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KANSAS
FIELD RESEARCH
2023

KANSAS STATE UNIVERSITY AGRICULTURAL EXPERIMENT STATION AND COOPERATIVE EXTENSION SERVICE

KANSAS
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Field Station Weather Reports

East Central Kansas Experiment Field: 2022 Growing Season

Introduction

The research program at the Kansas State University East Central Kansas Experiment Field is designed to keep area crop producers abreast of technological advances in agronomic agriculture. Specific objectives are to (1) identify top performing varieties and hybrids of wheat, corn, soybean, and grain sorghum; (2) establish the amount of tillage and crop residue cover needed for optimum crop production; (3) evaluate weed and disease control practices using chemical, no chemical, and combination methods; and (4) test fertilizer rates, timing, and application methods for agronomic proficiency and environmental stewardship.

Soil Description

Soils on the field's 160 acres are Woodson. The terrain is upland and level to gently rolling. The surface soil is a dark gray-brown, somewhat poorly drained silt loam to silty clay loam over slowly permeable clay subsoil. The soil is derived from old alluvium. Water intake is slow, averaging less than 0.1 in./hour when saturated. This makes the soil susceptible to water runoff and sheet erosion.

2022 Weather Information

The 2022 weather was a year of extremes with a cooler winter and warmer summer. Precipitation during 2022 was 8 inches under the average, and only 4 months had rainfall over the average (Table 1). The summer of 2022 had 56 days exceeding 90°F but none exceeding 100°F, which is above the average of 35 days exceeding 90°F the last 4 years. There were 20 days with low temperatures in the single digits, compared to an average of 10 days in the previous 4 years. The last freezing temperature in the spring was April 26 (average, April 18), and the first killing frost in the fall was October 17 (average, October 21). There were 174 frost-free days, fewer than the long-term average of 185.

Rainfall and cooler temperatures from May through early June made planting and field work challenging in the spring. Replanting was required for several soybean studies. There was adequate moisture to grow corn and grain sorghum through a hot and dry June. The corn and grain sorghum hybrid trials averaged 183 and 109 bu/a, respectively. The early maturing soybean variety trial averaged 46.8 bu/a and the later maturing trial averaged 50.8 bu/a, both below well below the averages of the last year.

Kansas River Valley Experiment Field: 2022 Growing Season

Introduction

The Kansas River Valley Experiment Field was established to study management and effective use of irrigation resources for crop production in the Kansas River Valley (KRV). The Paramore Unit consists of 80 acres located 3.5 miles east of Silver Lake on U.S. Highway 24, then 1 mile south of Kiro, and 1.5 miles east on 17th street. The Rossville Unit consists of 80 acres located 1 mile east of Rossville or 4 miles west of Silver Lake on U.S. Highway 24.

Soil Description

Soils on the two fields are predominately in the Eudora series. Small areas of soils in the Sarpy, Kimo, and Wabash series also occur. Except for small areas of Kimo and Wabash soils in low areas, the soils are well drained. Soil texture varies from silt loam to sandy loam, and the soils are subject to wind erosion. Most soils are deep, but texture and surface drainage vary widely.

2022 Weather Information

The year was generally cooler in the winter and warmer in the summer than last year, with rainfall 5–6 inches lower for the year and below average for 5 of the 6 months of the growing season. The frost-free season was 180 and 178 days at both Rossville and Paramore units, respectively (average = 173 days), with 23 and 24 days of temperatures in the single digits (°F) or lower at Rossville and Paramore, respectively, which were more days of severe cold than in the last 4 years. The last spring freeze was April 18 and 19 for Rossville and Paramore, respectively (average = April 21), and the first fall freeze was October 15 and 14, respectively (average = October 11). There were 49 and 59 days above 90°F at Paramore and Rossville, respectively, and 2 above 100°F at Paramore. Precipitation was below normal at both fields for the year (Table 2), with 9 months below average. May rainfall was about twice of the normal received for that month. Irrigation for corn started in June, much earlier than normal, with an average total of 5.3 inches for the corn. Soybeans were irrigated an average of 5.3 inches from mid-July through early September. The corn performance trials averaged 237 bu/a for the irrigated and 151 bu/a for the dryland. The soybean performance trials averaged 63.0 bu/a for the irrigated and 65.8 bu/a for the dryland. The sudden death syndrome foliar symptoms were first seen in mid-August in most soybean fields in 2022, causing significant yield loss in susceptible soybeans in the irrigated trial due to the disease.

Table 1. Precipitation at the East Central Kansas Experiment Field, Ottawa

Month	2022	30-year avg. 1991–2022	Month	2022	30-year avg. 1991–2022
	---------------- in. ----------------			---------------- in. ----------------	
January	0.05	1.22	July	5.36	3.75
February	0.29	1.57	August	1.76	4.63
March	3.00	2.29	September	1.29	4.05
April	1.59	3.79	October	0.91	3.08
May	8.28	5.82	November	4.31	2.39
June	2.76	5.55	December	1.42	1.17
			Annual total	31.02	39.85

Table 2. Precipitation at the Kansas River Valley Experiment Field

	Rossville Unit		Paramore Unit	
Month	2022	30-year avg. 1991–2020	2022	30-year avg. 1991–2020
	-- in. --			
January	0.14	0.74	0.09	0.89
February	0.08	1.18	0.07	1.31
March	3.59	2.08	3.61	2.25
April	1.45	3.48	1.35	3.81
May	10.05	5.06	10.61	5.17
June	3.64	5.11	3.23	4.92
July	3.07	4.32	2.99	3.99
August	1.79	4.60	1.75	4.55
September	1.54	3.75	1.31	3.52
October	1.42	2.71	1.19	2.85
November	3.44	1.67	3.02	1.78
December	0.70	1.37	0.55	1.49
Total	30.86	36.07	29.77	36.53

Table 3. Precipitation at Ashland Bottoms, Belleville, and Garden City

	Ashland Bottoms		Belleville		Garden City	
	Actual	**Normal**	**Actual**	**Normal**	**Actual**	**Normal**
January	0.11	0.64	0.10	0.61	0.47	0.30
February	0.04	1.14	0.00	0.97	0.01	0.40
March	2.40	2.17	1.57	1.49	0.29	1.07
April	0.95	3.38	1.88	2.75	0.39	1.46
May	8.15	5.23	4.80	4.57	2.15	2.52
June	6.21	5.47	2.44	4.34	1.25	3.51
July	5.91	4.62	3.96	4.46	2.13	3.43
August	1.55	4.40	1.61	3.72	0.40	2.49
September	1.72	3.41	3.72	3.12	0.58	1.37
October	1.25	2.50	1.09	2.50	0.02	1.42
November	3.28	1.62	0.40	1.15	0.10	0.42
December	1.05	1.19	0.85	0.92	0.03	0.56
Annual	32.62	35.77	22.42	30.60	7.82	18.95
Last spring freeze	4/26/2022		4/26/2022		4/25/2022	
First fall freeze	10/18/2022		10/17/2022		10/17/2022	
Frost free days	174		173		174	
Number of days >= 90°F	61		56		97	
Number of days >= 100°F	3		2		29	
Number of days < 10°F	24		35		32	

Normal = 30-year average, 1991-2020.

Table 4. Precipitation at Great Bend, Hays, and Hutchinson

	Great Bend		Hays		Hutchinson	
	Actual	**Normal**	**Actual**	**Normal**	**Actual**	**Normal**
January	0.21	0.71	0.20	0.56	0.07	0.72
February	0.01	0.89	0.00	0.81	0.07	1.12
March	1.88	1.56	1.21	1.32	1.60	2.21
April	0.39	2.15	0.42	2.13	0.81	2.51
May	4.57	4.83	3.40	3.60	6.88	4.67
June	2.62	3.66	1.41	3.03	2.68	4.58
July	1.05	3.86	1.77	3.95	1.70	3.65
August	1.45	3.69	1.39	3.47	0.27	3.56
September	1.29	1.98	2.12	2.13	1.44	2.48
October	0.21	1.96	0.17	1.68	0.44	2.38
November	1.74	1.00	0.22	0.90	1.49	1.28
December	0.53	1.01	0.66	0.86	0.98	1.13
Annual	15.95	27.30	12.97	24.44	18.43	30.29
Last spring freeze	4/26/2022		4/26/2022		4/26/2022	
First fall freeze	10/17/2022		10/17/2022		10/17/2022	
Frost free days	173		173		173	
Number of days >= 90°F	96		87		91	
Number of days >= 100°F	19		26		19	
Number of days < 10°F	21		31		19	

Table 5. Precipitation at Kiro, Leoti, and Manhattan

	Kiro		Leoti		Manhattan	
	Actual	**Normal**	**Actual**	**Normal**	**Actual**	**Normal**
January	0.09	0.89	0.20	0.38	0.27	0.64
February	0.07	1.31	0.00	0.51	0.08	1.14
March	3.61	2.25	0.22	1.27	2.23	2.17
April	1.35	3.81	0.59	1.95	1.01	3.38
May	10.61	5.17	2.31	2.31	9.08	5.23
June	3.23	4.92	1.34	2.58	6.08	5.47
July	2.99	3.99	4.08	2.87	5.04	4.62
August	1.75	4.55	1.89	3.11	1.31	4.40
September	1.31	3.52	0.58	1.40	2.29	3.41
October	1.19	2.85	0.02	1.66	1.18	2.50
November	3.02	1.78	0.00	0.64	3.57	1.62
December	0.55	1.49	0.02	0.60	1.17	1.19
Annual	29.77	36.53	11.25	19.28	33.31	35.77
Last spring freeze	4/26/2022		4/25/2022		4/26/2022	
First fall freeze	10/14/2022		10/17/2022		10/18/2022	
Frost free days	170		174		174	
Number of days >= 90°F	59		84		60	
Number of days >= 100°F	2		19		4	
Number of days < 10°F	24		28		23	

Table 6. Precipitation at Ottawa, Rossville, and Scandia

	Ottawa, ECK		Rossville, KRV		Scandia	
	Actual	**Normal**	**Actual**	**Normal**	**Actual**	**Normal**
January	0.05	1.22	0.14	0.89	0.05	0.61
February	0.33	1.57	0.08	1.31	0.00	0.97
March	3.00	2.29	3.59	2.25	1.78	1.49
April	1.59	3.79	1.45	3.81	1.37	2.75
May	8.28	5.82	10.05	5.17	3.99	4.57
June	2.76	5.55	3.64	4.92	2.65	4.34
July	5.36	3.75	3.07	3.99	4.35	4.46
August	1.76	4.63	1.79	4.55	1.43	3.72
September	1.29	4.05	1.54	3.52	1.52	3.12
October	0.91	3.08	1.42	2.85	0.85	2.50
November	4.31	2.39	3.44	1.78	0.66	1.15
December	1.42	1.71	0.65	1.49	0.72	0.92
Annual	31.06	39.85	30.86	36.53	19.37	30.60
Last spring freeze	4/26/2022		4/26/2022		5/22/2022	
First fall freeze	10/17/2022		10/15/2022		10/17/2022	
Frost free days	173		171		147	
Number of days >= 90°F	57		49		51	
Number of days >= 100°F	0		0		1	
Number of days < 10°F	20		26		40	

Table 7. Precipitation at Solomon, Topeka, and Wamego

	Solomon		Topeka, KRV		Wamego	
	Actual	**Normal**	**Actual**	**Normal**	**Actual**	**Normal**
January	0.15	0.86	0.09	0.89	0.28	0.69
February	0.03	1.43	0.07	1.31	0.00	1.16
March	1.70	2.23	3.61	2.25	2.11	2.09
April	0.64	3.26	1.35	3.81	1.13	3.50
May	7.85	5.20	10.61	5.17	9.57	5.11
June	3.14	4.18	3.23	4.92	6.89	5.19
July	3.55	4.75	2.99	3.99	5.01	4.66
August	1.47	4.27	1.75	4.55	1.08	4.11
September	2.79	2.54	1.31	3.52	1.82	2.86
October	0.60	2.47	1.19	2.85	0.94	2.41
November	2.23	1.59	3.02	1.78	3.12	1.67
December	0.68	1.50	0.55	1.49	0.97	1.28
Annual	24.83	34.28	29.77	36.53	32.92	34.73
Last spring freeze	5/1/2022		4/26/2022		4/26/2022	
First fall freeze	10/17/2022		10/14/2022		10/18/2022	
Frost free days	168		170		174	
Number of days >= 90°F	78		59		53	
Number of days >= 100°F	18		2		1	
Number of days < 10°F	25		24		27	

Table 8. Location references per field locations

Field location	Mesonet site	Normals site
Ashland Bottoms	Ashland Bottoms	Manhattan (MHTK1)
Belleville	Belleville 2W	Belleville (BLVK1)
Garden City	Garden City	Garden City Rgnl. Apt. (GCK)
Great Bend	St. John 1NW	Great Bend 3W (GRBK1)
Hays	Hays	Hays 1S (HASK1)
Hutchinson	Hutchinson 10SW	Hutchinson 10SW (HINK1)
Kiro	Silver Lake 4E	Topeka ASOS (TOP)
Leoti	Leoti	Leoti (LEOK1)
Manhattan	Manhattan	Manhattan (MHTK1)
Ottawa, ECK	Ottawa 2SE	Ottawa (OTTK1)
Rossville, KRV	Rossville 2SE	Topeka ASOS (TOP)
Scandia	Scandia	Belleville (BLVK1)
Solomon	Gypsum	Abilene (ABLK1)
Topeka, KRV	Silver Lake 4E	Topeka ASOS (TOP)
Wamego	Rocky Ford	Wamego 4W (WAMK1)

Source-Sink Manipulation and Its Impacts on Canola Seed Filling Period

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Summary

Canola yield production is driven by the balance between source (leaves) and sink (pods and seeds) activity during the reproductive period of a crop. However, previous literature has not reported the impact of source-sink limitations under different nitrogen (N) supplies, and its effect on seed filling. Therefore, the objectives of this study were to 1) explore the impact of source-sink manipulations during the seed filling period and its main parameters: duration and rate; and 2) understand the interactions between N supply and source-sink manipulations to explain variations in seed weight. With these objectives, a field experiment was conducted during 2019–2020 and 2020–2021 (Kansas, U.S.). One winter canola hybrid was tested under two N fertilization levels (0 and 134 lb/a), and three source-sink modifications (control; reduced sink, 50% pod removal at pod setting; and reduced source, 100% defoliation at pod setting). The reduced sink treatment resulted in a larger seed weight relative to the control. The duration of seed filling was longer for the control relative to the rest of the treatments. Even though no significant differences were found with different N fertilization, the highest seed weight values were obtained with the high N level (134 lb/a).

Introduction

Canola's (*Brassica napus* L.) planted area has grown in the United States from 155,000 to 1,824,000 acres for the 1991–2021 period (USDA-ERS, 2021). Due to its heart-healthy attributes (Lin et al., 2013) and industrial uses, canola demand is increasing. Canola oil produces one of the healthiest cooking oils due to its low saturated fat, high omega-3 fatty acid content (*www.uscanola.com*). In addition, canola is used as feedstock for biodiesel, renewable diesel, and jet biofuel (*www.uscanola.com*).

Canola offers several benefits for agricultural systems as well. One advantage is that it helps break pest and disease cycles when introduced in crop rotation systems where cereal is the main crop (Bushong et al., 2012). Additionally, the strong demand for this crop in the U.S. domestic market, which far outpaces the supply, emphasizes the relevance of its research.

To ensure optimal yield production of canola, it is important to consider the balance between source and sink activity. Source activity refers to the production of assimilates by the photosynthetic organs, while sink activity is the utilization of these assimilates by the seeds (Egli, 1998). Therefore, a comprehensive understanding of the source-sink relationship is essential for maximizing crop productivity. However, there is a clear knowledge gap in understanding the impact of source-sink limitations with different nitrogen (N) supplies for winter canola in the Great Plains region of the United States, and its impact on the seed filling period. The objectives of this study were to 1) explore the impact of source-sink manipulations during the seed filling period (SFP) and its main parameters: seed filling duration (SFD) and seed filling rate (SFR); and 2) understand the interactions between N supply and source-sink manipulations to explain seed weight variations.

Procedures

Sites and Measurements

Field experiments were conducted during 2019–2020 (North Agronomy Farm, Manhattan, KS) and 2020–2021 (Ashland Bottoms Research Farm, Manhattan, KS). The experimental design was a randomized complete block design (RCDB) with three replications. Factors and levels tested were 1) two N fertilization levels (0 and 134 lb/a), and 2) three source-sink manipulations: control, reduced sink (50% pod removal at pod setting), and reduced source (100% defoliation at pod setting). Plot size was 5 feet wide by 25 feet long and 10 inches of row spacing. A winter canola hybrid, Pioneer 46W94 (Johnston, IA, U.S.), was sown at a seeding rate of 3 lb/a.

During the vegetative stage, plants were divided into leaves and stem organs, and during the reproductive period, the same vegetative components, plus flowers (when available), pods, and seeds (seeds individualized during seed filling measurements). Three weeks after flowering the sampling started and continued in weekly intervals until the beginning of ripening. After that the sampling was performed twice per week. At all sampling times, the proportion of the pod and the rest of the plant was estimated to calculate the reproductive partition of the plant during the SFP.

During harvest, yield and its components (number of seeds, seed weight, and harvest index) and the number of branches per plant in each treatment as well as pods on the main stem versus branches were determined.

At each sampling, three consecutive plants were harvested. For each of these plants, one pod was sampled from the top, middle, and bottom of the main stem (9 pods in total). For each plant, one branch was selected to retrieve one pod from the bottom and one pod from the upper section (6 pods total). The seeds from both the main stem and branches were weighed and counted, values were averaged, and results expressed in weight per seed.

Results

The analysis of variance showed significant differences in grain weight for the source-sink manipulation treatments. No significant differences were found for the N fertilization treatment nor for the interactions between these variables. The control treatment had significantly lower grain weight than the reduced sink treatment. The control and the reduced source treatment did not present significant differences (Table 1).

Figures 1a and 1b show the values of maximum seed weight and effective seed filling duration (SFD) and rate (SFR) for the different source-sink manipulation treatments and two levels of N (0 and 134 lb/a). The maximum weight (maxW) was obtained with the reduced sink treatment (3.95 mg/seed), in which 50% of the pods were removed at the beginning of the pod formation stage (Figure 1a; 1b). The control treatment presented an intermediate maxW (3.45 mg/seed) and the reduced source treatment had the lowest maxW (3.36 mg/seed), all under the high N fertilizer rate level. The SFD was longest for the control treatment, intermediate for the reduced sink treatment, and shortest for the reduced source treatment. The control treatment exhibited the lowest SFR, as depicted in Figure 1a and 1b. However, these results revealed a compensatory relationship between SFD and SFR (Figure 1a). Treatments characterized by shorter SFD displayed higher rates, whereas those with extended SFD values showed a lower SFR.

Conclusion

The evaluated treatments showed that source-sink changes affected grain weight, seed fill duration, and seed fill rate. The maximum weight (maxW) was obtained with the reduced sink treatment, followed by the control treatment and the source treatment, in all cases under the high N rate level. The control treatment had the longest effective SFD and the lowest SFR. For both the reduced sink and source treatments, SFD and SFR compensated each other, with long SFD and shorter SFR. In this work, N fertilization did not show changes in seed weight or interaction with the treatments analyzed. Nonetheless, future research is needed to further explore these interactions and their overall impacts on final seed yield at farm scale.

Acknowledgments

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Table 1. Analysis of variance for grain weight

Treatment	Chi squared	DF	*P*-value
Source-sink manipulation (SS)	2276	3	***
N fertilization treatment (NF)	0.66	1	ns
SS × NF	0.22	2	ns

Treatment	Mean, mg/seed	SE	Group
Sink	2.7	0.09	A
Source	2.5	0.09	AB
Control	2.2	0.09	B

*** *P*-value < 0.001

ns = not significant.

DF = degree of freedom.

SE = standard error.

