, variety, or irrigation level. However, early planted cotton maintained one more first position boll below white flower than late planted cotton from the beginning of boll formation. In early October (147 DAP), cracked bolls first appeared in early planted cotton. Cracked bolls were not identified in late planted cotton before harvest aid application.

End of season bolls/plant were unaffected by variety, planting date, or irrigation rate (Figure 2a;c;d). However, bolls/plant were greater under the low seeding rate compared to the medium and high seeding rates (Figure 2b). Locks/boll were unaffected by any treatments and averaged 4.5 locks/boll in this study. Seeds/lock were unaffected by variety, seeding rate, or irrigation rate (Figure 3a;b;d), but were greater with the early planting date than the late planting date (Figure 3c). Cotton lint yield was greater with PHY 205 than PHY 332 (Figure 4a) and greater with the early planting date than with the late planting date (Figure 4c). Lint yield was increased with increasing seeding rate to the order of 75,000 > 50,000 > 25,000 (Figure 4b) but was unaffected by irrigation rate (Figure 4d). Plants/a was the only yield component significantly correlated with lint yield (Table 1) though plants/a was also significantly correlated with bolls/plant. Lint percent was greater with PHY 205 than PHY 332 (Figure 5a) and greater with the early planting date than the late planting date (Figure 5c). Lint percent was greater with the highest seeding rate than the lowest seeding rate (Figure 5b) but was unaffected by irrigation rate (Figure 5d).

Conclusion

Increasing cotton production in thermally-limited southwest Kansas could stabilize irrigated acreage as well as on-farm economic returns. It could potentially reduce the rate of aquifer depletion if management practices are identified to avoid yield and quality penalties due to the narrow production window between planting and physiological maturity. In this study, cotton yield components were most responsive to seeding rate followed by planting date and then variety maturity. Cotton yield components were least responsive to irrigation rate. Good stand establishment is essential to success with cotton in thermally-limited Kansas. Any in-season stressors that reduce stand density could significantly limit final lint and seed yields. Future research in southwest Kansas will investigate the impacts of variety maturity and deficit irrigation strategies on cotton growth and development in this thermally-limited environment.

Acknowledgments

This research on the northern frontier of cotton production was funded fully or in part by Cotton Incorporated and the Ogallala Aquifer Program.

Table 1. Correlation analysis of cotton yield components

	Bolls/plant	Locks/boll	Seed/lock	Lint yield
				lb/a
Plants/a	-0.38**†	0.05	-0.01	0.61****
Bolls/plant		-0.18	0.13	-0.20
Locks/boll			0.05	0.22
Seed/lock				0.20

† *P* <0.1000*, *P* <0 .0100**, *P* < 0.0010***, *P* < 0.0001****

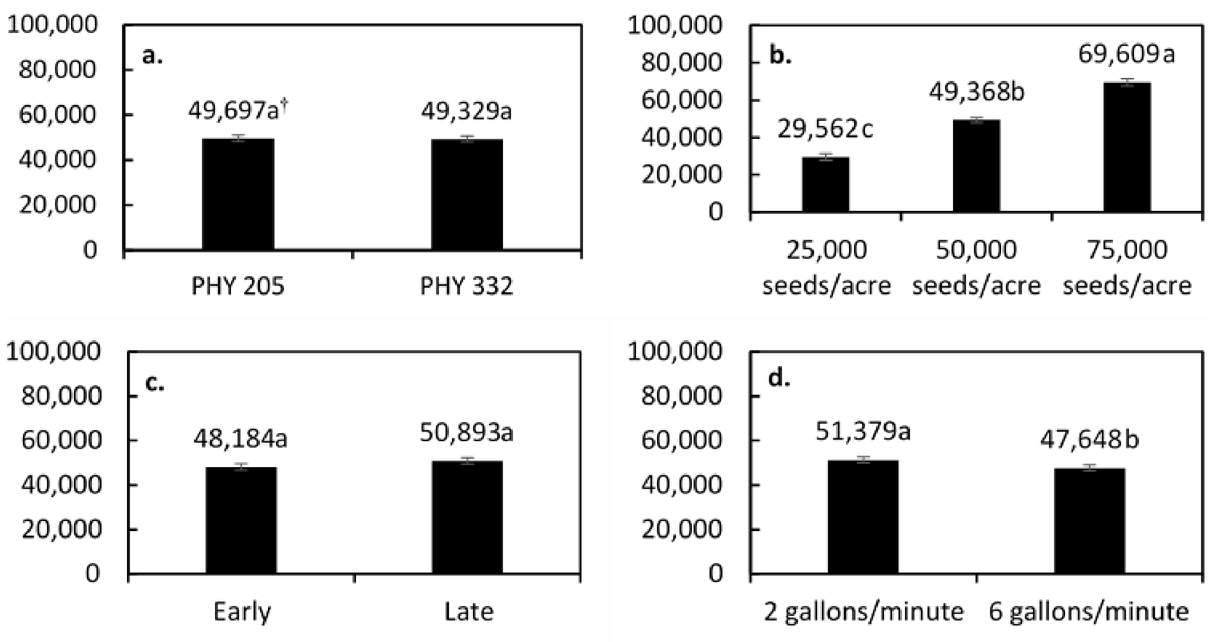

Figure 1. Cotton variety selection (a), seeding rate (b), planting date (c), and irrigation rate (d) impacts on stand density (plants/a) in thermally-limited southwest Kansas. †Error bars indicate standard error ($\alpha = 0.05$) and bars with the same letter are not significantly different ($\alpha = 0.05$) among treatments within the same year.

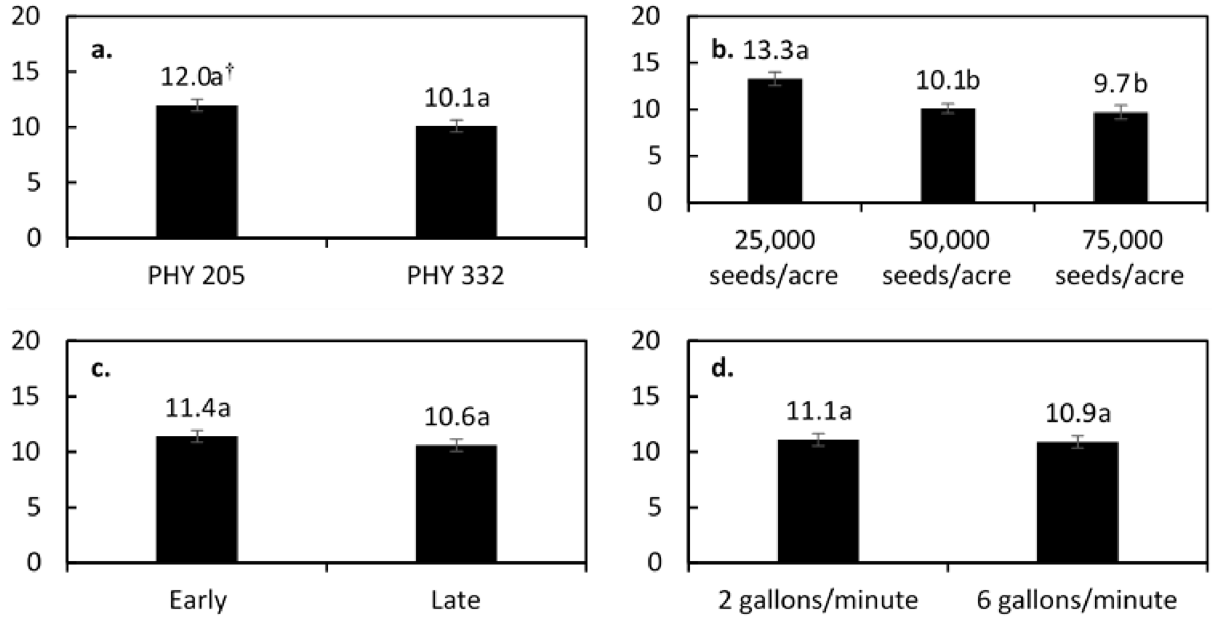

Figure 2. Impacts of cotton variety selection (a), seeding rate (b), planting date (c), and irrigation rate (d) on cotton bolls/plant in thermally-limited southwest Kansas. †Error bars indicate standard error ($\alpha = 0.05$) and bars with the same letter are not significantly different ($\alpha = 0.05$) among treatments within the same year.

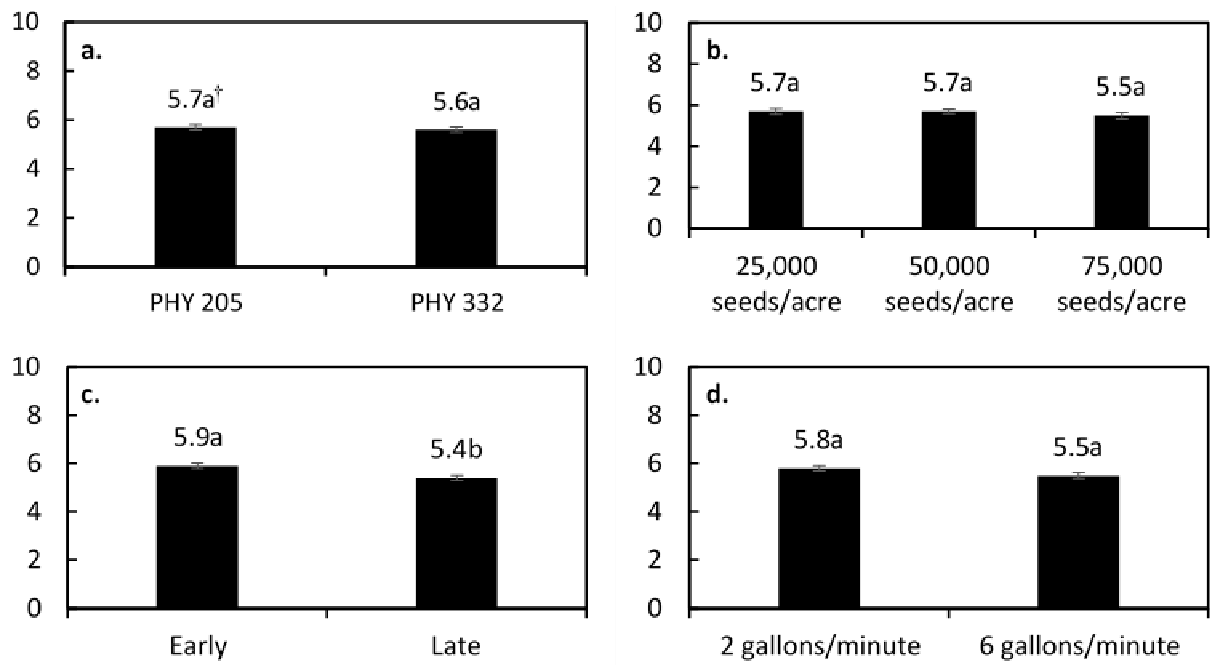

Figure 3. Cotton variety selection (a), seeding rate (b), planting date (c), and irrigation rate (d) impacts on seed/lock in thermally-limited southwest Kansas. †Error bars indicate standard error ($\alpha = 0.05$) and bars with the same letter are not significantly different ($\alpha = 0.05$) among treatments within the same year.

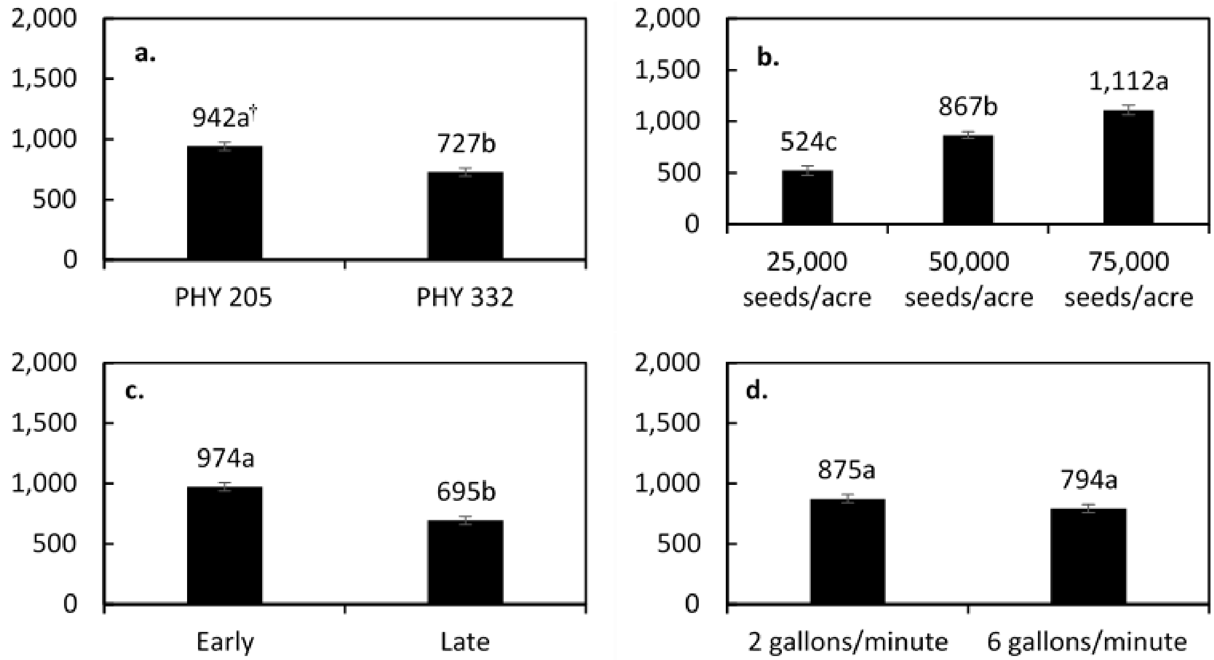

Figure 4. Impacts of cotton variety selection (a), seeding rate (b), planting date (c), and irrigation rate (d) on cotton lint yield (lb/a) in thermally-limited southwest Kansas. †Error bars indicate standard error ($\alpha = 0.05$) and bars with the same letter are not significantly different ($\alpha = 0.05$) among treatments within the same year.

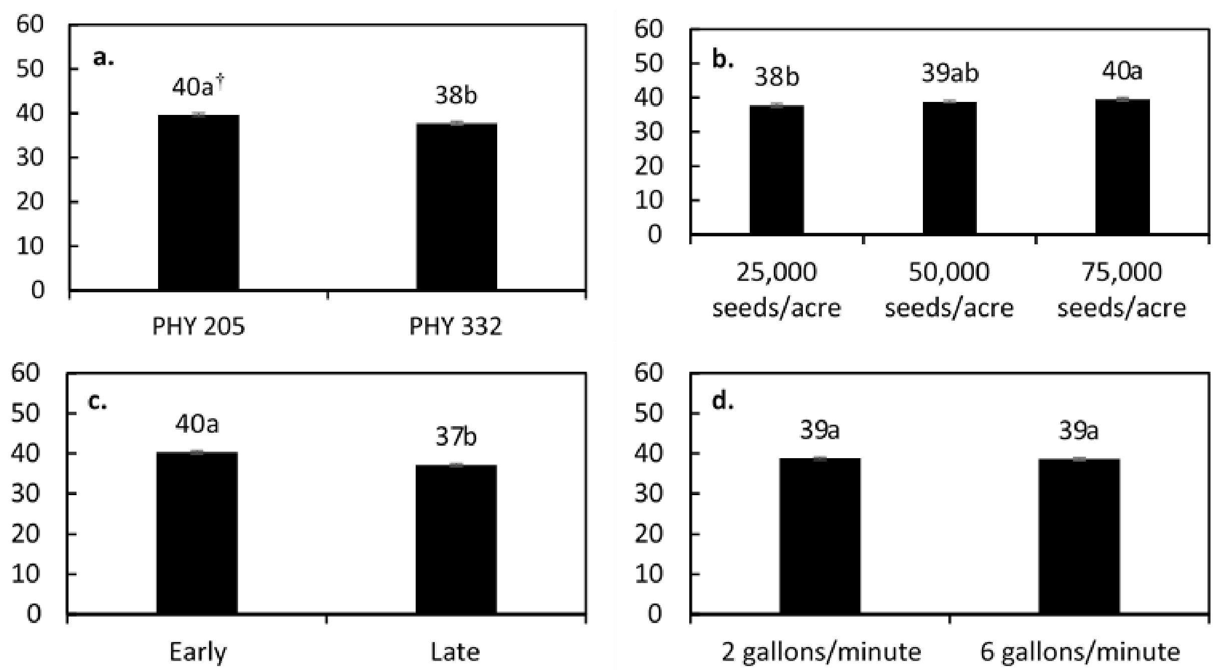

Figure 5. Cotton variety selection (a), seeding rate (b), planting date (c), and irrigation rate (d) impacts on lint percent (%) in thermally-limited southwest Kansas. †Error bars indicate standard error ($\alpha = 0.05$) and bars with the same letter are not significantly different ($\alpha = 0.05$) among treatments within the same year.

Impact of Cover Crop Planting Timing and Fallow Management on Biomass Production and Soil Properties in Dryland Cropping Systems

Priscilla Sedem Akporsoe, Augustine Obour, Zachariah Carson, Logan Simon, and John Holman

Summary

Soil health and ecosystem benefits of cover crops (CCs) in semi-arid dryland cropping systems are dependent on CC biomass productivity. The objectives of this study were to evaluate the effects of CC planting time (spring vs. fall) on CC biomass, and fallow management [no-tillage (NT) vs. occasional tillage (OT)] and CC effects on residue cover, and soil aggregate stability in a winter wheat (*Triticum aestivum* L.)-sorghum (*Sorghum bicolor* Moench)-fallow (WSF) rotation. The experiment was conducted at the Kansas State University Hearting Beason (HB) Ranch using a split-plot randomized complete block design with four replications. The main plots were crop phase and sub-plot treatments with triticale (×*Triticosecale* Wittm.), pea (*Pisum sativum* L.) and rapeseed (*Brassica napus var. napus*) mixture planted in the fall, oat (*Avena sativa* L.), triticale and pea CC mixture planted in the spring, NT fallow, and OT fallow. Results showed that CC biomass productivity was not significantly different between fall and spring-planted CCs. However, there was a trend for greater biomass production with fall-planted CCs. This suggests flexibility in planting time for maximizing CC biomass productivity in the WSF rotation. Fall-planted CCs had the highest residue cover (89%), followed by spring planting (81%), and NT (78%), while OT had the lowest (67%) due to increased soil disturbance. Soil aggregate stability was greatest under fall and spring-planted CCs, while OT reduced aggregate stability compared to CCs or NT fallow. These findings showed NT with CCs either planted in the fall or spring can maintain soil health by increasing residue cover and soil aggregation in semi-arid dryland cropping systems.

Introduction

In semi-arid environments like the central Great Plains, improving soil health is crucial for sustainable agriculture. Cover crops (CCs) in dryland cropping systems can play a significant role in enhancing soil properties, improving nutrient cycling, and increasing water retention. However, their effectiveness is highly dependent on productivity from CC biomass. The timing of CC establishment influences growth duration, biomass accumulation, and soil health benefits, making it a critical factor for farmers and land managers in these water-limited environments.

Cover crops contribute to soil health improvements by increasing organic matter, enhancing microbial activity, and reducing soil erosion. Early-planted CCs could produce greater biomass due to an extended growing period, leading to improved soil cover and associated soil health benefits. Conversely, delayed planting may limit biomass accumulation due to a shorter growth period and reduced soil moisture availability, which are major concerns in semi-arid regions where precipitation is scarce.

In semi-arid environments, improper timing of CCs can lead to soil moisture depletion, potentially competing with cash crops for water resources. However, when effectively managed, CCs can enhance soil water infiltration, increase water retention, and promote wet aggregate stability, which contributes to improved soil resilience over time. Understanding the relationship between CC timing, management strategies, and soil properties is essential for developing best management practices to improve soil sustainability and productivity in semi-arid environments.

This study investigated the effect of CC planting time (fall or spring) on CC biomass production, fallow management, and CC effects on soil properties in a semi-arid cropping system.

Procedures

This study is a component of a larger CC field experiment that was initiated in spring 2015 at the Kansas State University Hearting Beason (HB) Ranch near Brownell, KS. The overall goal of the CC trials was to develop climate-specific management options for integrating CCs into dryland cropping systems in western Kansas. The current study was established in fall 2023 to investigate the effects of timing of cover crop planting and fallow management on biomass productivity and soil physical properties. The study design was a split-plot randomized complete block with four replications. Crop phase was the main plot and split-plots treatments were triticale (×*Triticosecale* Wittm.), pea (*Pisum sativum* L.) and rapeseed (*Brassica napus var. napus*)**,** oat (*Avena sativa* L.), triticale and pea CC mixture, no-tillage (NT) fallow, and occasional tillage (OT) fallow. The CCs were grown during the fallow phase of a winter wheat (*Triticum aestivum* L.)-sorghum (*Sorghum bicolor* Moench)-fallow (WSF) rotation, planted either in the spring or in fall. Cover crops were managed as standing cover and were compared to NT and OT fallow treatments. The OT treatment was accomplished by tilling to a depth of 3 inches once in July or August during the fallow phase of the rotation prior to winter wheat planting using a sweep plow equipped with 5-ft blades and treaders (Premier Tillage Inc., Quinter, KS, USA). This is a non-inversion, conservation tillage implement commonly used in the semi-arid central Great Plains.

Cover crop biomass was determined by hand-clipping, close to the ground level (~ 1 inch above the soil surface), two areas of 2 × 3 ft per plot. Samples were dried at 122°F in a forced-air oven and weighed to determine dry matter. Intact soil samples were carefully obtained using a flat shovel to determine stability of water-stable aggregates . These samples were air-dried and gently passed through a 19-mm sieve to separate larger aggregates. Subsamples of <8-mm diameter aggregates were then obtained and used to estimate the mean weight diameter (MWD) of water-stable aggregates (WSA) using the wet-sieving method. Residue cover was determined using the line transect method. Statistical analysis was performed using the PROC GLIMMIX procedure in SAS version 9.4, with significance set at $P < 0.10$.

Results and Discussion

Biomass production and residue cover

Biomass of the fall-planted CCs was not significantly different from spring-planted CCs (Figure 1). This suggests that both planting times are viable options for maximizing CC biomass, offering flexibility for when CCs can be planted after sorghum in the WSF rotation.

Fall-planted CCs had the highest residue cover (89%) and it was significantly greater than all other treatments (Figure 2). Although significantly lower than fall-planted CCs, spring-planted CCs (81%) and NT (78%) maintained adequate residue cover compared to the OT (67%). The lower residue cover in OT is likely due to soil disturbance due to tillage, which incorporates some residue into the soil and accelerates residue decomposition.

Aggregate stability

The distribution of water-stable aggregates varied across treatments. Fall and spring-planted CCs had the highest percentage of larger water-stable aggregates (>2-mm diameter), suggesting better soil stability (Table 1). In contrast, OT resulted in the smallest proportion of large aggregates and the highest amount of microaggregates (<0.25-mm diameter). This finding indicates OT could break down soil structure and could predispose dryland soils to erosion. The NT treatment had a similar proportion of small macroaggregates (0.25- to 2-mm diameter) compared to the CC treatments, showing that NT can preserve soil aggregation.

Mean weight diameter of water-stable aggregates was in the order of spring-planted CCs, then fall-planted CCs, then NT fallow, and then OT fallow (Table 1). Overall, these results suggest that CCs and NT help maintain greater soil structure, while OT could reduce soil aggregate stability.

Conclusion

This study highlights the impact of cover crop planting time on biomass production and soil properties in a semi-arid cropping system. Fall planting produced slightly more biomass than spring planting, but the difference was not statistically significant, suggesting flexibility in planting times for biomass production. Planting CCs in the fall resulted in greater residue cover, but soil improvement as indicated by aggregate stability was not different from spring-planted CCs. The OT treatment had the lowest (67%) residue cover and aggregate stability, likely due to soil disturbance, residue incorporation, and residue breakdown. Overall, cover cropping, either planting in the spring or fall, and NT practices maintained the soil health by increasing residue cover and soil aggregation in this dryland WSF cropping system.

Acknowledgments

This work was jointly supported by Kansas Agricultural Experiment Station, USDA National Institute of Food and Agriculture (Hatch Project 1019594); USDA Ogallala Aquifer Grant Program [Grant no. 58-3090-5-007]; and USDA North Central Sustainable Agricultural Research and Education Program [Grant no. LNC 18-411].

Table 1. Effects of cover crop planting time and tillage on water-stable aggregate size distribution and mean weight diameter (MWD)

Treatment	>2mm	2-0.25mm	<0.25mm	MWD
	----------------------	%	----------------------	mm
Fall planted	11.9a	35.9ba	52.3b	0.92ba
Spring planted	12.1a	38.9ba	48.9b	0.98a
Occasional tillage fallow	6.8b	31.3b	61.8a	0.65c
No tillage fallow	7.4b	41.9a	50.6b	0.73bc

Means followed by the same letter within a column are not significantly different *(P < 0.10)*.

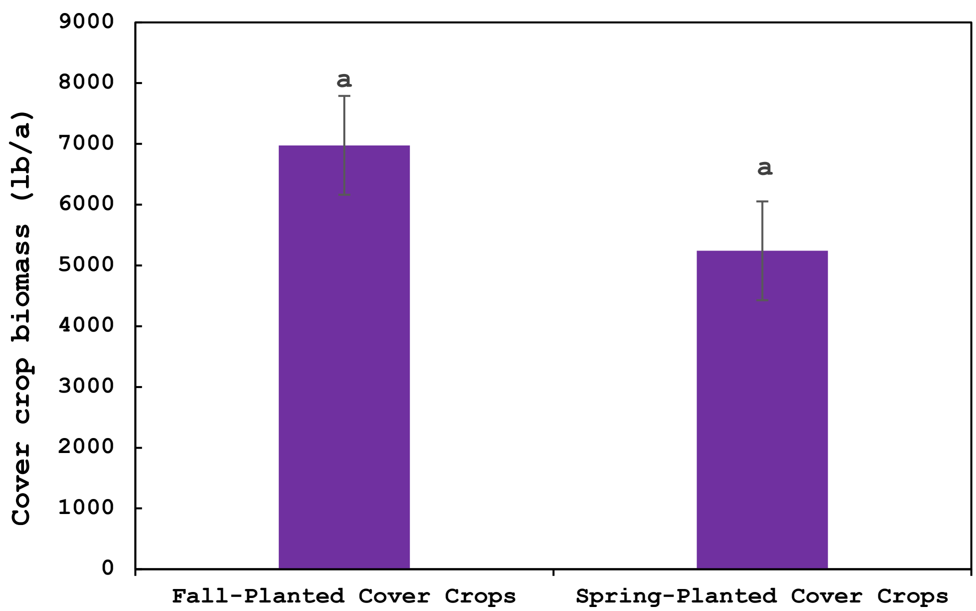

Figure 1. Effects of cover crop planting time on biomass productivity in 2024 at Hays, KS. Means with the same letter are not significantly different (P < 0.10).