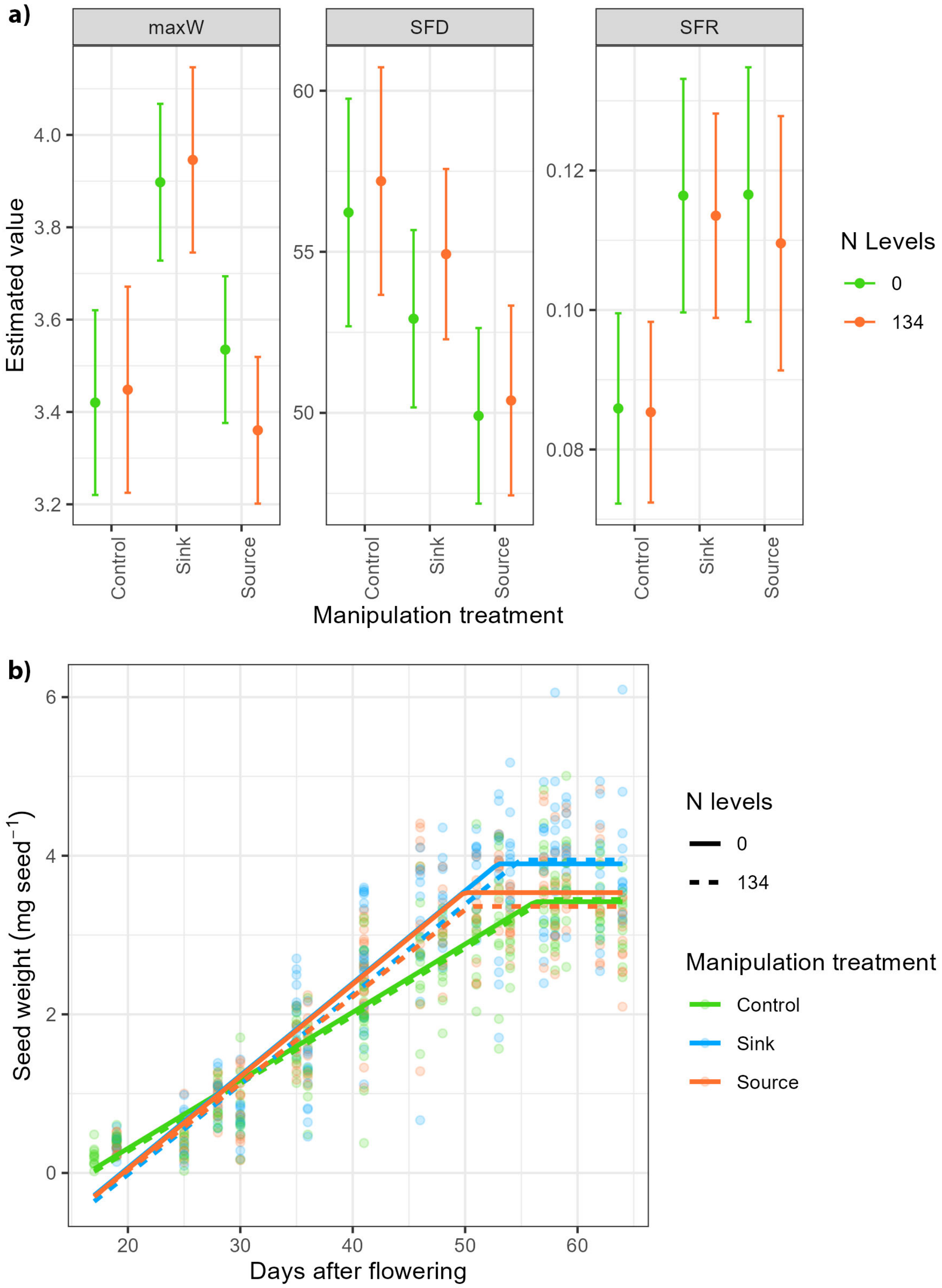

Figure 1. a) Values of maximum seed weight (in mg/seed), effective duration (SFD, in days) and rate (SFR, mg seed day^{-1}), for the different treatments analyzed (control, sink, and source) and two levels of N (0 and 134 lb/a). b) Seed weight per day after flowering for the different treatments analyzed (control, sink, and source) and two levels of N (0 and 134 lb/a).

Performance of Corn Hybrids with Contrasting Maturity in Northeastern Kansas

L.N. Lingua, I. Massigoge, A. J. P. Carcedo, and I.A. Ciampitti

Summary

Corn (*Zea mays* L.) hybrid selection is one of the most important agricultural management decisions made by farmers. Both genetic yield potential and adaptation to the local environment vary widely across corn hybrids, and have a direct impact on yield and input costs. This study compared the performance of corn hybrids with contrasting comparative relative maturity (CRM, referring to their growth cycle), to evaluate their differences in crop phenology, grain yield and its components—grain number and grain weight. The field experiment was conducted during the 2022 growing season in Manhattan, KS (U.S.), testing five commercial corn hybrids with contrasting CRM under rainfed conditions. The overall length (days) of crop growth cycle across all corn hybrids ranged from 92 to 120 days, and the grain yield ranged from 102 to 146 bu/a. The variation in grain yield across hybrids was mainly explained by differences in grain number and grain weight.

Introduction

Corn's (*Zea mays* L.) planting date and hybrid maturity are the main management factors regulating the length of the growing season and, therefore, determining grain yield potential (Capristo et al., 2007). Thus, early planting dates and long maturing hybrids are commonly used to maximize corn yield potential in the U.S. Corn Belt (Baum et al., 2019). However, shorter maturing corn hybrids are recommended when moving toward higher latitudes, where radiation and temperature impose limitations, especially during the grain filling stage.

Kansas, located in the U.S. Central Great Plains region, ranks seventh in corn production by state (Kansas Department of Agriculture, 2017). However, to our knowledge there is no information on the yield performance of short maturing hybrids (< 90 comparative relative maturity; CRM). Use of such hybrids is an approach to intensify our less current, less diversified farming systems. This work aims to quantify changes in crop phenology and final yields (and its components) for corn hybrids with contrasting maturity in the state of Kansas, U.S.

Procedures

A field experiment was conducted at the Kansas State University Experimental Field located at Manhattan, KS, U.S. (39°13'04.5"N; 96°35'55.6"W) during the 2022 growing season on a silty clay loam soil. Initial soil analyses at pre-planting are described in Table 1. Daily temperature data were retrieved from the Manhattan Kansas Mesonet weather station (Kansas Mesonet, 2023), located less than 1 mile from the experimental site.

The experimental design was a randomized complete block design (RCBD) with five replicates. The treatments consisted of five different hybrids from Corteva Agriscience (Johnston, IA, U.S.) of varying hybrid maturity: 75, 82, 91, 101, and 111 CRM. Plots were eight rows, 2.5 ft apart, and 32.8 ft long. The experiment was planted on May 10, and in order to maximize radiation capture, plant population increased as hybrid maturity decreased (Edwards et al., 2005; Assefa et al., 2016). Thus, target seeding rates were 56,000, 54,000, 48,000, 43,000, and 37,000 seeds/a for the 75, 82, 91, 101, and 111 CRM, respectively. Crops were maintained without nutrient limitations through the application of fertilizers during the crop cycle. Weeds were controlled by a combination of pre- and post-emergence herbicides. Plots were also hand weeded to control remaining weeds. The experiment was managed under rainfed conditions (without additional irrigation) and conventional tillage.

Date of silking and physiological maturity (black layer observed in grains of the midportions of the ear) were recorded when 50% of the plants in each plot reached these stages using the scale proposed by Ritchie et al. (1986). Thermal time, measured in growing degree-days (GDD, °F per day), from planting to silking and from silking to physiological maturity were calculated using the following equation:

$$GDD = \left[\frac{T_{max} + T_{min}}{2} \right] - T_b$$

where T_{max} is the daily maximum air temperature, T_{min} is the daily minimum air temperature, and T_b is the temperature below which the process of interest does not progress, in that study 50°F (Gilmore and Rogers, 1958).

After physiological maturity (R_6), 16.4 linear feet of the two central rows were evaluated to determine total biomass and grain yield. The yield was calculated based on harvested area and adjusted to 15.5% standard grain moisture. Furthermore, 1,000-grain weight was determined by counting and weighing 200 grains, and the number of grains ft^{-2} was calculated from grain yield and 1,000-grain weight.

To analyze the effect of hybrid maturity on grain yield, yield components, and harvest index, mixed effect models were fitted with the lme4 (Bates et al., 2015) package in RStudio (RStudio team, 2020) and then analyzed with ANOVA. Treatment was set as a fixed effect factor, while block was included as a random effect. Pairwise comparisons were conducted with a Tukey-Kramer method using a significance level of $\alpha = 0.05$.

Results

The observed days from planting to maturity ranged from 92 (522 GDD) to 120 (807 GDD) for the 75 and 111 CRM, respectively (Figure 1A and 1B), with major differences for the reproductive period [flowering (R1) to maturity (R6)].

Longer hybrids (111 CRM) achieved higher yields (Figure 2). The observed values ranged from 102 to 146 bu/a for CRM 75 and 111, respectively, a 25% yield gap. Thus, for each day that the relative maturity is shortened, corn yield decreased by 1.5 bu/a.

Likewise for yield, both yield components had significant differences among corn hybrids ($P \leq 0.05$, Figure 3). Regarding grain number, there was an increasing trend from CRM 82 (246/ft^2) to CRM 101 (315 grains/ft^2), plateauing for 101 and 111 CRM (Figure 3A). Furthermore, the longest hybrid maturity (CRM 111) presented larger grain weight (303 mg per grain) compared to the medium (~ 251 mg per grain; CRM 101, 91, and 82) and short hybrids (~210 mg per grain; CRM 75) (Figure 3B).

Conclusion

This study showed that with regular planting dates, long-maturing corn hybrids achieved greater yields compared to shorter maturing hybrids. These variations in grain yield were explained by differences in grain number and grain weight. However, it should be noted that there is a research gap regarding the behavior of different maturity types across a wider range of planting dates, especially for late planting dates. Therefore, future studies should evaluate different planting dates to measure the impact of placing the crop growth stages at different times of the year.

Acknowledgments

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Table 1. Soil characterization (pH, organic matter [OM], Mehlich phosphorus, sand, silt, and clay content, N-NO$_3^-$ and N-NH$_4^+$) of corn experiments carried out in Manhattan, KS, in 2022

Depth	pH	OM	P	Sand	Silt	Clay	N-NO$_3$	N-NH$_4^+$
inches		%	ppm	%	%	%	ppm	ppm
0–8	6.9	2.3	19.33	13	59	28	---	---
0–24	---	---	---	---	---	---	8.04	6.1

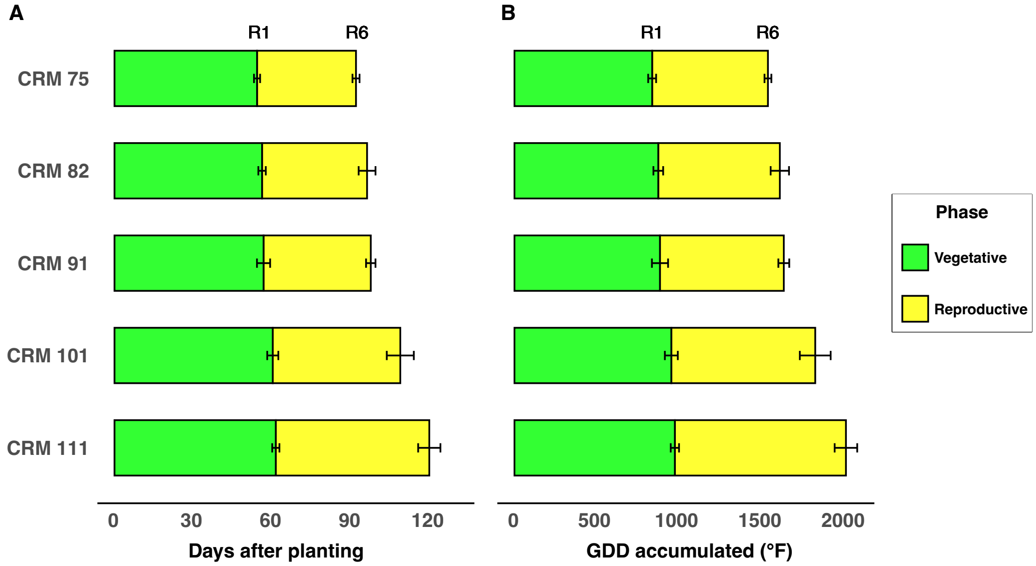

Figure 1. Comparison of the different corn hybrid maturities in accumulated days (A, days after planting) and growing degree days (B; GDD in °F) from planting to flowering (R$_1$) and from flowering to maturity (R$_6$).

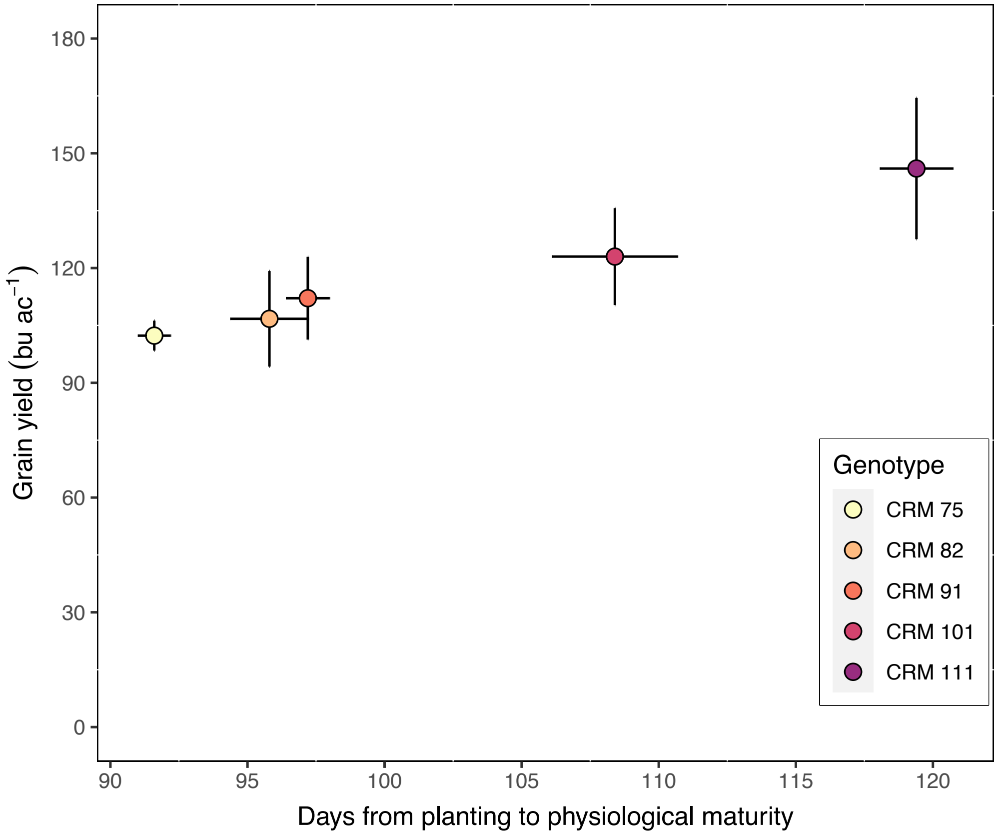

Figure 2. Relationship between grain yield (bu/a) and days to physiological maturity (after planting) for five hybrids at Manhattan, KS, in 2022. The error bar represents the standard error of the means.

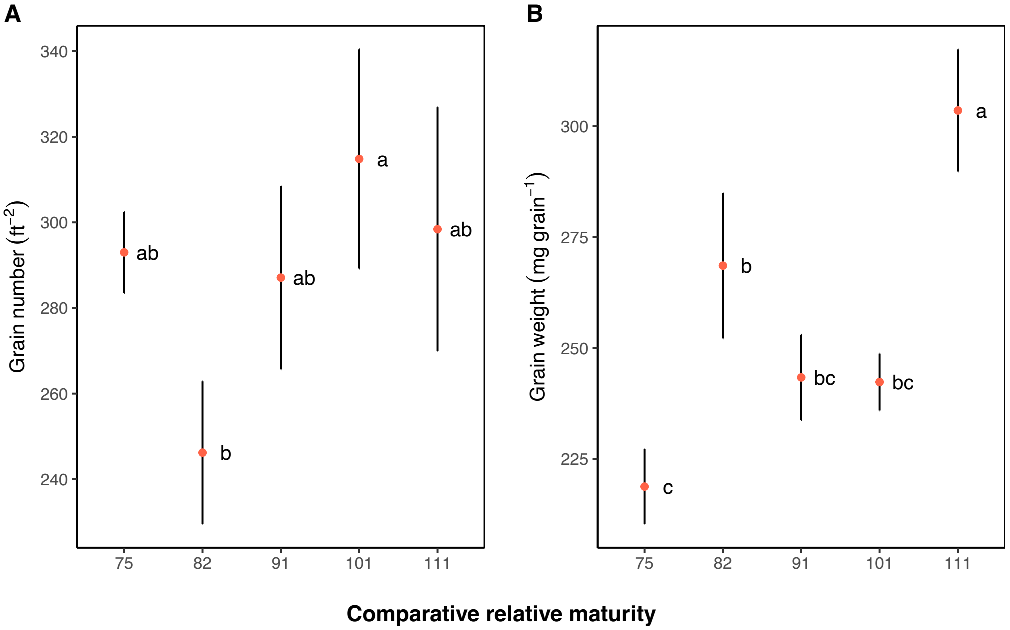

Figure 3. Grain number (A; grains/ft²) and grain weight (B; mg per grain) for five different hybrid maturities during the 2022 growing season. The error bar represents the standard deviations of the means. Different lowercase letters indicate significant differences among hybrids according to Tukey test ($P < 0.05$).

Planting Green: Potential Benefits and Disadvantages of Planting Corn into Live Cereal Rye Cover Crop

A. Correira, P. Tomlinson, and D. Presley

Summary

Although cover crops are typically terminated 2–4 weeks prior to cash crop planting, there may be situations where late-burndown or planting into a living cover crop (planting green) may be necessary or even beneficial. This experiment investigated the effect of cover crop termination date on corn (*Zea mays*) yield and the presence of beneficial insects. Three different termination dates were tested: 4 weeks prior to planting (brown), 7 to 14 days prior to planting (green-brown), and at planting (green), as well as a check treatment with no cover crop planted. The site year by termination date interaction was significant for cover crop biomass and thus each year was analyzed separately. Preliminary results of sentinel prey assessments indicate no significant difference in the presence of beneficial insects in the systems. However, there was a significant yield decrease in treatments where corn was planted into a green cover crop in both 2021 and 2022. Cover crop yields in 2022 were 50% lower than those observed in 2021. The control and planting brown treatments resulted in significantly higher yields than the planting green-brown and green treatments in 2022.

Introduction

Cover crops continue to be studied in the Midwest for their potential benefit to agricultural soils. They have been found to improve soil physical properties which result in improved soil moisture retention and increased crop yields during shorter dry periods (Fageria et al., 2005). Research from the northeastern United States has found that delayed termination of cover crops can provide additional ecosystem services in the form of pest management for slug species (*Deroceras sp.*), but not without the risk of yield loss where corn was planted into a living cover crop (Le Gall et al., 2022). Another study from the same region concluded that a no-till system with or without cover crops provides sufficient habitat complexity to support predative insect communities, which can reduce pest problems (Rowen and Tooker, 2021). To our knowledge, these effects of planting green have not been investigated in Kansas prior to this study.

Procedures

This experiment was conducted in Junction City, KS, on a Reading silty clay loam in 2021 and a Kahola silt loam in 2022. Both fields were in dryland production, and the experimental design consisted of 16 plots that were 50 ft by 40 ft with 16 rows of corn in each. The cover crop species for this study was exclusively cereal rye (*Secale cereale*), which was planted in mid-to-late October in 2020 and 2021 following soybean harvest. The four treatments in the study were a bare-ground check, and three different termination dates; 4 weeks prior to planting (brown), 7–14 days prior to planting (green-brown), and at planting (green). Cover crops were terminated using a mix of glyphosate and 2,4-D. Cover crop biomass was collected from four locations in each plot the day before termination, dried at 140°F for five days, and weighed. Corn planting dates for 2021 and 2022 were April 30 and May 11, respectively. Throughout the growing season, sentinel prey assessments were executed at V3, V5, and R3 growth stages. Bait for the sentinel prey assessments was waxworms (*Galleria mellonella*) pinned to clay balls that were partially buried in the soil so the worms were exposed. Small mammal-exclusion cages were placed over each sentinel pray trap. Six waxworms were distributed in each plot at 8 p.m. and were then assessed for predation at 8 a.m. and 8 p.m. the following day. The corn yield was determined by hand harvesting 17.5 ft of row from the two center rows which was equivalent to 1/1000th acre. The corn ears were shelled, and the grain weight and moisture determined.

Results

Cover Crop Growth

Cover crop biomass was lowest in the brown treatment and ranged from 2.0 ton/a in 2021 to 0.4 ton/a in 2022 (Table 1). Cover crop biomass in the green-brown treatment was higher than the brown treatment and lower than the green treatment in 2021 and 2022, and ranged from 3.6 to 0.8 ton/a (Table 1). The planting green treatment had the greatest cover crop biomass in 2021 and 2022 ranging from 5.5 to 1.8 ton/a (Table 1). Cover crop biomass was reduced by more than 65% in 2022 compared to 2021. This reduced biomass was likely a result of the lower winter precipitation observed in 2022 (Figure 1).

Insect Predation

Insect predation was not statistically different between the cereal rye cover crop termination date treatments, and the no cover crop control. Regardless of treatment, almost all waxworms were predated by the end of the assessment periods. The rye cover crop may have provided habitat for predatory insects, but the presence or absence of a cover crop did not make a significant difference in overall predation (Table 2). These results were consistent with what was observed by Rowen and Tooker in 2021.

Corn Yield

A significant impact of cover crop termination date on yield was observed in 2021 and 2022. In both years, the yields from planting green plots were significantly lower than those from the other treatments. In 2021, yields were not significantly different between control, planting brown, and planting green-brown (Table 2). In 2022, the difference in yields between treatments were more significant, and the planting green plots produced approximately 50% less than the control plots (Table 2). Yields in 2022 were overall lower than those observed in 2021, possibly due to less precipitation in the winter and spring (Figure 1). The cereal rye, especially in the late termination plots, may have depleted the soil of stored moisture prior to corn planting, and the impact of this was exaggerated in the drier 2022 season. Other potential causes of the reduced yield in the treatments with late-termination of the cereal rye are decreased soil temperatures or decreased solar radiation reaching seedlings due to shading from the cover crop residue (Yang et al., 2021).

Acknowledgments

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Table 1. Cover crop biomass and corn yield by termination date

	Average cover crop biomass (ton/a)		Average yield (bu/a)	
Treatment	**2021**	**2022**	**2021**	**2022**
Control	---	---	222.3 a	127.5 a
Brown	2.0 c	0.4 c	225.6 a	119.4 ab
Green-Brown	3.6 b	0.8 b	206.5 a	96.7 b
Green	5.5 a	1.8 a	175.3 b	53.6 c

Different letters indicate statistically different values ($P < 0.05$).
Control = check treatment with no cover crop planted. Brown = 4 weeks prior to planting.
Green-brown = 7 to 14 days prior to planting. Green = at planting.

Table 2. Significance of termination date and insect predation at V3, V5, and R3

	P-values	
Growth stage	**2021**	**2022**
V3	0.34	0.66
V5	0.13	0.4
R3	0.57	0.79

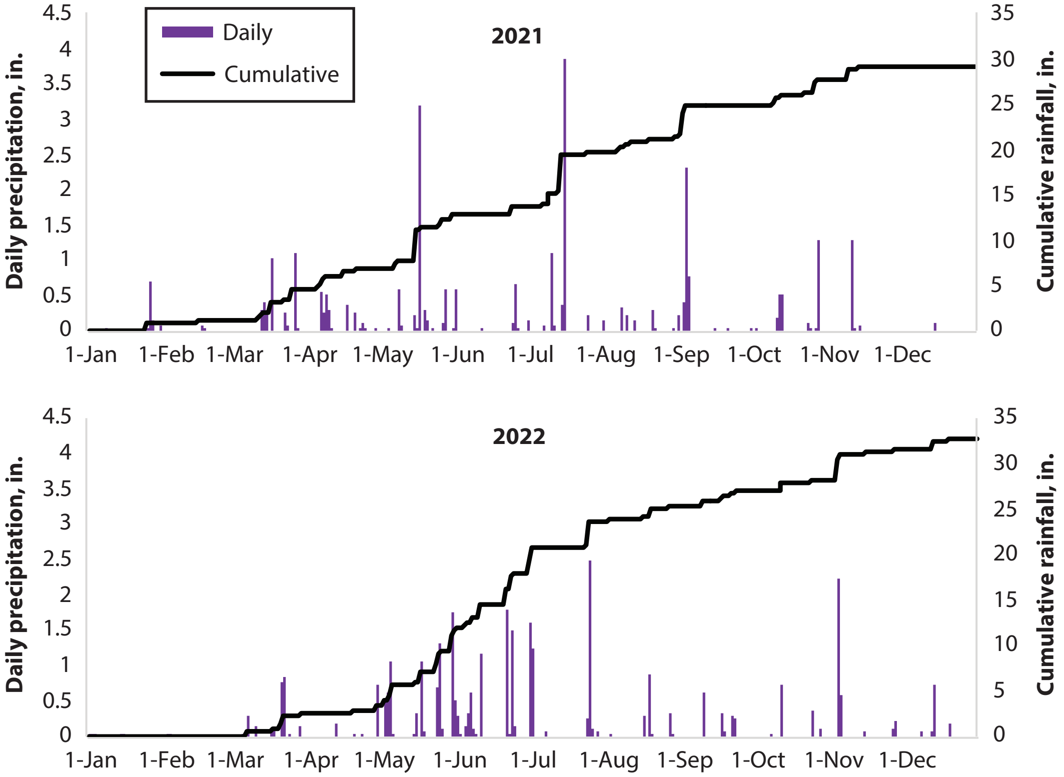

Figure 1. Annual precipitation, Ashland Bottoms (~10 miles from experiment sites, nearest Kansas Mesonet Station).

Effect of Defoliation at Different Stages on Grain Sorghum

K.L. Roozeboom and B. Owuoche

Summary

Loss of leaf area usually results in yield loss in grain crops, but the amount of yield loss varies with extent and timing of defoliation. Grass crops, such as corn and grain sorghum, are particularly sensitive to leaf area loss near the time of seed set because there is little opportunity for the plant to compensate. An experiment to quantify yield reductions associated with various levels of defoliation imposed at different stages of grain sorghum development was conducted at Manhattan, KS, in 2022. Target defoliations of 0, 33, 66, and 100% were imposed at 5-leaf, flag-leaf-appearance, half-bloom, and hard-dough stages. Defoliation of 5-leaf sorghum resulted in minimal yield loss unless the defoliation rate was 100%, which delayed heading and reduced head size and seed size. Leaf area losses of 50% or more at the hard dough stage caused yield reductions of only about 10–12%. Yield reductions were greatest when leaf area was lost at flag leaf appearance or half bloom. Leaf area loss of 60% and 100% caused yield losses of 25% and 75%, respectively. These yield losses were associated with different combinations of reductions in head size and seed size.

Introduction

Leaves are the primary source of energy for growth and grain filling in grain sorghum. Although dry matter is translocated from the stem to grain during grain filling, leaf area is required to deposit that dry matter in the stems. Hail damage tends to cause the greatest loss of leaf area on a field level and can be eligible for compensation via crop insurance. Usually, greater leaf area loss is associated with greater yield loss. However, that relationship changes as the sorghum crop develops. Leaf loss early in the season usually causes minimal yield loss because the lost leaf area is a relatively small fraction of the total. Additional leaves that emerge after the defoliation may support near normal seed set and grain fill. Leaf loss late in the season may cause minimal yield loss because grain fill has neared completion, and dry matter translocation from stems may somewhat compensate for the loss of new photosynthate. However, leaf area losses near the time of seed set are likely to cause the largest yield losses in sorghum and other grass crops because most of the leaf area has already emerged, and grain fill has just started. These relationships have been characterized in the past, but the response of modern sorghum hybrids in contemporary production systems is lacking. The objective of this experiment was to characterize the response of a modern grain sorghum hybrid to varying levels of leaf loss at different stages of crop development.

Procedures

Experiment Site and Agronomic Management

The experiment was located at Manhattan, KS, on a Kahola silt loam. Sorghum hybrid P84G62 was planted on June 6, 2022, at 75,000 seeds per acre using a White 9000 series planter with Precision Planting seed meters and 20|20 seed monitoring system. Fertilizer was applied before planting as a mix of 28% UAN and ammonium polyphosphate to supply 90 pounds of nitrogen and 55 pounds of P_2O_5 per acre. A residual herbicide mix was applied on May 17, and a burndown herbicide application was made immediately after planting. A mix of Huskie herbicide and Lambda Cy insecticides was applied on June 21 to control late-emerging Palmer amaranth and chinch bugs migrating from an adjacent wheat field, respectively. Plots were harvested on October 5–7 after reaching physiological maturity.

Treatments and Experimental Design

Treatments consisted of four levels of defoliation imposed at four developmental stages. The target defoliation levels were 0, 33, 66, and 100% and were imposed using a cordless hedge trimmer plus hand trimming the 100% treatment as needed. The sorghum stages when defoliations were imposed were S2 (5 leaves fully emerged), S4-flag (leaf visible in whorl), S6 (half bloom), and S8 (early hard dough). All treatments were arranged in a randomized complete block experimental design with five replications.

Data Collection and Analysis

Immediately after each defoliation, plants were clipped from a 3-foot section of row. Samples were refrigerated until processed to determine leaf area using a LiCor LI3100C area meter. Actual defoliation rate was calculated as the leaf area remaining immediately after defoliation as a percent of the 0% defoliation plots in each replication. Leaf area index (LAI) was calculated by dividing the sample leaf area by the sample soil surface area. Percent canopy coverage of the soil surface was estimated using the Canopeo app immediately after each defoliation. Days to half bloom was the number of days from planting until at least half the plants in the center two rows of each plot displayed anthers at least half-way down the head. The number of plants per acre was determined by counting all plants in the center two rows of each plot at sorghum stage S1 (3 leaves fully emerged) and dividing by the plot area in acres. The number of heads per plant was determined by dividing the number of heads per acre (counted at harvest) by the number of plants per acre. Seed size was determined by weighing 300 seeds. The number of seeds per head was calculated using the mass of grain, head number, and seed size. Grain yield was calculated by dividing the mass of grain by the harvest area and converted to bushels. Effect of defoliation was characterized by regressing days to half bloom, yield components, and yield on measured defoliation rate separately for each developmental stage. Pearson correlation coefficients were calculated for all combinations of variables using PROC CORR in SAS to characterize relationships between variables ($\alpha = 0.05$).

Results

Defoliation of S2 sorghum resulted in minimal yield loss unless the defoliation rate was 100%, which delayed heading and reduced head size and seed size. An accidental over-application of Aim and 2,4-D herbicides to the entire experiment to control surviving Palmer amaranth plants was made on June 27, the same day the S2 defoliations were imposed. Although most plants recovered rapidly, data from the S2 defoliations were eliminated from the summaries presented below because plant recovery after defoliation was likely affected by the herbicide application.

Effect of Defoliation on Remaining Leaf Area and Bloom Date

Increasing rates of defoliation were strongly negatively correlated with leaf number, LAI, canopy coverage, and S9 LAI over all developmental stages and within each developmental stage (Table 1). Greater defoliation rates increased days to half bloom only at S4 (Table 1, Figure 1).

Effect of Defoliation on Yield Components and Yield

Defoliation affected yield components differently depending on the developmental stage when the defoliation was imposed. Plants per acre were not affected by defoliation rate (Figure 2) and were strongly correlated only with heads per plant (Table 1). Defoliation had a minimal effect on heads per plant (Figure 3). Head size decreased with greater defoliation (Figure 4), with the largest decreases when defoliated at S4 and the smallest when defoliated at S8 (Table 1). Seed size decreased only at high rates of defoliation (Figure 5) and was reduced the most when defoliated at S6 and the least when defoliated at S8 (Table 1). Yield was reduced by 60 to 80% with high rates of defoliation at developmental stages S4 and S6, but yield reduction was minimal with defoliation at S8 (Figure 6, Table 1).

Relationships Among Sorghum Response Variables

Defoliation had strong, negative correlations with the various measures of leaf area over defoliations at all developmental stages and at each stage (Table 1). Defoliations imposed at S4 and S6 also had strong, negative correlations with head size, seed size, and yield. However, defoliation at S8 was not strongly correlated with any yield component or yield.

Conclusion

Defoliation tended to reduce yield, but the degree of yield reduction varied with timing and extent of defoliation. The greatest yield reductions resulted from defoliations at S4 and S6, which reduced both head size and seed size. Yield reductions were minimal with defoliations at S8 and were associated with reductions in seed size.

Acknowledgments

National Crop Insurance Services provided guidance on experimental design. Kaori Kayabushi, Ike Bahr, Jessica Grünberg, and Sarah Frye helped with imposing treatments and data collection.

Table 1. Pearson correlation coefficients for defoliation of grain sorghum at Manhattan, KS, 2022

	Defoliation	Days bloom	Plants/ acre	Heads/ plant	Seeds/ head	Seed size	No. leaves	LAI[1]	Canopy[2]	S9 LAI[1]	Yield
↓ stage 4 (flag leaf appearance, upper right) ↓											
Defoliation		**0.75**	0.07	0.08	**-0.93**	**-0.48**	**-0.87**	**-0.99**	**-0.95**	**-0.87**	**-0.90**
Days bloom	0.34		-0.09	0.21	**-0.72**	-0.17	**-0.68**	**-0.72**	**-0.75**	**-0.61**	**-0.62**
Plants/acre	0.01	**-0.33**		**-0.78**	-0.18	-0.10	-0.22	-0.10	-0.03	-0.18	-0.18
Heads/plant	0.12	**0.38**	**-0.66**		0.05	0.11	0.15	-0.01	-0.11	0.14	0.14
Seeds/head	**-0.66**	**-0.46**	-0.12	-0.16		**0.46**	**0.90**	**0.91**	**0.92**	**0.86**	**0.95**
Seed size	**-0.56**	-0.07	0.01	0.02	**0.47**		**0.66**	**0.52**	**0.57**	**0.46**	**0.71**
No. leaves	**-0.80**	**-0.29**	-0.12	-0.14	**0.77**	**0.61**		**0.88**	**0.89**	**0.77**	**0.93**
LAI	**-0.97**	**-0.32**	0.00	-0.13	**0.64**	**0.56**	**0.79**		**0.94**	**0.86**	**0.91**
Canopeo	**-0.81**	**-0.28**	0.01	-0.04	**0.50**	**0.54**	**0.61**	**0.73**		**0.86**	**0.91**
S9 LAI	**-0.93**	-0.23	-0.01	-0.06	**0.53**	**0.57**	**0.69**	**0.94**	**0.75**		**0.85**
Yield	**-0.71**	**-0.36**	-0.08	0.00	**0.90**	**0.78**	**0.78**	**0.69**	**0.59**	**0.63**	
↑ across all stages (lower left) ↑											
↓ stage 8 (hard dough, upper right) ↓											
Defoliation		0.21	-0.05	0.33	-0.39	-0.26	**-0.77**	**-0.97**	**-0.92**	**-0.97**	-0.31
Days bloom	-0.07		**-0.70**	**0.70**	-0.13	-0.30	-0.16	-0.17	-0.17	-0.17	-0.15
Plants/acre	0.01	-0.33		**-0.65**	-0.24	0.24	-0.06	0.07	0.08	0.07	-0.01
Heads/plant	-0.22	0.14	**-0.66**		-0.28	-0.15	-0.33	-0.31	-0.34	-0.31	-0.01
Seeds/head	**-0.69**	-0.07	0.07	-0.13		0.20	0.39	0.30	0.34	0.30	**0.66**
Seed size	**-0.83**	0.03	-0.09	0.13	**0.81**		0.15	0.27	0.36	0.27	**0.78**
No. leaves	**-0.88**	0.13	-0.07	0.10	**0.83**	**0.94**		**0.73**	**0.76**	**0.73**	0.20
LAI	**-1.00**	0.08	0.00	0.21	**0.69**	**0.83**	**0.88**		**0.87**	**1.00**	0.27
Canopeo	**-0.92**	0.13	-0.01	0.11	**0.80**	**0.90**	**0.95**	**0.92**		**0.87**	0.34
S9 LAI	**-1.00**	0.08	0.00	0.21	**0.69**	**0.83**	**0.88**	**1.00**	**0.92**		0.27
Yield	**-0.83**	-0.05	-0.02	0.09	**0.93**	**0.95**	**0.92**	**0.83**	**0.89**	**0.83**	
↑ stage 6 (half bloom, lower left) ↑											

[1] LAI = leaf area index. S9 LAI = LAI at sorghum developmental stage 9, physiological maturity.

[2] Estimate of % ground cover using the Canopeo App.

Bold values indicate 95% confidence of significant correlation.

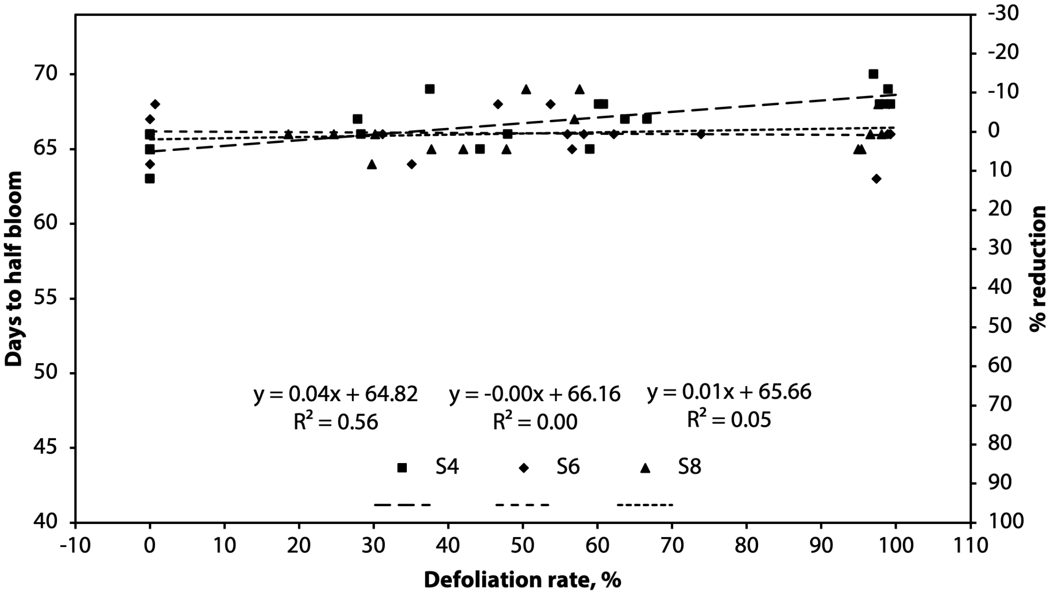

Figure 1. Effect of defoliation at three grain sorghum developmental stages on days to half bloom at Manhattan, KS, in 2022.

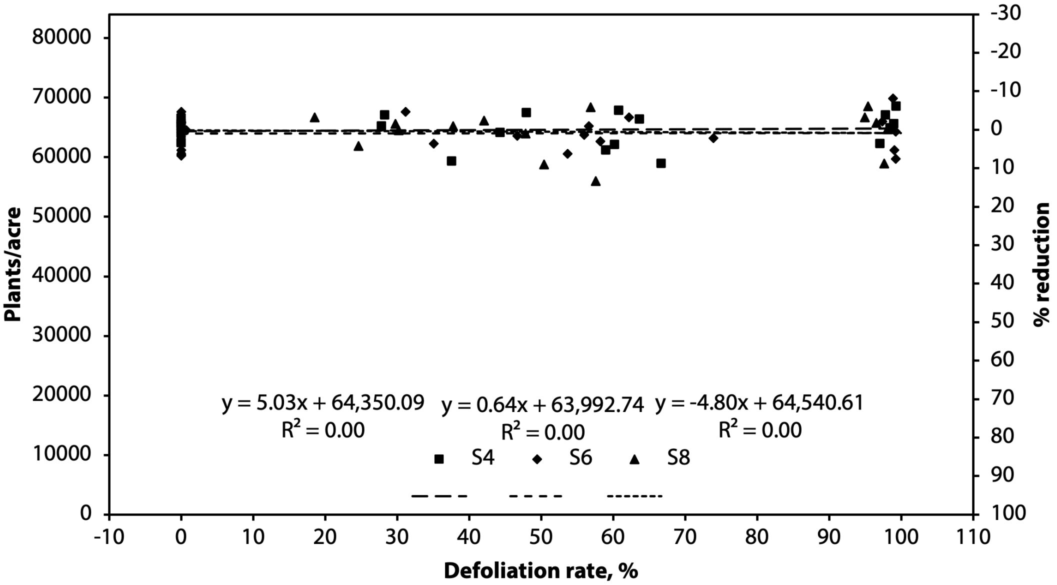

Figure 2. Effect of defoliation at three grain sorghum developmental stages on plant density at Manhattan, KS, in 2022.