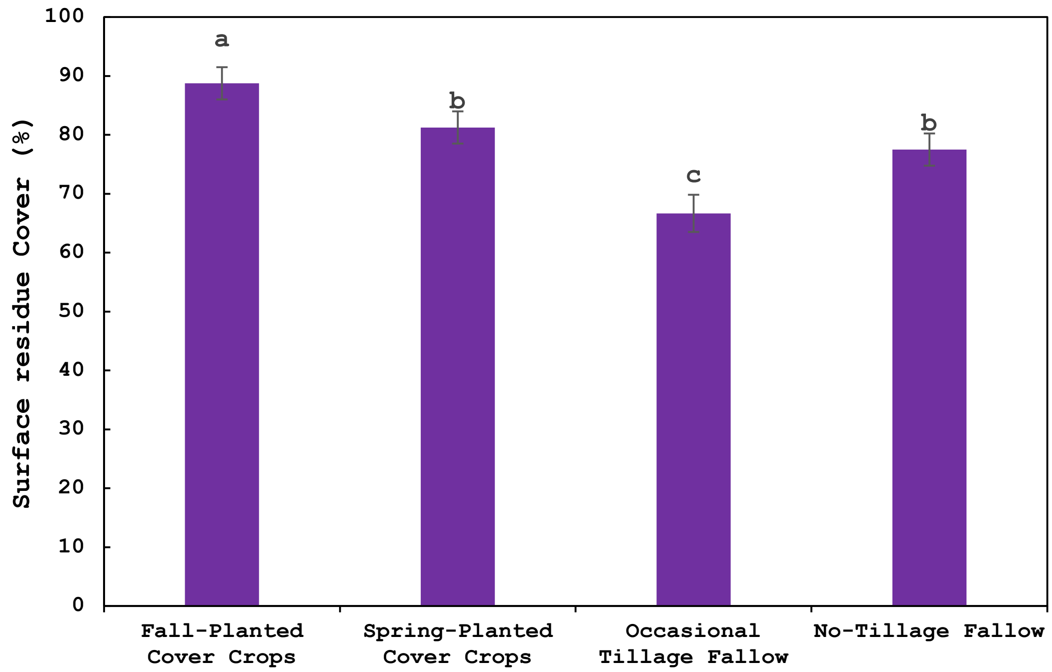

Figure 2. Effects of cover crop planting time and tillage on soil surface residue cover. Means with the same letter are not significantly different ($P < 0.10$).

Cover Crop Biomass Removal Rates to Optimize Livestock Production and Soil Health in Dryland Cropping Systems

Logan Simon, Zachariah Carson, Augustine Obour, Frank Weber, Stacie Minson, and Craig Dinkel

Summary
Grazing cover crops (CCs) could provide an economic benefit to offset potential lost revenue when grain crop yields are decreased after CCs in dry years. However, there is limited guidance on the optimum biomass removal rate that balances soil health and grazing goals. An on-farm study was established in fall 2022 on a 50-acre producer field in Russell County, KS, to investigate the effects of CC biomass removal with cattle grazing on soil health parameters and grain crop yields, and profitability in no-till (NT) dryland cropping systems. The study design was a randomized complete block with three treatments and four replications. The treatments included ungrazed CCs, "take-half-leave-half" (T-H-L-H, 50% biomass removal), and "graze-out" (G-O, 90% biomass removal). Averaged across 2023-2024, the T-H-L-H and G-O significantly reduced CC residue amount, height, and residue cover when compared to ungrazed CCs. Cover crop management had no significant effect on soil organic carbon and particulate organic matter. However, phosphorus (P) concentrations were reduced by T-H-L-H and G-O when compared to ungrazed CCs, likely due to purposefully avoiding sampling near manure piles in the grazed plots that may be high in P. Take-half-leave-half and G-O also increased soil bulk density compared to ungrazed CCs. Soil penetration resistance, wind-erodible fraction, mean weight diameter of water-stable aggregates, time-to-runoff, and subsequent grain sorghum yields were unaffected by CC management. These results suggest that farmers and ranchers may be able to graze CCs at greater intensities than T-H-L-H to maximize livestock gains while maintaining soil health. This can increase adoption of CCs and benefit water quality protection and improvement efforts in reaching the goals of the approved 9 Element Watershed Plan through the Kansas Department of Health and Environment and the Environmental Protection Agency. However, these observations were made in a two-year study and under exceptional drought conditions, so further investigation will be necessary under conditions of average or above average precipitation when wet soils may be more susceptible to soil compaction by cattle hoof traffic.

Introduction
No-tillage (NT) and cover crops (CCs) have been widely recommended to regenerate soils degraded after many years of conventionally-tilled, low-intensity crop production. Soil health benefits of CCs in NT cropping systems include increased soil organic carbon (SOC), enhanced nutrient cycling, reduced compaction, increased water infiltration, and reduced wind and water erosion. However, several barriers to adoption of CCs exist in water-limited regions, including the costs of establishing CCs (seed, machinery, labor, and fuel) and the risk of CCs reducing subsequent grain yields due to reduced soil water at next crop planting. Some producers have sought to overcome

these barriers by integrating livestock to graze CCs, which has been widely promoted for diversifying agricultural production systems.

Previous research has shown most CC species can provide high-quality forage for livestock, which can extend the grazing season and reduce the need for feeding costly stored forages in concentrated feeding sites for extended periods. Grazing CCs can delay grazing of native rangelands and allow for longer periods of rest and improved rangeland health. Previous research has demonstrated increased system profitability with integrated crop-livestock systems. However, subsequent grain yields have been variable, with incidences of reduced yield often attributed to soil compaction, aggregate destruction, and reduced water infiltration due to excessive animal hoof traffic. For long-term practitioners of NT, this is a major concern as yield-limiting soil compaction could require tillage for remediation.

At this time, there is limited guidance on the optimum biomass removal rate that balances soil health and grazing goals. Previously, USDA-NRCS has made no provisions for grazing CCs, and current Kansas NRCS recommended stocking rates are based on those developed for native rangelands (T-H-L-H, 50% biomass removal). Previous research suggests that conservative stocking densities that remove 40% to 50% of biomass do not negatively affect soil properties compared to ungrazed CCs, this suggests that greater levels of biomass removal with grazing could be practical, especially when regrowth occurs after grazing and would generate greater profit for farmers and ranchers. However, higher stocking rates (70% to 90% removal) have occasionally resulted in compaction and reduced water infiltration in some studies. The objective of this research is to determine the optimum amount of CC biomass removal with livestock grazing to optimize farm profits and enhancements in soil health on no-tillage dryland cropping systems in Kansas.

Procedures

An on-farm study was established in fall 2022 on a 50-acre producer field in Russell County, KS, (38° 42' 2.2" N, 98° 37' 58.3" W) located in the KSU Kanopolis Reservoir Big Creek Middle Smoky Hill River Watershed Restoration and Protection Strategies (WRAPS) Area. This study investigated the effects of CC biomass removal rate by grazing cattle on soil health parameters, grain crop yields, and system profitability in NT dryland cropping systems. Soil types at the study site are the Crete silt loam (72%) and Harney silt loam (28%), and long-term average (30-yr) annual precipitation is 26 inches. However, the study period coincided with a period of exceptional drought. The study design was a randomized complete block with three treatments and four replications. Treatments included ungrazed CCs, "take-half-leave-half" (T-H-L-H, 50% biomass removal), and "graze-out" (G-O, 90% biomass removal).

In fall 2022, a three-species CC mixture of triticale, pea, and rapeseed was planted into wheat stubble about October 1 at 60, 15, and 2 lb/a, respectively, using an NT drill. Again, the field was planted to the same CC mixture in fall 2023 after grain sorghum harvest. No fertilizers were applied to CCs in either year of the study. In spring 2023, treatments were established with ungrazed plots of about 1.5 acre and grazed plots of about 5 acres each replicated and randomized across the field. Plots were grazed with yearlings beginning in the last week of April and moved plot-to-plot every 1 to 2 days across the eight grazed plots to achieve desired CC biomass removal rates based on visual assessment. Plots were only grazed once because of declining apparent forage quality (increasing plant maturity) and limited regrowth because of dry conditions. In May 2023 and 2024, following the end of grazing but before chemical termination, CC biomass was measured in all plots by hand-clipping, to the ground level, two areas of 2 × 3 ft per plot. Samples were dried at 122°F for a minimum of 48 hours in a forced-air oven and weighed to determine dry matter. Cover crops were chemically terminated in the third week of May, and the whole field was planted to grain sorghum with an NT planter approximately two weeks after termination, or about the first week of June. Fertilizer applied to sorghum was based on the standard producer practice and kept consistent across treatments. Grain sorghum was harvested with a field scale combine equipped with a calibrated yield monitor about the last week of October. Plot level yield and moisture content data were extracted using QGIS 3.34 Prizren software, and yields were adjusted to 13.5% moisture content.

At the initiation of the study in fall 2022 before planting CCs, soil samples and water infiltration measurements were collected from the 0- to 2-inch and 2- to 6-inch soil depths for initial characterization of soil chemical and physical properties. Again, in spring 2023 and 2024, soil samples and water infiltration measurements from ungrazed, T-H-L-H, and G-O plots were collected to determine the effects of CC biomass removal on soil chemical and physical properties. Soil bulk density (BD) was determined as mass of oven-dry soil divided by volume of the core following oven-drying at 221°F for 48 hours. Penetration resistance (PR) was measured at 10 random points within each plot using a hand cone penetrometer (Eijkelkamp Co., Giesbeek, The Netherlands) and readings were divided by the area of the cone (0.31 in.^{2}). Values of penetration resistance were adjusted to a field capacity gravimetric water content of 0.35 (g/g).

Additionally, 10 soil cores were randomly collected within each plot, divided into the 0- to 2-inch and 2- to 6-inch depths, and composited by depth. The soil sampling for nutrient analysis purposefully avoided sampling near cattle manure piles because of the likelihood of greater nutrient concentrations in these areas. Samples were air-dried, crushed, and sieved to pass through a 0.08-inch stainless steel screen. The SOC and particulate organic matter (POM, <0.0021 inch) concentrations were determined by loss-on-ignition. Soil pH was determined potentiometrically by an electrode. Soil NO_3-N concentrations in samples were determined with a segmented flow analyzer after extracting the soil with 2 M KCl. Available P was determined by the Mehlich-3 extraction method, and P concentration in the extract was measured using inductively coupled plasma-optical emission spectrometry (ICP-OES). Lastly, intact soil samples were carefully collected with a flat shovel and were allowed to air-dry and then gently passed through a 0.75-inch sieve. Subsamples of <0.31-inch diameter aggregates were obtained and used to estimate mean weight diameter (MWD) of water stable aggregates by the wet-sieving method. The remaining sample was used to estimate the wind-erodible fraction (WEF) (<0.03-inch) by the dry-sieving method. Analyses of CC biomass, grain yields, as well as soil chemical and physical properties were performed using the PROC GLIMMIX procedure in SAS ver. 9.4.

Results

The 2023-2024 average results from this study showed that T-H-L-H and G-O significantly reduced CC residue amount and height compared to ungrazed CCs (Fig. 1), though T-H-L-H maintained greater CC residue amount and height compared to G-O. However, percentage residue cover with G-O was not significantly different from the ungrazed treatment, and T-H-L-H was slightly less than G-O and ungrazed CCs (Figure 1). This suggests that increasing grazing intensity maintained residue cover on the soil surface similar to ungrazed CCs despite reducing residue amount primarily by reducing residue height. Cover crop management had no significant effect on SOC or POM, while P concentrations were reduced by T-H-L-H and G-O, likely due to avoiding manure piles high in P while sampling at subsequent grain sorghum planting in spring 2023 and 2024 (Table 1). Phosphorus concentrations may not be significantly different or potentially increased by T-H-L-H and G-O in the long term, when manure piles are more evenly distributed across the treatments measured. These results suggest that increasing grazing intensity overall maintained the soil chemical properties similar to ungrazed CCs. However, SOC, POM, and P concentrations were all greater in the 0- to 2-inch soil depth compared to 2- to 6 inch.

Soil BD was increased with T-H-L-H and G-O grazing management strategies at subsequent grain sorghum planting compared to ungrazed CCs and study initiation (Table 1). The wind erodible fraction (WEF) at subsequent grain sorghum planting was greater in all CC treatments compared to study initiation, but was not affected by CC management (Table 1). Cover crop management had no significant effect on PR, MWD, or time-to-runoff (TTR). These results suggest that increasing grazing intensity may slightly increase some indicators of soil compaction (i.e., BD) in the months following CCs termination before subsequent cash crop planting. However, increasing the grazing intensity maintained indicators of soil erodibility (i.e., MWD and WEF) and water infiltration (i.e., TTR) similar to ungrazed CCs. This was potentially because of exceptional drought conditions during the CC growing season and grazing period that resulted in very dry soils that were less susceptible to degradation by cattle hoof traffic. Results showed no significant effect of CC management on subsequent grain sorghum yields, which were 83, 89, and 89 bu/a for ungrazed CCs, T-H-LH, and G-O, respectively. This suggests that increasing grazing intensity maintained similar subsequent cash crop yields to ungrazed CCs.

Conclusion

Results showed that T-H-L-H and G-O CC grazing strategies significantly reduced CC residue amount and height compared to ungrazed CCs. However, the percent soil surface residue cover was similar to ungrazed CCs. Cover crop management had no significant effect on SOC or POM, while P concentrations were reduced by T-H-L-H and G-O in this short-term study. Take-half-leave-half somewhat increased soil BD compared to ungrazed CCs, though both were similar to G-O. Soil PR, WEF, MWD, TTR, and subsequent grain sorghum yield were unaffected by CC management. These results suggest that increasing grazing intensity maintained soil health indicators and subsequent grain crop yields similar to ungrazed CCs. Farmers and ranchers may be able to graze CCs at greater intensities than T-H-L-H to maximize livestock gains while maintaining soil health. This could increase adoption of CCs and benefit water quality protection and improvement efforts in reaching the goals of the approved 9 Element

Watershed Plan through the Kansas Department of Health and Environment and the Environmental Protection Agency. Nevertheless, these observations were made in a 2-year study and under exceptional drought conditions, so further investigation will be necessary under conditions of average or above average precipitation when wet soils may be more susceptible to degradation by cattle hoof traffic.

Table 1. Cover crop management and sampling depth effects on average soil organic carbon (SOC), particulate organic matter (POM), phosphorus (P), soil bulk density (BD), penetration resistance (PR), mean weight diameter (MWD) of water stable aggregates, wind-erodible fraction (WEF), and time-to-runoff (TTR) at subsequent grain sorghum planting in 2023 and 2024 near Dubuque, KS.

Treatment	SOC	POM	P	BD	PR	MWD	WEF	TTR
	%	%	ppm	g/cm3	MPa	mm	%	min
Management								
Initial	1.94†	1.00	14.7b	1.25b	---	1.23	23.7b	16.4a
Ungrazed CCs	2.00	1.04	20.2a	1.30b	0.88	1.51	34.9a	7.6b
Take-half-leave-half (50% removal)	1.93	0.88	15.3b	1.35a	0.86	1.49	32.7a	7.6b
Graze-out (90% removal)	1.89	0.91	15.6b	1.36a	0.83	1.40	32.7a	7.4b
Depth								
0-2 inch	2.36a	1.49a	22.7a	1.19b	0.63b	---	---	---
2-6 inch	1.52b	0.42b	10.2b	1.45a	1.08a	---	---	---
Type III test of fixed effects								
Parameter	*P*-values							
Management (M)	0.5382	0.1808	0.0329	0.0053	0.8958	0.8186	0.0024	<.0001
Depth (D)	<.0001	<.0001	<.0001	<.0001	<0.0001	---	---	---
M × D	0.9805	0.9312	0.6228	0.1353	0.9682	---	---	---

†Means with the same letter are not significantly different across treatments ($\alpha \leq 0.05$).

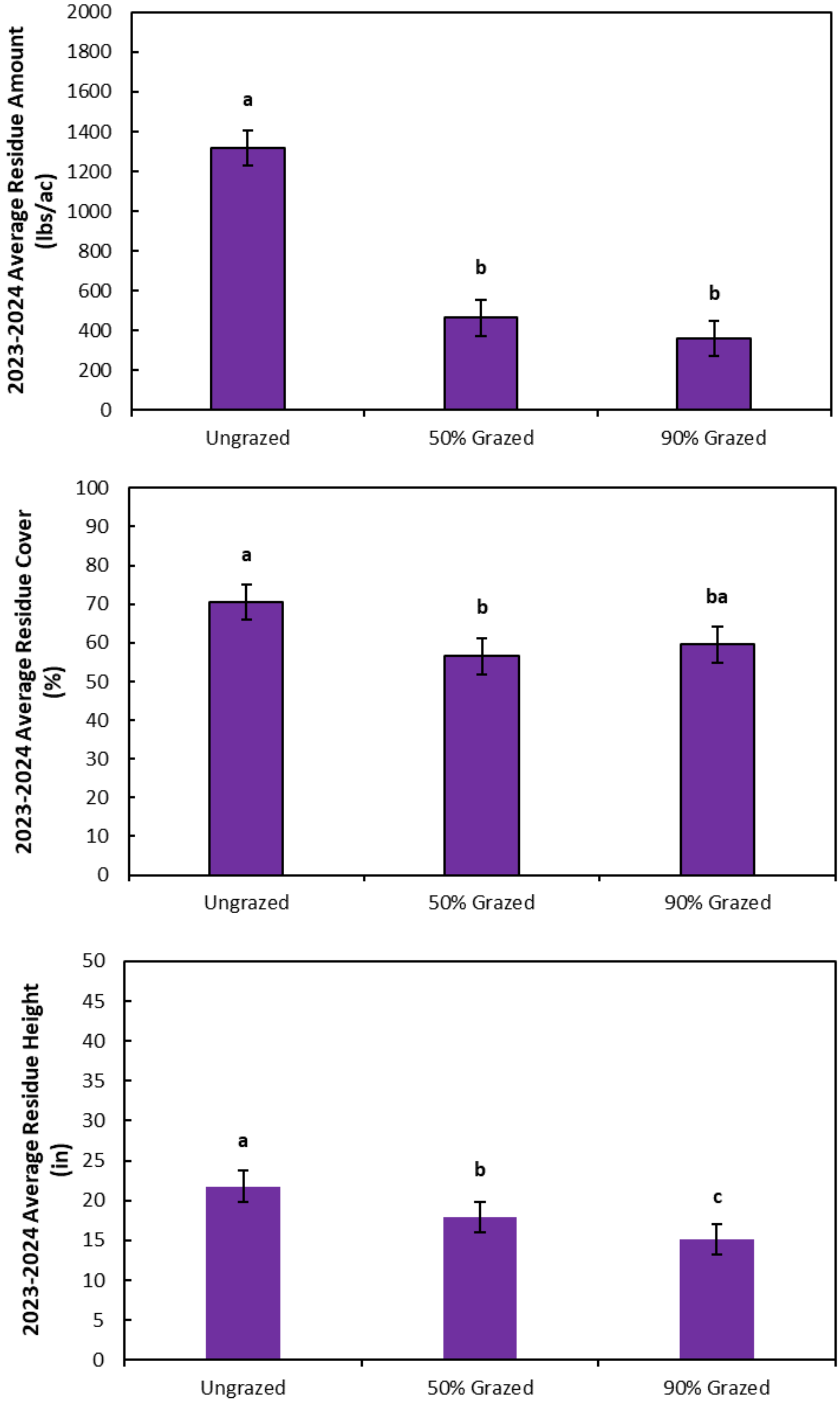

Figure. 1. Cover crop residue amount, cover, and height at cover crop termination near Dubuque, KS, in 2023 and 2024 growing seasons. Bars with the same letter are not significantly different across treatments ($\alpha \leq 0.05$). Error bars indicate standard error of the mean.

Crop Production and Soil Properties Impacts of Integrating Annual Forages and Ruminant Livestock into Wheat-Based Cropping Systems

Zachariah C. Carson, Augustine K. Obour, John D. Holman, Logan Simon and Kraig L. Roozeboom

Summary

Integrating annual forages and ruminant livestock to intensify dryland cropping systems can increase profitability, increase water use efficiency, and improve soil health. The objective of this study was to determine the crop yield and soil property impacts of intensifying traditional no-till winter wheat (*Triticum aestivum* L.)-grain sorghum (*Sorghum bicolor* Moench)-fallow (WW-GS-F) with annual forages as well as integrating livestock to graze forages and crop residues. This study was initiated in 2021 at the Kansas State University Agricultural Research Center-Hays in Hays, KS. Treatments were WW-GS-F (control), WW-GS-F with grain sorghum residues grazed, winter wheat/forage sorghum-forage sorghum-fallow (WW/FS-FS-F) with forage sorghum grazed, and WW/FS-FS-F with forage sorghum hayed. The treatments were replicated four times with all phases of the rotation present each year. Grain yields were determined in 2023 and 2024, while forage yields were determined every year with sampling to characterize soil properties in the fall of 2023 and 2024. Results showed that full-season forage sorghum harvested for hay produced 5255 lb/a on average, while post-wheat forage sorghum harvested for hay produced 2042 lb/a. Before grazing, full-season forage sorghum produced 8617 lb/a with about 51% of biomass remaining as residue after livestock were removed. On average, post-wheat forage sorghum produced 3399 lb/a before grazing. Because of smaller yields, post-wheat forage sorghum plots were grazed in only 2 years when 46% of biomass remained as residue on the plots after livestock were removed. In 2023 and 2024, WW yields averaged 16 bu/a due to dry weather, with no difference among treatments. Averaged across 2023 and 2024, the WW/FS-FS-F (grazed) treatment had greater crop residue cover (78%) at winter wheat planting than all other treatments (63%). No differences in bulk density in the 0- to 2-inch and 2- to 6-inch soil depths were observed across treatments. While penetration resistance did not show any differences in the top 0- to 2-inch depth, there was a significant decrease in penetration resistance in the 2- to 6-inch depth with WW/FS-FS-F treatments. Despite no differences in bulk soil organic carbon (SOC) in the 0- to 2-inch and 2- to 6-inch soil depths, dry and wet aggregate associated SOC was significantly greater with WW-GS-F (grazed) and WW/FS-FS-F (grazed) treatments than WW-GS-F and WW/FS-FS-F (hayed). No differences in mean weight diameter (MWD) of water stable aggregates or the wind-erodible fraction were observed across treatments. These preliminary results suggest that intensifying the WW-GS-F rotation with annual forages and integrating livestock increased available forage, soil residue cover, and aggregate associated organic carbon with no effect on winter wheat yields.

Introduction

Intensifying dryland cropping systems with annual forages and integrating ruminant livestock can increase profitability, enhance fallow water use efficiency, and improve soil health by increasing residue cover and reducing wind and water erodibility. Currently, the most common crop rotation in this region is winter wheat (WW)-summer crop-F. The most common crops utilized within that rotation are grain sorghum (GS) *(Sorghum bicolor* (L.) Moench*)* and corn *(Zea mays* L.*)* (Schlegel et al., 2002). Typically, after the summer crop is harvested, a 12- to 14-month fallow period is used to build soil water content for the next WW crop. Due to high evaporation in this climate, only 17% to 30% of precipitation is retained as stored soil moisture during the fallow period (Peterson & Westfall et al., 2004). Even with no-till (NT), less than half of the precipitation is retained, and soil cover is lost. Intensifying the rotation with annual forages may reduce soil water and have a negative impact on subsequent grain yield, but the forage that is produced for grazing and haying may offset negative impacts to profitability. Adding annual forages in wheat-based systems may even boost profitability (Holman et al., 2023). Concerns also may arise with the negative impacts that haying and grazing could potentially have on soil organic carbon (SOC) reserves, water-stable aggregates, and wind-erodible fraction due to grazing or haying the crop residue. Grazing is often seen negatively as it may increase soil compaction as indicated by greater bulk density (BD) and penetration resistance (PR). The objective of this study was to determine crop yield and soil health impacts of intensifying a traditional NT WW-GS-F system with annual forages, and integrating ruminant livestock to graze forages and crop residues.

Procedures

This study was initiated at the Kansas State University Agricultural Research Center-Hays in Hays, KS, with all phases of the experiment in place by 2021. The study design was a randomized complete block with four replications in a WW-GS-F rotation system. The study compared a WW-GS-F rotation with grazing of the GS stalks and with grazing or haying of annual forages grown in place of GS. Each crop phase and the hayed or grazed treatments were present each year. The plots were 60-ft wide by 127-ft long for the grazed treatments, and 30-ft wide by 127-ft long for the hayed treatments. Each treatment was grown under NT conditions.

Treatments:

Year 1: winter wheat; Year 2: grain sorghum; Year 3: fallow: (WW-GS-F)

Year 1: winter wheat; Year 2: grain sorghum (grazed stalks);
Year 3: fallow: (WW-GSG-F)

Year 1: winter wheat/double-crop forage sorghum (grazed);
Year 2: forage sorghum (grazed); Year 3: fallow: (WW/FSG-FSG-F)

Year 1: winter wheat/double-crop forage sorghum (hayed);
Year 2: forage sorghum (hayed); Year 3: fallow: (WW/FSH-FSH-F)

Winter wheat was planted at the end of September, GS and FS were planted at the beginning of June, and post-wheat FS was planted as soon as WW was harvested. Winter wheat was harvested in mid-late June, and GS was harvested in mid-October. All grain crops were harvested using a Massey Fergusson 8XP plot combine with a 5-ft wide header attached. Grain yields were determined by a single 5-ft by 127-ft pass with the combine. Hayed FS was harvested at the end of August. Forage sorghum yields were determined by a single harvest of a 3-ft by 127-ft pass with a Carter forage harvester at heading. Grazing of GS stocks occurred post GS harvest and at heading in FS. To determine the FS amount before grazing, a 2-ft by 3-ft quadrant was used to sample two different locations within the plot. After grazing, the methods were repeated to determine the amount of residue remaining.

In August 2023 and 2024, soil samples were collected and residue cover (RC) was measured from each plot pre-wheat planting. The soil properties examined were RC, wet and dry aggregate stability, BD, PR, SOC, and particulate organic matter (POM). Residue cover was analyzed using the line transect method. Two samples were collected per plot for aggregate stability and BD, while 10 soil samples per plot were collected for all other soil property analyses. Wet aggregate stability (MWD) was conducted by the wet sieving method using intact soil samples collected at the 0- to 2-inch depth (Nimmo and Perkins, 2002). Dry aggregate stability was determined using a set of rotary sieves, and the wind erodible fraction was estimated as the proportion of aggregates <0.84 mm at the 0- to 2-inch depth (Chepil, 1962). Wet and dry aggregates were then analyzed for SOC for the >2 mm, 2- to 0.25 mm, and <0.25 mm size distributions using the dry combustion method (Helmke et al., 2013). Particulate organic matter was determined using the procedure outlined by Cambardella and Elliot (1992) at the 0- to 2-inch and 2- to 6-inch depths. Bulk density was determined by the core method with samples taken from 0- to 2-inch and 2- to 6-inch depths (Grossman and Reinsch, 2002). Penetration resistance was determined using an Eijkelkamp Hand Penetrometer (Eijkelkamp Soil & Water, Morrisville, NC). Statistical analyses were completed in SAS version 9.4 (SAS Institute, 2012, Cary, NC) using PROC GLIMMIX with year and treatment considered as fixed and replication considered random. Treatment differences were considered significant at $P < 0.05$.