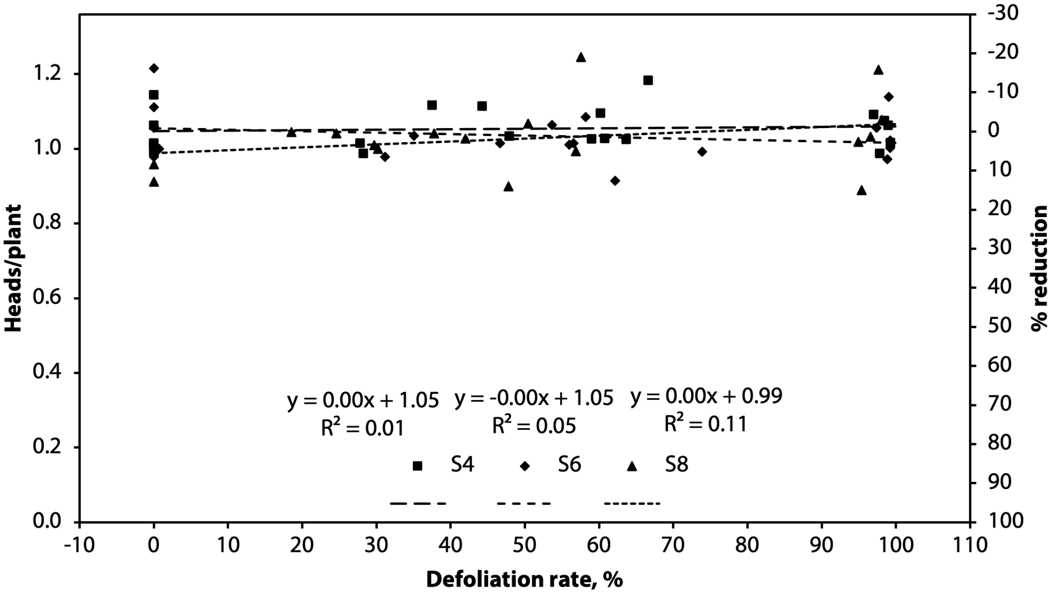

Figure 3. Effect of defoliation at three grain sorghum developmental stages on number of heads per plant at Manhattan, KS, in 2022.

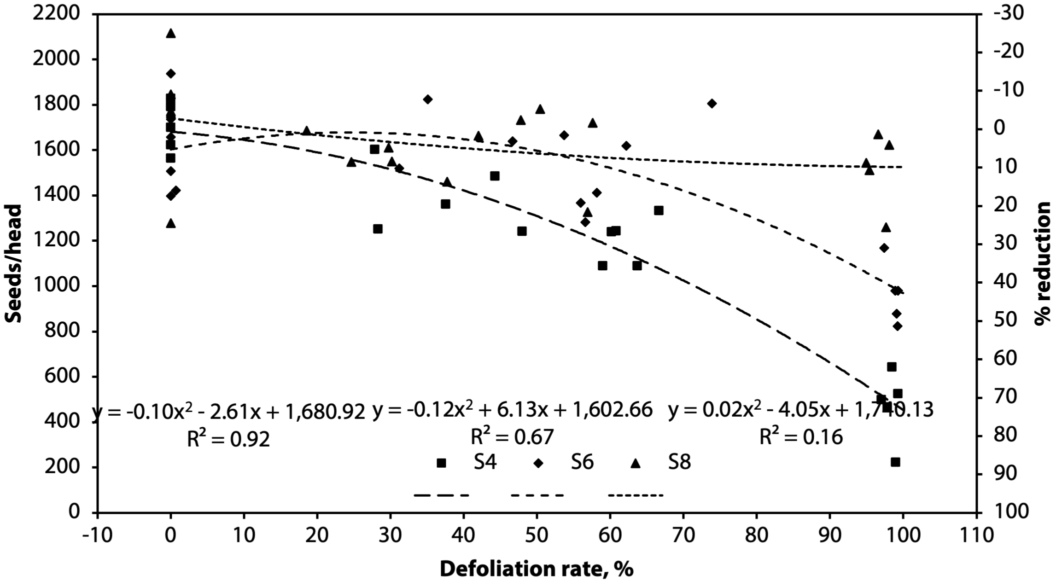

Figure 4. Effect of defoliation at three grain sorghum developmental stages on number of seeds per head at Manhattan, KS, in 2022.

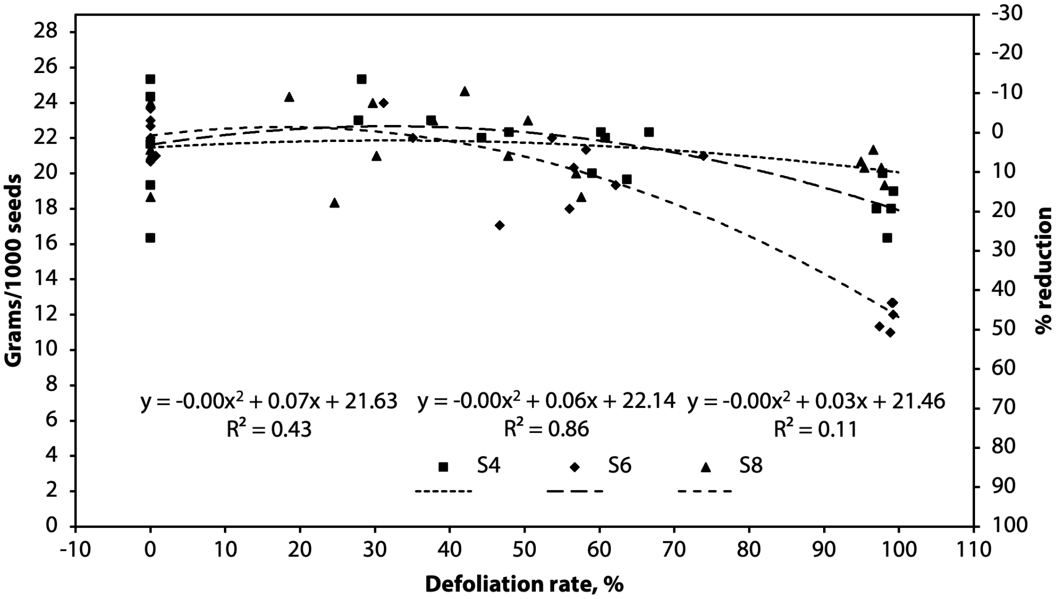

Figure 5. Effect of defoliation at three grain sorghum developmental stages on seed size at Manhattan, KS, in 2022.

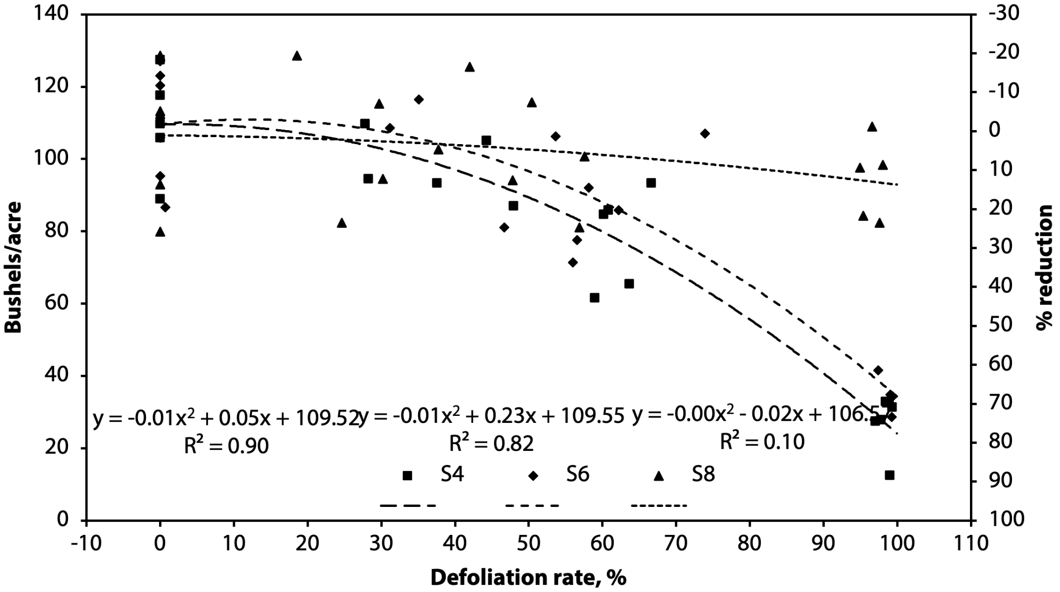

Figure 6. Effect of defoliation at three grain sorghum developmental stages on grain yield at Manhattan, KS, in 2022.

Dynamics of Oil and Fatty Acid in Historical Sorghum Varieties

N.S. Volpato, A.J.P. Carcedo, T. Durrett,[1] L. Marziotte, L. Mayor,[2] I.A. Ciampitti

Summary

One of the important characteristics of cereal crops is their diverse pool of fatty acids. This study aims to determine the changes in sorghum oil content and fatty acid profile across many years of the market's variety releases. Six sorghum varieties, all released between 1960 and 2019, were evaluated and grain traits were analyzed using linear models. Ten different fatty acids were characterized, but only three out of the total represented more than 90% of the total oil concentration: linoleic, oleic, and palmitic acid. Total oil and linoleic acid concentration (g of oil/kg) slightly decreased across years of release. In contrast, palmitic and oleic acid concentrations (g of oil/kg) increased over time. These results indicate past breeding efforts have not substantially modified sorghum's profile of fatty acids.

Introduction

Sorghum [*Sorghum bicolor (L.) Moench*] is a versatile crop that can be grown as a grain or forage. Sorghum has a remarkable ability to maintain yields under adverse conditions, especially drought, compared with other grain crops. This makes sorghum an important source of food, feed, fiber, and fuel in the global agro-ecosystem (Kresovich et al., 2005). The sorghum grains contain 8 to 12% protein, 3 to 4% oil, approximately 76% starch, and approximately 2% fiber. The oil in sorghum grain provides high quality food. Although cereal crops with low oil concentration may not confer much as domestic oil sources, their importance is driven by advantages of their fatty acid (FA) constituents (Mehmood et al., 2008). Therefore, considering the importance of biochemical analysis of sorghum, it is relevant to explore from a historical perspective the effects of breeding and variety development on FA profile, which to our knowledge, is currently lacking in the scientific literature. The present study was conducted to quantify potential changes in sorghum oil concentration and fatty acid profile across the different years of market release for commercial hybrids.

Procedures

Field Experiments

This research project was conducted in Wamego, KS, United States, during the 2021 growing season. Sorghum was planted on June 7, 2021, and standard agronomic practices were followed to maintain the field free of weeds, pests, and diseases during the season. Six sorghum varieties from Corteva Agriscience (Johnston, Iowa, US) released between 1960 and 2019 were evaluated, herein termed as hybrid 1 (1960), hybrid 2 (1982), hybrid 3 (1997), hybrid 4 (2006), hybrid 5 (2010), and hybrid 6 (2019). Genotypes are representative of each year of release and were widely grown in the Midwest

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region of the US. All sorghum grains were sampled at physiological maturity to determine their fatty acid composition.

Total Oil and Fatty Acid Content Determination

Seed oil content and fatty acid composition were quantified using a well-established method (Miquel and Browse, 1992) with minor modifications. Briefly, dry seeds were powdered, and 1.5 mL of toluene was added, to which 100 µg of triheptadecanoin was added as an internal standard. Total lipids were transmethylated by adding 1 mL of 2.5% (v/v) H_2SO_4/methanol and heating at 90°C (194°F) for 1 h. The fatty acid methyl esters were extracted from the organic phase after the addition of 1.5 mL of potassium chloride and 2 mL hexane, and quantified by gas chromatography using a DB-23 column on a Shimadzu GC2100+ gas chromatograph. The oven temperature was initially 200°C (392°F) for 2 min; then ramped to 240°C (464°F) at 10°C/min (50°F/min) and held at that temperature for 4 min. Chromatogram peak areas were corrected for flame ionization detector response, and oil content was determined as described previously (Li et al., 2006). After obtaining FA concentration in grains, total oil concentration was quantified as the sum of each individual FA. Fatty acids content and total oil for each sample were estimated as the product between seed dry weight and component concentration.

Statistical Analysis

Traits were analyzed using linear models in R software (lm and emmeans package, lm function) (Bates et al., 2015). The year of release was used as a continuous numerical variable. Differences between varieties were analyzed using analysis of variance for variety, year of release, and their interaction as fixed effects. When significant effects were found ($P \leq 0.05$), comparisons were performed using Tukey's test.

Results

Ten fatty acids in sorghum grain oil were detected and quantified in all the years of release (Fig 1). Linoleic acid (18:2), oleic acid (18:1), and palmitic acid (16:0) were the three predominant fatty acids. Low amounts of alpha-linolenic acid (18:3), arachidic acid (20:0), behenic acid (22:0), erucic acid (22:1), palmitoleic acid (16:1), stearic acid (18:0), and gondoic acid (20:1) were also present.

Total seed oil concentration varied significantly across years of release ($P < 0.001$; Figure 2), presenting a negative trend over time. Similarly, the polyunsaturated FA linolenic acid was also affected by the year of release ($P < 0.001$; Figure 3A) with an overall decrease in its concentration. On the other hand, the saturated FA palmitic acid showed a small trend to increase its amount in the total oil concentration (Figure 3B). No clear relationship was found for oleic acid ($r^2 = 0.1$).

Conclusion

Total oil and linoleic acid concentrations were negatively associated with year of release. Contrastingly, palmitic acid increased with the year of release. The identified changes in the oil profile were relatively low, indicating that past breeding efforts have not substantially modified sorghum fatty acids profile.

Acknowledgments

Kansas Sorghum Checkoff. Corteva Agriscience.

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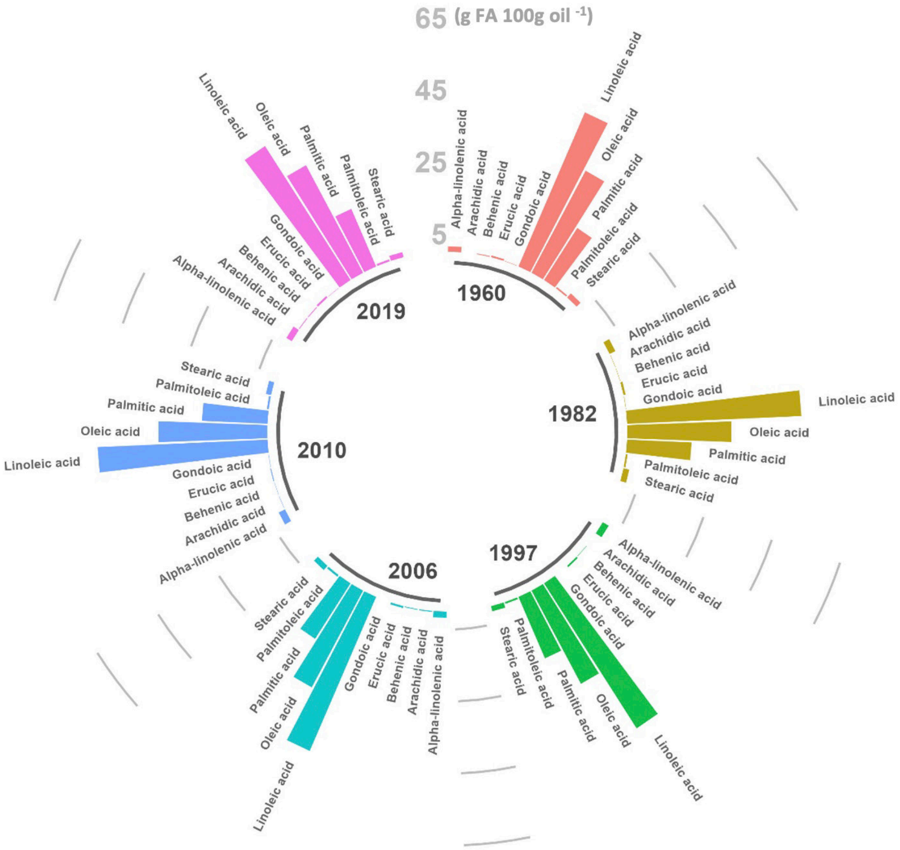

Figure 1. Fatty acids profile in sorghum grains in different years of release.

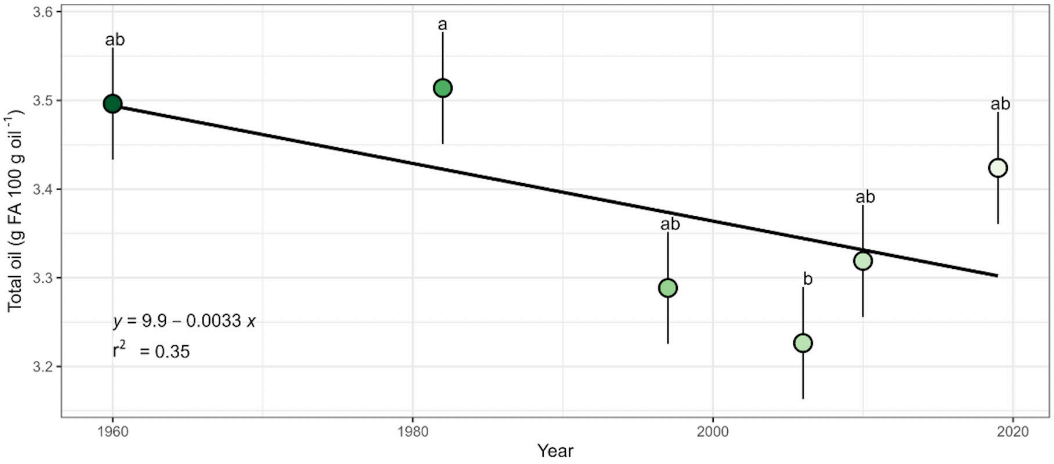

Figure 2. Relationship between year of release and total oil concentration. The error bar represents the standard deviations of the mean. Different lowercase letters indicate significant differences among years of release according to Tukey's test ($P \leq 0.05$).

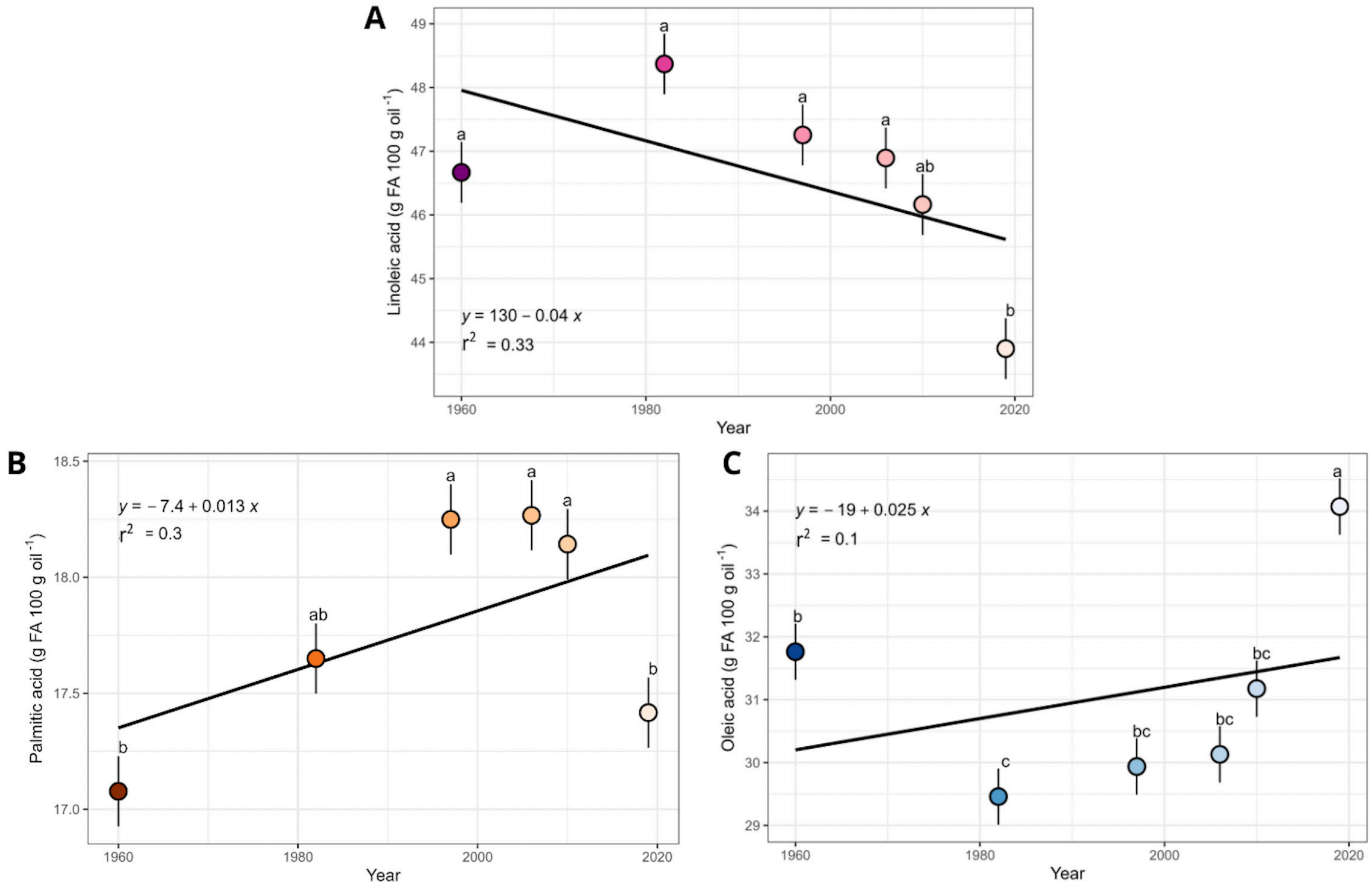

Figure 3. Relationship between year of release and linoleic acid (A), palmitic acid (B), and oleic acid (C). The error bar represents the standard deviations of the mean. Different lowercase letters indicate significant differences among years of release according to Tukey's test ($P \leq 0.05$).

Algorithm to Estimate Sorghum Grain Number from Panicles Using Images Collected with a Smartphone at Field-Scale

G.N. Santiago, A.J.P. Carcedo, L. Marziotte, and I.A. Ciampitti

Summary

An estimation of on-farm yield before harvest is important to help farmers make decisions about additional input use, time to harvest, and options for end uses of the harvestable product. However, obtaining a rapid assessment of on-farm yield can be challenging, especially for a sorghum (*Sorghum bicolor* L.) crop due to the complexity of counting the total number of grains in a panicle at field-scale. One alternative to reduce labor is to develop a rapid assessment method employing computer vision algorithms. Computer vision has already been utilized to account for the number of grains within a panicle, yet it has only been tested under controlled conditions. The objective of this study was to estimate the number of grains in a sorghum panicle using imagery data captured from a smartphone device at field-scale. During the pre-harvest season, sorghum panicles of several commercial hybrids were photographed in the field. Later, the plants corresponding to those panicles were harvested to determine the final number of grains, to develop a benchmarking dataset. Using Python language and the OpenCV library, each image was filtered, blurred, and contours were applied to estimate the number of grains in each sorghum panicle. The absolute mean difference obtained using the algorithm output for the observed and the estimated number of grains was 570 (root mean square percentage error = 53%).

Introduction

Production estimations are valuable information for farmers (Fountas et al., 2015). For sorghum, an attempt to estimate grain numbers using a traditional and imagery approach has been done but not transferred at field-scale (Ciampitti et al., 2014; 2015). One alternative to estimate production relies on the usage of computer vision algorithms (Wan and Goudos, 2020) to generate meaningful information from images and videos (Davies, 2005). The usage of computer vision is already established in several knowledge areas such as medicine (Dey et al., 2021), industry (Kakani et al., 2020), and agriculture (Mogili and Deepak, 2018). In agriculture, computer vision is mostly used to determine diseases (Liu et al., 2016), quality (Olgun et al., 2016), phenology (Naik et al., 2017), nutritional status (Romualdo et al., 2014), and production estimates (Ramos et al., 2017). Komyshev et al. (2017) evaluated the use of imagery documenting the estimation of sorghum grain number under controlled conditions. However, to assist farmers in their estimates of crop production, the process of counting grains must migrate from a laboratory environment to field applications (Fernandez-Gallego et al., 2018). Following this rationale, the aim of this study was to estimate the number of grains from a sorghum panicle using images collected with a smartphone at field-scale.

Procedures

Image Capture and Measurements

A total of 100 sorghum plants from different hybrids (five plants per hybrid) were selected during the pre-harvest (October 2022), KS, U.S. Two pictures of each plant were collected without removing the panicle from the plant. The pictures centralized a single panicle in the image, with the presence of other plants in the background. After the images were taken, the sorghum panicles were harvested, and grains were counted manually. A generic smartphone was used with a camera of 64 MP and set on automatic mode of image capture. In all images, the sunlight was in the same direction as the camera.

Image Processing and Models Generation

All the images were cropped centering the sorghum panicle in a 9:16 ratio frame rectangle. Later, the images were separated into two groups: white and red sorghum panicles (160 red sorghum and 40 white sorghum). Using Python (Van Rossum and Drake, 2009) and OpenCV library (Bradski, 2000), color filter, blur, and contouring processes were adjusted for each sorghum group. This adjustment was done considering the absolute mean difference between the observed and the estimated number of grains. As an example of the process, Figure 1A shows an untreated image taken at field-scale. Figure 1B shows the same image after the filter and blurring processes have been applied. In Figure 1C, the contours were applied to the image after the filter and blurring processes. Finally, the grain number per panicle was estimated by counting the number of contours.

Results

Figure 2 shows a scatter plot associating the observed and the algorithm estimation for sorghum grain number. The root mean square percentage error (RMSPE) was 53% and the difference between the observed and estimated number of grains in a panicle head was 570. This difference represents ~24% of the total number of grains in an average panicle.

Conclusions

The algorithm produced in this study represents the first attempt to estimate the grain number from sorghum panicles using images captured from a smartphone device at field-scale. An adequate estimation of sorghum grain number was achieved (relative high values of RMSPE). Future works should focus on developing an artificial intelligence model to recognize one panicle per image; and embed the whole algorithm into a mobile app.

Acknowledgments

Funding provided by the United Sorghum Checkoff.

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Van Rossum, G., & Drake, F. L. (2009). Python 3 Reference Manual. Scotts Valley, CA: CreateSpace. Figure 1. (A) Image of sorghum panicle captured in field, (B) image after color filtering and blurring process, and (C) image after contours applied.

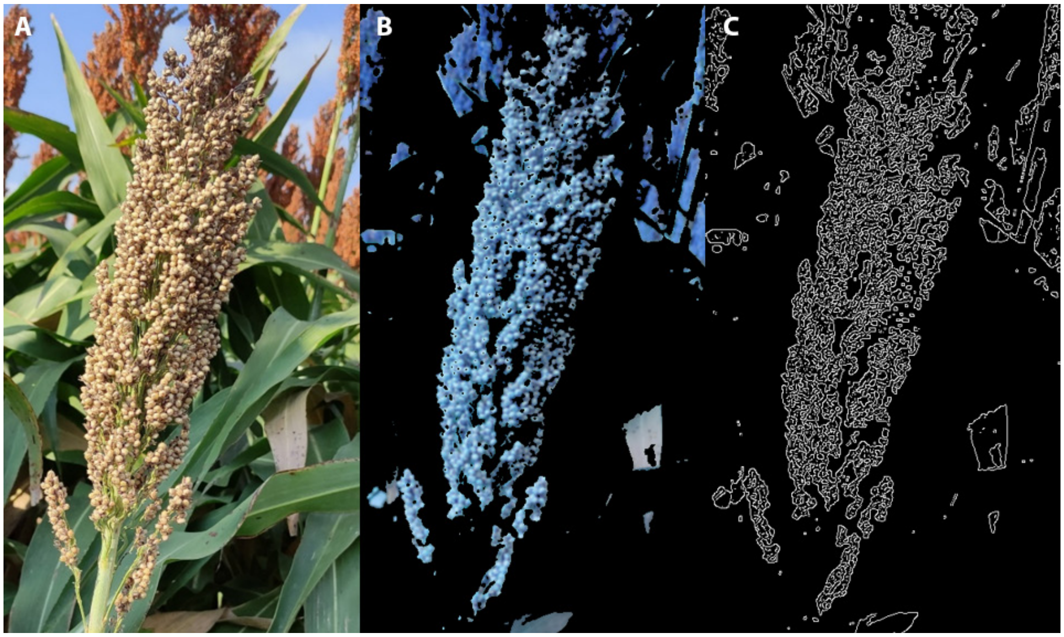

Figure 1. (A) Image of sorghum panicle captured in field, (B) image after color filtering and blurring process, and (C) image after contours applied.

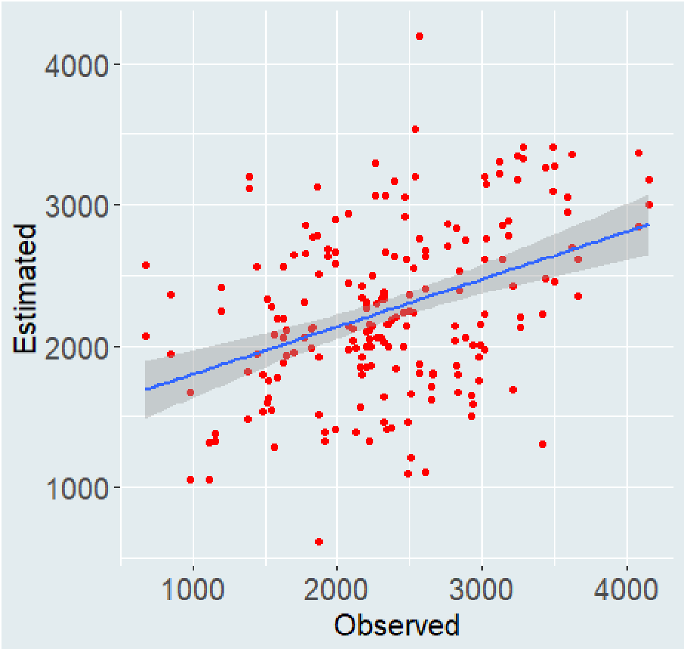

Figure 2. Scatter plot of Estimated vs. Observed using the estimation obtained from the algorithm.

Impact of Different Plant Canopy Traits on Sorghum Yields

M.F. Lucero, A.J.P. Carcedo, L. Marziotte, L. Mayor,[1] and I.A. Ciampitti

Summary

Studying changes in plant canopy can help to improve plant architecture and increase yields. Specifically, for sorghum (*Sorghum bicolor* L.), characterizing and identifying relevant canopy traits can be helpful not only to improve its productivity but to better fit this crop in the rotation from a system perspective. With this purpose, morphological characteristics of 20 sorghum hybrids were measured during the 2022 growing season in Wamego, KS, U.S. (United States). The most relevant canopy traits examined were leaf angle and leaf area at leaf- and at canopy-level (leaf area index, LAI), all determined at different points of the crop growth cycle (seventh-leaf, V7, flowering, and physiological maturity). Furthermore, duration of the vegetative and reproductive phases were also recorded as days to flowering, and days to maturity. A conditional decision tree analysis was employed to cluster the hybrids according to their variation in canopy characteristics and impact on yield. In summary, end of season LAI (at physiological maturity) was one of the most relevant plant canopy traits to group the hybrids and it accounted for ~70% of the variation. Hybrids with high LAI at V7 and low LAI at maturity, in addition to their longer time to maturity, presented greater yields. These findings can lead to future investigation using the same traits under different climatic conditions.

Introduction

Sorghum (*Sorghum bicolor L.*) is grown in the United States within the sorghum belt, a region which includes the states of Kansas, Texas, Colorado, Oklahoma, and South Dakota (Ciampitti and Prasad, 2020). The U.S. is one of the main world producers, with a proportion of 17% of the global sorghum production (FAOSTAT, 2022). Sorghum is known to be tolerant to water and heat stress, making it a suitable crop for overcoming adverse weather conditions. The canopy architecture plays a key role in explaining this tolerance (Kholová et al., 2013), and it was identified as one of the potential drivers of genetic gain (Demarco et al., 2022). Furthermore, changes in the canopy architecture had been employed to increase the number of plants per acre without yield penalties per plant, resulting in an increase of yield per acre (Duvick, 2005). However, even though sorghum presents great diversity in canopy architectures, to our knowledge no studies have explored the impact of these plant traits on U.S. commercial sorghum hybrids.

Therefore, this study proposes to identify the importance of plant canopy traits associated with yield, via characterizing different canopy structures in a wide range of hybrids.

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[1] Corteva Agriscience, Wamego, KS.

Procedures

Twenty hybrids were evaluated during the 2022 growing season at the Corteva Agriscience Station in Wamego, KS, U.S. The sorghum hybrids were planted on June 15 in a randomized complete block design, with three repetitions. Each plot consisted of eight rows with an interrow space of 30 in.

At the beginning of the season, 12 plants were selected per plot. The number of expanded leaves was recorded weekly. At three sampling moments (V7, flowering, and maturity) four plants were collected to measure leaf angle, and leaf area per leaf. Leaf area was measured per leaf, and then used to calculate the per unit area leaf area index (LAI).

The accumulated precipitation for the year was 33 in., and the mean temperature was 55°F (Figure 1). Precipitation for the year fell primarily (60% of the total) during May, June, and July, leading to low water availability late in the season.

The effect of canopy variation on yield was analyzed using analysis of variance (ANOVA). A conditional decision tree analysis was employed to group the hybrids according to the impact on yield of their canopy characteristics. All statistical analyses were performed with R software.

Results

The highest yield was achieved by the hybrid G6 (142 bu/a), while the lowest yield (66 bu/a) was attained by the hybrid G1 (Table 1). The hybrid G1 had a final number of leaves above the average (20 leaves) resulting also in greater LAI at both flowering and maturity. The hybrid with the highest yield presented a lower number of leaves (18 leaves) and lower LAI at both flowering and maturity when compared with the rest of the hybrids. The average time to flowering was 54 days across hybrids, ranging from 45 (hybrid G19) to 64 days (hybrid G2). Days to maturity presented an average across hybrids of 101 days but it ranged from 89 days (G19) to 111 days (G5). The hybrid G19 was the earliest for the group evaluated, with 45 days and 89 days to flowering and maturity, respectively. However, its yield was not the lowest among all hybrids (84 bu/a).

Results of ANOVA showed that yield was significantly influenced by LAI at maturity ($P \leq 0.05$). Furthermore, LAI at V7 and days to maturity showed a lower significance effect on grain yield ($P \leq 0.1$).

In accordance with these results, the percentages of variation explained by these traits were the highest among the explored traits (Figure 2). The leaf area index at maturity explained 36% of the yield variability, standing as the most relevant plant canopy trait. Other important traits to explain yield were LAI at V7 and days to maturity, explaining 16% and 15%, respectively. Traits such as leaf angle at maturity, leaf angle at V7, and leaf number at maturity explained a very minor proportion of the yield variation (Figure 2).

The conditional inference tree analysis grouped the hybrids according to the impact of tested plant canopy traits on yield. The most relevant trait to classify hybrids was LAI at maturity, separating hybrids with a LAI lower than 2.6, those sorghum materials resulting in greater yields. Days to maturity was the next relevant trait that divided the hybrids with lower LAI (Figure 3). Hybrids with durations greater than 93 days to maturity showed greater yields, highlighting the relevance of having a longer grain-filling period.

Conclusion

Leaf area index at maturity, LAI at V7, and days to maturity explained 70% of the yield variation and could be considered traits of interest in a breeding program. Hybrids with reduced LAI at maturity, also with greater LAI at V7, presented greater yields. These results might be dependent on the hybrids tested (canopy architecture) and characteristics of the climatic year (genotype × environment). Therefore, future studies should explore these traits in a broader range of environments.

Acknowledgments

Funding support is provided by Corteva Agriscience and the Sorghum Checkoff.

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Table 1. Mean and standard deviation of the evaluated traits for the three phenological states across hybrids

	V7				Flowering						Maturity									
	Angle (°)		LAI		Angle (°)		LAI		DTF (days)		Angle (°)		LAI		DTM (days)		Leaf number		Yield (bu/a)	
Hybrid	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
G1	29	5	0.6	0.1	33	4	5	1	62	2	39	6	3	0.5	109	4	20	0.6	66	5
G2	34	6	0.7	0.2	39	4	5	0.2	64	6	38	3	3	0.8	110	2	21	0.6	82	9
G3	31	5	0.8	0	39	3	6	0.2	60	1	37	6	3	0.2	106	4	20	1	111	9
G4	35	4	0.5	0.2	38	4	4	0.9	64	6	43	4	3	1.1	108	6	22	0.6	69	23
G5	26	6	0.7	0.5	32	1	5	0.1	60	2	34	2	3	0.8	111	0	20	0.6	129	27
G6	34	1	0.6	0.1	32	2	4	0.5	56	0	38	9	2	0.2	109	4	18	0.6	142	13
G7	25	3	0.6	0	29	4	4	0.9	59	2	46	11	2	0.6	109	4	19	0	117	3
G8	33	5	0.6	0.1	28	3	4	0.5	56	1	32	2	2	0.2	106	4	18	0.6	110	14
G9	29	5	0.7	0.1	35	2	5	0.9	56	0	36	3	2	0.3	105	3	19	0.6	122	7
G10	28	1	0.5	0.1	31	4	4	1.6	56	0	36	1	2	0.1	108	4	20	1	118	6
G11	33	6	0.5	0.2	33	4	3	0.4	48	4	40	1	2	0.1	96	6	18	0.6	96	19
G12	26	1	0.6	0.2	26	1	4	0.6	56	0	25	2	3	0.4	105	3	19	0	114	14
G13	27	3	0.7	0.2	27	4	4	0.5	49	6	28	2	2	0.9	99	5	18	0.6	98	11
G14	26	3	0.5	0.2	24	4	3	0.2	46	1	30	2	2	0.1	90	1	20	3.8	109	10
G15	29	4	0.7	0.2	28	1	4	0.5	48	4	37	7	2	0.3	96	7	17	0	102	14
G16	25	1	0.7	0.2	30	5	4	0.4	55	2	33	6	3	0.1	98	4	19	1	110	16
G17	29	2	0.5	0.1	32	1	4	0.3	49	6	31	4	2	0.2	92	5	17	0.6	108	17
G18	23	5	0.5	0.2	28	2	3	0.2	46	0	31	5	2	0.2	92	4	17	1.5	95	10
G19	32	7	0.5	0.1	35	3	2	0.3	45	1	44	5	2	0	89	0	16	0.6	84	7
G20	36	4	0.7	0.4	40	4	2	0.3	46	0	43	5	2	0.2	90	1	16	1.2	95	1

Angle refers to the leaf angle insertion. LAI = leaf area index. DTF = days to flowering. DTM = days to maturity. Leaf number = the last leaf registered. SD = standard deviation.