Results and Discussion

Crop yields

Average hayed full season FS removed 5255 lb/a, while post-wheat hayed FS removed 2042 lb/a (6 inches of stalk remaining after haying). The maximum hayed full season FS removed was in 2021 (8812 lb/a), while the maximum post-wheat hayed FS removed was in 2024 (3703 lb/a) for hayed treatments. Full season grazed FS produced 8617 lb/a on average before grazing and left approximately 51% of the forage as residue. Post-wheat FS was grazed for only two years during the study due to extreme droughts in 2022 and 2023. The maximum post-wheat FS was produced in 2021 (5348 lb/a), and approximately 82% of the total biomass was left after grazing due to trampling.

Due to a severe hail event in 2021 and an extreme drought in 2022, the only WW yields recorded were in 2023 and 2024. Yields were low due to dry weather, with an average of 16 bu/a and no significant differences in yields across treatments (data not shown).

Grain sorghum yield has only been recorded in 2024 after treatments had completed a full phase (3 years). There was no significant yield difference between the grain sorghum treatments (W-GS-F and W-GSG-F), with an average grain yield of 51 bu/a (data not shown).

Residue cover and soil properties

Averaged across years, the WW/FSG-FSG-F had the greatest residue cover (78%) (Figure 1). The next highest treatment was WW-GS-F (68%), with WW/FSH-FSH-F and WW-GSG-F having the least cover (58%).

Despite the differences in residue cover, bulk SOC was not significantly different among treatments. However, treatments differed significantly in dry and wet aggregate-associated carbon in all three aggregate size classes (>2 mm, 2-0.25 mm, and >0.25 mm) (Figure 2). Grazed treatments (WW-GSG-F and WW/FSG-FSG) ranked first or second in SOC in nearly all aggregate size classes compared to WW-GS-F and WW/FSH-FSH-F. Meaning although we have not seen a difference in bulk SOC, we are seeing an accumulation and stabilization of carbon within the individual aggregates, which can increase long-term carbon sequestration. However, POM measured in 2023 and 2024 did not differ among treatments at the 0- to 2-inch or 2- to 6-inch depths. Similarly, average wet aggregate stability and dry aggregate stability (MWD) and wind erodible fraction were not different across treatments at the 0- to 2-inch depth. Soil compaction indicator, BD, measured in 2023 and 2024 at 0- to 2-inch and 2- to 6-inch depths was not different across treatments. While penetration resistance was not different in the 0- to 2-inch depth, it was significantly different in the 2-to 6-inch depth, with the more intensive cropping rotations (WW/FSG-FSG-F and WW/FSH-FSH-F) having a lower penetration resistance (Table 1).

Conclusion

Intensifying the WW-GS-F rotation with annual forages and integrating ruminant livestock significantly increased aggregate associated organic carbon and residue cover, while the intensification decreased PR in the 2- to 6-inch depth. The addition of annual forages and livestock had no effect on MWD, WEF, BD, bulk SOC, WW, and GS yields. These results occurred while making an additional forage available for haying and grazing, potentially increasing profits.

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Table 1. Treatment effects on average soil organic carbon (SOC), particulate organic matter (POM), soil bulk density (BD), penetration resistance (PR), mean weight diameter (MWD) of water stable aggregates, and wind-erodible fraction (WEF) in 2023 and 2024 near Hays, KS

Depth	Treatment	SOC	POM	PR	BD	MWD	WEF
		%	%	MPa	g/cm^{-3}	mm	%
0-2 in	W-GS-F	1.27†	0.58	0.55	1.23	1.0	28
	W-GSG-F	1.31	0.53	0.49	1.22	1.0	29
	W/FSG-FSG-F	1.34	0.59	0.46	1.23	1.1	27
	W/FSH-FSH-F	1.27	0.54	0.56	1.15	1.1	32
2-6 in	W-GS-F	1.09	0.16	0.90a	1.41	---	---
	W-GSG-F	1.16	0.17	0.91a	1.45	---	---
	W/FSG-FSG-F	1.14	0.17	0.75b	1.45	---	---
	W/FSH-FSH-F	1.14	0.18	0.84ba	1.46	---	---

†Means with the same letter are not significantly different across treatments ($\alpha \leq 0.05$).

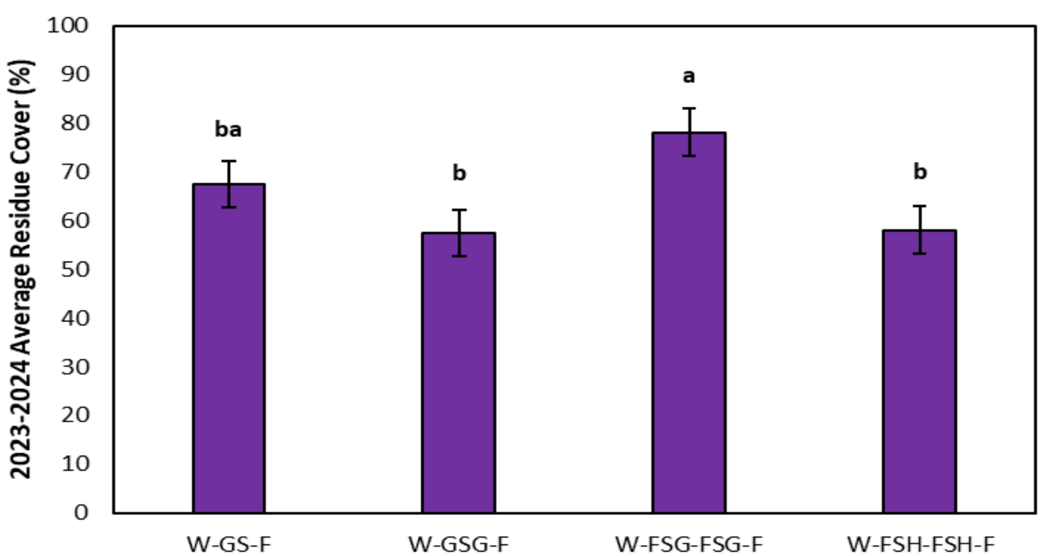

Figure 1. 2023-2024 average effects of intensification of WW-GS-F with grazing and forage sorghum on residue cover. Means with the same letter are not significantly different ($P < 0.05$).

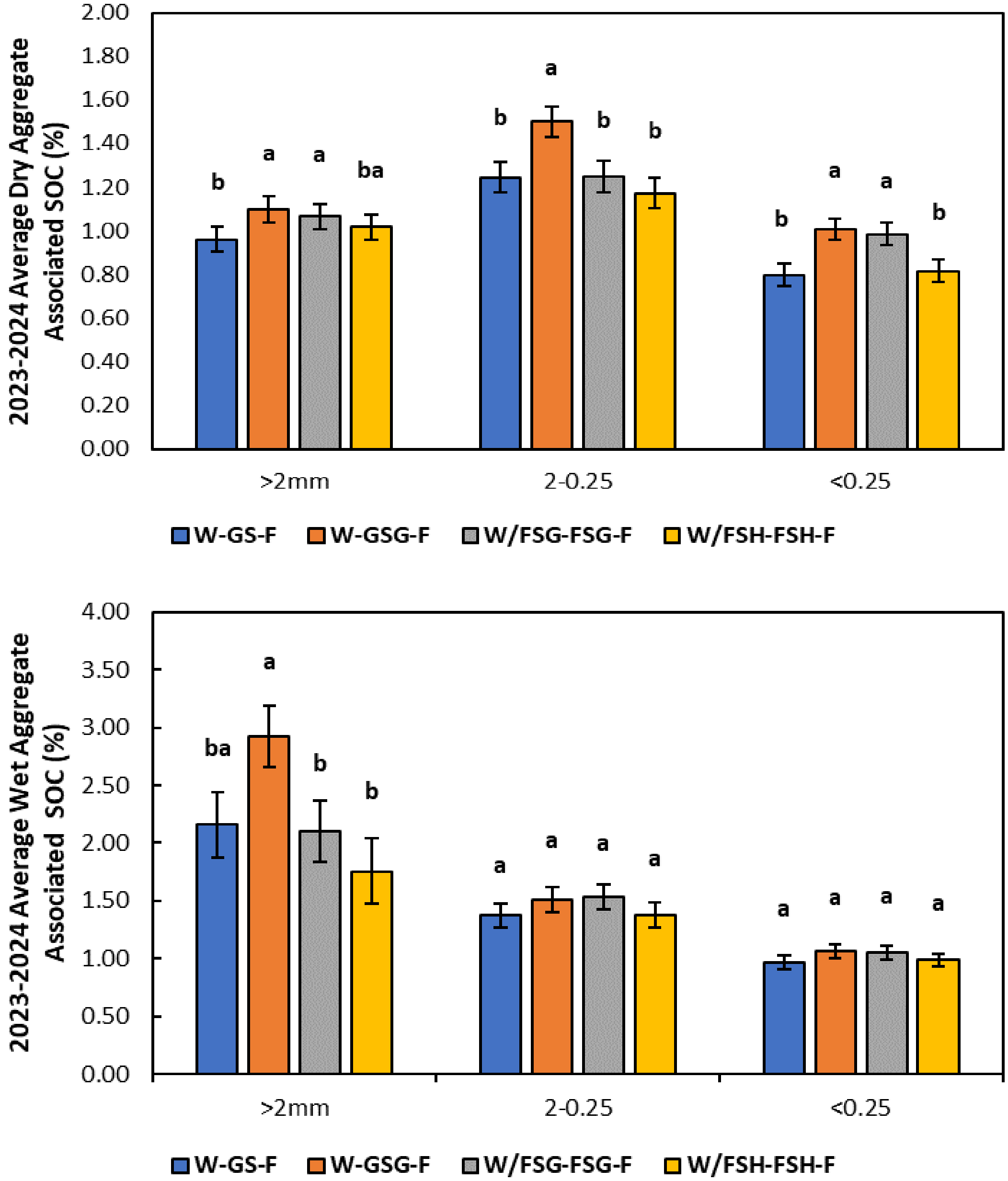

Figure 2. 2023-2024 average effects of intensification of WW-GS-F with grazing and forage sorghum on dry and wet aggregate-associated soil organic carbon (SOC). Means with the same letter are not significantly different ($P < 0.05$).

Occasional Tillage in a Wheat-Sorghum-Fallow Rotation

John Holman, Augustine Obour, and Lucas Haag

Summary

Beginning in 2012, research was conducted near Garden City and Tribune, KS, to determine the effect of a single tillage operation every 3 years on grain yields in a wheat-sorghum-fallow (WSF) rotation. Treatments included no-till, single tillage post wheat harvest in mid-August, and single tillage in mid-June during the fallow phase. This study was revised with the addition of two more intensive tillage treatments since 2019. The two additional treatments were 1) two tillage operations during the fallow phase, and 2) one tillage during fallow phase and one tillage post wheat harvest. Grain yield varied greatly by year and location. Wheat yields ranged across years from mid-20s to 90 bu/a at Tribune and less than 10 to 100 bu/a at Garden City. Grain sorghum yields ranged from 40 to greater than 140 bu/a, depending upon year and location. Drought and hail at Garden City resulted in several years of no harvestable grain sorghum at Garden City. Wheat yields were greater when tillage occurred during the fallow phase at Garden City. There were no differences in wheat yield at Hays or Tribune. Grain sorghum yield was greater in no-till at Tribune. There were no differences in grain sorghum yield at Garden City or Hays. There are some year-by-treatment differences, and treatment differences might be increasing over time. For these reasons, more years of data are needed. Currently, this study supports the hypothesis that if herbicide-resistant weed populations are a challenge, an occasional tillage operation will have little effect on crop yield.

Introduction

Previous research showed lower dryland wheat and grain sorghum yields with reduced tillage compared with no-tillage in a wheat-sorghum-fallow (WSF) rotation near Tribune, KS (Schlegel et al., 2018). The reduced tillage systems generally used four or more tillage operations in the 3-year rotation. With the increased incidence of herbicide-resistant weeds, the use of a complete no-tillage system may not be economical, and tillage may be needed for effective control. The objective of the research project is to determine the effect of occasional tillage (1-2 tillage operations every 3 years) on wheat and grain sorghum yields in a WSF rotation.

Procedures

Research on occasional tillage in a WSF rotation at the Kansas State University Southwest Research-Extension Center research stations at Garden City and Tribune was initiated in 2014 and at Hays in 2015. Initially, three tillage treatments were compared: 1) single tillage in May or June during fallow, 2) single tillage after wheat harvest, and 3) no-tillage system. Beginning in 2017, two additional treatments were added: 4) single tillage in fallow plus single tillage after wheat harvest, and 5) two tillage operations during fallow. All treatments are arranged in a split-plot randomized complete block with four replications. The main plot is crop phase (all crop phases present each year), and split-plot was tillage treatment.

A sweep plow (Minimizer by Premier Tillage) was used for all tillage operations. Herbicides were used to control weeds across all treatments. All other cultural practices (variety/hybrid, seeding rate, fertilization, etc.) varied by location but were consistent within a location for all treatments.

Results and Discussion

Weeds were effectively controlled in all treatments although herbicide resistant kochia and Johnsongrass at Garden City were difficult to control.

At Garden City, treatment differences varied by year, but in most years and across years the tillage during the fallow year increased yield (Table 1). Drought and hail damage resulted in some years of no sorghum yield at Garden City. No treatment differences in grain sorghum yields occurred at Garden City (Table 2).

At Hays, wheat and grain sorghum yields were not affected by treatment (Table 3 and Table 4).

At Tribune, treatment did not affect wheat yield (Table 5). Grain sorghum yield was greatest in no-till and least in the treatment with both tillage in fallow and post-wheat harvest (Table 6).

In other research (Schlegel et al. 2018), reduced tillage systems (with four tillage operations) produced lower yields than no-till in a WSF rotation. Yield differences in this prior study became more apparent after 10 years. Yield differences in the current study may also start to become more apparent with time. With the exception of maybe Tribune, an occasional tillage operation to manage herbicide-resistant weeds appeared to have little effect on crop yield.

Acknowledgment

This research was supported in part by the Ogallala Aquifer Program, a consortium between USDA Agricultural Research Service, Kansas State University, Texas AgriLife Research, Texas AgriLife Extension Service, Texas Tech University, and West Texas A&M University.

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Table 1. Occasional tillage treatment effect on wheat yields, 2014 through present at Garden City, KS

Year	No-till	June tillage in fallow	July after wheat	June and July in fallow	June in fallow and July after wheat	*P* > F
2014	7.3	5.7	8.0	---	---	---
2015	31.7	32.6	28.3	---	---	---
2016	51.5	55.8	52.4	---	---	---
2017	20.0	19.5	23.0	---	---	---
2018	3.6	3.4	6.6	8.6	7.4	0.04
2019	89.5	100.3	83.0	95.2	100.0	0.00
2020	26.9	29.0	24.3	32.1	32.4	0.01
2021	41.3	72.8	46.1	65.1	66.1	0.00
2022	22.9	30.1	17.1	26.1	28.1	0.04
2023	24.2	23.4	18.4	15.3	21.8	0.01
2024	42.5	43.0	47.5	42.9	46.5	0.72
Average						
2014-present	32.9	37.8	32.2	---	---	---
2018-present	32.9b	37.8a	32.2b	40.8a	43.2a	<0.0001

Letters different within a row significant at $P \leq 0.05$

Table 2. Occasional tillage treatment effect on sorghum yields, 2014 through present at Garden City, KS

Year	No-till	June tillage in fallow	July after wheat	June and July in fallow	June in fallow and July after wheat	*P* > F
2014	54.3	53.4	44.1	---	---	---
2015	58.6	57.4	67.7	---	---	---
2016	108.5	112.8	65.8	---	---	---
2017	50.6	46.4	44.1	---	---	---
2018	97.7	88.5	93.1	---	---	---
2019	40.7	40.9	39.8	41.8	37.9	0.8
2020	46.8	46.3	47.2	44.4	45.0	1.0
2021	---	---	---	---	---	---
2022	10.4	10.4	3.7	11.7	7.1	0.1
2023	---	---	---	---	---	---
2024	---	---	---	---	---	---
Average						
2014-present	58.4	57.0	50.7	---	---	---
2019-present	32.6a	32.5a	30.2a	32.6a	30.0a	0.8

Letters different within a row significant at $P \leq 0.05$

Table 3. Occasional tillage treatment effect on wheat yields, 2015 through 2024 at Hays, KS

Year	No-till	June tillage in fallow	June and July in fallow	July after wheat	June in fallow and July after wheat	*P* > F
2015	12b	16.3a	14.3ab	---	---	0.06
2016	60.3ab	58.3b	63.7a	---	---	0.09
2017	35.0a	43.0a	33.7a	---	---	0.28
2018	29.0a	28.3a	26.7a	---	---	0.79
2019	42.3a	52.7a	46.7a	---	---	0.21
2020	57.3a	62.7a	58.7a	---	---	0.45
2021	---	---	---	---	---	---
2022	36.7a	39.7a	39.7a	39.3a	38.7	0.96
2023	14.0a	12.7a	16.7a	18.7a	21.3a	0.69
2024	27.3a	24.3a	26.0a	26.7a	25.3a	0.82
Average						
2022-present	26.0a	25.6a	29.0a	28.2a	26.9a	0.82
2015-present	34.9a	37.6a	36.6a	---	---	0.96

Letters different within a row significant at $P \leq 0.05$

Table 4. Occasional tillage treatment effect on grain sorghum yields, 2015 through 2024 at Hays, KS

Year	No-till	June tillage in fallow	June and July in fallow	July after wheat	June in fallow and July after wheat	*P* > F
2015	102.6a	85.0b	90.3ab	---	---	0.07
2016	97.7a	97.3a	91.0a	---	---	0.40
2017	92.0a	80.0a	95.0a	---	---	0.27
2018	95.3a	98.0a	87.7a	---	---	0.21
2019	106.0a	96.0ab	92.0b	---	---	0.10
2020	105.7a	97.0 b	91.3b	---	---	0.08
2021	73.0 a	67.3a	76.0a	62.3a	65.0a	0404
2022	46.7 a	33.0 a	34.0 a	36.0 a	31.7 a	0.50
2023	42.3a	52.3a	36.3a	42.0a	51.7a	0.21
2024	62.7a	55.7abc	51.3bc	49.0c	59.0ab	0.06
Average						
2021-present	56.2a	50.8a	49.4a	48.9a	51.8a	0.85
2015-present	82.4a	75.6a	74.5a	---	---	0.42

Letters different within a row significant at $P \leq 0.05$

Table 5. Occasional tillage effect on wheat grain yields, K-State SWREC-Tribune

Year	No-till	June in fallow	July after wheat harvest	June in fallow and July after wheat harvest	June and July in fallow
2014	28.0	22.3	23.2	---	---
2015	23.7	21.7	20.6	---	---
2016	74.7	81.3	76.8	---	---
2017	30.2	24.6	26.6	---	---
2018	57.3	58.0	56.8	---	---
2019	93.4	89.3	88.9	92.4	88.2
2020	45.1	40.1	42.3	40.7	40.3
2021	68.8	64.5	66.6	69.5	71.4
2022	---	---	---	---	---
2023	16.1	21.3	25.3	30.3	22.9
2024	29.2	29.5	29.8	30.1	31.6
Average					
2014-present	46.7	45.3	45.7	---	---
2019-present	50.5a	48.9a	50.6a	52.6a	50.9a

Letters different within a row significant at $P \leq 0.05$

Table 6. Occasional tillage effect on sorghum grain yields, K-State SWREC-Tribune

Year	No-till	June in fallow	July after wheat harvest	June in fallow and July after wheat harvest	June and July in fallow
2014	77.0	84.2	86.1	---	---
2015	132.8	113.7	107.9	---	---
2016	129.4	128.6	126.5	---	---
2017	147.3	145.3	140.9	---	---
2018	130.0	123.2	114.9	---	---
2019	132.0	128.7	130.7	132.0	133.3
2020	98.9	102.2	94.0	86.3	95.5
2021	120.5	109.8	115.3	115.9	120.0
2022	75.0	66.0	60.9	64.0	73.9
2023	86.3	74.4	77.5	55.0	65.6
2024	99.7	77.6	72.3	45.8	71.7
Average					
2014-present	111.7a	104.9b	102.5b	---	---
2019-present	102.1a	93.1b	91.8b	83.1c	93.3b

Letters different within a row significant at $P \leq 0.05$

Identifying the Maximum Allowable Soil Moisture Depletion to Enhance Cotton Production Irrigated by Multiple Sprinkler Irrigation Technologies

Farzam Moghbel and Jonathan Aguilar

Summary

Proper irrigation scheduling is one of the critical fundamentals of successful cotton establishment in arid and semi-arid regions. Soil moisture monitoring could be one of the practical methods to schedule irrigations to optimize cotton growth. However, finding a suitable value of soil moisture that can be used as a trigger point for irrigation initiation during the growing season has remained unsolved. In this study, the profitability of cotton production was considered along with a water conservation perspective to identify this trigger point when monitoring soil moisture. Therefore, field experiments were conducted in 2024 to investigate the cotton response to a particular maximum allowable soil moisture depletion, which could protect cotton final production and result in water resources conservation under various irrigation technologies in western Kansas. The research outputs showed that the highest cotton yield (2682.7 lb/a) was detected when applying irrigation, followed by 50% depletion of available soil moisture, regardless of irrigation technologies. However, applying irrigation followed by an 80% depletion of available soil moisture is recommended when the water supply is highly limited. The irrigation that was triggered by 80% soil moisture depletion resulted in a 20% reduction in cotton production compared to 50% soil moisture depletion conditions under all irrigation technologies (bubbler, sprayer, and MDI's sprayer). In this study, for the first time, the functionality of the sprayers attached to mobile drip irrigation (MDI) laterals was tested for cotton production. These sprayers are connected to the drip lines to be used for germination purposes and in circumstances where laterals cannot be used. In this growing season, the highest cotton production (2252.7 lb/a) was found to utilize these attached sprayers compared to other irrigation technologies. However, a similar cotton yield (2212.4 lb/a) was found using bubblers as target irrigation technology. Overall, the results of this study could be used as a baseline for producers of cotton in western Kansas, especially when their water is limited, and an acceptable cotton yield is needed.

Procedures

Practicing suitable agricultural water management techniques is one of the key factors to cope with water scarcity in arid and semi-arid regions to maintain the profitability of the agricultural industry. The semi-arid region of Western Kansas in the U.S. Central High Plains has faced many challenges in protecting the sustainability of irrigated agriculture (Deines et al., 2019). This is due to significant reductions in the Ogallala aquifer that supplies the water for agricultural production in the region (Drysdale and Hendricks, 2018; Klocke et al., 2011). Cultivating cotton, an alternative to high water-demanding crops, has higher water use efficiency and is resistant to drought, which could be a potential approach to deal with the issue (Cheng et al., 2021). The successful combination of cotton cultivation with deficit irrigation practices seems to be a proper water-conservative solution (Bordovsky et al., 2015). Water-conservative irrigation strategies aim to save water by reducing irrigation water application while minimizing the adverse impacts on the quality and quantity of the crop yield. Variable approaches have been pursued in studies regarding the effects of irrigation strategies on cotton yield. One of the practical methods could be pursuing conservative irrigation strategies by controlling soil maximum allowable depletion (MAD). The MAD determines the allowable soil water content deficit from field capacity as a trigger point for irrigation scheduling (Kirkham, 2014). This approach could be used as crop-based strategic supplementary irrigation under high MAD levels. Our literature review found a lack of information regarding the proper MAD values for cotton irrigation management that could maintain the profitability of the crop and simultaneously preserve the sustainability of water resources. Therefore, as the cotton establishment in Kansas requires a reliable approach to implement irrigation scheduling, a field study was conducted in 2024 with the following objectives: a) determining the cotton responses to various MAD levels, b) identifying the effects of sprinkler irrigation nozzle technologies on adaptability of cotton at the MAD levels.

The experimental site was located at Kansas State University, Southwest Research-Extension Center near Garden City, Kansas, USA (38°01’20.87” N, 100°49’26.95” W). The well-drained Ulysses silt loam with pH = 8.1 was the abundant soil type of the experimental field. The soil’s physical characteristics are presented in Table 1 (Araya et al., 2017; Kocke et al., 2011).

The average annual precipitation and evaporation are 18.77, and 71.25 inches, respectively, based on long-term weather characteristics data in Garden City, KS.

1.1. Experimental design and treatments

The field experiments with a complete randomized block design were conducted in 2024 with three replications. Maximum allowable depletion treatments were implemented to trigger the irrigations when the soil water depleted to 50%, 60%, and 80% of field capacity. A four-span center pivot sprinkle irrigation unit was equipped with a variable rate irrigation (VRI) device and four different irrigation nozzle technologies, including two mobile drip irrigation (MDI) configurations, low energy precision application (LEPA), and low elevation sprayer application (LESA). However, due to technical issues in the filtering system during the 2024 growing season, the MDI laterals had to be closed and switched to attached sprayers. The VRI prescription was prepared and loaded at each irrigation event according to the target treatments.

1.2. Field management and data collection

The weather characteristics data, including daily relative humidity, precipitation, solar radiation, wind speed, and minimum and maximum temperature, were obtained from the closest weather tower belonging to the K-State Mesonet network. Afterward, the daily evapotranspiration values were calculated based on the FAO-56 Penman method (Allen et al., 1998). The daily weather data for both growing seasons are presented in Figure 1.

Eight different SENTEK Bluetooth drill and drop sensors (Stepney SA 5069, Australia) were installed in the field to continuously monitor volumetric soil water to 110 cm soil depth with 5 cm increments. The sensors' data were downloaded every three days to examine the status of soil water content in terms of reaching the designated maximum allowable depletion levels and implementing the corresponding irrigation depths. The applicable irrigation depth by the majority of the sprinkler irrigation systems in the U.S. Central High Plains is one inch per irrigation event, which corresponds to soil water content replenishment to 18 inches soil depth. Hence, the soil water content data from the soil surface to 18 inches of soil depth was considered in MAD level determination.

The PhytoGen205 cotton (*Gossypium*) seeds were planted on June 6, 2024, with 60,000 seeds/a density. The crop row spacing was 2.5 ft. Cotton growth stages were recorded throughout the growing seasons. Agronomic practices, such as the application of fertilizer, pesticide, crop growth regulator, and weed management, were pursued based on local guidelines. The cotton yield was hand-harvested on November 22, 2024. Based on the previous studies conducted at K-State Southwest Research-Extension Center, 8% of total hand-harvested samples were considered trash and subtracted from the corresponding yield values.

Results and Discussion

Cotton yield (Seed + Lint)

The results found significant effects of implementing various maximum allowable depletion (MAD) effects on cotton yield under various irrigation technologies (Figure 2). The highest cotton yield (2682.7 lb/a) was found for implementing the 50% MAD under the bubbler irrigation nozzle, while similar results were found for the sprayer systems that are attached to mobile drip irrigation. Pursuing cotton irrigation under sprayer nozzles resulted in the lowest cotton yield (1553.4 to 2004.3 lb/a), regardless of the MAD-based irrigation strategies. Under all three irrigation technologies, increasing the MAD level from 50% to 80% drastically reduced cotton yield. However, there was a minimal difference in increasing MAD 60% to 80% for irrigating cotton in western Kansas. Thus, increasing MAD levels from 60% to 80% is recommended to face severe water shortages in the region. Considering the results obtained during the 2024 growing season, cotton production under the MDI sprayer would show higher tolerance to increasing MAD levels by 80% when the MDI sprayer was used as irrigation technology. These findings emphasized that in case of failure of MDI irrigation, such as what happened during our study, the accompanying sprayers to MDI irrigation laterals could be safely used as an alternative to the MDI laterals until proper maintenance takes place.