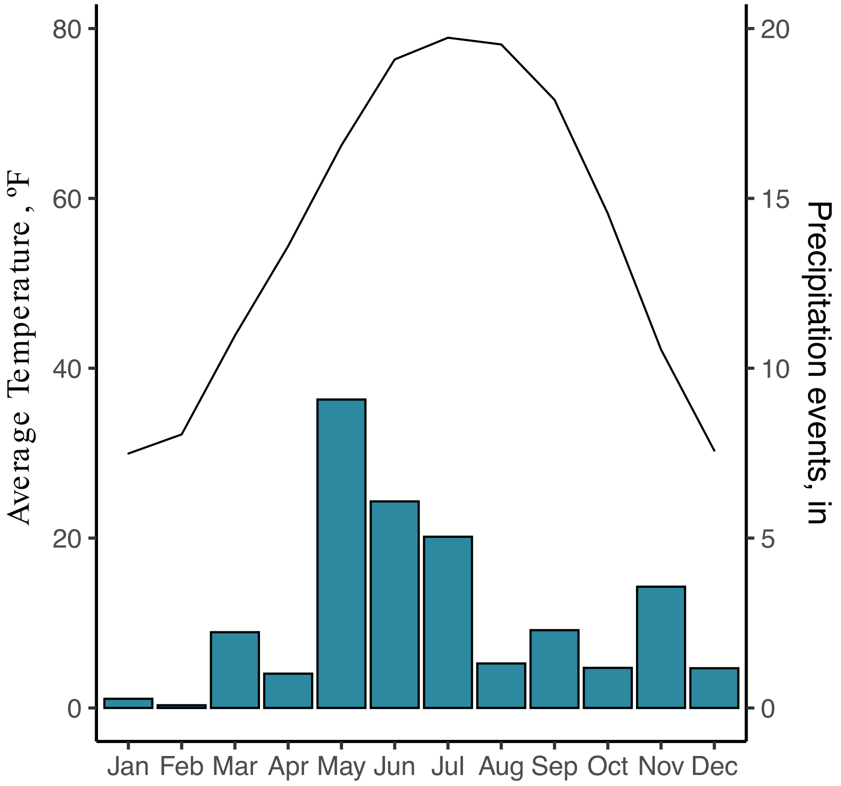

Figure 1. Monthly distribution of the daily average temperature and cumulative precipitation, across the 2022 year for Wamego, KS.

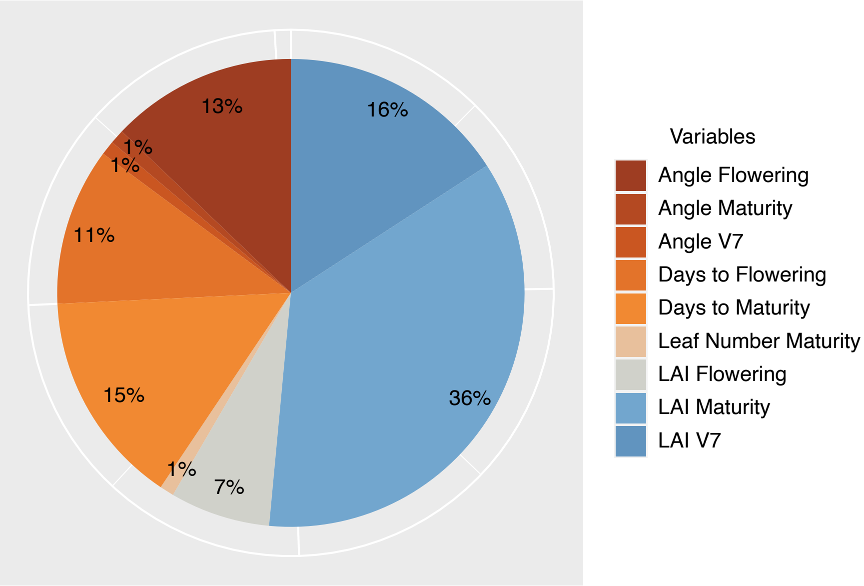

Figure 2. Distribution of the explained yield variance by the canopy architecture traits and phenology. These percentages were calculated based on the sum of squares obtained in the ANOVA analysis.

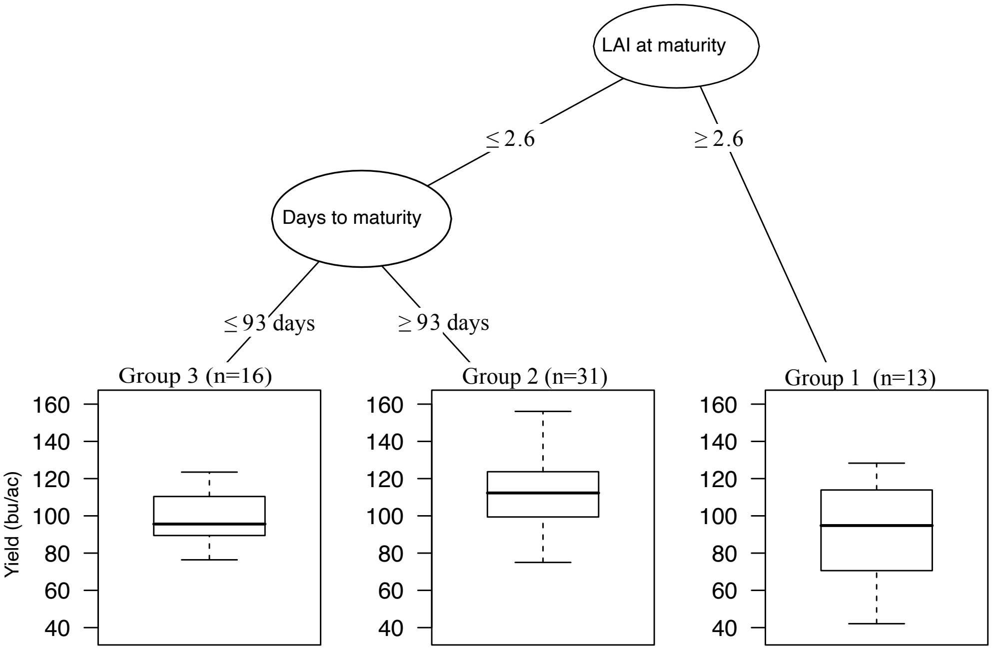

Figure 3. Conditional inference tree explaining the yield variation employing the canopy architecture and phenology traits. In each boxplot, the central rectangle spans the first to the third yield quartiles. The solid line inside the rectangle shows the mean. The upper and lower whiskers represent the maximum and minimum values.

Tillage Study for Corn and Soybeans: Comparing Vertical, Deep, and No-Tillage / Year 10

E. Adee

Summary

Trends from a tillage study conducted since 2011 have shown no clear differences between tillage systems for either corn or soybeans in lighter soils under irrigation. One year out of eight years has shown a yield advantage for either corn or soybeans for any tillage system, which appears to be related to environmental conditions experienced during the season. Averaged across all years of the study, the treatments with deep tillage either every or every-other year had about 4.5% higher corn yields, and soybeans had up to a 3.2% yield increase with some form of tillage.

Introduction

The need for tillage in corn and soybean production in the Kansas River Valley continues to be debated. The soils of the Kansas River Valley are highly variable, with much of the soil sandy to silty loam in texture. These soils tend to be relatively low in organic matter (< 2%) and susceptible to wind erosion. Although typically well drained, these soils can develop compaction layers under certain conditions. A tillage study was initiated in the fall of 2011 at the Kansas State University Kansas River Valley Experiment Field near Topeka to compare deep vs. shallow vs. no-tillage vs. deep tillage in alternate years. Corn and soybean crops are rotated annually. This is intended to be a long-term study to determine if soil characteristics and yields change in response to a history of each tillage system.

Procedures

A tillage study was laid out in the fall of 2011 in a field that had been planted with soybean. The tillage treatments were (1) no-tillage, (2) deep tillage in the fall and shallow tillage in the spring every year, (3) shallow tillage in the fall following both crops, and (4) deep tillage followed by a shallow tillage in the spring only after soybean, and shallow tillage in the fall after corn. In the fall of 2010, prior to the soybean crop, the entire field was subsoiled with a John Deere V-ripper. After soybean harvest, 30- × 100-ft individual plots were tilled with a Great Plains TurboMax vertical tillage tool at 3 in. deep or a John Deere V-ripper at 14 in. deep. Spring tillage was conducted with a field cultivator. Starting in the fall of 2012 through fall of 2017, the treatments were conducted with the TurboMax or a Great Plains Sub-soiler Inline Ripper SS0300. Spring tillage in 2013–2016 was conducted with the TurboMax, and a field cultivator in 2017 on the required treatments. Starting in the fall of 2017, the vertical tillage treatments were made using a Kuhn Krause Excelerator 8005. Each tillage treatment had 4 replications.

Dry fertilizer (11-52-60 nitrogen (N), phosphorus (P), and potassium (K)) was applied to the entire field prior to fall tillage in 2012 and to the soybean stubble in 2013 and 2014. In the fall of 2015, 2016, and 2017, 14-52-40-10 (N, P, K, and sulfur (S)) fertilizer was applied to the soybean stubble prior to fall tillage. The application of 16-75-75-10 (S) was conducted similarly in the fall of 2019, and 20-94-94-12.5 (S) was applied in the fall of 2020. Nitrogen (150 lb in 2012 and 2013; 180 lb in 2014, 2015, 2016, 2017, 2018, 2020, and 2021; and 160 lb in 2019) was applied in March prior to corn planting. Soybeans were planted after soybeans in the setup year. Planting, harvest, and irrigation information for the study is included in Table 1. Irrigation was calibrated to meet evapotranspiration (ET) rates. All corn was planted in 30-inch rows, as well as soybeans through 2016. Soybeans were planted in 15-inch rows in 2017 through 2020. Soybeans were planted in 30-in. rows in 2021 and 2022.

Results

Yields of corn or soybeans did not differ due to tillage in the setup year (2012) of the study (Table 2). The yields were respectable considering the extreme heat and drought experienced this growing season. The growing conditions were better in 2013, resulting in higher yields in both corn and soybeans, but with no significant differences between tillage treatments (Tables 3 and 4). In 2014, the corn yields were very good and Sudden Death Syndrome lowered soybean yields, but there were no differences between tillage treatments (Tables 3 and 4). The cool and rainy start to the season in 2015 slowed corn growth and lowered yields, while the soybeans had very good yields (Tables 3 and 4). In 2016, extremes in soil moisture from dry to saturated resulted in higher yields for the deep tillage treatments than did shallow tillage in corn, but soybean yields were similar for both tillage treatments. There were soil moisture extremes again in 2017, but a cooler August was very favorable for yields of both crops, with no differences between yields with the different tillage systems. The 2018 growing season started off very cool, but quickly had above normal temperatures. The corn yields were very good, with no difference between tillage systems. The soybean yields were very good, the highest was with the more conventional annual tillage and the vertical tillage systems. The 2019 season started off cool for most of May, then had near average temperatures for June and July, followed by a cooler August. The growing season was very wet except for July. The corn yields in 2019 were very good and the soybean yield was the highest observed in the study to date. The season in 2020 started off cool, but turned very hot and dry in June, requiring irrigation. July was very wet, with August near normal, resulting in average corn yields and very good soybean yields (no SDS symptoms). The 2021 season started off very similar to 2020 through June, with July and August drier at near normal temperatures with corn yields down some, and soybean yields were very good. In 2022, the temperatures were average to above average in the spring, with one cool week the first part of May, which had rainfall twice the monthly average. Then the weather turned hot and dry the rest of the growing season, requiring irrigation to start 2 to 3 weeks earlier than normal for both crops.

Combining data from 2013–2022 for analysis showed corn yields are favored by deep tillage, and soybean yields were higher with any kind of tillage (Tables 3 and 4). Corn with deep tillage showed significant yield advantages in 4 of the 10 years, while soybeans were not as responsive in a given year to tillage. Averages of stand counts taken at the V5 stage in the corn for 2014–2022 did not show any differences (Table 3). We anticipated that it would take several years for any characteristics of a given tillage system to build up to the point of influencing yields. Deep soil samples were collected in the fall of

2020 to compare soil properties and soil health between tillage systems. Results of those data will be reported when analysis completed.

Conclusions

The influence of tillage system on corn or soybean yield appears to be dependent on the year. A given set of environmental conditions may favor a system, but in Kansas the conditions can vary considerably each year. Corn is more responsive in yield to a tillage system, probably because uniform emergence is a foundational factor for yield potential. While there were no differences in population count in corn, data were not collected on uniformity of emergence. In contrast, soybeans were much less sensitive to population and uniformity in emergence, with their ability to compensate for missing or late plants through the season. Therefore, early season differences in soybeans with the different tillage systems will probably not have an effect on the yield.

These studies were conducted on well-drained soils under irrigation. As a result, any potential benefits for a specific tillage system to have an advantage in either too wet or too dry conditions were not as pronounced. In heavier soils and/or under dryland conditions, the advantages of any of these tillage systems would probably be greater in a given year.

Numerous other factors need to be considered when comparing tillage systems, such as soil erosion, water conservation, weed control options (becoming more challenging with herbicide-resistant weeds), labor, equipment costs, and time available to conduct field work. The yield-limiting conditions may vary between fields based on soil type and environmental conditions during a season and over the long term.

Table 1. Cropping details for tillage study at Kansas River Valley Experiment Field

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Corn										
Planting date	30-Apr	21-Apr	14-Apr	11-Apr	24-Apr	23-Apr	22-Apr	22-Apr	April 26	April 21
Hybrid/variety	Pioneer P1498 HR AQ	Pioneer P1105AM	Pioneer P1105AM	AgriGold 6538	Midland 534	Golden Harvest 11B63	Pioneer 1197	Pioneer 1197	NK 13-54	DeKalb 65-95
Seeding rate	30K	32K	31.7K	31.7K	32K	32K	32.4K	32.4K	33K	31.7K
Row spacing (inches)	30	30	30	30	30	30	30	30	30	30
Harvest date	27-Sep	11-Sep	10-Sep	19-Sep	20-Sep	31-Aug	17-Sept	15-Sept	Sept 13	Sept 21
Irrigation (inches)										
May	0	0	0	0	0	0	0	0	0	0
June	1.58	0	1.58	2.24	2.88	4.71	1.03	4.8	1.7	.68
July	3.51	4.74	2.29	4.40	3.63	6.55	2.36	0.8	2.55	3.93
August	0.77	2.19	2.87	0.70	1.81	0.84	0	.8	2.55	2.42
September	0	0	0	0	0	0	0	0	0	0
Soybean										
Planting date	15-May	21-May	1-Jun	31-May	26-May	7-May	6-June	19-May	13-May	9-May
Hybrid/variety	Pioneer P94Y01	Asgrow 3833	Midland 3884NR2 + ILeVO	Stine 42RE02	Pioneer P39T67 + ILeVO	Midland 4373 RR2	Asgrow 36x6 + ILeVO	Pioneer P37A27+ ILeVO	AG40X70+ ILeVO	AG43XF2 + ILeVO
Seeding rate	144K	140K	144K	140K	140K	140K	140K	140K	140K	136K
Row spacing (inches)	30	30	30	30	15	15	15	15	30	30
Harvest date	8-Oct	9-Oct	13-Oct	17-Oct	17-Oct	17-Oct	17-Oct	9-Oct	Oct 7	Oct 18
Irrigation (inches)										
May	0	0	0	0	0	0	0	0	0	0
June	1.58	0	0.74	0.74	0	0	0	0	0	0
July	3.51	1.55	0.74	4.40	1.82	3.90	1.51	0	.85	.85
August	2.27	2.19	2.87	1.54	1.81	0.84	0	1.6	2.55	1.08
September	2.18	0	0	0	0	0	0	0	.85	.99

Table 2. Effects of tillage treatments on corn and soybean yields in 2012 at Kansas River Valley experiment fields

Tillage treatment	Corn yield	Soybean yield
	------------------------------ bu/a	------------------------------
No-tillage	196	59.9
Fall subsoil/spring field cultivate	202	55.5
Fall vertical tillage	198	57.9
Pr>F *	0.64	0.14

*The lower the Pr>F value, the greater probability that there is a significant difference between yields.

Table 3. Effects of tillage treatments on corn yields and plant stands in 2013–2022 at Kansas River Valley experiment fields

	Corn yield, bu/a										Average corn yield	Average stand, plants/a
Tillage treatment	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2013–2022**	**2014–2022**
No-tillage	221	243	205 b	183 b[*]	226	206	218	207	187 b	199 b	209 b	31,807
Fall subsoil/spring field cultivate	223	259	215 a	202 a	236	214	228	212	202 a	231 a	222 a	31,693
Fall vertical tillage	196	259	207 b	189 b	226	210	219	211	191 b	234 a	214 b	31,775
Fall subsoil after soybean/vertical tillage after corn	214	256	211 ab	195 a	231	209	227	216	198 a	235 a	220 a	31,499
Pr>F[#]	0.14	0.27	0.05	0.005	0.46	0.7	0.22	0.36	0.006	0.0002	0.001	0.70

[*] Values followed by the same letter are not significantly different at $P = 0.05$.

[#] The lower the Pr>F value, the greater probability that there is a significant difference between yields.

Table 4. Effects of tillage treatments on soybean yields in 2013–2022 at Kansas River Valley experiment fields

	Soybean yield, bu/a										Average soybean yield
Tillage treatment	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2013–2022**
No-tillage	62.4	52.8	69.7	80.2	67.4	69.3	78.1	73.1	80.3	67.0 b	69.0 b
Fall subsoil/spring field cultivate	64.3	55.2	73.1	76.0	72.8	71.2	79.2	72.5	85.8	72.8 a	71.3 a
Fall vertical tillage	64.4	55.5	72.8	78.6	68.1	75.0	80.5	76.0	84.4	72.8 a	71.6 a
Fall subsoil after soybean/vertical tillage after corn	66.3	52.8	70.9	75.8	70.1	70.2	80.1	74.0	82.9	66.8 b	70.3 ab
Pr>F[#]	0.52	0.40	0.23	0.12	0.098	0.51	0.87	0.54	0.32	0.002	0.01

[*] Values followed by the same letter are not significantly different at $P = 0.05$.

[#] The lower the Pr>F value, the greater probability that there is a significant difference between yields.

Effect of Early Planting on Soybean Yield: 2022 Growing Season

E. Adee, S. Dooley, and B. Pedriera

Summary

In an effort to increase soybean yield potential, early planting dates have been promoted as a management practice that can increase yield of soybeans. Early planting of soybeans can be a relative term, meaning late April/early May for some soybean producers in Kansas, but this definition of early planted soybeans is late March/early April. Theoretically, the earlier planting date could allow for more vegetative growth and interception of more light before blooming, increasing the yield potential. With the improvement of soybean seed treatments to protect seed when emergence is slowed due to cool and wet conditions, the early planting may be a viable option. The planting dates were late March, mid-late April, and May. At both irrigated locations, the highest yield was with the earlier planting date. At one location, the shorter season variety did not show a response to planting date.

Procedures

Early soybean planting studies were conducted at two Kansas State University Experiment Fields, Kansas River Valley (Topeka), and North Central (Scandia), and at the Southeast Research and Extension Center, Parson, KS, in 2022. The study location at Parsons received very little rainfall, resulting in extremely low yields, so no data were recorded from that location. The experiment at Topeka was irrigated, receiving 4.97 inches of water from July 12 to September 6. The experiment at Scandia was irrigated, receiving 8.55 inches from June 30 to September 14. Two varieties were planted at two seeding rates (100,000 and 150,000 seeds/a) at each of three planting dates in both studies. The varieties at Topeka were Golden Harvest GH3728X (Maturity Group 3.7) and GH3982X (MG 3.9), and at Scandia were Golden Harvest GH3442XF (MG 3.4) and GH4222XF (MG 4.4). The seed at both locations was treated with CruiserMaxx + Vibrance + Saltro. The planting dates at Topeka were April 4, April 21, and May 9, and at Scandia were April 6, April 27, and May 17. Soybeans were planted in four 30-inch row plots at 10 ft wide × 40 to 50 feet long. The experimental design utilized at Topeka and Scandia was a randomized complete block design with four replications. Yields were determined from the middle two rows of each plot to avoid influence from neighboring plots. Yields were corrected to 13% grain moisture. Weed control was managed to have no effect on yields.

Results

The first planting date at Topeka had emerged by April 25. In spite of taking three weeks to emerge there were no large gaps in the stand. The second planting date emerged 12-14 days after planting, and the third took 7 days. The first planting date emerged 99 growing degree days (GDD) before the second planting date and 338 GDD before the third date.

Canopy closure with the April 4 planting date was 0.5 and 2.4 days earlier than closure dates for the April 21 and May 9 planting dates at Topeka. Maturity dates of the three planting dates at Topeka were less than 2 days apart with all treatments. Foliar symptoms of sudden death syndrome (SDS) were visible at a very low level (<5%) at R6 on September 6, and there were no differences between treatments.

The highest yields were just over 80 bu/a with both varieties planted April 4 at 150,000 seeds/a at Topeka, and the lowest yield was 76 bu/a planted May 9 (Figure 1). There was no significant difference between yields of any of the variety/seeding rate/planting date combination yielding between the high and low yielding treatments.

At Scandia, there was a significant yield response to planting date (Figure 2). The fuller season variety yields ranged from 84 bu/a with the first planting date to 64 bu/a in the third. (Figure 2). The shorter season variety showed no response to planting date with an average yield of 72.8 bu/a. (Figure 2).

This is the second year that this study has been conducted at Topeka and Scandia. The first years' data were reported in 2022 Kansas Field Research Report (Adee and Dooley, 2022). While caution should be used in making conclusions from this limited data set, it was shown that there can be a very positive yield response to planting soybeans in late March/early April for certain variety/seeding rate combinations. For most variety/seeding rate treatments, there was no major yield loss due to early planting. The last planting date in these studies is often before most producers historically start planting soybeans in the respective locations. Previous work reported in the Kansas Field Research publications had planting dates from early May to late June at Topeka, showing a yield increase with the earlier planting dates if steps were taken to reduce SDS. Further research is needed to determine if these trends for yield response are consistent. An additional research objective could be to identify varieties that respond with increased yield due to the early planting date more consistently than other varieties.

Acknowledgments

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References

Adee, E. and Dooley, S. (2022) "Effect of Early Planting on Soybean Yield," *Kansas Agricultural Experiment Station Research Reports*: Vol. 8: Iss. 4. *https://doi.org/10.4148/2378-5977.8299*

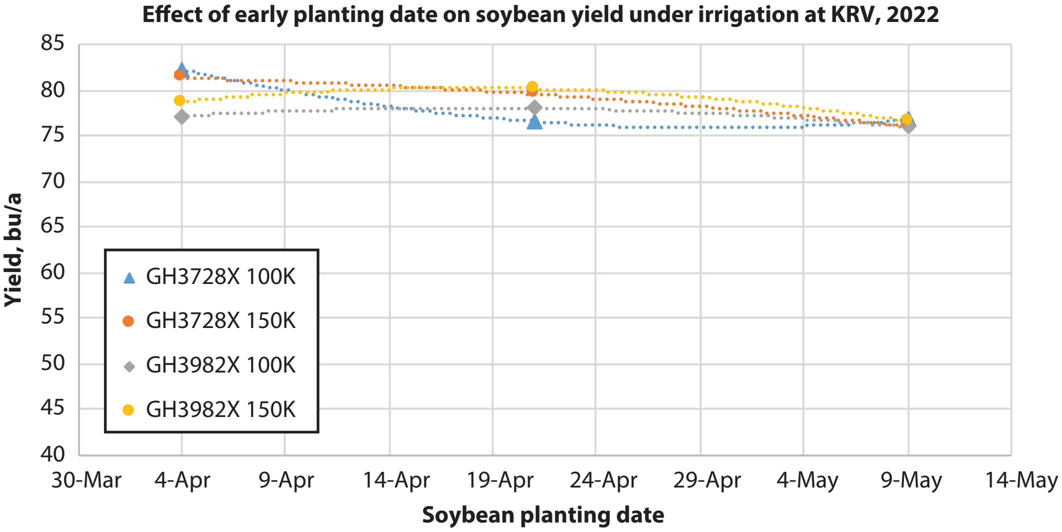


Figure 1. Effect of soybean planting date with soybean varieties of different maturity groups, planted at two seeding rates on yield at Kansas River Valley Experiment Field, Topeka, 2022.

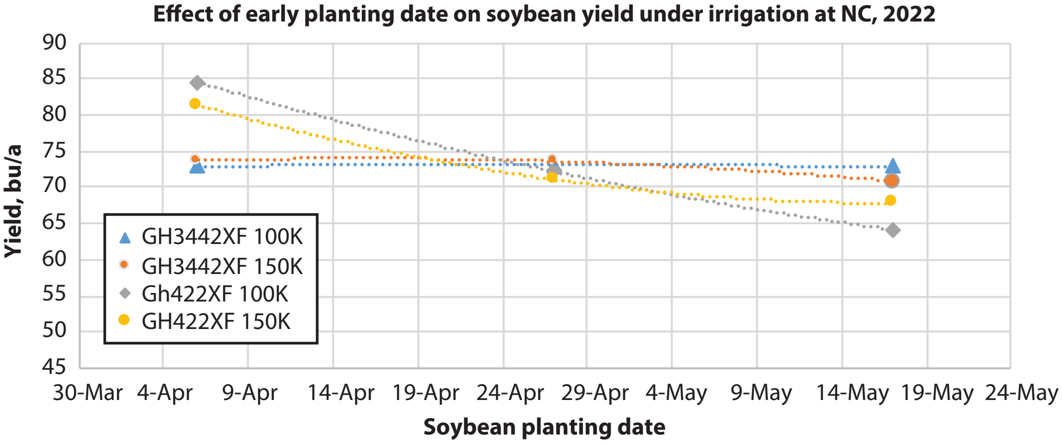


Figure 2. Effect of soybean planting date with soybean varieties of different maturity groups, planted at two seeding rates on yield at North Central Experiment Field, Scandia, 2022.

Effect of Corn Row Spacing on Herbicide Effectiveness for Weed Control in 2022

S.H. Lancaster and E. Adee

Summary

Cultural weed control practices such as narrow row spacing can be a key component of successful weed management. Experiments were conducted in the Kansas River Valley to evaluate interactions of herbicide programs and corn row spacings on weed control and grain yield. There were no differences in weed control at a site with low weed density. However, at a site with high Palmer amaranth density, Resicore applied to 15- and 30-inch rows and Bicep + Acuron applied to 15-inch rows resulted in the greatest weed control. Corn yield was similar across all treatments at both locations.

Introduction

Increased prevalence of herbicide resistant weed populations has led to a need for more complex mixtures of herbicides and multiple herbicide application timings throughout the year. Herbicide resistance has also led to a need for nonchemical means of weed management. Understanding how cultural or mechanical weed management practices and herbicides interact is important to maximize weed control.

Light interception can be an effective practice in reducing competition, especially through reduced weed seed germination. Narrower row spacing has been shown as an effective means to help control weeds in crops such as wheat and soybeans. However, little work has been done with corn row spacing to enhance weed control. Unlike wheat or soybeans, which have the option of being planted in rows as narrow as seven inches with a drill, corn is somewhat limited in row spacing by the harvest equipment currently available. Currently, harvest equipment for 15-inch rows is the narrowest available for corn. Additionally, seeding rates for wheat and soybeans are much more variable than for corn, as the plants can adjust to the seeding rate. The increased seeding rates for wheat or soybeans in narrower rows can promote earlier canopy development. Corn typically has a fairly narrow seeding rate range for specific environments due to the architecture of the plant and also the seed cost; therefore, significant increases in seeding rates for corn are not a viable option.

Procedures

Studies were conducted to determine if weed control with different herbicide programs in corn was improved when corn was planted in narrower rows. Two studies were established under dryland or irrigated crop production in Shawnee County, KS, in 2022. The experimental design was a randomized complete block with four replications. There was a two by six factorial arrangement of treatments with two row spacings (15 or 30 inch) and five herbicide programs (Table 1) plus a weedy control. Plots were 10 × 30 feet (7 × 15 inch rows, 4 × 30 inch rows). The dryland field at Wolf Farm, near Topeka, KS, was Eudora-Kimo complex soil, which had the soybean stubble vertical tilled prior to planting Pioneer 0955 corn at 28,000 seeds per acre. The irrigated field at the Kansas River Valley Experiment Field-Rossville was Eudora silt loam. Soybean stubble was subsoiled in the fall and vertical tilled prior to planting Pioneer 1289 corn at 31,700 seeds per acre. Both studies were planted with a Kinze 3000 planter and the preemergence herbicides were applied on April 26. Both fields received just over 20 inches of rain from April through August, and the irrigated field received an additional 8 inches of water from the middle of June through the middle of August.

Herbicides were applied using a CO_2-pressurized backpack sprayer and a 5-foot hand boom equipped with XR8002 nozzles calibrated to deliver 15 gallons per acre. A postemergence application of Sinate was made at Rossville to manage escaped Palmer amaranth. Weed control was visually estimated throughout the summer until September 12. At Wolf Farm, henbit was the dominant weed species early in the growing season; however a mixture of species that included marestail, dandelion, prickly sida, hophornbeam copperleaf, and green foxtail was present at harvest. Palmer amaranth was the dominant species present at Rossville throughout the growing season. Yield data were collected from four of the middle rows in the 15-inch row spacing and the two middle rows of the 30-inch row spacing with a JD 3300 plot combine equipped with a HarvestMaster Classic Grain Gauge on September 21 and 27 (dryland and irrigated, respectively). Yields were calculated to bushels per acre at 15.5% grain moisture.

Five weeks after planting and herbicide application, Palmer amaranth control at Rossville ranged from 2 to 75 percent (Figure 1, top). The greatest weed control was observed in 15-in. rows treated with Resicore plus Aatrex, and the lowest weed control was observed in 30-in. rows treated with Harness Xtra. In treatments that contained 6 fl oz of Callisto, Palmer amaranth control was greater in 30-in. rows compared to 15-in. rows. However, weed control was greater in 15-in. rows when Acuron or Resicore were applied. There were no differences in henbit control at Wolf Farm 5 weeks after planting, with all treatments resulting in 99% control (Figure 2, bottom).

At harvest, weed control at Rossville ranged from 33 to 76% (Figure 2), while there were fewer differences among treatments compared to early-season ratings. Only the Acuron plus Bicep applied to 15-in. rows resulted in weed control that was greater than the non-treated check. At Wolf Farm, weed control ranged from 56 to 95%; however, there were no statistical differences due to variability among weed populations in the field.

Corn yield was similar across all treatments at both locations (Figure 3). Yields ranged from 172 to 216 bu/a at Rossville and 167 to 193 bu/a at Wolf Farm. Greater maximum yield at Rossville was likely due to the use of irrigation at that site.

Weed control data reflect differences in weed populations among the two locations. The dense Palmer amaranth population at Rossville required additional management and weed control was fair to poor for most treatments. However, weed density was much less at Wolf Farm and weed control ranged from fair to excellent. Corn yields were not affected by any treatment and were similar to the nontreated check in both 15- and 30-inch rows. The main effect of row spacing did not affect either weed control or corn yield at either location.

Acknowledgments

This research was funded by the Kansas Agricultural Experiment Station project Developing Integrated Weed Management (IWM) Strategies for Kansas Cropping Systems (KS-00-0067-HA).

Table 1. Herbicides and rates applied to corn planted in 15- and 30-inch rows at Rossville and Wolf Farm near Topeka, KS, on April 26, 2022

Treatment	Abbreviation	Herbicide	Rate/acre
1	Bic + Cal	Bicep II Magnum +	2.1 qt
		Callisto	6 fl oz
2	Deg + Cal	Degree Xtra +	3 qt
		Aatrex +	0.5 qt
		Callisto	6 fl oz
3	Har	Harness Xtra +	1.9 qt
		Aatrex	0.7 qt
4	Acu + Bic	Acuron	1.5 pt
		Bicep II Magnum +	1 pt
5	Res	Resicore +	1.5 pt
		Aatrex	1 qt

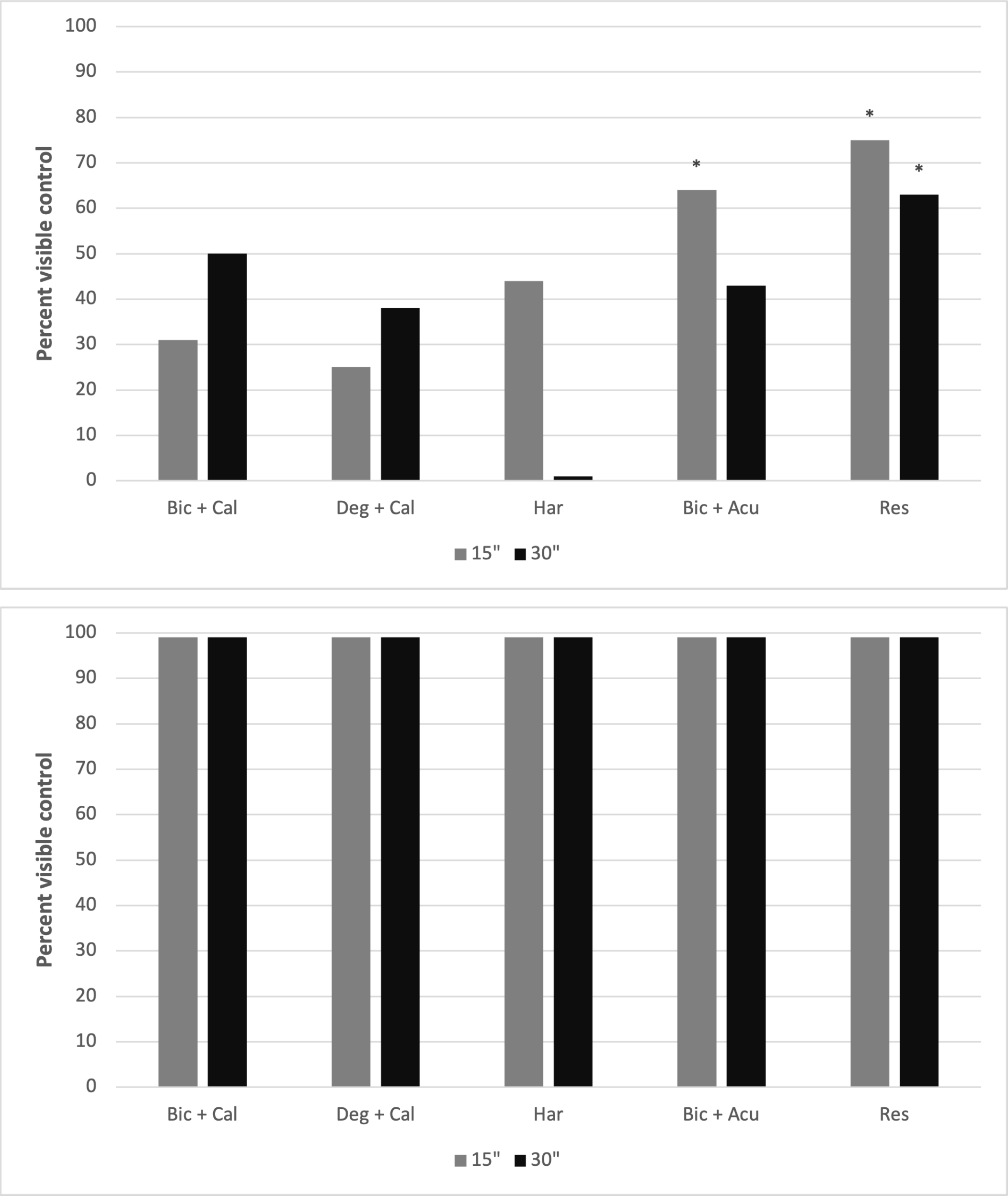


Figure 1. Weed control at Rossville (top) and Wolf Farm (bottom) corn fields five weeks after herbicide application (WAT). The primary weed species present was Palmer amaranth at Rossville and henbit at Wolf Farm. Asterisk indicates control different from nontreated check according to Tukey's HSD ($\alpha = 0.05$). See Table 1 for the list of treatment abbreviations.

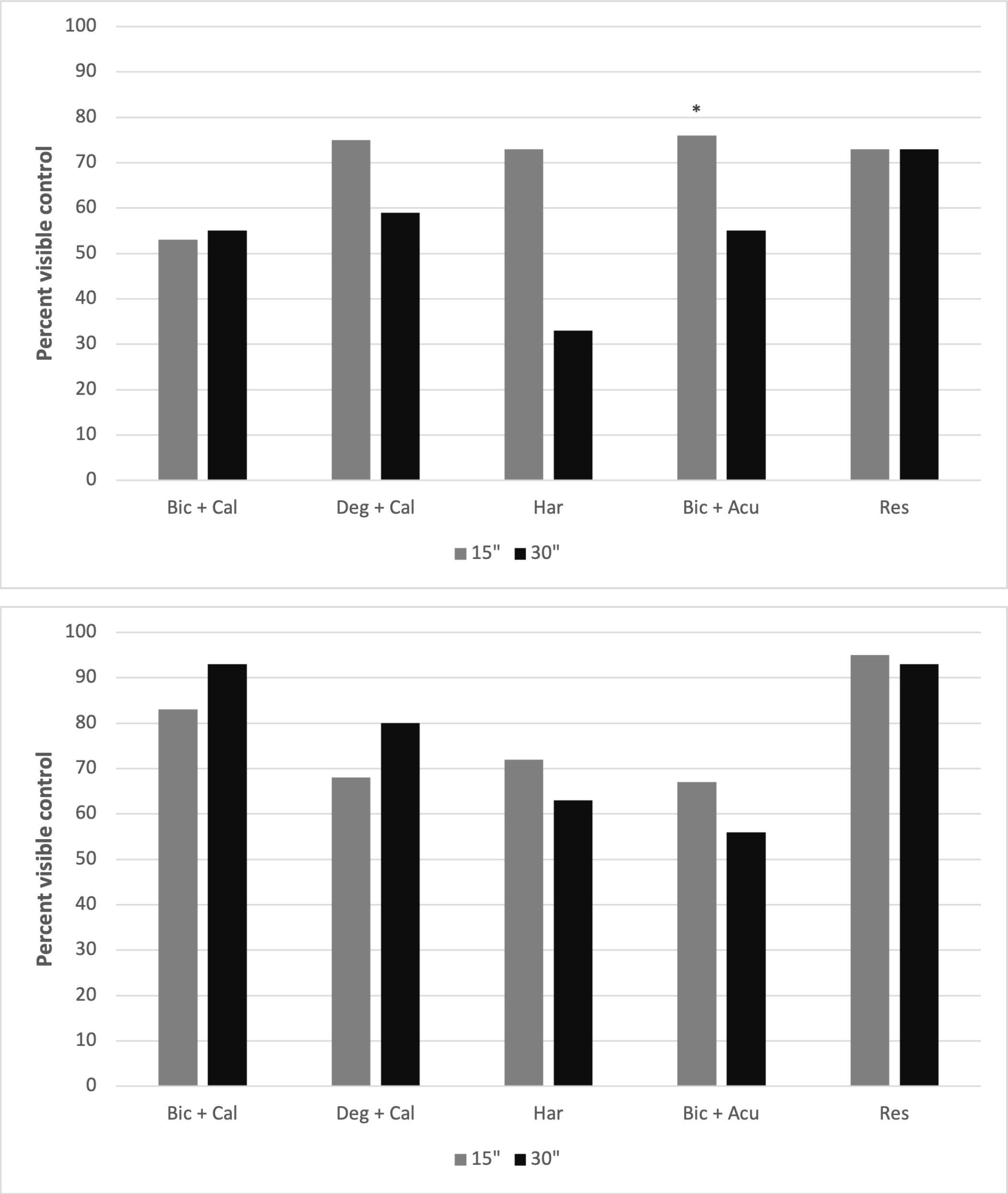
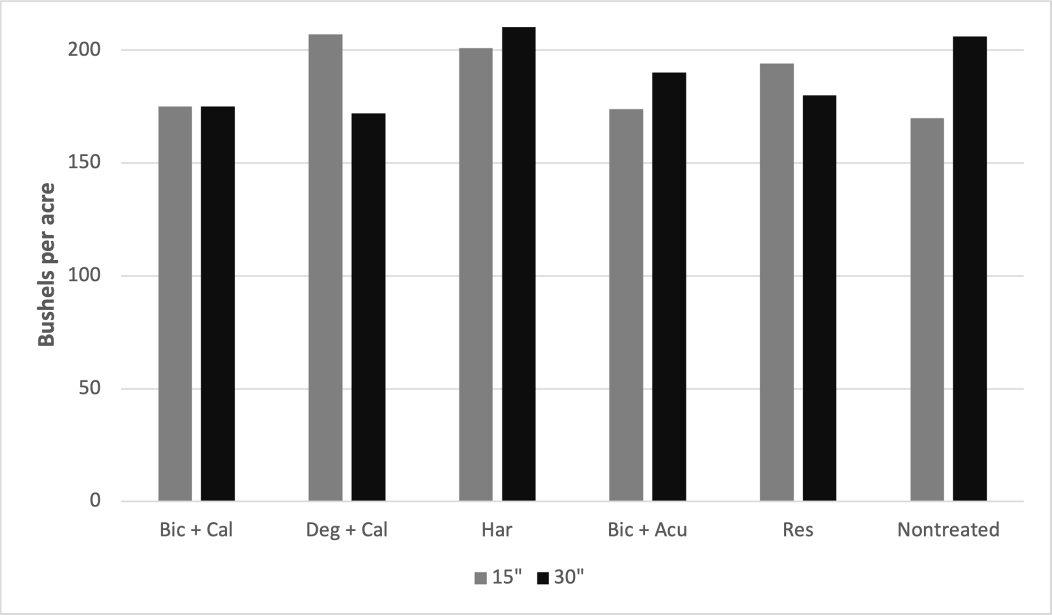


Figure 2. Weed control at Rossville (top) and Wolf Farm (bottom) corn fields seventeen weeks after herbicide application (WAT). The primary weed species present was Palmer amaranth at Rossville and a mixture of species was present at Wolf Farm. Asterisk indicates control different from nontreated check according to Tukey's HSD ($\alpha = 0.05$). See Table 1 for the list of treatment abbreviations.