In addition to the interaction effects of the treatments, the cotton yield was analyzed against both MAD and irrigation technologies separately (Figure 3). Similar to the above-mentioned results, applying the 50% MAD level significantly increased cotton yield compared to 60% and 80% MAD applications. The cotton yield obtained under MDI's sprayer and bubbler nozzle was almost identical (2252.7 and 2212.4 lb/a). The sprayer nozzle was again found to be the least promising irrigation technology for cotton production.

Acknowledgments

This study was financially supported by Cotton Incorporated, which is highly appreciated.

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Table 1. The soil physical characteristics of the experimental field near Garden City, KS

Depth	Sand	Silt	Clay	Soil texture	Bulk density	Saturation	Field capacity	Permanent wilting point
in.					g cm^{-3}	---------------------	%	---------------------
0-10	18.5	52.5	29	Silty Clay Loam	1.37	46.2	30.7	16
10-30	18	57	25	Silt Loam	1.38	44.8	35.1	15.1
30-96	19	57	24	Silt Loam	1.39	44.6	35.2	14
0 - 96	18.5	55.5	26	Silt Loam	1.38	45.2	33	15

The saturation and field capacity soil water content limits are volumetric values.

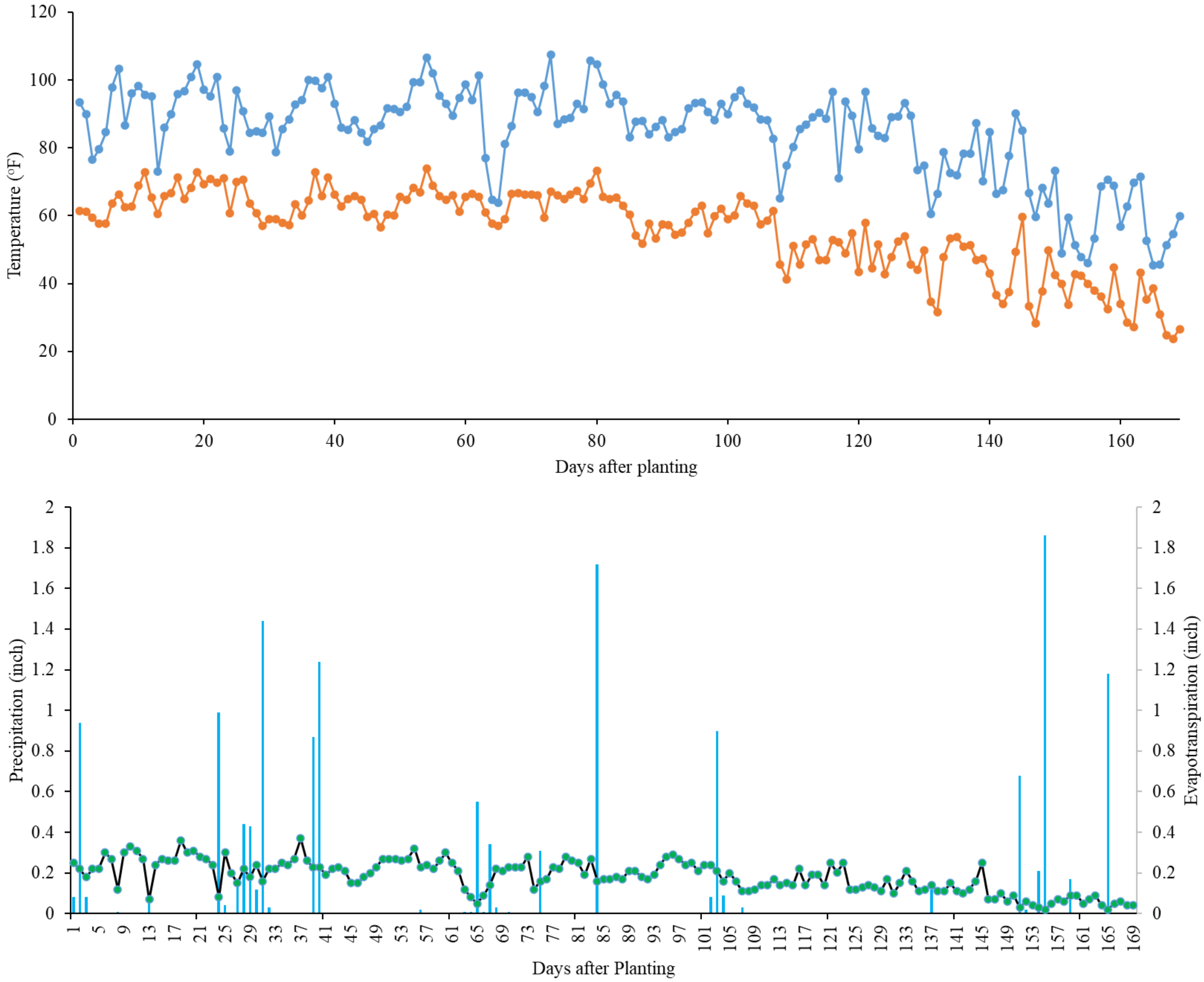

Figure 1. Daily weather characteristics data for the 2024 cotton growing season. The planting date was June 6, 2024.

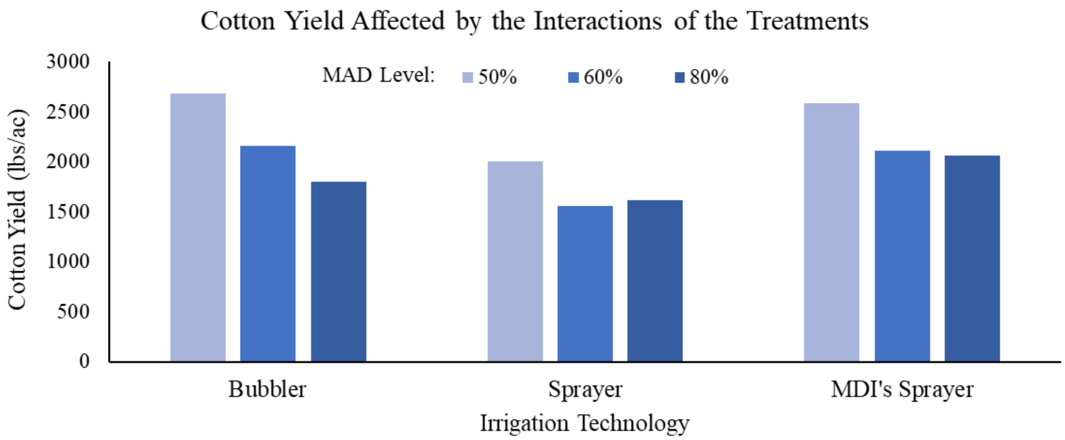

Figure 2. Cotton yield (seed + lint) as affected by interactions of implementing three levels of maximum allowable depletion (MAD) and irrigation technologies in western Kansas during the 2024 growing season.

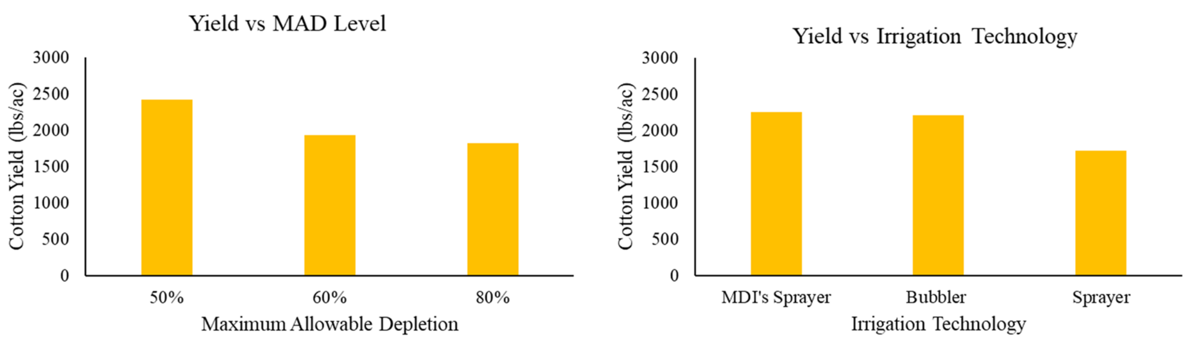

Figure 3. Exploring individual cotton yield responses to MAD levels and irrigation technologies in western Kansas during the 2024 growing season.

Glufosinate Products and Timings for Efficacy in Corn

Patrick W. Geier

Summary
This study compared several glufosinate-containing herbicides for efficacy in Enlist corn. Treatments were applied at several application timings, including preemergence (PRE), early postemergence (EPOST), postemergence (POST), and late postemergence (LPOST). All herbicides controlled velvetleaf, Venice mallow, and Russian thistle well late in the season. Atrazine PRE followed by Surmise 5, Zalo plus S-metolachlor EPOST, and Zalo EPOST followed by Zalo POST were less effective on Palmer amaranth and kochia than other herbicides by season's end. For green foxtail, only Zalo plus S-metolachlor EPOST and the atrazine followed by Surmise treatments provided less than 95% control.

Introduction
Several new products are coming onto the market that contain glufosinate, a nonselective herbicide that can be used in glufosinate-resistant corn. Zalo combines glufosinate with quizalofop, a grass herbicide that can be sprayed in corn containing the Enlist trait. Liberty Ultra is a new formulation of glufosinate that contains a greater concentration of the herbicidally active isomer per gallon, allowing for a 25% reduction in the amount of product used. This study was conducted to compare several glufosinate-based herbicides at various timings for efficacy in corn.

Experimental Procedures
An experiment compared several glufosinate-containing products (Zalo, Liberty Ultra, and Surmise 5) at several application timings for efficacy in corn. All herbicides were applied using a tractor-mounted, compressed-CO_2 sprayer delivering 19.4 gpa at 30 psi and 4.1 mph. Application, environmental, and plant information is shown in Table 1. Plots were 10 by 35 ft, and arranged in a randomized complete block design replicated four times. Soil was Ulysses silt loam having 2.7% organic matter, pH of 7.9, and cation exchange capacity (CEC)of 28.4. Visual weed control was determined on June 12 and July 8, 2024. These dates were 1 day after the POST (C) treatments (1 DAC) and 14 days after the LPOST (D) treatments (14 DAD), respectively.

Results and Discussion
Generally, atrazine applied PRE followed by Surmise 5 and Callisto LPOST was the least effective herbicide on the weed species tested, especially early in the season (Tables 2 and 3). All other treatments provided good control of Palmer amaranth, Russian thistle, velvetleaf, and Venice mallow at 1 DAC. Surtain applied PRE followed by Liberty Ultra and Status was less effective on green foxtail (85%) than S-metolachlor PRE followed by Zalo plus S-metolachlor EPOST (100%) at 1 DAC. Zalo applied PRE, EPOST, and/or POST provided the best kochia control early in the season. By 14 DAD, no differences between herbicides were observed for velvetleaf, Venice mallow, or Russian thistle. Kochia and Palmer amaranth control at 14 DAD was best (89%

to 100%) when S-metolachlor PRE was followed by Zalo EPOST, or when Surtain, Resicore, or Storen were applied PRE. Green foxtail control was 95% or more late in the season with all herbicides except Zalo plus S-metolachlor EPOST or Atrazine PRE followed by Surmise 5 LPOST.

Acknowledgments
Partial funding for this research was provided by AMVAC Corporation and BASF Corporation.

Table 1. Application, environmental, and plant information for the glufosinate corn trial

Application timing	Preemergence	Early POST[1]	Post-emergence	Late POST
Application date	May 3, 2024	June 4, 2024	June 11, 2024	June 24, 2024
Air temperature (F)	61	72	82	71
Relative humidity (%)	53	100	53	76
Soil temperature (F)	60	70	70	75
Wind speed (mph)	6 to 10	2 to 5	3 to 7	1 to 4
Wind direction	Southeast	East	Southwest	South
Soil moisture	Dry	Wet	Good	Fair
Corn				
Height (in.)	---	4 to 7	8 to 12	16 to 28
Leaves (no.)	0	3 to 4	4 to 5	6 to 7
Kochia				
Height (in.)	---	1 to 4	2 to 6	2 to 6
Density (plants/ft^2)	0	2.5	1.5	1.5
Velvetleaf				
Height (in.)	---	1 to 3	4 to 7	---
Density (plants/ft^2)	0	0.3	0.1	0
Russian thistle				
Height (in.)	---	2 to 5	3 to 6	1 to 2
Density (plants/ft^2)	0	0.3	0.1	0.1
Venice mallow				
Height (in.)	---	1 to 3	---	---
Density (plants/ft^2)	0	0.2	0	0
Palmer amaranth				
Height (in.)	---	0.5 to 2	1 to 3	1 to 3
Density (plants/ft^2)	0	1	0.1	0.1
Green foxtail				
Height (in.)	---	0.5 to 2	1 to 4	1 to 5
Density (plants/ft^2)	0	1	1	0.1

[1] POST is postemergence.

Table 2. Efficacy of glufosinate products on kochia, velvetleaf, and Venice mallow in corn

			Kochia		Velvetleaf		Venice mallow	
Treatment[1]	Rate	Timing[2]	1 DAC[3]	14 DAD[3]	1 DAC	14 DAD	1 DAC	14 DAD
	oz/a		% Visual					
Zalo	32	EPOST	86	84	100	100	95	100
COC	1.0%	EPOST						
AMS	3 lb	EPOST						
Zalo	32	POST						
COC	1.0%	POST						
AMS	3 lb	POST						
Zalo	32	EPOST	91	80	100	100	98	100
S-metolachlor	21	EPOST						
COC	1.0%	EPOST						
AMS	3 lb	EPOST						
S-metolachlor	21	PRE	95	89	100	100	100	100
Zalo	32	EPOST						
S-metolachlor	21	EPOST						
COC	1.0%	EPOST						
AMS	3 lb	EPOST						
Surtain	14	PRE	80	89	100	100	100	100
Liberty Ultra	24	LPOST						
Status	5.0	LPOST						
AMS	0.1 lb	LPOST						
Atrazine	32	PRE	43	78	45	100	73	98
Surmise 5	16.4	LPOST						
Callisto	3.0	LPOST						
AMS	0.1 lb	LPOST						
Resicore	80	PRE	75	90	100	100	100	100
Enlist Duo	76	LPOST						
Zidua SC	3.0	LPOST						
AMS	3 lb	LPOST						
Storen	77	PRE	81	90	100	100	98	100
Atrazine	32	LPOST						
Glyphosate	28	LPOST						
AMS	3 lb	LPOST						
LSD (0.05)			6	5	4	NSD	11	NSD

[1] COC is crop oil concentrate, AMS is ammonium sulfate.
[2] PRE is preemergence, EPOST is early postemergence, POST is postemergence, and LPOST is late postemergence.
[3] DAC is days after the postemergence treatment, DAD is days after the late postemergence treatments.

Table 2. Efficacy of glufosinate products on Palmer amaranth, Russian thistle, and green foxtail in corn

			Palmer amaranth		Russian thistle		Green foxtail	
Treatment[1]	Rate	Timing[2]	1 DAC[3]	14 DAD[3]	1 DAC	14 DAD	1 DAC	14 DAD
	oz/a		% Visual					
Zalo	32	EPOST	100	91	100	100	90	95
COC	1.0%	EPOST						
AMS	3 lb	EPOST						
Zalo	32	POST						
COC	1.0%	POST						
AMS	3 lb	POST						
Zalo	32	EPOST	100	91	98	94	96	84
S-metolachlor	21	EPOST						
COC	1.0%	EPOST						
AMS	3 lb	EPOST						
S-metolachlor	21	PRE	100	99	100	100	100	100
Zalo	32	EPOST						
S-metolachlor	21	EPOST						
COC	1.0%	EPOST						
AMS	3 lb	EPOST						
Surtain	14	PRE	100	100	98	96	85	96
Liberty Ultra	24	LPOST						
Status	5.0	LPOST						
AMS	0.1 lb	LPOST						
Atrazine	32	PRE	53	88	70	98	50	81
Surmise 5	16.4	LPOST						
Callisto	3.0	LPOST						
AMS	0.1 lb	LPOST						
Resicore	80	PRE	100	100	100	100	93	100
Enlist Duo	76	LPOST						
Zidua SC	3.0	LPOST						
AMS	3 lb	LPOST						
Storen	77	PRE	93	98	80	95	94	100
Atrazine	32	LPOST						
Glyphosate	28	LPOST						
AMS	3 lb	LPOST						
LSD (0.05)			9	8	20	NSD	12	5

[1] COC is crop oil concentrate, AMS is ammonium sulfate.
[2] PRE is preemergence, EPOST is early postemergence, POST is postemergence, and LPOST is late postemergence.
[3] DAC is days after the postemergence treatment, DAD is days after the late postemergence treatments

Status Compared to Standards for Early Postemergence Efficacy in Corn

Patrick W. Geier

Summary
The addition of Status herbicide to Halex GT generally increased the control of kochia, Palmer amaranth, and johnsongrass compared to Halex GT alone. The tank mixture of Status plus Zidua SC with or without Callisto was as effective as Resicore, Halex GT plus Status, Acuron GT plus Status, and Callisto plus Sequence and Status on kochia and Palmer amaranth. Diflexx Duo plus atrazine controlled kochia and Palmer amaranth similarly to the Status tank mixtures, but was less effective on johnsongrass. Grain yields increased 9- to 14-fold with all herbicide-treated corn relative to the untreated controls.

Introduction
A key method of managing herbicide resistant weeds is to combine herbicides with different modes of action. The goal of this approach is to overcome weeds that may have one resistance mechanism with an herbicide from a different chemical family. Status herbicide combines dicamba and diflufenzopyr, which controls weeds by mimicking auxins and inhibiting their transport within the plants. The objective of the trial was to combine Status with various other herbicides for early postemergence weed control in corn.

Experimental Procedures
An experiment evaluated Status herbicide combined with other herbicides for early postemergence weed control in corn. Herbicides were applied using a compressed-CO_2 backpack sprayer delivering 19.4 gpa at 32 psi and 3.0 mph. Application, environmental, and plant information is shown in Table 1. Plots were 10 by 35 ft, and arranged in a randomized complete block design replicated four times. Soil was Beeler silt loam having 2.4% organic matter, pH of 7.5, and cation exchange capacity (CEC) of 17.8. Visual weed control was determined on July 1 and August 6, 2024. These dates were 28 and 64 days after herbicide application (DAT). Corn yields were determined on October 17, 2024 by mechanically harvesting the center two rows of each plot and adjusting grain moistures to 15.5%.

Results and Discussion
Early season kochia control was 95% or more with all treatments except Halex GT and Acuron GT at 28 DAT (Table 2). By 64 DAT, kochia control exceeded 90% with all herbicides except with Halex GT, Acuron GT, or Diflexx Duo plus atrazine. The addition of Status improved kochia control compared to Halex GT alone, but not when added to Acuron GT. Status with Zidua SC, Halex GT, Acuron GT, or Sequence provided 94 to 96% Palmer amaranth control at 28 DAT, and was similar to Resicore plus glyphosate or Diflexx Duo plus atrazine. Palmer amaranth control increased 11% when Status was added to Halex GT or Acuron GT. At 64 DAT, Palmer amaranth was controlled 74 to 80% with Halex GT, Acuron GT, or Diflexx Duo plus atrazine,

whereas Status-containing treatments provided 85 to 90% control. Most treatments provided 90% or more johnsongrass control at 28 DAT; Diflexx Duo plus atrazine did not. Treatments containing Status plus Zidua SC, Halex GT, or Acuron GT were the most effective for controlling johnsongrass at 64 DAT (86 to 91%). Corn receiving herbicide treatments yielded 90 to 148 bu/a more grain than the nontreated checks (10.1 bu/a). However, yields were best when Resicore, Diflexx Duo plus atrazine, Status plus Halex GT, or Status plus Zidua and Callisto were applied (133 to 158 bu/a).

Acknowledgments

Funding for this research was provided by BASF Corporation.

Table 1. Application, environmental, and plant information for the Status corn trial

Application date	June 3, 2024
Air temperature (F)	76
Relative humidity (%)	60
Soil temperature (F)	70
Wind speed (mph)	2 to 5
Wind direction	South
Soil moisture	Wet
Corn	
Height (in.)	4 to 7
Leaves (no.)	2 to 4
Kochia	
Height (in.)	3 to 6
Density (plants/ft^2)	0.3
Palmer amaranth	
Height (in.)	1 to 7
Density (plants/ft^2)	5
Johnsongrass	
Height (in.)	2 to 5
Density (plants/ft^2)	0.5

Table 2. Weed control and crop yield in the early postemergence Status corn experiment

Treatment[1]	Rate	Kochia		Palmer amaranth		Johnsongrass		Grain yield
		28 DAT[2]	64 DAT	28 DAT	64 DAT	28 DAT	64 DAT	
	oz/a	% Visual						bu/a
Untreated control	---	---	---	---	---	---	---	10.1
Status Zidua SC Glyphosate COC AMS	5.0 2.5 30 1.0% 1.0%	95	93	96	88	97	89	100.3
Status Zidua SC Callisto Glyphosate COC AMS	5.0 2.5 3.0 30 1.0% 1.0%	98	94	96	90	96	91	154.7
Halex GT NIS AMS	60 0.25% 1.0%	89	84	84	74	90	78	123.9
Acuron GT COC AMS	60 1.0% 1.0%	91	88	85	79	93	83	124.1
Resicore Glyphosate COC AMS	50 30 1.0% 1.0%	99	91	93	83	93	85	156.8
Halex GT Status NIS AMS	60 5.0 0.25% 1.0%	99	95	95	85	96	86	133.1
Acuron GT Status COC AMS	60 5.0 1.0% 1.0%	95	94	96	86	93	89	117.9
Callisto Sequence Status COC AMS	3.0 32 5.0 1.0% 1.0%	99	96	94	88	90	83	121.1
Diflexx Duo Atrazine Glyphosate COC AMS	24 16 30 1.0% 1.0%	95	89	90	80	88	80	157.7
LSD (0.05)		6	7	6	8	6	5	33.2

[1] COC is crop oil concentrate, AMS is ammonium sulfate, NIS is nonionic surfactant.
[2] DAT is days after treatment.

Voraxor for Burndown and Residual Weed Control in Spring Fallow

Patrick W. Geier

Summary
The addition of Voraxor improved the burndown rate of all weed species evaluated compared to Zidua SC plus Enlist One, Boundary 6.5, or Matador-S alone early in the season. The 1.0 oz rate of Voraxor was as effective as the 1.4 oz rate for most species evaluated; only Palmer amaranth and green foxtail responded differently between Voraxor rates. Voraxor-containing treatments controlled Palmer amaranth, Russian thistle, and green foxtail 90% or more at 35 days after treatment, and kochia and puncturevine 84% to 100%.

Introduction
Fallow weed control between crops is an important component of reduced and no-till agriculture on the Plains of the Western U.S. However, the widespread development of herbicide resistant weeds has impaired fallow weed control efforts in recent years. Consequently, development of novel herbicides to combat resistant weeds has become increasingly important. Voraxor herbicide combines saflufenacil with a new herbicide, trifludimoxazin, for burndown and residual weed control. The objective of this study was to evaluate Voraxor for efficacy in spring fallow.

Experimental Procedures
An experiment compared Voraxor at two rates in combination with various tank mixtures for weed control in spring fallow. Herbicides were applied using a tractor-mounted, compressed-CO_2 sprayer delivering 19.4 gpa at 30 psi and 4.1 mph. Application, environmental, and plant information is shown in Table 1. Plots were 10 by 35 ft, and arranged in a randomized complete block design replicated four times. Soil was Ulysses silt loam having 2.7% organic matter, pH of 7.9, and cation exchange capacity (CEC) of 28.4. Visual weed control was determined on May 30 and July 1, 2024. These dates were 3 and 35 days after herbicide application (DAT).

Results and Discussion
At 3 DAT, Voraxor at 1.0 or 1.4 oz increased the control (burndown) of kochia, Palmer amaranth, Russian thistle, puncturevine, and green foxtail compared to Zidua SC plus Enlist One, Boundary 6.5, or Matador-S alone (Table 2). This trend continued for kochia control at 35 DAT. By 35 DAT, either rate of Voraxor improved Palmer amaranth control compared to Boundary 6.5 or Matador-S alone, but only the higher rate improved Palmer amaranth compared to Zidua SC plus Enlist One. For Russian thistle and puncturevine at 35 DAT, Voraxor did not improve control compared to Zidua SC plus Enlist One or Matador alone, but did improve control compared to Boundary 6.5. Neither rate of Voraxor improved green foxtail control with Zidua SC plus Enlist One at 35 DAT. However, green foxtail control at 35 DAT was slightly less when the 1.0 oz rate of Voraxor was added to Boundary or Matador-S, and similar when the 1.4 oz rate was used.

Acknowledgments

Funding for this research was provided by BASF Corporation.

Table 1. Application, environmental, and plant information for the Voraxor fallow trial

Application date	**May 27, 2024**
Air temperature (F)	75
Relative humidity (%)	31
Soil temperature (F)	69
Wind speed (mph)	2 to 5
Wind direction	Northeast
Soil moisture	Fair
Palmer amaranth	
Height (in.)	0.5 to 2
Density (plants/ft^2)	0.2
Kochia	
Height (in.)	1 to 3
Density (plants/ft^2)	3
Russian thistle	
Height (in.)	1 to 3
Density (plants/ft^2)	0.2
Puncturevine	
Diameter (in.)	1 to 4
Density (plants/ft^2)	0.2
Green foxtail	
Height (in.)	1 to 2
Density (plants/ft^2)	0.2

Table 2. Efficacy of Voraxor plus tank mixtures in spring fallow

		Kochia		Palmer amaranth		Russian thistle		Puncturevine		Green foxtail	
Treatment[1]	**Rate**	**3 D[2]**	**35 D[2]**	**3 D**	**35 D**	**3 D**	**35 D**	**3 D**	**35 D**	**3 D**	**35 D**
	oz/a	% Visual									
Zidua SC Enlist One COC	3.25 32 1.0%	53	45	65	86	58	98	58	90	53	90
Voraxor Zidua SC MSO	1.0 3.25 1.0%	93	88	100	90	100	94	99	91	96	91
Voraxor Zidua SC MSO	1.4 3.25 1.0%	93	88	100	92	100	100	100	96	94	90
Voraxor Zidua SC Enlist One MSO	1.0 3.25 32 1.0%	95	86	100	94	100	100	100	95	99	93
Voraxor Zidua SC Enlist One MSO	1.4 3.25 32 1.0%	95	90	100	96	100	100	100	100	98	91
Boundary 6.5 COC	24 1.0%	40	50	55	73	53	78	58	70	53	98
Voraxor Boundary 6.5 MSO	1.0 24 1.0%	94	93	100	94	100	100	100	89	98	90
Voraxor Boundary 6.5 MSO	1.4 24 1.0%	97	93	100	96	100	100	100	84	98	94
Matador-S COC	48 1.0%	50	53	50	78	55	93	48	93	53	100
Voraxor Matador-S MSO	1.0 48 1.0%	95	95	100	97	100	100	100	98	98	94
Voraxor Matador-S MSO	1.4 48 1.0%	97	96	100	95	99	100	100	100	98	94
LSD (0.05)		6	7	7	8	5	7	6	11	7	6

[1] All treatments included glyphosate at 22 oz/a plus ammonium sulfate at 8.5 lb/100 gallons. COC is crop oil concentrate, MSO is methylated seed oil.

[2] D is days after herbicide application.

Intrava DX for Residual Weed Control in Spring Fallow

Patrick W. Geier and K.B. Jeremie Kouame

Summary
Intrava DX, KFD-881, and Preview herbicide mixtures provided excellent control of kochia, Palmer amaranth, and Russian thistle through four weeks following application at Garden City and near complete common lambsquarters and horseweed control at Hays. At Garden City, Russian thistle control exceeded 94% with all herbicides at 77 days after treatment (DAT). Kochia control remained excellent with Preview at either rate 77 DAT as well. Only the high rates of Intrava DX and KFD-881 provided as much as 70% Palmer amaranth control at 77 DAT at Garden City. Overall, Palmer amaranth control was higher at Hays, but the high rates of Intrava DX and KFD-881 were most effective at this location as well. These results show promise that these herbicides may effectively control weeds in fallow for extended periods of time.

Introduction
Widespread herbicide resistance has made weed control during the fallow period between crops increasingly difficult. Biotypes of weeds such as kochia and Palmer amaranth have developed multiple resistance to several of the commonly used fallow herbicide classes. Therefore, the development of new herbicides to control these weeds is important. Amicarbazone is an herbicide not currently registered in fallow that may help control these weeds. The objective of these trials was to compare three herbicide mixtures — Intrava DX (amicarbazone + metribuzin), KFD-881 (amicarbazone + mesotrione), and Preview (metribuzin + sulfentrazone) — for residual weed control in spring fallow.

Experimental Procedures
Two experiments in Kansas compared Intrava DX, KFD-881, and Preview herbicides, each at two rates for preemergence weed control in spring fallow. Herbicides were applied using either a tractor-mounted, compressed-CO_2 sprayer delivering 19.4 gpa or a compressed-CO_2 backpack sprayer delivering 21 gpa. Application, environmental, and plant information is shown in Table 1. Plots were 10 by 30 or 35 ft, and arranged in a randomized complete block design replicated four times. Soil at each location was a silt loam. At Garden City, visual weed control was determined on May 28 and July 16, 2024. These dates were 28 and 77 days after herbicide application (DAT), respectively. At the Hays location, weed control was assessed visually on June 27 and July 12 (29 and 44 DAT, respectively).

Results and Discussion
At Garden City, kochia control at 28 DAT was 88% or more regardless of herbicide treatment (Table 2). KFD-881 at 21 oz/a and Preview at 14 or 21 oz/a gave the best kochia control (96 to 100%). Kochia control remained best (98 to 99%) with either rate of Preview at 77 DAT, whereas Intrava DX and KFD-881 controlled kochia 78% to 89%. Palmer amaranth control did not differ between any herbicide tested at 28

DAT, exceeding 95%. By 77 DAT, only Intrava DX and KFD-881, each at 21 oz/a, provided more than 70% Palmer amaranth control. Intrava DX, KFD-881, and Preview were very effective (95% or more) at controlling Russian thistle throughout the growing season.

At Hays, control of common lambsquarters was essentially complete regardless of rating date (Table 3), as was control of horseweed (data not shown). At 29 DAT, kochia control was best with the 21 oz/a rates of KFD-881 or Preview, and with the atrazine plus Starane Ultra treatment (Table 3). All herbicides except the low rates Intrava DX and Preview provided at least 90% kochia control at 44 DAT. Overall, Palmer amaranth control at Hays was greater than at Garden City with these herbicides. While most herbicides controlled Palmer amaranth 90% or more at Hays, the 21 oz/a rates of Intrava DX and KFD-881 were most effective (95 to 97%) at 29 and 44 DAT. These results suggest each of these herbicides can be effective at controlling troublesome weeds in fallow.

Acknowledgments

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Table 1. Application, environmental, and plant information for the Intrava DX fallow trial

Location	Garden City	Hays
Application date	April 30, 2024	May 29, 2024
Air temperature (F)	57	83
Relative humidity (%)	78	51
Soil temperature (F)	58	77
Wind speed (mph)	3 to 5	3 to 5
Wind direction	South	Southeast
Soil moisture	Dry	Good

Table 2. Efficacy of Intrava DX applied preemergence in spring fallow at Garden City

		Kochia		Palmer amaranth		Russian thistle	
Treatment[1]	**Rate**	**28 DAT[2]**	**77 DAT[2]**	**28 DAT**	**77 DAT**	**28 DAT**	**77 DAT**
	oz/a	------------------------------------ % Visual ------------------------------------					
Intrava DX	14	88	78	100	60	98	100
Intrava DX	21	91	81	98	73	98	98
KFD-881	12	91	80	98	60	98	98
KFD-881	21	96	89	100	73	100	95
Preview	14	97	99	98	43	100	100
Preview	21	100	98	100	63	100	100
Atrazine	32	91	78	96	33	100	98
Starane Ultra	8						
LSD (0.05)		4	7	NS	10	NS	NS

[1] All treatments included glyphosate at 22 oz/a, dicamba at 16 oz/a, nonionic surfactant at 0.25% V/V and ammonium sulfate at 3.0 lb/a.

[2] DAT is days after herbicide application.

Table 3. Efficacy of Intrava DX applied preemergence in spring fallow at Hays

		Kochia		Palmer amaranth		Lambsquarters	
Treatment[1]	**Rate**	**29 DAT[2]**	**44 DAT[2]**	**29 DAT**	**44 DAT**	**29 DAT**	**44 DAT**
	oz/a	------------------------------------ % Visual ------------------------------------					
Intrava DX	14	73	78	88	92	98	100
Intrava DX	21	80	90	96	95	100	100
KFD-881	12	71	90	92	92	100	100
KFD-881	21	87	93	97	97	100	100
Preview	14	80	74	91	91	100	100
Preview	21	87	91	94	93	100	100
Atrazine	32	93	95	95	90	100	100
Starane Ultra	8						
LSD (0.05)		7	5	3	3	NS	NS

[1] All treatments included glyphosate at 22 oz/a, dicamba at 16 oz/a, nonionic surfactant at 0.25% V/V and ammonium sulfate at 3.0 lb/a.
[2] DAT is days after herbicide application.

Residual Herbicide Programs With Multiple Sites-of-action Improved Weed Control in Grain Sorghum

Olumide S. Daramola, K.B. Jeremie Kouame, Taylor Lambert, Matthew Vredenburg, and Atong A. Akom

Summary

A strong preemergence herbicide program is an essential best management practice for multiple herbicide-resistant weeds. Palmer amaranth is a prolific seed producer that has evolved resistance to 6 herbicide sites-of-action in Kansas. The objective of this study was i) to evaluate the effectiveness and crop safety of residual herbicide programs with single and multiple sites-of-action used for weed control in no-till dryland grain sorghum production systems of western Kansas and ii) the impact of lowering the rate of Callisto in mixture with Dual II Magnum on weed control in no-till dryland grain sorghum production systems of western Kansas. Results showed that the preemergence herbicide treatments controlled Palmer amaranth (96-100%), puncturevine (93-100%), and large crabgrass (96-100%) 22 days after application. However, control of these weeds decreased at 43 days after treatment, with atrazine providing the least control (63-70%) compared to other herbicide combinations, including FulTime NXT, Calibra, atrazine + Calibra, Verdict + Outlook, or Dual II Magnum + Callisto (83-100%). Sorghum injury ranged from 1.3% to 17% 15 days after treatment, but sorghum recovered with injury levels of 7% or less at 43 days after treatment. The Dual II Magnum + Callisto combinations resulted in higher yields (92-94 bu/a) compared to the untreated control (69 bu/a). The results suggest that the herbicides evaluated can be safely applied to sorghum for weed control under favorable environmental conditions. Higher rates of Callisto in combination with Dual II Magnum did not offer additional weed control benefits compared to the lower rates used in this trial. Regardless of application rates, herbicide programs incorporating active ingredients targeting multiple sites-of-action resulted in improved weed control compared to those targeting a single site-of-action. Therefore, these herbicide programs can help minimize Palmer amaranth escapes and prevent the replenishment of the soil seedbank.

Grain sorghum is a weak competitor with most weeds because it grows slowly, particularly during the early stage of growth (Thompson et al. 2019). This results in ample opportunity for weeds to occupy space, compete with the crop, and reduce yields. Research has shown that even light weed infestations in the early growing season will reduce yields significantly. Weed control options in grain sorghum are more limited compared to corn, cotton, and soybeans. Grain sorghum is not tolerant to many widely used grass and broadleaf herbicides and can sometimes suffer injury from herbicides that are labeled for use in sorghum. In addition, the effectiveness of many herbicides has been reduced due to the development of resistant weeds (Thompson et al. 2019). One of the most troublesome weeds in Kansas grain sorghum production is Palmer amaranth due to its ability to develop resistance to multiple herbicides (Heap, 2025). It has evolved metabolic resistance to six different herbicide sites-of-action within the state and is known for its high seed production, which allows it to rapidly replenish the soil seedbank. Therefore, effective management of herbicide-resistant weeds such as Palmer amaranth in grain sorghum requires the implementation of a strong residual herbicide program. In fact, previous research on the emergence patterns of glyphosate-resistant Palmer amaranth, using a resistance-simulation model, emphasized the importance of residual herbicides in ensuring season-long weed suppression and reducing seed production. Moreover, keeping crop fields free of weeds, especially in conservation-tillage systems where preplant tillage is not an option, requires the application of residual herbicides. The objectives of this study were to evaluate the effectiveness of weed control and crop tolerance in no-till dryland grain sorghum production systems of western Kansas resulted from i) residual herbicide programs with single and multiple sites-of-action and ii) the impact of lowering the rate of Callisto in mixture with Dual II Magnum herbicide programs for weed control.

Procedures

This study was conducted during the 2024 growing season at K-State Agricultural Research Center near Hays, Kansas, on a soil classified as a Harney silt loam, with a slope range of 0 - 1% (USDA-SCS, 1969) and a pH of 6.4. Particle size analysis revealed that the soil consisted of 8% sand, 54% silt, and 38% clay. The field site had a natural infestation of Palmer amaranth (*Amaranthus palmeri*), puncturevine (*Tribulus terrestris*), and large crabgrass (*Digitaria sanguinalis*). The experiment was implemented in a no-till system. The study was arranged in a randomized complete block design with 4 replications. Plot size was 10 feet by 27 feet. In total, 12 pre-emergence herbicide programs were evaluated (Table 1).

All the pre-emergence herbicides were applied on the day of grain sorghum planting. A CO_2-pressurized backpack sprayer with TeeJet AIXR11002 nozzles (Spraying Systems Co., Glendale Heights, IL) calibrated to deliver 15 gpa spray volume, at 3 mph, was used to spray the pre-emergence herbicide treatments. Weed control was assessed visually at 22 and 43 days after treatment, while crop injury was assessed visually at 15, 29, and 43 days after preemergence herbicide application on a scale of 0% to 100% (where 0% is no injury and 100% is complete death of the plant). K-State Research and Extension recommendations for agronomic practices were followed. Yield was determined at physiological maturity by harvesting the middle two rows of each plot, and yields from each treatment were converted to bushel/a at 13% moisture content.

Results and Discussion

Palmer amaranth control

All the pre-emergence herbicide programs suppressed Palmer amaranth compared to the non-treated control throughout the period of observation. Palmer amaranth control was similar among the pre-emergence herbicide treatments and ranged from 96% to 100% at 22 days after treatment (data not shown). However, as the season progressed, Palmer amaranth control with atrazine 43 days after treatment (63%) was lower relative to other pre-emergence herbicide treatments (83% to 99%) (Figure 1). Regardless of application rates, the mixtures of Dual II Magnum + Callisto provided greater control of Palmer amaranth (91% to 99%) compared with sole application of atrazine, Dual II Magnum, Outlook, or Warrant (63% to 88%). Palmer amaranth control with mixtures of Dual II Magnum + Callisto at rates of 5, 4, 3, or 2 oz/a showed no differences, indicating that higher rates of Callisto in combination with Dual II Magnum did not offer additional weed control benefits compared to the lower rates used in this study. Consequently, using higher rates may increase the cost of weed control without providing added effectiveness.

This study demonstrates that herbicide programs incorporating active ingredients targeting multiple sites-of-action resulted in improved weed control compared to those targeting a single site-of-action. Palmer amaranth in Kansas has developed metabolic resistance to six herbicide sites-of-action (Heap 2025). Additionally, a single female plant can produce 600,000 seeds, allowing it to rapidly replenish the soil seedbank. Minimizing Palmer amaranth escapes and preventing its seedbank replenishment requires herbicide programs with multiple sites of action.

Puncturevine Control

Puncturevine control with the pre-emergence herbicide programs was similar 22 days after treatment, with effectiveness ranging from 93% to 100%. This suggests that these herbicides provided effective suppression of puncturevine early in the growing season (data not shown). However, 43 days after treatment, puncturevine control with atrazine was only 65% compared with 75% to 99% with the other pre-emergence herbicide programs. The mixtures of atrazine + Calibra, Verdict + Outlook, or Dual II Magnum + Callisto at rates of 5, 4, 3, or 2 oz/a provided 84% to 99% control of puncturevine 43 days after treatment. These herbicide programs provided greater puncturevine control than sole application of Outlook, Warrant, atrazine, or Dual Magnum, indicating the benefit of herbicide mixture for better weed control than single herbicide application (Figure 2).

Crabgrass Control

All the pre-emergence herbicide programs suppressed crabgrass compared to the non-treated control throughout the period of observation. Crabgrass control was similar across the pre-emergence herbicide treatments, with effectiveness ranging from 96% to 100% at 22 days after treatment (data not shown). Crabgrass control at 43 days after treatment was not greater than 70%. All the herbicide treatments provided better crabgrass control compared with atrazine 43 days after treatments. Crabgrass control with FulTime NXT, Calibra, mixtures of atrazine + Calibra, Verdict + Outlook, or Dual II Magnum + Callisto at rates of 5, 4, 3, or 2 oz/a was greater than control with Outlook and Warrant alone (Figure 3).

Crop Injury

Sorghum injury 15 days after pre-emergence herbicide treatments ranged from 1.3% to 17%. Treatments with atrazine, atrazine + Callisto, Dual, Dual + Callisto at 5 oz/a, Dual + Callisto at 3 oz/a, Verdict + Outlook, and Warrant resulted in greater injury (10% to 17%) compared to Calibra, Outlook, and Dual + Callisto at 3 or 5 oz/a (<10%). However, sorghum recovered with injury levels of 9% or less at 29 and 43 days after treatment (Table 2). By 43 days after treatment, only Dual, Outlook, Verdict + Outlook, and Dual + Callisto at 3 oz/a caused visual crop injury, and the injury was not greater than 7% (Table 2). These results suggest that these herbicides can be safely applied to sorghum for weed control under favorable environmental conditions.

Sorghum Yield
All pre-emergence herbicide treatments resulted in similar sorghum yields, ranging from 69 to 92 bu/a. The pre-emergence application of mixtures of Dual II Magnum + Callisto at rates of 5, 4, 3, or 2 oz/a produced higher yields (92 to 94 bu/a) compared to the nontreated control. However, other pre-emergence herbicide treatments resulted in yields similar to those of the nontreated control (Figure 4). The higher yields observed from herbicide treatments including the mixtures of Dual II Magnum + Callisto may be attributed in part to more effective residual weed control at 43 days after treatment, compared to other herbicide programs.

This study demonstrates that herbicide programs incorporating active ingredients targeting multiple sites-of-action resulted in improved weed control compared to those targeting a single site-of-action. In Kansas, Palmer amaranth has developed metabolic resistance to six herbicide sites-of-action. Additionally, female plants are prolific seed producers and can replenish the soil seedbank. To combat the increasing prevalence of multiple herbicide-resistant weeds, particularly Palmer amaranth, a strategy that prevents seed production is recommended. Therefore, herbicide programs that incorporate active ingredients with multiple sites-of-action, which proved effective in this study, are essential to reduce Palmer amaranth escapes and prevent the replenishment of the soil seedbank.

Acknowledgment
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Table 1. Preemergence herbicide programs evaluated, active ingredients modes of action and rates of application

Product	Active ingredient*	SOA group #+	Rates
Atrazine	Atrazine	5	1 qt/a
Atrazine + Calibra	Atrazine + (*S*-metolachlor + Mesotrione)	5 + (15+ 27)	1 qt/A + 2.25 qt/a
Calibra	(*S*-metolachlor + Mesotrione)	(15 + 27)	2.25 qt/a
Dual	*S*-metolachlor	15	1.6 pt/a
Dual + Callisto	*S*-metolachlor + Mesotrione	15 + 27	1.6 pt/A + 2 oz/a
Dual + Callisto	*S*-metolachlor + Mesotrione	15 + 27	1.6 pt/A + 3 oz/a
Dual + Callisto	*S*-metolachlor + Mesotrione	15 + 27	1.6 pt/A + 4 oz/a
Dual + Callisto	*S*-metolachlor + Mesotrione	15 + 27	1.6 pt/A + 5 oz/a
FulTime NXT	(Acetochlor + Atrazine)	(15 + 27)	2.25 qt/a
Outlook	Dimethenamid-p	15	18 oz/a
Verdict + Outlook	(Dimethenamid-p + Saflufenacil) + Dimethenamid-p	(14 +15) + 15	10 oz/A +10 oz/a
Warrant	Acetochlor	15	2 qt/a

* Active ingredients in parentheses are premixes.
+ SOA: site-of-action.

Table 2. Sorghum injury at 15, 29, and 43 days after preemergence herbicide treatment (DAT). Means followed by the same letter(s) within a week of observation are not significantly different using the least squares means (LSMEANS) and adjusted Tukey multiple comparison procedure (*P* > 0.1)

	Injury rating (%)		
Herbicide program	15 DAT	29 DAT	43 DAT
Atrazine	10 ab	2 a	0 a
Atrazine + Calibra	12.5 ab	4.5 a	0 a
Calibra	8.8 ab	0 a	0 a
Dual	15 a	8.8 a	7 a
Dual 1.6 pt/a + Callisto 2oz/a	1.3 b	0 a	0 a
Dual 1.6 pt/a + Callisto 3oz/a	10.5 ab	5 a	1.8 a
Dual 1.6 pt/a + Callisto 4oz/a	2.5 b	0 a	0 a
Dual 1.6 pt/a + Callisto 5oz/a	17 a	0 a	0 a
FulTime NXT	15 a	7 a	0 a
Outlook	7 b	2 a	2 a
Verdict + Outlook	11.3 a	5.8 a	2.5 a
Warrant	11.3 a	4.5 a	0 a

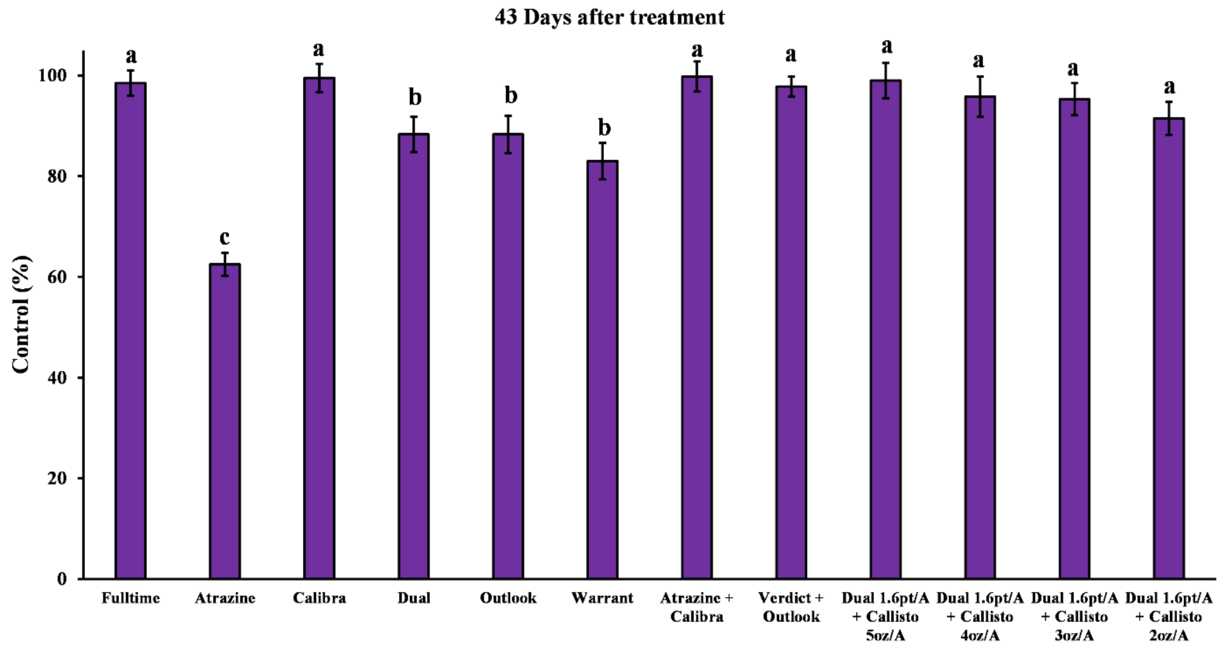

Figure 1. Palmer amaranth control 43 days after preemergence herbicide treatment. Error bars represent one standard error of the mean. Means followed by the same letter(s) are not significantly different using the least squares means (LSMEANS) and adjusted Tukey multiple comparison procedure (*P* > 0.1).

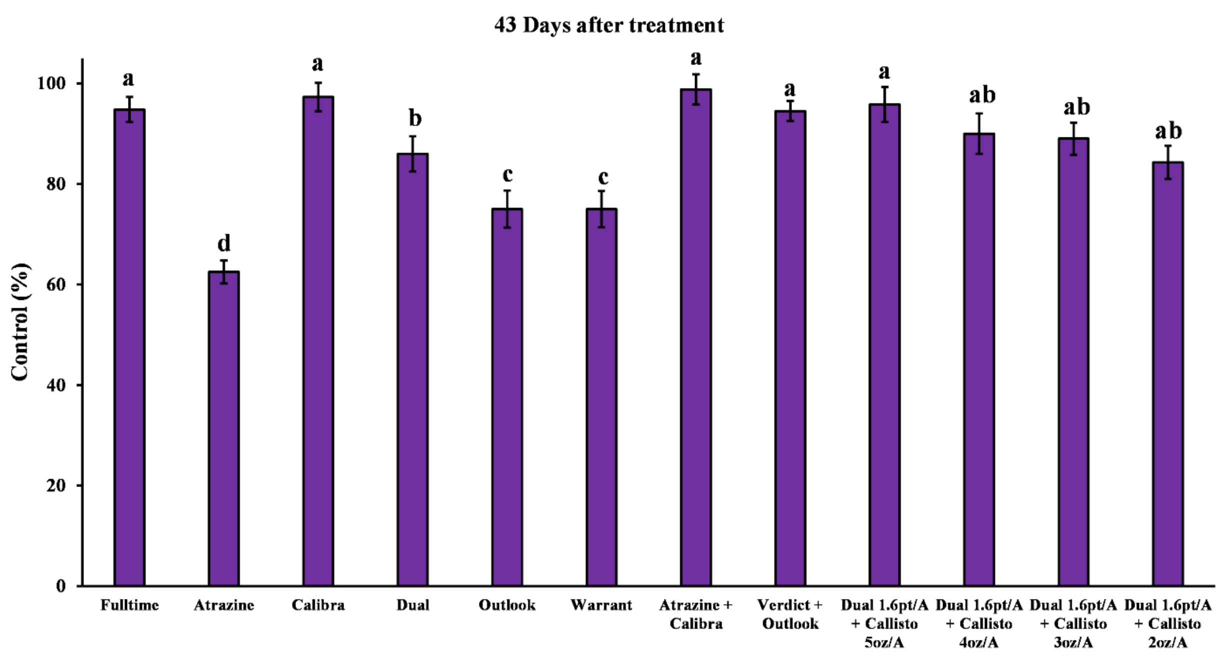

Figure 2. Puncturevine control at 43 days after preemergence herbicide treatment. Error bars represent one standard error of the mean. Means followed by the same letter(s) are not significantly different using the least squares means (LSMEANS) and adjusted Tukey multiple comparison procedure (*P* > 0.1).

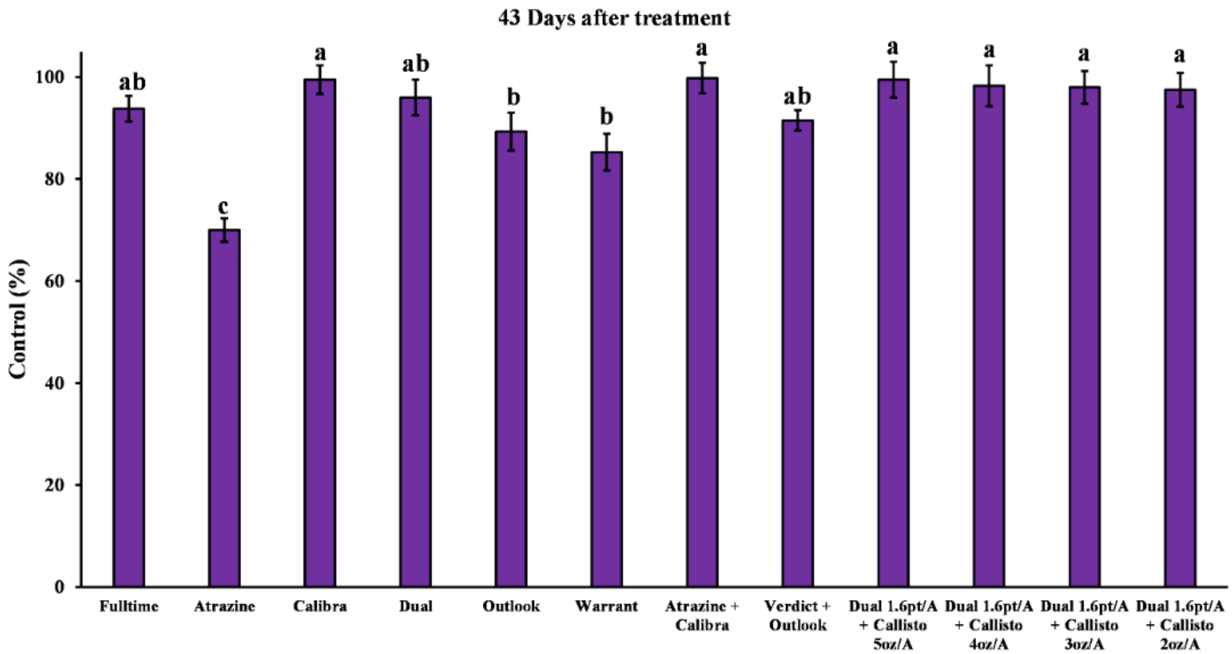

Figure 3. Crabgrass control 43 days after preemergence herbicide treatment. Error bars represent one standard error of the mean. Means followed by the same letter(s) are not significantly different using the least squares means (LSMEANS) and adjusted Tukey multiple comparison procedure (*P* > 0.1).

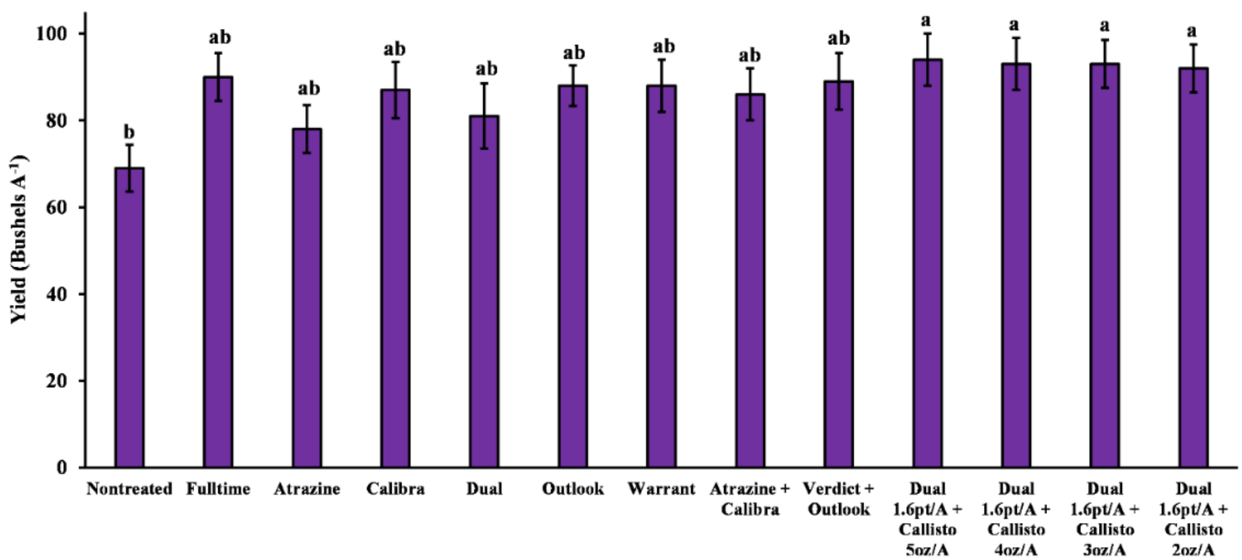

Figure 4. Sorghum yield as affected by pre-emergence herbicide programs. Error bars represent one standard error of the mean. Means followed by the same letter(s) are not significantly different using the least squares means (LSMEANS) and adjusted Tukey multiple comparison procedure (*P* > 0.1).

Integrating Weed Management Strategies to Reduce Seed Production and Viable Seed Dispersal in Kansas Soybean Production

Taylor Lambert and K.B. Jeremie Kouame

Summary

The management of Palmer amaranth (*Amaranthus palmeri*) is a challenge in Kansas soybean production, particularly due to its high seed production, persistence in the soil seedbank, and herbicide resistance concerns. Harvest Weed Seed (HWSD) control strategies have shown promise in mitigating this issue by targeting weed seeds during harvest. A field trial assessed the effectiveness of herbicide programs and cover crops on Palmer amaranth biomass and seed production, and the effectiveness of the HWSD in reducing Palmer amaranth seed viability in soybean fields. Results indicated that the herbicide programs were not different in their impact on biomass and seed production. In contrast, use of cover crops reduced the biomass and seed production ≥ 50%. Also, HWSD significantly reduced the viability of Palmer amaranth seeds exiting the back of the combine when the seed control unit was engaged (93% non-viable seed), contributing to a more effective seedbank management practice.

Introduction

Palmer amaranth is one of the most problematic weeds in U.S. agriculture, particularly in soybean production. Its ability to produce large numbers of seeds, coupled with its resistance to multiple herbicides (Heap, 2024), has made it a persistent challenge for farmers. Previous research has demonstrated that a female Palmer amaranth plant can produce enormous quantities of seed, with some studies reporting up to 600,000 seeds/plant (Ward et al., 2013). Seed retention at harvest has been identified as a critical factor in weed seedbank management (Soni et al., 2020). Harvest Weed Seed Control technologies, which manage or collect weed seeds during harvest, offer a promising solution (Walsh et al., 2017; Walsh et al., 2017; Walsh et al., 2018; Walsh et al., 2018; Walsh & Powles, 2014; Walsh et al., 2021). Previous research reported the effectiveness of the Harvest Weed Seed Destructor (HWSD) to render weed seeds non-viable (Schleich et al., 2023). However, its effectiveness could be compromised by several factors, including poor weed seed retention on the plant at harvest and losses from the combine header during harvest (Schleich et al., 2023). In particular, header losses — which occur when the combine header reel and sickle bar shake the plant, causing seeds to fall to the ground instead of being collected — can significantly reduce the number of weed seeds entering the combine (Schleich et al., 2023). As a result, understanding the performance of the HWSD requires conducting more research to quantify header losses as they occur in the field during harvest. Therefore, the objectives of this research were to evaluate (i) the impact of cover crop treatments and herbicide programs on Palmer amaranth biomass and seed production, (ii) the effectiveness of the HWSD to render Palmer amaranth seed non-viable, and (iii) to quantify header loss.

Procedures

A field trial was conducted in a Kansas soybean field west of Great Bend to evaluate i) the impact of cover crop treatments and herbicide programs on Palmer amaranth biomass and seed production, (ii) the effectiveness of the HWSD to render Palmer amaranth seed non-viable, and (iii) to quantify header loss. The experiment had 8 treatments (two herbicide programs, two cover crop programs (with and without), and two HWSD levels (on and off)) replicated 3 times. Each plot was 36 ft wide by 150 ft long. Four major response variables were quantified: biomass production, seed production, header loss, and seed viability. To determine the impact of cover crop treatment and herbicide programs on Palmer amaranth biomass and seed production, a female Palmer amaranth plant was harvested pre-harvest from each plot. To measure Palmer amaranth header loss during the harvest process, two pans were placed on either side of two female Palmer amaranth plants. The combine was operated at 4 mph until the header had cut across the weed and passed over the pans, which were automatically removed and bagged separately. To determine the impact of the seed control unit on Palmer amaranth seed viability, one pan was placed behind either side (there are two impact mills on this machine) of the back of the combine while it was operating to collect Palmer amaranth seed exiting the HWSD (with the seed control on or off). The pans from both spots were bagged together. Following harvest, Palmer amaranth seed samples were cleaned of any foreign material. The seeds from the chaff trays were categorized into four groups based on their level of damage (intact, slight, moderate, and fully destructed) after exiting the combine with an engaged seed control unit (Figure 1). A 0.0035 oz sub-sample was taken from the total seed sample to determine the proportion of seeds in each category. Previous studies have shown that only intact seeds retain viability after passing through the HWSD system (unpublished data); thus, only intact seeds were considered viable, while damaged seeds (slight, moderate, and destructed) were categorized as non-viable. Seed viability was calculated as the percentage of intact seeds in the total sample, both with and without the HWSD engaged.

Weed biomass and seed data were subjected to ANOVA using the GLIMMIX procedure with SAS software (version 9.4; SAS Institute Inc., Cary, NC) and treatment means were separated using Tukey's adjustment ($\alpha = 0.05$). A two-sample t-test (within SAS) was used to evaluate the impact of the seed control unit (On/Off) on the viability of seed exiting the combine and the header loss.

Results and Discussion

Biomass and seed production

No significant cover crop-by-herbicide interaction ($P = 0.3360$) was detected, and the two herbicide programs did not differ in their impact on Palmer amaranth biomass ($P = 0.8225$). In contrast, cover crop use decreased Palmer amaranth biomass production ($P = 0.0005$). On average, Palmer amaranth biomass was 0.52 lb without cover crops but decreased by 54% with the implementation of cover crops (0.24 lb) (Figure 2).

No significant cover crop-by-herbicide interaction ($P = 0.0816$) was detected, and the two herbicide programs did not differ in their impact on Palmer amaranth seed production ($P = 0.8374$). In contrast, cover crop use decreased Palmer amaranth seed production ($P = 0.0056$). On average, Palmer amaranth produced 120,090 seeds/plant without cover crops, but the seed number decreased by 50% with the implementation of cover crops (59,990 seeds) (Figure 3). These results are consistent with earlier research showing that a cereal rye cover crop reduced waterhemp seed production 90% compared to treatments without the cover crop, while herbicides had no significant impact on waterhemp seed production (Schleich et al., 2023). Additionally, the high seed production of Palmer amaranth in this study is similar to the findings of previous research (Ward et al., 2013).

Header Loss

As expected, having the seed control engaged or disengaged did not impact the header loss ($P = 0.6050$). Palmer amaranth seeds collected in the pans showed that an average of 2,650 seeds were lost at the header, which equated to a 3.3% loss of viable seed during harvest. Header loss results are variable in scientific literature. For example, Schleigh et al. (2023) reported waterhemp header loss of 2.6% and the loss was not affected by cover crop, herbicide program, or combine speed. Winans et al. (2023) reported that across 7 site-years, on average 31% of waterhemp seed that remained at harvest was lost at the combine header due to shatter, regardless of harvesting methods (either conventional or with the impact mill). The same authors reported a header loss value of 89% for velvetleaf in 1-year data. Morningglory header loss was 48% and 58% in two different years, whereas 1-year data showed header loss values of 52% and 34% for giant foxtail and common lambsquarters, respectively. The variability of values reported in the scientific literature and the ones obtained in the present study might be due to many factors that affect header loss, including weed density at harvest at the specific site and the plant moisture content at the time of harvest.

Seed Viability

As expected, the percentage viability was affected by the status (On/Off) of the seed control unit ($P < .0001$). The viability of seeds that passed through the engaged seed control unit was significantly reduced, with only 7% of intact and viable seeds quantified in the present study (Figure 4). In contrast, when the HWSD was off, 83% of the seeds remained viable. This research needs to be repeated across years and locations to evaluate the impact of the seed control unit (On/Off) on seed viability.

The results of this study demonstrate that the HWSD system is highly effective in reducing the viability of Palmer amaranth seeds during harvest and can play a crucial role in reducing Palmer amaranth seedbank replenishment in soybean fields. The results about the viability of seed exiting the seed control unit are comparable to what was obtained by previous research. Ninety-six percent of waterhemp seeds that entered the combine at harvest were destroyed and seed destruction effectiveness was not affected by cereal rye cover crop, herbicide program, or combine speed (Schleich et al., 2023). Winans et al. (2023) reported 94% of waterhemp seed destructed across 7 site-years, with damage percentages ranging between 77% and 99%. Walsh et al. (2018) reported 100% Palmer amaranth seed destruction in North American soybean.

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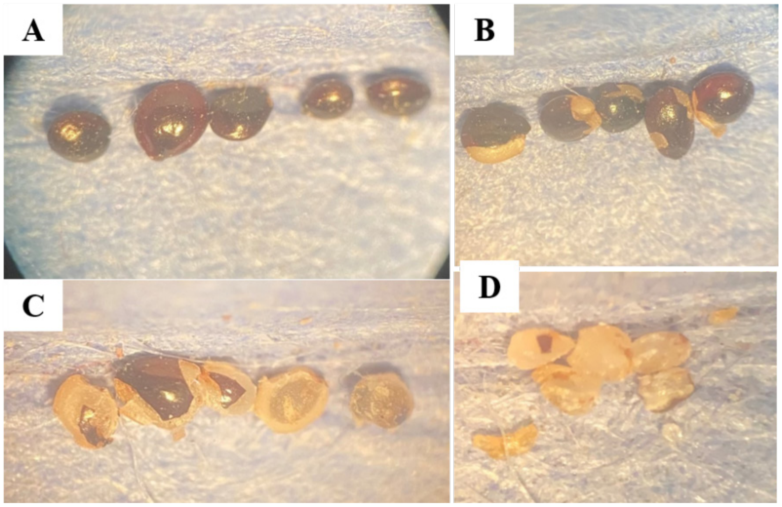

Figure 1. Categorization of damaged and non-damaged Palmer amaranth seeds collected from the seed control unit showing, threshing loss (A) intact seed, (B) slightly damaged seeds, (C) moderately damaged, and (D) fully destructed.

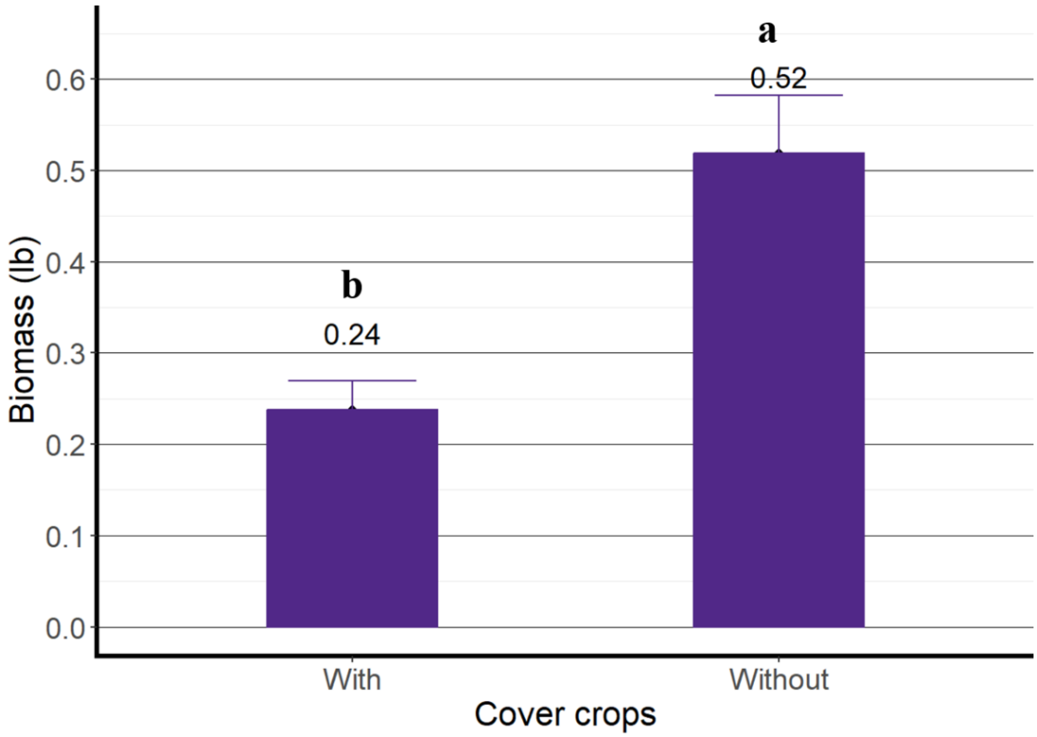

Figure 2. Impact of cover crops on Palmer amaranth biomass production.

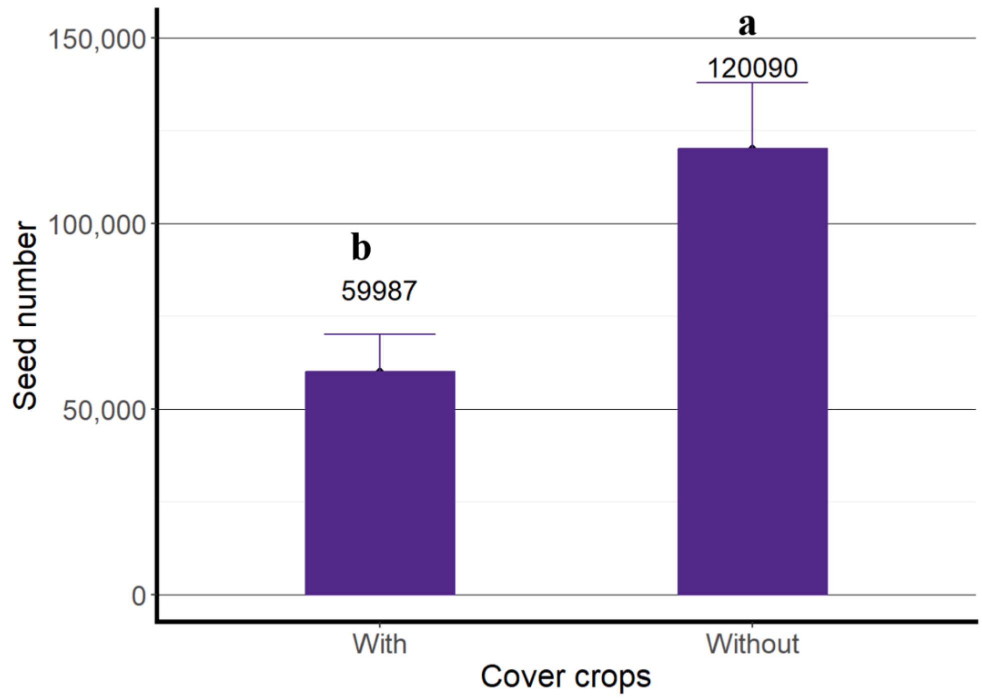

Figure 3. Impact of cover crops on Palmer amaranth seed production.

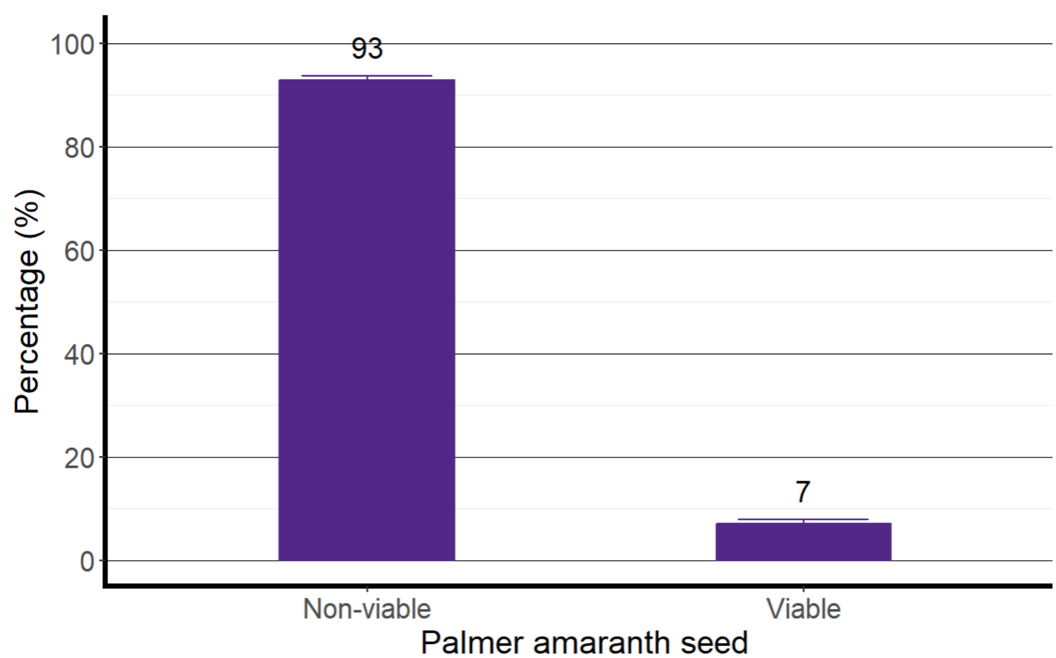

Figure 4. Impact of the engaged seed control unit on Palmer amaranth seed viability.

Overlapping and Mixing Residual Herbicide Programs for Weed Control in Grain Sorghum

Olumide S. Daramola, K.B. Jeremie Kouame, Taylor Lambert, Matthew Vredenburg, Atong A. Akom

Summary
A strong preemergence herbicide program is an essential best management practice for multiple herbicide-resistant weeds. Palmer amaranth is a prolific seed producer that has evolved resistance to 6 herbicide sites-of-action in Kansas. The objective of this study was to evaluate the effectiveness of overlapping and mixing residual herbicide programs with different sites-of-action for weed control in grain sorghum. Results showed that preemergence herbicide treatments controlled the Palmer amaranth (97%-100%) and puncturevine (97%-99%), 15 days after application. At 43 days after treatment, Outlook + Aatrex 4L and Parallel + Aatrex 4L provided the least control of Palmer amaranth (88%) and puncturevine (61%-74%) compared to other herbicide combinations, including Bicep Lite II Magnum + Callisto, FulTime NXT + Callisto, Lumax EZ + Aatrex 4L, Lumax EZ *fb* Degree Xtra, Lexar EZ, Lumax EZ *fb* Outlook + Aatrex 4L, Outlook + Aatrex 4L and Parallel + Aatrex 4L (97%-100%). Palmer amaranth and puncturevine control with Bicep Lite II Magnum at 1.5 qt/aa + Callisto at 5 oz/a or Bicep Lite II Magnum at 1.9 qt/a + Callisto at 5 oz/a showed no differences, indicating that higher rates of Bicep Lite II Magnum in combination with Callisto did not offer additional weed control benefits compared to the lower rate. Sorghum injury ranged from 2% to 10% 15 days after treatments and was not greater than 4% 22 days after treatment, suggesting that these herbicides can be safely applied to sorghum for weed control under favorable environmental conditions. Sorghum yield was not different among the pre-emergence herbicide treatments, ranging from 87 to 98 bu/a. However, the herbicide programs that provided 88% control of Palmer amaranth are not advisable given the prolific seed-producing nature of this weed and its consequences on soil seedbank replenishment and its ability to evolve resistance to herbicides targeting multiple sites-of-action.

Weed management is critical to achieve high yields and a successful harvest in sorghum. However, effective weed control in sorghum production can be challenging. Sorghum is a small-seeded grass and is relatively slow growing in the first few weeks after emergence (Thomson et al., 2019). In addition, sorghum is sensitive to many herbicides that work well on other major crops like corn and soybeans. The combination of slow seedling growth, limited herbicide options, and low application rates creates a challenge for weed control. While grass weeds in established sorghum can be a significant issue, technologies like igrowth sorghum provide solutions for grass control. However, the list of herbicides available for controlling broadleaf weeds after sorghum emerges is limited, and their effectiveness has been reduced due to the development of resistant weeds. One of the most problematic weeds in grain sorghum production in Kansas is Palmer amaranth. This weed has evolved metabolic resistance to 6 herbicide sites-of-action in the state (Heap 2025), is a prolific seed producer with the ability to quickly replenish the soil seedbank. Implementing a strong residual herbicide program is a best management practice for multiple herbicide-resistant weeds such as Palmer amaranth. Previous data on the emergence patterns of glyphosate-resistant Palmer amaranth, using a resistance-simulation model, highlighted the crucial role of residual herbicides in maintaining effective weed control throughout the season and in preventing glyphosate resistant Palmer amaranth seed production (Jha and Norsworthy 2009; Neve et al. 2011). Additionally, maintaining crop fields weed-free, particularly in conservation-tillage systems where preplant tillage is not an option, requires residual herbicides. For slow-growing crops like grain sorghum, an additional application of residual herbicides, before the dissipation of the effectiveness of the initial application, helps reduce selection pressure from relying solely on POST herbicides (Neve et al., 2003). Therefore, the objective of this study was to evaluate the effectiveness of overlapping and mixing residual herbicide programs with different sites-of-action for weed control in no-till dryland grain sorghum production systems of western Kansas.

Procedures

This study was conducted in the 2024 growing season at K-State Agricultural Research Center near Hays, Kansas, on a soil classified as a Harney silt loam, with a slope range of 0 - 1% (USDA-SCS, 1969) and a pH of 6.4. Particle size analysis revealed that the soil consisted of 8% sand, 54% silt, and 38% clay. The field site had a natural infestation of Palmer amaranth and puncturevine. The experiment was implemented in a no-till system. The study was arranged in a randomized complete block design with four replications. Plot size was 10 ft by 27 ft. In total, nine pre-emergence herbicide programs were evaluated, including two treatments with overlapping residuals (Table 1). A nontreated control was also included for treatment evaluation. All the pre-emergence herbicides were applied on the day of grain sorghum planting. A CO_2-pressurized backpack sprayer with TeeJet AIXR11002 nozzles (Spraying Systems Co., Glendale Heights, IL) calibrated to deliver 15 GPA spray volume, at 3 mph, was used to spray the pre-emergence herbicide treatments. Weed control was assessed visually at 22 and 43 days after treatment, while crop injury was assessed visually at 15 and 22 days after preemergence herbicide application on a scale of 0% to 100% (where 0% is no injury and 100% is complete death of the plant). Kansas State University Research and Extension recommendations for agronomic practices were followed. Yield was determined at physiological maturity by harvesting the middle two rows of each plot, and yields from each treatment were converted to bushel/a at 13%.

Results and Discussion

Palmer Amaranth Control

All pre-emergence herbicide programs effectively suppressed Palmer amaranth compared to the non-treated control throughout the observation period. Palmer amaranth control was comparable across the pre-emergence herbicide treatments, with efficacy ranging from 97% to 100% at 15 days after treatment (data not shown). However, 43 days after treatment, Palmer amaranth control with Outlook + Aatrex 4L and Parallel + Aatrex 4L (88%) was lower relative to other pre-emergence herbicide treatments (98% to 100%). Palmer amaranth control with Bicep Lite II Magnum at 1.5 qt/a + Callisto at 5 oz/a or Bicep Lite II Magnum at 1.9 qt/a + Callisto at 5 oz/a showed no differences (Figure 1), indicating that higher rates of Bicep Lite II Magnum in combination with Callisto did not offer additional weed control benefits compared to the lower rate used in this study. Consequently, using higher rates may increase the cost of weed control without providing added effectiveness.

Puncturevine

All pre-emergence herbicide programs effectively suppressed puncturevine compared to the non-treated control throughout the observation period. Puncturevine control was consistent across the pre-emergence herbicide treatments, with efficacy ranging from 97% to 99% 15 days after treatment (data not shown). However, at 43 days after treatment, control with Outlook + Aatrex 4L (61%) and Parallel + Aatrex 4L (74%) was lower compared to other pre-emergence herbicide treatments (97% to 100%). Puncturevine control with Bicep Lite II Magnum at 1.5 qt/a + Callisto at 5 oz/a or Bicep Lite II Magnum at 1.9 qt/a + Callisto at 5 oz/a showed no differences (Figure 2).

Crop Injury

Sorghum injury 15 days after pre-emergence herbicide treatments ranged from 2% to 10% and was similar among the pre-emergence treatments. Crop injury was not greater than 4% at 22 days after treatment (Table 2), suggesting that these herbicides can be safely applied to sorghum for weed control under favorable environmental conditions.

Sorghum Yield

Sorghum yield was not different among the pre-emergence herbicide treatments, ranging from 87 to 98 bu/a. All the preemergence herbicide treatments resulted in greater yield than the non-treated control (Figure 3). However, treatments with improved control are essential to minimize weed escapes and prevent the replenishment of the weed seedbank as a component of herbicide-resistant management.

This study demonstrates that herbicide programs with overlapping residuals and herbicide mixture with three sites-of-action improved the Palmer amaranth control. Palmer amaranth has evolved metabolic resistance to six different herbicide sites-of-action in Kansas. Given the prolific seed production of female plants and their ability to replenish the soil seedbank, a zero seed-production strategy is recommended to manage the increase of multiple herbicide-resistant weeds, particularly Palmer amaranth. Therefore, herbicide programs that incorporate active ingredients with multiple sites-of-action and overlapping residual effects are essential. These strategies showed improved control in this study and are crucial for minimizing Palmer amaranth escapes and preventing the replenishment of the soil seedbank. This study needs to be replicated in time and space to fully represent the variability across different soil types and environmental conditions.

Acknowledgment

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Table1. Preemergence herbicide programs evaluated, active ingredients, modes of action and rates of application

Product*	Active ingredient$	SOA group #+	Rates
Aatrex 4L + Outlook	Atrazine + Dimethenamid-p	5 + 15	0.5 oz/a +14 oz/a
Aatrex 4L + Parallel	Atrazine + Metolachlor	5 + 15	1 qt/a + 1.3 qt/a
Aatrex 4L + Lumax EZ	Atrazine + (*S*-metolachlor + Atrazine + Mesotrione)	5 + (5 + 15 + 27)	0.6 qt/a + 2.7 qt/a
Bicep Lite II Magnum + Callisto	(Atrazine + *S*-metolachlor) + Mesotrione	(5 + 15) + 27	1.5 qt/a + 5 oz/a
Bicep Lite II Magnum + Callisto	(Atrazine + *S*-metolachlor) + Mesotrione	5 + 15 + 27	1.9 qt/a + 5 oz/a
FulTime NXT + Callisto	(Atrazine + Acetochlor) + Mesotrione	(5 + 15) + 27	3 qt/a + 4 oz/a
Lumax EZ *fb* Degree Xtra	(Atrazine + *S*-metolachlor + Mesotrione) *fb* (Atrazine + Acetochlor)	(5 + 15 + 27) *fb* (5 + 15)	2.7 qt/a *fb* 2.5 qt/a
Lexar EZ	(Atrazine + *S*-metolachlor + Mesotrione)	(5 + 15 + 27)	3 qt/a
Lumax EZ *fb* Outlook + Aatrex 4L	(Atrazine + *S*-metolachlor + Mesotrione) *fb* Dimethenamid-p + Atrazine	(5 + 15 + 27) *fb* 5 + 15	2.7 qt/a *fb* 14 oz/a + 0.5 oz/a

**fb:* followed by
$active ingredients in parentheses are premixes.
+SOA: site-of-action

Table 2. Sorghum injury 15 and 43 days after preemergence herbicide treatment (DAT). Means followed by the same letter(s) within a week of observation are not significantly different using the least squares means (LSMEANS) and adjusted Tukey multiple comparison procedure ($P > 0.1$)

Treatments*	15 DAT	22 DAT
Aatrex 4L + Outlook	3 a	0 a
Aatrex 4L + Parallel	5 a	0 a
Aatrex 4L + Lumax EZ	2 a	1.3 a
Bicep Lite II Magnum + Callisto	5 a	1.3 a
Bicep Lite II Magnum + Callisto	5 a	0.5 a
FulTime NXT + Callisto	5 a	1.3 a
Lumax EZ *fb* Degree Xtra	10 a	4 a
Lexar EZ	5 a	2.5 a
Lumax EZ *fb* Outlook + Aatrex 4L	5 a	5 a

*Abbreviations: *fb*: followed by

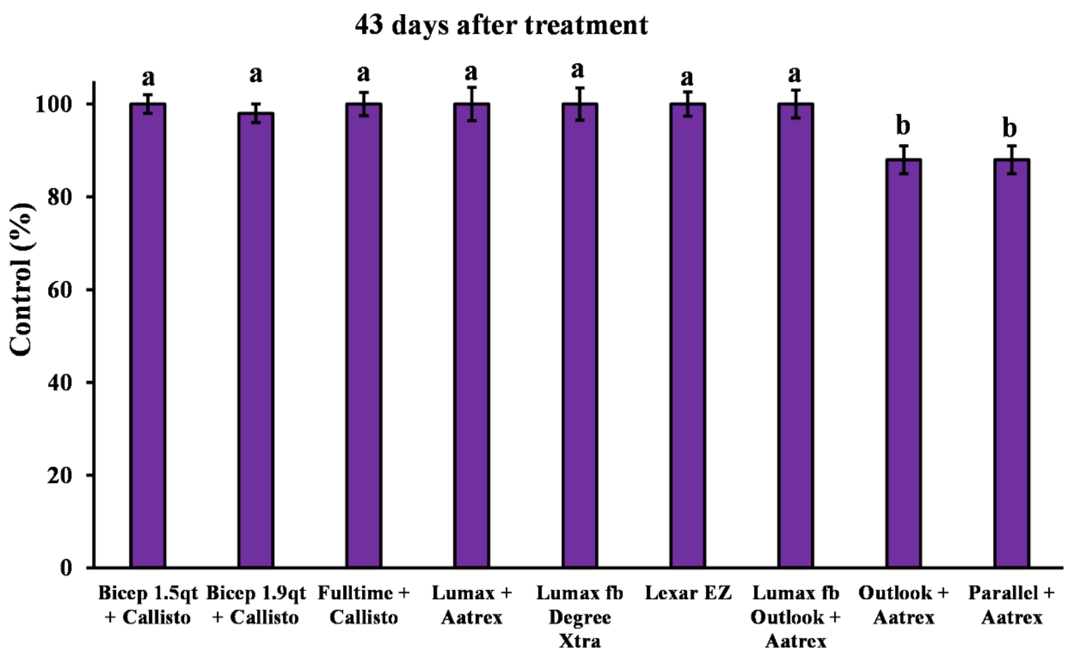

Figure 1. Palmer amaranth control 43 days after preemergence herbicide treatment. Error bars represent one standard error of the mean. Means followed by the same letter(s) are not significantly different using the least squares means (LSMEANS) and adjusted Tukey multiple comparison procedure ($P > 0.1$).

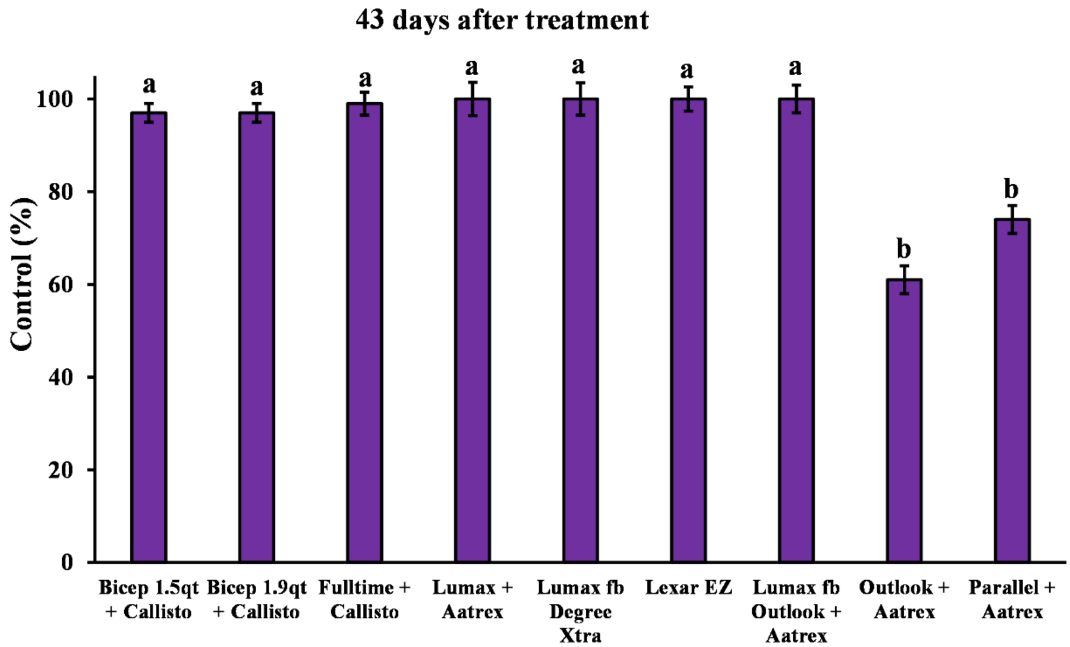

Figure 2. Puncturevine control 43 days after preemergence herbicide treatment. Error bars represent one standard error of the mean. Means followed by the same letter(s) are not significantly different using the least squares means (LSMEANS) and adjusted Tukey multiple comparison procedure ($P > 0.1$).

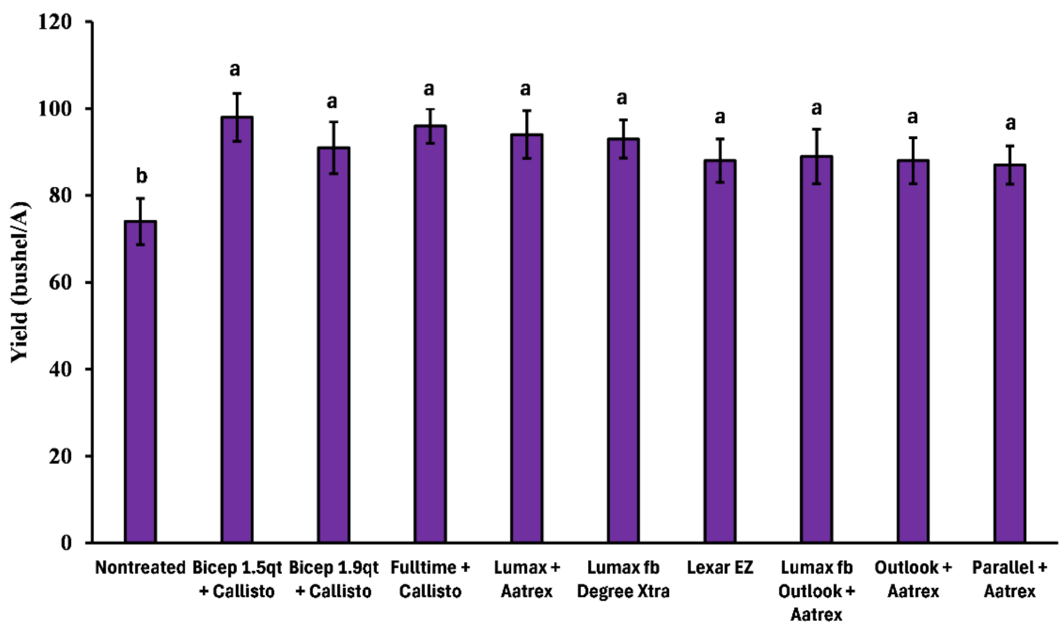

Figure 3. Sorghum yield as affected by pre-emergence herbicide programs. Error bars represent one standard error of the mean. Means followed by the same letter(s) are not significantly different using the least squares means (LSMEANS) and adjusted Tukey multiple comparison procedure ($P > 0.1$).

Weed Control and Corn Yield Following Preemergence and Sequential Applications of Mesotrione-based Premixtures

Patrick W. Geier and Sarah H. Lancaster

Summary

All herbicides evaluated provided good control of Palmer amaranth, kochia, and Russian thistle at Garden City and Palmer amaranth and common sunflower at Manhattan early in the season. Control of Russian thistle at Garden City, sunflower at Manhattan, and Palmer amaranth at both locations remained high with all treatments throughout the season. Trivolt at 20 oz/a controlled entireleaf morningglory 73% at Manhattan early in the season. Morningglory control was greater than 92% with all treatments except Storen at 2.4 qt/a plus atrazine or Acuron preemergence (PRE) later in the season. Minor (<10%) corn injury was observed at Manhattan, but grain yields did not differ by the end of the season. At Garden City, grain yields were highest when Acuron plus atrazine or Storen plus atrazine were applied PRE, and when split applications of Lumax EZ or Storen were applied PRE followed by postemergence (POST). Producers need to be aware that below-labeled rates of herbicides can increase the risk of herbicide resistance development, and control of late-emerging weeds is important.

Introduction

The use of residual herbicides containing multiple modes of action as a PRE treatment is an important practice for early-season weed management. If additional residual herbicide is applied later as a planned POST application, the weed-free period can be extended, protecting corn yield potential. The objective of these trials was to compare single and sequential applications of residual herbicides for weed control and crop response in corn.

Experimental Procedures

Experiments at Manhattan and Garden City compared the premixtures of Lumax EZ, Acuron, and Storen as preemergence or sequential applications for efficacy in corn in 2024. All herbicides were applied using either a tractor-mounted, compressed-CO_2 sprayer delivering 19.4 gpa or a backpack compressed-CO_2 sprayer delivering 15 gpa. Application, environmental, and plant information is shown in Table 1. Plots were 10 by 30 or 35 feet, and arranged in a randomized complete block design replicated four times. Visual weed control at Garden City was determined on June 14 and July 11, 2024. These dates were 28 and 55 days after POST applications (DAB), respectively. Weed control at Manhattan was determined visually on May 8 and July 2, 2024. These dates were 14 days after the preemergence treatments (DAA) and 55 DAB, respectively. Corn injury at Manhattan was visually rated on May 8 and May 16, 2024 (14 and 20 DAA). Corn yields were determined on September 18, 2024, at Manhattan and at Garden City on October 18, 2024, by mechanically harvesting the center two rows of each plot and adjusting grain moistures to 15.5%.

Results and Discussion

Herbicide treatments differed between the two locations, so results are presented separately (Tables 2 and 3). All PRE treatments controlled kochia, Russian thistle, and Palmer amaranth more than 95% at the time the POST applications were made at Garden City (data not shown). Kochia control was 96% or more with all herbicides except Lumax EX applied PRE at 28 DAB (Table 2). By 55 DAB, only Acuron applied PRE or PRE and POST and Storen applied PRE and POST controlled kochia 95% or more. Russian thistle control did not differ between treatments at 28 DAB (93 to 100%) and remained above 90% with all herbicides except Zidua SC plus atrazine PRE at 55 DAB. Similarly, Palmer amaranth control was essentially complete with all treatments at 28 DAB. By 55 DAB, only Bicep Lite II Magnum plus Callisto PRE provided less than 95% Palmer amaranth control. All herbicide treatments at Garden City increased grain yields relative to the nontreated controls. However, yields were greatest when Acuron plus atrazine or Storen plus atrazine were applied PRE, and when split applications or Lumax EZ or Storen were applied PRE followed by POST.

At the Manhattan location, common sunflower control was complete with all herbicides regardless of evaluation date (data not shown), and all PRE herbicides controlled Palmer amaranth completely at 14 DAA (Table 3). By 53 DAB, Palmer amaranth control was 98 to 99% regardless of herbicide. Entireleaf morningglory control was similar among all herbicides except Trivolt at 20 oz/a plus atrazine PRE (73%) at 14 DAA. However, all herbicides except Storen at 2.4 qt/a plus atrazine or Acuron preemergence PRE controlled morningglory more than 92% later in the season. Corn injury was observed with some Storen applications applied PRE and with Resicore at 14 DAA, and some injury persisted through 20 DAA. However, injury was less than 10%. At harvest, corn yields at Manhattan did not differ between any herbicide treatments (data not shown).

If a planned split-application of residual herbicides is to be used, producers should be aware that low rates of these products can be a risk factor for resistance development. As a best management practice, producers should ensure that the second application of these products is applied, or that any weed escapes are controlled.

Acknowledgments

Funding for this research was provided by Syngenta.

Table 1. Application, environmental, and plant information at two locations for the mesotrione-based herbicide studies in 2024

Location:	Garden City		Manhattan	
Application timing:	**PRE[1]**	**POST[1]**	**PRE**	**POST**
Application date	April 24	May 17	April 24	May 10
Air temperature (F)	56	60	67	77
Relative humidity (%)	34	66	41	43
Soil temperature (F)	54	59	59	80
Wind speed (mph)	4 to 7	1 to 3	1 to 2	1 to 2
Wind direction	East	South	Southeast	Northwest
Soil moisture	Fair	Good	Wet	Wet
Corn				
Height (inches)	---	3 to 5	---	3 to 5
Leaves (no.)	0	1 to 2	0	2
Kochia				
Height (inches)	---	0.75 to 2	---	---
Density (plants/ft^2)	0	0.1	0	0
Russian thistle				
Height (inches)	---	1 to 2	---	---
Density (plants/ft^2)	0	0.1	0	0
Palmer amaranth				
Height (inches)	---	0.5 to 1	---	0.5
Density (plants/ft^2)	0	0.1	0	0.1
Common sunflower				
Height (inches)	---	0.5 to 1	---	1
Density (plants/ft^2)	0	0.1	0	0.1
Entireleaf morningglory				
Height (inches)	---	---	---	0.5 to 1
Density (plants/ft^2)	0	0	0	0.1

[1] PRE is preemergence, POST is postemergence.

Table 2. Weed control and grain yield at Garden City in the mesotrione-based premixture study in corn

Treatment	Rate	Timing[1]	Kochia 28 DAB[2]	Kochia 55 DAB[2]	Russian thistle 28 DAB	Russian thistle 55 DAB	Palmer amaranth 28 DAB	Palmer amaranth 55 DAB	Grain yield
	qt/a		% visual						bu/a
Untreated control	---	---	---	---	---	---	---	---	50.3
Lumax EZ	2.7	PRE	91	89	100	100	99	98	106.6
Atrazine	0.5	PRE							
Acuron	3.0	PRE	100	98	100	100	99	98	115.7
Atrazine	0.5	PRE							
Storen	2.4	PRE	98	94	100	100	100	98	109.9
Atrazine	1.25	PRE							
Lumax EZ	1.35	PRE	96	91	100	100	100	99	113.4
Atrazine	0.25	PRE							
Lumax EZ	1.35	POST							
Atrazine	0.25	POST							
Glyphosate	25 oz	POST							
Ammonium sulfate	2.5%	POST							
Acuron	1.5	PRE	100	99	100	100	100	100	91.7
Atrazine	0.25	PRE							
Acuron	1.5	POST							
Atrazine	0.25	POST							
Glyphosate	25 oz	POST							
Ammonium sulfate	2.5%	POST							
Storen	1.2	PRE	100	100	100	100	100	100	120.7
Atrazine	0.63	PRE							
Storen	1.2	POST							
Atrazine	0.63	POST							
Glyphosate	25 oz	POST							
Ammonium sulfate	2.5%	POST							
Zidua SC	3.5 oz	PRE	98	85	93	90	98	95	90.8
Atrazine	1.25	PRE							
Fultime NXT	3.0	PRE	99	91	100	100	100	100	74.2
Callisto	5.0 oz	PRE							
Bicep II Lite Magnum	1.9	PRE	98	89	99	96	98	91	88.2
Callisto	5.0 oz	PRE							
LSD (0.05)			5	10	NSD	5	NSD	6	10.8

[1] PRE is preemergence, POST is postemergence.
[2] DAB is days after the postemergence treatments.

Table 3. Weed control and crop injury at Manhattan in mesotrione-based premixture study in corn

			Palmer amaranth		Entireleaf morningglory		Corn injury	
Treatment	**Rate**	**Timing[1]**	**14 DAA[2]**	**53 DAB[2]**	**14 DAA**	**53 DAB**	**14 DAA**	**20 DAA**
	qt/a		% visual					
Untreated control			---	---	---	---	0	0
Storen	2.1	PRE	100	99	100	96	5	1
Atrazine	0.75	PRE						
Storen	2.4	PRE	100	99	98	88	4	4
Atrazine	0.75	PRE						
Acuron	3.0	PRE	100	99	100	86	0	0
Resicore	2.5	PRE	100	99	100	93	4	3
Atrazine	0.75	PRE						
Resicore	3.0	PRE	100	98	90	96	8	8
Atrazine	0.75	PRE						
Trivolt	17.5 oz	PRE	100	98	100	96	0	0
Atrazine	0.75	PRE						
Trivolt	20 oz	PRE	100	98	73	95	1	0
Atrazine	0.75	PRE						
Maverick	0.75	PRE	100	99	100	98	0	0
Atrazine	0.75	PRE						
Maverick	1.0	PRE	100	99	100	98	1	4
Atrazine	0.75	PRE						
Storen	1.05	PRE	100	98	83	98	1	3
Atrazine	0.37	PRE						
Storen	1.05	POST						
Atrazine	0.37	POST						
Glyphosate	24 oz	POST						
Ammonium sulfate	2.5%	POST						
Storen	1.2	PRE	100	99	90	98	3	9
Atrazine	0.37	PRE						
Storen	1.2	POST						
Atrazine	0.37	POST						
Glyphosate	24 oz	POST						
Ammonium sulfate	2.5%	POST						
Storen	1.7	PRE	100	99	100	99	1	4
Atrazine	0.37	PRE						
Halex GT	1.8	POST						
Atrazine	0.5	POST						
Nonionic surfactant	0.25%	POST						
Ammonium sulfate	2.5%	POST						
Storen	2.1	POST	33	99	0	93	0	9
Atrazine	0.75	POST						
Glyphosate	24 oz	POST						
Dicamba	4.0 oz	POST						
Ammonium sulfate	2.5%	POST						

continued

Table 3. Weed control and crop injury at Manhattan in mesotrione-based premixture study in corn

			Palmer amaranth		Entireleaf morningglory		Corn injury	
Treatment	**Rate**	**Timing[1]**	**14 DAA[2]**	**53 DAB[2]**	**14 DAA**	**53 DAB**	**14 DAA**	**20 DAA**
	qt/a		------------------------------		% visual		------------------------------	
Storen	1.6	PRE	100	98	100	95	4	4
Atrazine	0.37	PRE						
Storen	0.8	POST						
Atrazine	0.37	POST						
Glyphosate	24 oz	POST						
Ammonium sulfate	2.5%	POST						
Storen	1.6	PRE	100	99	100	98	1	0
Atrazine	0.37	PRE						
Lexar EZ	2.0	POST						
Glyphosate	24 oz	POST						
Ammonium sulfate	2.5%	POST						
LSD (0.05)			12	NSD	20	8	3	5

[1] PRE is preemergence, POST is postemergence.

[2] DAA is days after the preemergence applications, DAB is days after the postemergence applications.

Maverick Rates and Application Timings for Weed Control in Kansas Corn

Patrick W. Geier and Sarah H. Lancaster

Summary
Maverick herbicide was evaluated as a preemergence (PRE) treatment at Manhattan, and as a PRE and postemergence (POST) treatment at Garden City. Early in the season, Maverick applied preemergence (PRE) was as effective as Bicep II Magnum, Harness Xtra, Verdict, Resicore, or Acuron for kochia, Palmer amaranth, and green foxtail control at Garden City. Maverick PRE also controlled Russian thistle 95% early. Later in the season, Maverick or Kyro postemergence (POST) provided at least 95% kochia control, 98% Palmer amaranth control, and complete Russian thistle and green foxtail control. At the Manhattan location, Maverick was as effective on Palmer amaranth as the competitive standards. Control of entireleaf morningglory and common sunflower were more variable, but Maverick controlled these species as well as the competitive standards. Herbicide treatment at Garden City increased grain yields 57% to 81% relative to the weedy controls.

Introduction
Herbicide combinations that contain multiple modes of action are necessary to control diverse weed populations and mitigate herbicide resistance. Maverick Corn Herbicide is a combination of mesotrione, clopyralid, and pyroxasulfone that was first available for weed control in corn during 2023. The objective of the study was to compare weed control and corn yield with Maverick rates and tank mixtures to industry standards.

Experimental Procedures
At Manhattan, herbicides were applied at planting using a compressed-CO_2 backpack sprayer delivering 15 gpa at 32 psi and 3.0 mph. At the Garden City experiment, Maverick was applied PRE and/or POST using a tractor-mounted, compressed-CO_2 sprayer delivering 19.4 gpa at 30 psi and 4.1 mph. Application, environmental, and plant information is shown in Table 1. Plots were 10 by 30 or 35 ft, and arranged in a randomized complete block design replicated four times. Soil at both locations was a silt loam. Weed control at Manhattan was visually rated on May 8, May 16, May 22, May 30, and June 13, 2024. These dates were 14, 22, 28, 36, and 50 days after the PRE treatments, respectively. Visual weed control was determined on June 6 and July 3, 2024, at Garden City. These dates were 1 day and 28 days after the POST treatments (DAB), respectively. Corn yields at Garden City were determined on October 18, 2024, by mechanically harvesting the center two rows of each plot and correcting grain moistures to 15.5%. Yield data were not collected at Manhattan.

Results and Discussion
At Garden City, PRE control of kochia was 95% or more with all treatments of Maverick, Harness Xtra 5.6, Resicore, and Acuron at 1 DAB (Table 2). Only Bicep II Magnum and Verdict applied PRE provided less than 90% kochia control. By 28 DAB, kochia control was 95% with all herbicides except Bicep II Magnum PRE

followed by Halex GT POST. Russian thistle control at 1 DAB was slightly less with Verdict or Maverick alone applied PRE. However, all herbicides controlled Russian thistle completely by 28 DAB. While minor differences between herbicides occurred for Palmer amaranth control at 1 DAB, no herbicide provided less than 93% control. At 28 DAB, all herbicides except Bicep II Magnum followed by Halex GT controlled Palmer amaranth 98% to 100%. Acuron was the only herbicide to control green foxtail less than 100% at 1 DAB (Table 3), but foxtail control was complete regardless of herbicide by 28 DAB. Control of Palmer amaranth, entireleaf morningglory, and common sunflower at Manhattan did not differ between herbicide treatments at 14, 22, 28, or 36 DAA (data not shown). Maverick was slightly more effective for Palmer amaranth control than Bicep II Magnum at 50 DAA (Table 4) and similar to Acuron, Resicore, Trivolt, or Storen PRE. Entireleaf morningglory control at Manhattan ranged from 70% to 93% at Manhattan late in the season, but did not differ between herbicides. Similarly, common sunflower control was 87% to 99% at Manhattan by 50 DAA but no differences occurred between herbicides.

Slight (6% to 11%) corn necrosis was observed with all POST treatments at Garden City at 7 DAB (data not shown). Injury did not persist past 14 DAB, and no injury was observed with the PRE treatments at Manhattan. Grain yields at Garden City ranged from 109 to 123 bu/a for herbicide-treated corn, and did not differ between any treatments (Table 3). However, all herbicide-treated corn yielded 39 to 56 bu/a more grain than the untreated corn.

Acknowledgments
Funding for this research was provided by Valent U. S. A.

Table 1. Application, environmental, and plant information for the Maverick corn trials

Location:	Garden City		Manhattan
Application timing	Preemergence	Postemergence	Preemergence
Application date	April 24, 2024	June 6, 2024	April 24, 2024
Air temperature (F)	50	67	58
Relative humidity (%)	38	78	50
Soil temperature (F)	52	64	57
Wind speed (mph)	3 to 6	4 to 7	1 to 2
Wind direction	East-northeast	South-southeast	Southeast
Soil moisture	Fair	Good	Good
Corn			
Height (inches)	---	8 to 13	---
Leaves (no.)	0	4 to 5	0
Kochia			
Height (inches)	---	1 to 4	---
Density (plants/ft^2)	0	0.2	0
Palmer amaranth			
Height (inches)	---	2 to 4	---
Density (plants/ft^2)	0	0.1	0
Russian thistle			
Height (inches)	---	1 to 3	---
Density (plants/ft^2)	0	0.1	0
Green foxtail			
Height (inches)	---	1 to 2	---
Density (plants/ft^2)	0	0.1	0
Entireleaf morningglory			
Height (inches)	---	---	---
Density (plants/ft^2)	0	0	0
Common sunflower			
Height (inches)	---	---	---
Density (plants/ft^2)	0	0	0

Table 2. Broadleaf weed control with Maverick in corn at Garden City

Treatment[1]	Rate	Timing[2]	Kochia 1 DAB[3]	Kochia 28 DAB	Russian thistle 1 DAB	Russian thistle 28 DAB	Palmer amaranth 1 DAB	Palmer amaranth 28 DAB
	oz/a		% visual					
Bicep II Magnum	57	PRE	83	88	100	100	93	93
Halex GT	57	POST						
NIS	0.25%	POST						
AMS	3.0 lb	POST						
Bicep II Magnum	57	PRE	80	95	100	100	94	99
Maverick	14	POST						
Glyphosate	27	POST						
NIS	0.25%	POST						
AMS	3.0 lb	POST						
Harness Xtra 5.6	64	PRE	100	100	100	100	100	100
Kyro	45	POST						
Glyphosate	27	POST						
NIS	0.25%	POST						
AMS	3.0 lb	POST						
Harness Xtra 5.6	64	PRE	98	100	100	100	99	100
Maverick	14	POST						
Glyphosate	27	POST						
NIS	0.25%	POST						
AMS	3.0 lb	POST						
Verdict	12	PRE	85	98	90	100	95	98
Armezon Pro	14	POST						
Glyphosate	27	POST						
NIS	0.25%	POST						
AMS	3.0 lb	POST						
Verdict	12	PRE	86	98	90	100	93	100
Maverick	14	POST						
Glyphosate	27	POST						
NIS	0.25%	POST						
AMS	3.0 lb	POST						
Resicore	45	PRE	99	99	99	100	98	100
Resicore	45	POST						
Glyphosate	27	POST						
NIS	0.25%	POST						
AMS	3.0 lb	POST						
Acuron	48	PRE	96	99	98	100	95	99
Acuron	48	POST						
Glyphosate	27	POST						
NIS	0.25%	POST						
AMS	3.0 lb	POST						

continued

Table 2. Broadleaf weed control with Maverick in corn at Garden City

			Kochia		Russian thistle		Palmer amaranth	
Treatment[1]	Rate	Timing[2]	1 DAB[3]	28 DAB	1 DAB	28 DAB	1 DAB	28 DAB
	oz/a		% visual					
Maverick	18	PRE	95	98	95	100	100	98
Maverick	14	POST						
Glyphosate	27	POST						
NIS	0.25%	POST						
AMS	3.0 lb	POST						
Maverick	18	PRE	100	100	100	100	99	100
Atrazine	32	PRE						
Maverick	14	POST						
Atrazine	32	POST						
Glyphosate	27	POST						
NIS	0.25%	POST						
AMS	3.0 lb	POST						
Maverick	24	PRE	100	100	100	100	100	100
Atrazine	32	PRE						
Status	5.0	POST						
Atrazine	32	POST						
Glyphosate	27	POST						
NIS	0.25%	POST						
AMS	3.0 lb	POST						
LSD (0.05)			5	5	4	NSD	6	5

[1] NIS is nonionic surfactant, AMS is ammonium sulfate.
[2] PRE is preemergence, POST is postemergence.
[3] DAB is days after the postemergence treatments.

Table 3. Green foxtail control and grain yield with Maverick in corn at Garden City

Treatment[1]	Rate	Timing[2]	Green foxtail 1 DAB[3]	Green foxtail 28 DAB	Corn yield
	oz/a		----------- % visual -----------		bu/a
Untreated control	---	---	---	---	69.3
Bicep II Magnum	57	PRE	100	100	110.7
Halex GT	57	POST			
NIS	0.25%	POST			
AMS	3.0 lb	POST			
Bicep II Magnum	57	PRE	100	100	109.3
Maverick	14	POST			
Glyphosate	27	POST			
NIS	0.25%	POST			
AMS	3.0 lb	POST			
Harness Xtra 5.6	64	PRE	100	100	113.1
Kyro	45	POST			
Glyphosate	27	POST			
NIS	0.25%	POST			
AMS	3.0 lb	POST			
Harness Xtra 5.6	64	PRE	100	100	125.2
Maverick	14	POST			
Glyphosate	27	POST			
NIS	0.25%	POST			
AMS	3.0 lb	POST			
Verdict	12	PRE	100	100	122.8
Armezon Pro	14	POST			
Glyphosate	27	POST			
NIS	0.25%	POST			
AMS	3.0 lb	POST			
Verdict	12	PRE	100	100	120.8
Maverick	14	POST			
Glyphosate	27	POST			
NIS	0.25%	POST			
AMS	3.0 lb	POST			
Resicore	45	PRE	100	100	112.9
Resicore	45	POST			
Glyphosate	27	POST			
NIS	0.25%	POST			
AMS	3.0 lb	POST			
Acuron	48	PRE	96	100	120.0
Acuron	48	POST			
Glyphosate	27	POST			
NIS	0.25%	POST			
AMS	3.0 lb	POST			

continued

Table 3. Green foxtail control and grain yield with Maverick in corn at Garden City

Treatment[1]	Rate	Timing[2]	Green foxtail 1 DAB[3]	Green foxtail 28 DAB	Corn yield
	oz/a		----------- % visual -----------		bu/a
Maverick	18	PRE	100	100	117.9
Maverick	14	POST			
Glyphosate	27	POST			
NIS	0.25%	POST			
AMS	3.0 lb	POST			
Maverick	18	PRE	100	100	118.3
Atrazine	32	PRE			
Maverick	14	POST			
Atrazine	32	POST			
Glyphosate	27	POST			
NIS	0.25%	POST			
AMS	3.0 lb	POST			
Maverick	24	PRE	100	100	108.8
Atrazine	32	PRE			
Status	5.0	POST			
Atrazine	32	POST			
Glyphosate	27	POST			
NIS	0.25%	POST			
AMS	3.0 lb	POST			
LSD (0.05)			3	NSD	25.6

[1] NIS is nonionic surfactant, AMS is ammonium sulfate.
[2] PRE is preemergence, POST is postemergence.
[3] DAB is days after the postemergence treatments.

Table 4. Weed control at the Maverick corn trial in Manhattan

Treatment[1]	Rate	Timing[2]	Palmer amaranth 50 DAA[3]	Entireleaf morningglory 50 DAA	Common sunflower 50 DAA
	oz/a		% visual		
Acuron	96	PRE	98	82	99
Glyphosate	20	POST			
NIS	0.25%	POST			
AMS	3.0 lb	POST			
Bicep II Magnum	67	PRE	96	70	87
Glyphosate	20	POST			
NIS	0.25%	POST			
AMS	3.0 lb	POST			
Resicore	88	PRE	98	72	93
Glyphosate	20	POST			
NIS	0.25%	POST			
AMS	3.0 lb	POST			
Maverick	24	PRE	99	80	93
Glyphosate	20	POST			
NIS	0.25%	POST			
AMS	3.0 lb	POST			
Maverick	24	PRE	99	84	97
Atrazine	24	PRE			
Glyphosate	20	POST			
NIS	0.25%	POST			
AMS	3.0 lb	POST			
Maverick	32	PRE	99	86	92
Glyphosate	20	POST			
NIS	0.25%	POST			
AMS	3.0 lb	POST			
Maverick	32	PRE	99	87	99
Atrazine	32	PRE			
Glyphosate	20	POST			
NIS	0.25%	POST			
AMS	3.0 lb	POST			
Trivolt	20	PRE	99	91	99
Glyphosate	20	POST			
NIS	0.25%	POST			
AMS	3.0 lb	POST			
Storen	77	PRE	99	93	99
Glyphosate	20	POST			
NIS	0.25%	POST			
AMS	3.0 lb	POST			
LSD (0.05)			3	NSD	NSD

[1] NIS is nonionic surfactant, AMS is ammonium sulfate.
[2] PRE is preemergence, POST is postemergence.
[3] DAA is days after the preemergence treatments.

Surtain Herbicide Programs for Weed Management in Corn

Patrick W. Geier and Sarah H. Lancaster

Summary

All herbicides evaluated provided good control of velvetleaf and Russian thistle at Garden City, and did not differ between treatments. Although slight differences occurred among treatments for kochia control, all herbicides provided at least 90% control early and late in the season. Surtain plus Armezon, atrazine, and glyphosate applied early postemergence (EPOST) as well as Surtain applied preemergence (PRE) followed by Armezon Pro, atrazine, and glyphosate postemergence (POST) or Status plus Zidua SC and glyphosate POST were the most effective herbicides for Palmer amaranth and johnsongrass control. At Manhattan, Palmer amaranth control did not differ between treatments at any rating date (98% to 100%). Storen PRE followed by Halex GT was slightly less effective on common sunflower early in the season, but control was nearly complete later in the season. By the end of the season, both Acuron or Storen PRE followed by Halex GT were less effective on entireleaf morningglory at Manhattan. The EPOST treatments of Surtain caused 20% corn necrosis at both locations, but injury did not persist. All herbicides increased yields relative to the untreated controls at both locations, but the difference between treatments only occurred at Garden City.

Introduction

Surtain herbicide is a newly registered premixture of pyroxasulfone, the active ingredient in Zidua and saflufenacil, the active ingredient in Sharpen. Surtain contains a microencapsulated formulation of saflufenacil that enables the herbicide to be applied to emerged corn; however, it will not control emerged weeds, and some risk of crop injury with Surtain applied POST still exists. The objective of these studies was to compare Surtain herbicide rates and application timings to commercial standards in corn at two Kansas locations.

Experimental Procedures

Experiments at Manhattan and Garden City compared Surtain herbicide as a PRE or EPOST and/or POST treatment to standard herbicides in corn. Herbicides were applied using either a tractor-mounted, compressed-CO_2 sprayer delivering 19.4 gpa or a compressed-CO_2 backpack sprayer delivering 15 gpa. Application, environmental, and plant information is shown in Table 1. Plots were 10 by 30 or 35 ft, and arranged in a randomized complete block design replicated four times. Soil was a silt loam at both locations. Visual weed control at Garden City was determined on June 6 and August 6, 2024. These dates were 5 days after the EPOST treatments (5 DAB) and 54 days after the POST treatments (54 DAC), respectively. At Manhattan, weed control was determined on May 8, May 22, May 30, June 6, and June 28, 2024. These dates were 14 days after the PRE treatments (DAA), and 12, 20, 27, and 49 DAB, respectively. Corn yields were determined on September 17, 2024, at Manhattan and on October 17, 2024, at Garden City by mechanically harvesting the center two rows of each plot and adjusting grain moistures to 15.5%.

Results and Discussion

The treatment structure differed between the two locations, so data are presented separately (Tables 2 and 3). At Garden City, all herbicides controlled velvetleaf 91% or more at 5 DAB and 54 DAC, and did not differ between treatments (data not shown). Similarly, Russian thistle control was 90% or more with all herbicides at 5 DAB, and 100% regardless of treatment at 54 DAC. Early season Palmer amaranth control was best when Surtain was applied EPOST with Armezon, atrazine, and glyphosate (Table 2). Palmer amaranth control at 5 DAB was 90% or less with all PRE-only herbicides except Surtain at 14 oz plus atrazine or Surtain at 17 oz. By 54 DAC, Palmer amaranth control was best when Surtain plus Armezon, atrazine, and glyphosate were applied EPOST, or when Surtain at 14 oz was applied PRE followed by Armezon Pro, atrazine, and glyphosate or Status, Zidua SC, and glyphosate POST. Surtain PRE followed by Status, Zidua SC, and glyphosate POST was the only treatment to provide less than 95% kochia control at 5 DAB. However, only Acuron PRE controlled kochia less than 96% late in the season. Trivolt applied PRE and Surtain plus Armezon, atrazine, and glyphosate controlled johnsongrass completely at 5 DAB. Surtain plus Armezon, atrazine, and glyphosate applied EPOST, Surtain PRE followed by Armezon Pro, atrazine and glyphosate, and Surtain PRE followed by Status, Zidua SC, and glyphosate POST controlled johnsongrass 95% or more by 54 DAC. At Manhattan, all herbicides provided nearly complete control of Palmer amaranth throughout the season (data not shown). Similarly, all herbicides controlled common sunflower later in the season. Acuron applied PRE followed by Halex GT was less effective on entireleaf morningglory at Manhattan throughout the season than other herbicides (Table 3).

When Surtain was applied as an EPOST treatment, 20% corn necrosis was observed at 5 DAB at Garden City and 20% to 21% at Manhattan at 14 DAA (data not shown), but necrosis did not persist more than 30 days. No other herbicide caused visible corn injury. Corn yields at Manhattan did not differ between herbicide treatments, but all herbicide-treated corn yielded 90 to 95 bu/a more grain than the untreated control (Table 3). Similarly, all herbicides increased grain yields relative to the untreated plots at Garden City (56 to 158 bu/a). However, yields were greatest when Surtain was applied PRE followed by Status plus Zidua or Armezon Pro plus atrazine POST (Table 2).

Acknowledgments

Funding for this research was provided by BASF Corporation.

Table 1. Application, environmental, and plant information for the Surtain corn trials in Kansas

	Garden City			Manhattan	
Application timing	Preemergence	Early postemergence	Postemergence	Preemergence	Postemergence
Application date	May 3, 2024	June 1, 2024	June 13, 2024	April 24, 2024	May 10, 2024
Air temperature (F)	53	82	83	68	76
Relative humidity (%)	66	59	52	47	54
Soil temperature (F)	58	74	74	57	74
Wind speed (mph)	2 to 4	4 to 7	4 to 7	1 to 2	4 to 5
Wind direction	East	South	South	Northwest	Northwest
Soil moisture	Dry	Wet	Good	Good	Good
Corn					
Height (inches)	---	4 to 6	12 to 18	---	3 to 5
Leaves (no.)	0	2 to 3	6 to 7	0	2
Kochia					
Height (inches)	---	2 to 5	2 to 6	---	---
Density (plants/ft^2)	0	0.3	0.1	0	0
Palmer amaranth					
Height (inches)	---	0.25 to 4	1 to 3	---	0.5
Density (plants/ft^2)	0	8	0.1	0	0.1
Russian thistle					
Height (inches)	---	2 to 4	2 to 4	---	---
Density (plants/ft^2)	0	0.2	0.1	0	0
Velvetleaf					
Height (inches)	---	1 to 3	---	---	---
Density (plants/ft^2)	0	0.4	0	0	0
Johnsongrass					
Height (inches)	---	0.5 to 2	---	---	---
Density (plants/ft^2)	0	1	0	0	0
Entireleaf morningglory					
Height (inches)	---	---	---	---	0.5 to 1
Density (plants/ft^2)	0	0	0	0	0.1
Common sunflower					
Height (inches)	---	---	---	---	0.5 to 1
Density (plants/ft^2)	0	0	0	0	0.1

Table 2. Weed control and grain yield at the Garden City Surtain corn trial

Treatment[1]	Rate	Timing[2]	Palmer amaranth 5 DAB[3]	Palmer amaranth 54 DAC[3]	Kochia 5 DAB	Kochia 54 DAC	Johnsongrass 5 DAB	Johnsongrass 54 DAC	Grain yield
	oz/a		% visual						bu/a
Untreated	---	---	---	---	---	---	---	---	16.9
Acuron	48	PRE	83	70	100	93	75	75	73.2
Resicore	40	PRE	89	70	98	98	81	78	132.0
Trivolt	12	PRE	81	70	100	100	100	89	82.1
Storen	38	PRE	88	75	100	100	83	78	113.3
Surtain	11	PRE	88	75	95	100	83	80	128.4
Surtain Atrazine	11 32	PRE PRE	90	80	100	100	90	81	131.3
Surtain	14	PRE	90	83	99	100	90	85	128.1
Surtain Atrazine	14 32	PRE PRE	94	88	100	96	91	85	157.9
Surtain	17	PRE	96	86	100	100	93	86	159.3
Surtain Clarity Glyphosate NIS AMS	14 8 30 0.25% 1.0%	EPOST EPOST EPOST EPOST EPOST	94	93	96	96	98	90	130.2
Surtain Armezon Atrazine Glyphosate COC AMS	14 0.75 32 30 1.0% 1.0%	EPOST EPOST EPOST EPOST EPOST EPOST	98	94	99	96	100	96	159.1
Surtain Armezon Pro Atrazine Glyphosate COC AMS	14 16 16 30 1.0% 1.0%	PRE POST POST POST POST POST	93	96	98	100	86	95	172.8
Surtain Status Zidua SC Glyphosate NIS AMS	14 5.0 2.5 30 0.25% 1.0%	PRE POST POST POST POST POST	91	100	90	99	89	100	175.4
LSD (0.05)			5	6	6	5	6	8	25.3

[1] NIS is nonionic surfactant, AMS is ammonium sulfate, COC is crop oil concentrate.
[2] PRE is preemergence, EPOST is early postemergence, POST is postemergence.
[3] DAB is days after the early postemergence treatments, DAC is days after the postemergence treatments.

Table 3. Weed control and corn yield at the Manhattan Surtain corn trial

Treatment[1]	Rate	Timing[2]	Sunflower	Entireleaf morningglory				Corn yield
			14 DAA[3]	12 DAB[3]	20 DAB	27 DAB	49 DAB	
	oz/a		---------------------- % visual ----------------------					bu/a
Untreated			---	---	---	---	---	167.7
Verdict	10	PRE	100	96	94	94	90	262.6
Status	5.0	POST						
Zidua SC	2.5	POST						
Glyphosate	30	POST						
COC	1.0%	POST						
AMS	1.0%	POST						
Surtain	14	PRE	100	100	100	99	99	261.5
Surtain	11	POST						
Armezon	0.75	POST						
Atrazine	32	POST						
Glyphosate	30	POST						
COC	1.0%	POST						
AMS	1.0%	POST						
Surtain	14	PRE	100	100	99	99	99	262.8
Status	5.0	POST						
Zidua SC	2.5	POST						
Glyphosate	30	POST						
NIS	0.25%	POST						
AMS	1.0%	POST						
Acuron	48	PRE	100	90	76	68	69	258.1
Halex GT	60	POST						
NIS	0.25%	POST						
AMS	1.0%	POST						
Storen	38	PRE	95	96	91	88	81	258.9
Halex GT	60	POST						
NIS	0.25%	POST						
AMS	1.0%	POST						
Resicore	40	PRE	100	96	94	90	89	257.5
Resicore	40	POST						
Glyphosate	30	POST						
NIS	0.25%	POST						
AMS	1.0%	POST						
LSD (0.05)			4	4	11	15	17	43.4

[1] COC is crop oil concentrate, AMS is ammonium sulfate, NIS is nonionic surfactant.
[2] PRE is preemergence. POST is postemergence.
[3] DAA is days after the preemergence treatments, DAB is days after postemergence treatments.

Intrava DX Tank Mixtures for Weed Control in Corn

Patrick W. Geier and Sarah H. Lancaster

Summary
Intrava DX is a new premix herbicide for potential use in fallow and corn. Data from Manhattan showed Intrava DX provided exceptional (≥ 95%) weed control of key weed species when applied preemergence (PRE) to corn. Corn injury was less than 6%, and no difference was observed in grain yield . At Garden City, most Intrava DX treatments provided greater than 90% visual weed control throughout the season. Weed densities were reduced by more than 90%, and grain yields were 3.8 to 4.2 times higher when corn received Intrava DX compared to the weedy controls. Intrava DX may be an important component of an integrated weed management system to combat resistance.

Introduction
Novel herbicides are an important component of integrated weed management programs to combat herbicide-resistant weeds. Intrava DX is a premix of amicarbazone and metribuzin, two Group 5 herbicides that inhibit photosynthesis. Amicarbazone is not currently labeled in U. S. row crops, but may have utility as a burndown product in fallow fields and as a preemergence product in corn. Amicarbazone would be beneficial because no weeds are currently resistant to the herbicide, and it would allow for more strategic use of atrazine. These trials aimed to evaluate Intrava DX as a preemergence treatment for efficacy and crop response in corn.

Experimental Procedures
Trials were conducted at Manhattan and Garden City, KS, in 2024 to evaluate Intrava DX plus tank mix partners for PRE efficacy in corn. All herbicides were applied using either a tractor-mounted, compressed-CO_2 sprayer delivering 19.4 gpa or a backpack compressed-CO_2 sprayer delivering 15 gpa. Application, environmental, and plant information is shown in Table 1. Plots were 10 by 30 or 35 ft, and arranged in a randomized complete block design replicated four times. Soil was a silt loam at each location. Visual weed control at Garden City was determined on June 13 and July 25, 2024. These dates were 28 days after the preemergence applications (DA) and 45 days after the postemergence applications (DB). Weed counts were determined at Garden City on June 14, which was 29 DA. Weed control at Manhattan was determined May 10, May 28, and June 6, 2024. These dates were 17 DA, 5 DB, and 14 DB, respectively. Corn yields were determined on September 17, 2024, at Manhattan and on October 17, 2024, at Garden City by mechanically harvesting the center two rows of each plot and adjusting grain weights to 15.5% moisture.

Results and Discussion
Treatment structure differed between the two locations, so data are presented separately (Tables 2 and 3). At Manhattan, excellent weed control was observed when Intrava DX plus Moccasin II, Motif, or Coyote was applied PRE. Control of all species (Palmer amaranth, entireleaf morningglory, and common sunflower) remained 95%

or more by 14 DB. Minor crop injury was observed at Manhattan at 29 DA, but was not significant (Table 2). Likewise, no differences in corn yield were observed between treatments.

Intrava DX applied PRE controlled Russian thistle and johnsongrass 96% or more regardless of rating date at Garden City (data not shown). Palmer amaranth control by Intrava DX was slightly better than Acuron PRE at 28 DA (Table 3), and control ranged from 88% to 95% at 45 DB. Kochia control with all PRE herbicides was greater than 95% at 28 DA, whereas Intrava DX plus Motif PRE followed by InterMoc postemergence was the only treatment to control kochia less than 96% at 45 DB. Intrava DX treatments also reduced the densities of all weed species 92% to 100% at 29 DA. All herbicide-treated corn yielded 104 to 119 bu/a more grain than the untreated control plots (data not shown).

Acknowledgments

Funding for this research was provided by UPL Limited.

Table 1. Application, environmental, and plant information for the Intrava DX trials in Kansas in 2024

Location	Garden City		Manhattan	
Application timing	PRE[1]	POST[1]	PRE	POST
Application date	May 1	June 13	April 24	May 23
Air temperature (F)	77	83	64	74
Relative humidity (%)	31	52	50	61
Soil temperature (F)	67	74	57	70
Wind speed (mph)	1 to 4	4 to 7	2 to 3	2 to 3
Wind direction	Northeast	South	Southeast	Southeast
Soil moisture	Good	Good	Good	Good
Corn				
Height (inches)	---	10 to 12	---	6 to 8
Leaves (no.)	0	4 to 5	0	3 to 4
Palmer amaranth				
Height (inches)	---	1 to 3	---	0.5
Density (plants/ft^2)	0	0.1	0	0.1
Kochia				
Height (inches)	---	1 to 4	---	---
Density (plants/ft^2)	0	0.1	0	0
Johnsongrass				
Height (inches)	---	1 to 3	---	---
Density (plants/ft^2)	0	0.1	0	0
Entireleaf morningglory				
Height (inches)	---	---	---	0.5 to 1
Density (plants/ft^2)	0	0	0	0.1
Common sunflower				
Height (inches)	---	---	---	0.5 to 1
Density (plants/ft^2)	0	0	0	0.1

[1] PRE is preemergence, POST is postemergence.

Table 2. Weed control and crop response in the Intrava DX corn trial at Manhattan, KS

			Weed control			Corn	
			AMAPA[2]	IPOHG[2]	HELAN[2]	Injury	
Treatment	Rate	Timing[1]	14 DB[3]	14 DB[3]	14 DB[3]	29 DA[3]	Yield
	oz/a		% visual				bu/a
Intrava DX	21	PRE	100	95	100	5	256.2
Moccasin II Plus	21	PRE					
Glyphosate	36	PRE					
Nonionic surfactant	0.25%	PRE					
Ammonium sulfate	3.0 lb	PRE					
InterMoc	64	POST					
Ammonium sulfate	3.0 lb	POST					
Intrava DX	16	PRE	100	98	100	3	256.6
Motif	4.5	PRE					
Glyphosate	36	PRE					
Nonionic surfactant	0.25%	PRE					
Ammonium sulfate	3.0 lb	PRE					
InterMoc	64	POST					
Ammonium sulfate	3.0 lb	POST					
Intrava DX	16	PRE	100	100	100	1	258.7
Coyote	77	PRE					
Glyphosate	36	PRE					
Nonionic surfactant	0.25%	PRE					
Ammonium sulfate	3.0 lb	PRE					
InterMoc	64	POST					
Ammonium sulfate	3.0 lb	POST					
LSD (0.05)			NSD	NSD	NSD	NSD	NSD

[1] PRE is preemergence, POST is postemergence.
[2] AMAPA is Palmer amaranth, IPOHG is entireleaf morningglory, HELAN is common sunflower.
[3] DA is days after the preemergence applications, DB is days after the postemergence applications.

Table 3. Visual weed control and density reductions in the Intrava DX corn trial at Garden City, KS

			AMAPA[3]		KCHSC[3]		AMAPA	KCHSC	SASKR[3]	SORHA[3]
Treatment[1]	**Rate**	**Timing[2]**	**28 DA[4]**	**45 DB[4]**	**28 DA**	**45 DB**	**29 DA**			
	oz/a		% visual				No./meter^2			
Untreated	---	---	---	---	---	---	47	16	3	12
Intrava DX	21	PRE	100	94	96	96	1	1	0	1
Moccasin II Plus	21	PRE								
Glyphosate	36	PRE								
NIS	0.25%	PRE								
InterMoc	64	POST								
AMS	3.0 lb	POST								
Intrava DX	16	PRE	98	88	99	91	0	0	0	1
Motif	4.5	PRE								
Glyphosate	36	PRE								
NIS	0.25%	PRE								
InterMoc	64	POST								
AMS	3.0 lb	POST								
Intrava DX	16	PRE	100	95	100	100	0	0	0	0
Coyote	77	PRE								
Glyphosate	36	PRE								
NIS	0.25%	PRE								
InterMoc	64	POST								
AMS	3.0 lb	POST								
Acuron	48	PRE	93	90	100	100	2	0	0	1
Acuron	32	POST								
Liberty 280	32	POST								
AMS	3.0 lb	POST								
LSD (0.05)			2	6	3	3	13	2	2	6

[1] NIS is nonionic surfactant, AMS is ammonium sulfate.
[2] PRE is preemergence, POST is postemergence.
[3] AMAPA is Palmer amaranth, KCHSC is kochia, SASKR is Russian thistle, and SORHA is johnsongrass.
[4] DA is days after the preemergence treatments, DB is days after the postemergence treatments.

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Sorghum Partners
Star Seed
Texas A&M AgriLife Foundation Seed
Walter Moss Seed
Ward Seed
Watley Seed
Winfield United

2025 WESTERN KANSAS AGRICULTURAL RESEARCH

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Brand names appearing in this publication are for product identification purposes only. No endorsement is intended, nor is criticism implied of similar products not mentioned. Experiments with pesticides on nonlabeled crops or target species do not imply endorsement or recommendation of nonlabeled use of pesticides by Kansas State University. All pesticides must be used consistent with current label directions. Current information on weed control in Kansas is available in *2025 Chemical Weed Control for Field Crops, Pastures, Rangeland, and Noncropland*, Report of Progress 1190, available from the KSRE Bookstore, 24 Umberger Hall, Kansas State University, or at: ***www.bookstore.ksre.ksu.edu/*** (type Chemical Weed Control in search box).

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