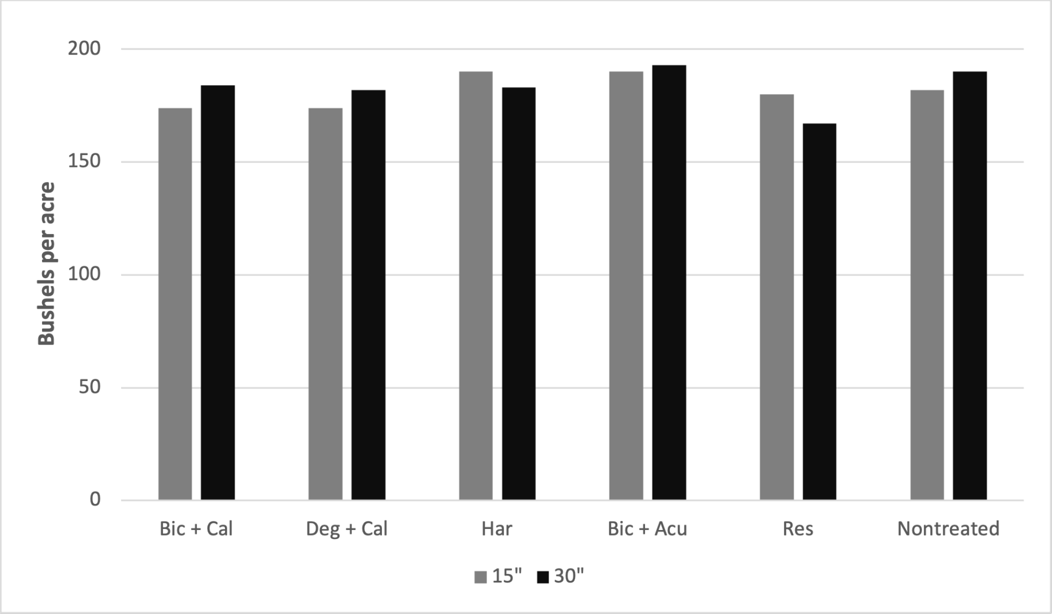


Figure 3. Corn grain yield (adjusted to 15.5% moisture) at Rossville (top) and Wolf Farm (bottom). No statistical differences were observed among treatments at either location. See Table 1 for the list of treatment abbreviations.

ImiFlex Evaluation at Two Kansas Locations in Igrowth Grain Sorghum

P.W. Geier, R.S. Currie, S.H. Lancaster, and C.M. Weber

Summary

Herbicide-tolerant grain sorghums, such as Igrowth (imidazolinone-resistant) hybrids were recently commercialized in Kansas. Even though the active ingredient of the herbicide associated with these systems, imazamox, is used in other crops, data are needed to define best practices for use in grain sorghum. The objective of these studies was to evaluate ImiFlex (imazamox) herbicide in Igrowth grain sorghum at two Kansas locations in 2022. ImiFlex applied postemergence provided 93% volunteer corn control, and 90 to 95% johnsongrass control regardless of application timing at Garden City. At Manhattan, ImiFlex controlled Palmer amaranth 90 to 99%. Early season grain sorghum injury was 13% or less, and generally did not persist. Grain yields from ImiFlex-treated sorghum were significantly greater than yields from the nontreated controls and from treatments that did not contain ImiFlex.

Introduction

Historically, grain sorghum producers have relied on preemergence herbicides to control grass weeds in their fields because few herbicides were registered for postemergence grass control in grain sorghum and their efficacy was limited. Recent introductions of herbicide-resistant hybrids have expanded the postemergence herbicide options for grain sorghum producers. These studies focused on ImiFlex efficacy and crop response in Igrowth grain sorghum.

Procedures

Two experiments in Kansas, at Garden City and Manhattan, investigated ImiFlex herbicide for use in Igrowth grain sorghum. All herbicides were applied using either a backpack or tractor-mounted, compressed CO_2 sprayer delivering 15 to 19.4 gpa. Application information is given in Tables 1 and 2. Treatments at each location were arranged as completely randomized designs with four replications. Weed control ratings at Manhattan were taken at 18 and 42 days after the postemergence treatments (DA-B), sorghum injury was determined at 18 and 56 DA-B, and sorghum heights were taken at 28 DA-B. Weed control at Garden City was determined at 11 and 52 DA-B, and sorghum injury determined at 1 and 11 DA-B. Sorghum maturity (days to 50% pollen shed) and grain yields were also determined at Garden City.

Results

At Garden City, ImiFlex applied either preemergence (PRE) or postemergence (POST) controlled volunteer corn 65 to 75% 11 DA-B (Table 3) and volunteer corn greater than 90% at 52 DA-B. Johnsongrass control at Garden City with any ImiFlex treatment was 90% or more regardless of rating date, and did not differ between treatments. Palmer amaranth control was 98 to 100% at Garden City (data not shown) and 90 to 99% at Manhattan, regardless of treatment (Table 4). Motif and Coyote (mesotrione)-containing treatments caused minor sorghum chlorosis at 1 DA-B at

Garden City, whereas Clarity (dicamba)-containing treatments resulted in 6 to 13% sorghum epinasty at 11 DA-B (Table 5). However, sorghum recovered completely by 43 DA-B. Sorghum receiving ImiFlex plus Moccasin II Plus (*S*-metolachlor) PRE, followed by atrazine POST or Coyote (*S*-metolachlor/mesotrione) PRE, followed by ImiFlex and atrazine POST matured sooner than sorghum in the nontreated control, or grain sorghum treated with Coyote PRE followed by Clarity and atrazine POST. Yields from ImiFlex-treated grain sorghum were 34 to 46 bu/a greater than yields from the nontreated controls. Sorghum receiving other herbicides yielded comparably to the check. All ImiFlex treatments caused 5 to 13% sorghum injury 18 DA-B at Manhattan (Table 6); however, injury was less than 5% by 56 DA-B. Likewise, sorghum heights at Manhattan did not differ between treatments at 28 DA-B.

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. Persons using such products assume responsibility for their use in accordance with current label directions of the manufacturer.

Table 1. Application and plant information for the ImiFlex grain sorghum trial at Garden City, KS

Application timing	Preemergence	Postemergence
Application date	June 11, 2022	June 27, 2022
Air temperature, °F	80	70
Relative humidity, %	80	33
Soil temperature, °F	71	68
Wind speed, mph	3 to 5	5 to 10
Wind direction	South	South-southwest
Soil moisture	Good	Good
Grain sorghum		
Leaves, no.	0	4 to 5
Volunteer corn		
Height, inches	---	3 to 6
Johnsongrass		
Height, inches	---	2 to 5
Palmer amaranth		
Height, inches	---	1 to 3

Table 2. Application and plant information for ImiFlex grain sorghum trial in Manhattan, KS

Application timing	Preemergence	Postemergence
Application date	June 17, 2022	July 8, 2022
Air Temperature, °F	100	81
Relative humidity, %	51	78
Soil temperature, °F	90	83
Wind speed, mph	1 to 5	1 to 4
Wind direction	East-northeast	North-northwest
Soil moisture	Good	Fair
Grain sorghum		
Leaves, no.	---	6 to 7
Palmer amaranth		
Height, inches	---	1 to 3

Table 3. Weed control at Garden City, KS, in the Igrowth grain sorghum study

			Volunteer corn		Johnsongrass	
Treatment	**Rate**	**Timing[1]**	**11 DA-B[2]**	**52 DA-B**	**11 DA-B**	**52 DA-B**
	oz/a		% Visual			
ImiFlex	9.0	PRE	73	83	100	95
Moccasin II Plus	21	PRE				
Atrazine	32	POST				
Crop oil concentrate	1.0%	POST				
ImiFlex	9.0	PRE	68	83	100	93
Motif	6.0	PRE				
Atrazine	32	POST				
Crop oil concentrate	1.0%	POST				
ImiFlex	9.0	PRE	65	83	95	93
Moccasin II Plus	21	PRE				
Motif	6.0	POST				
Atrazine	1.0	POST				
Crop oil concentrate	1.0%	POST				
Moccasin II Plus	21	PRE	75	93	95	93
Motif	6.0	PRE				
ImiFlex	6.0	POST				
Atrazine	1.0	POST				
Crop oil concentrate	1.0%	POST				
Urea-ammonium nitrate	2.5%	POST				
Moccasin II Plus	21	PRE	75	93	100	90
Motif	6.0	PRE				
ImiFlex	6.0	POST				
Clarity	6.0	POST				
Atrazine	32	POST				
Nonionic surfactant	0.25%	POST				
Urea-ammonium nitrate	2.5%	POST				
Moccasin II Plus	21	PRE	0	0	0	0
Atrazine	32	PRE				
Clarity	6.0	POST				
Nonionic surfactant	0.25%	POST				
Urea-ammonium nitrate	2.5%	POST				
Coyote	64	PRE	0	0	0	0
Clarity	6.0	POST				
Atrazine	32	POST				
Nonionic surfactant	0.25%	POST				
Urea-ammonium nitrate	2.5%	POST				
LSD (0.05)			10	11	5	10

[1] PRE = preemergence. POST = postemergence.

[2] DA-B = days after the postemergence treatments.

Table 4. Palmer amaranth control with ImiFlex in grain sorghum, Manhattan, KS, 2022

Treatment	Rate	Timing[1]	18 DA-B[2]	42 DA-B
	oz/a		------------ % Visual ------------	
Nontreated check	---	---	---	---
Moccasin II Plus	1.33 pt	PRE	90	96
Atrazine	32	PRE		
ImiFlex	6.0	POST		
Nonionic surfactant	0.5%	POST		
Urea-ammonium nitrate	1.0%	POST		
Moccasin II Plus	1.33 pt	PRE	96	97
Atrazine	32	PRE		
Huskie	16	POST		
Nonionic surfactant	0.5%	POST		
Urea-ammonium nitrate	1.0%	POST		
Moccasin II Plus	1.33 pt	PRE	94	97
Atrazine	32	PRE		
Huskie	16	POST		
ImiFlex	6.0	POST		
Nonionic surfactant	0.5%	POST		
Urea-ammonium nitrate	1.0%	POST		
Moccasin II Plus	1.33 pt	PRE	97	99
Atrazine	32	PRE		
Huskie	16	POST		
ImiFlex	6.0	POST		
Atrazine	16	POST		
Nonionic surfactant	0.5%	POST		
Urea-ammonium nitrate	1.0%	POST		
LSD (0.05)			NS	NS

[1] PRE = preemergence. POST = postemergence.

[2] DA-B = days after the postemergence treatments.

Table 5. Grain sorghum response to ImiFlex at Garden City, KS, 2022

			Chlorosis	Epinasty		
Treatment	**Rate**	**Timing[1]**	**1 DA-B[2]**	**11 DA-B**	**Maturity**	**Yield**
	oz/a		--------- % Visual ---------		DAP[3]	bu/a
Nontreated check	---	---	0	0	64	39.5
ImiFlex	9.0	PRE	3	1	63	85.3
Moccasin II Plus	21	PRE				
Atrazine	32	POST				
Crop oil concentrate	1.0%	POST				
ImiFlex	9.0	PRE	9	0	63	80.6
Motif	6.0	PRE				
Atrazine	32	POST				
Crop oil concentrate	1.0%	POST				
ImiFlex	9.0	PRE	5	0	62	76.9
Moccasin II Plus	21	PRE				
Motif	6.0	POST				
Atrazine	32	POST				
Crop oil concentrate	1.0%	POST				
Moccasin II Plus	21	PRE	4	0	62	73.8
Motif	6.0	PRE				
ImiFlex	6.0	POST				
Atrazine	32	POST				
Crop oil concentrate	1.0%	POST				
Urea-ammonium nitrate	2.5%	POST				
Moccasin II Plus	21	PRE	6	13	63	80.9
Motif	6.0	PRE				
ImiFlex	6.0	POST				
Clarity	6.0	POST				
Atrazine	32	POST				
Nonionic surfactant	0.25%	POST				
Urea-ammonium nitrate	2.5%	POST				
Moccasin II Plus	21	PRE	0	10	63	48.4
Atrazine	32	PRE				
Clarity	6.0	POST				
Nonionic surfactant	0.25%	POST				
Urea-ammonium nitrate	2.5%	POST				
Coyote	64	PRE	8	6	64	38.9
Clarity	6.0	POST				
Atrazine	32	POST				
Nonionic surfactant	0.25%	POST				
Urea-ammonium nitrate	2.5%	POST				
LSD (0.05)			5	3	1.5	13.8

[1] PRE = preemergence. POST = postemergence.

[2] DA-B = days after the postemergence treatments.

[3] DAP = days after planting.

Table 6. Grain sorghum response to ImiFlex at Manhattan KS, 2022

Treatment	Rate	Timing[1]	Injury 18 DA-B[2]	 56 DA-B	Height 28 DA-B
	oz/a		--------- % Visual ---------		inches
Nontreated check	---	---	0	0	29
Moccasin II Plus	1.33 pt	PRE	10	1	31
Atrazine	32	PRE			
ImiFlex	6.0	POST			
Nonionic surfactant	0.5%	POST			
Urea-ammonium nitrate	1.0%	POST			
Moccasin II Plus	1.33 pt	PRE	10	3	32
Atrazine	32	PRE			
Huskie	16	POST			
Nonionic surfactant	0.5%	POST			
Urea-ammonium nitrate	1.0%	POST			
Moccasin II Plus	1.33 pt	PRE	5	4	32
Atrazine	32	PRE			
Huskie	16	POST			
ImiFlex	6.0	POST			
Nonionic surfactant	0.5%	POST			
Urea-ammonium nitrate	1.0%	POST			
Moccasin II Plus	1.33 pt	PRE	13	4	31
Atrazine	32	PRE			
Huskie	16	POST			
ImiFlex	6.0	POST			
Atrazine	16	POST			
Nonionic surfactant	0.5%	POST			
Urea-ammonium nitrate	1.0%	POST			
LSD (0.05)			NS	NS	NS

[1] PRE = preemergence. POST = postemergence.

[2] DA-B = days after the postemergence treatments.

Weed Control With ImiFlex in Igrowth Forage Sorghum

R.S. Currie, P.W. Geier, S.H. Lancaster, and C.M. Weber

Summary

Igrowth (imidazolinone-resistant) forage sorghum hybrids were recently commercialized in Kansas. Even though the active ingredient of the herbicide associated with these systems, imazamox, is used in other crops, data are needed to define best practices for use in forage sorghum. The objective of experiments in Manhattan and Garden City, KS, was to investigate the use of ImiFlex (imazamox) herbicide in Igrowth (imidazolinone-tolerant) forage sorghum. At Garden City, volunteer corn and johnsongrass control 29 days after treatment was 90% or greater in all treatments that included ImiFlex. Similarly, Palmer amaranth control 28 days after treatment was 91% or greater at Manhattan. Forage sorghum injury (5%) was noted 18 days after treatment in Manhattan, however, by 28 days after treatment plants had recovered. These results suggest that Igrowth forage sorghum may help Kansas farmers manage troublesome weeds; however, proper stewardship of the technology will be necessary.

Introduction

Weed control in sorghum has largely been dependent on preemergence herbicides, particularly for grass species. Few postemergence options for grasses were available until the recent introduction of herbicide-resistant sorghum hybrids. Igrowth forage sorghum allows preemergence or postemergence application of ImiFlex herbicide for broadleaf and grass weed control. Two experiments in Kansas examined ImiFlex efficacy and crop response in Igrowth forage sorghum in 2022.

Procedures

Experiments were conducted at Manhattan and Garden City, KS, to examine ImiFlex herbicide in Igrowth forage sorghum. Herbicides were applied either at 15 or 19.4 gpa using either a backpack or tractor-mounted compressed CO_2 sprayer. Application information for each location is given in Tables 1 and 2. Treatments at each location were arranged in randomized complete blocks and replicated four times. Forage sorghum response to ImiFlex at Manhattan was evaluated at 18 and 28 days after the postemergence (DA-B), and weed control was taken 28 and 56 DA-B. Forage sorghum response and weed control at Garden City was determined at 2 and 29 DA-B.

Results

Preemergence applications of ImiFlex provided less than 50% volunteer corn control early in the season at Garden City (Table 3). However, volunteer corn control 29 DA-B was 90% or more with all ImiFlex treatments, except when ImiFlex plus Moccasin II Plus (*S*-metolachlor) PRE was followed by atrazine POST. Johnsongrass control at Garden City 2 DA-B was better in treatments that included ImiFlex compared to those that did not. By 29 DA-B, ImiFlex applied PRE or POST controlled johnsongrass 90% or more. All herbicides controlled Palmer amaranth and crabgrass 90% or more throughout the season at Garden City (data not shown). Palmer amaranth control at

Manhattan was 87% or more regardless of treatment (Table 4). Postemergence treatments containing Clarity (dicamba) caused 18% sorghum injury early on, but no visible injury was detected at 29 DA-B (data not shown). At 18 DA-B, minor injury occurred when ImiFlex was applied with Huskie (pyrasulfotole/bromoxynil) and atrazine at Manhattan (Table 5). However, no injury was visible by 28 DA-B.

Table 1. Application, environmental, and plant information for the Igrowth forage sorghum trial

Application timing	Preemergence	Postemergence
Application date	June 10, 2022	June 27, 2022
Air temperature, °F	76	70
Relative humidity, %	86	35
Soil temperature, °F	67	69
Wind speed, mph	3 to 7	7 to 11
Wind direction	North	South-southwest
Soil moisture	Good	Good
Forage sorghum		
Leaves, no.	0	4 to 5
Volunteer corn		
Height, inches	---	6 to 8
Johnsongrass		
Height, inches	---	2 to 4
Palmer amaranth		
Height, inches	---	1 to 2
Crabgrass		
Height, inches	---	0.5 to 1

Table 2. Application and plant information for ImiFlex forage sorghum trial in Manhattan, KS

Application timing	Preemergence	Postemergence
Application date	June 17, 2022	July 8, 2022
Air temperature, °F	100	81
Relative humidity, %	51	78
Soil temperature, °F	90	83
Wind speed, mph	1 to 5	1 to 4
Wind direction	East-northeast	North-northwest
Soil moisture	Good	Fair
Forage sorghum		
Leaves, no.	---	6 to 7
Palmer amaranth		
Height, inches	---	1 to 3

Table 3. Weed control in the Igrowth forage sorghum study at Garden City, KS

			Volunteer corn		Johnsongrass	
Treatment[1]	**Rate**	**Timing**[2]	**2 DA-B**[3]	**29 DA-B**	**2 DA-B**	**29 DA-B**
	oz/a		% Visible control			
Moccasin II Plus	21	PRE	0	0	60	0
Atrazine	38	POST				
COC	1.0%	POST				
Moccasin II Plus	21	PRE	38	85	73	93
ImiFlex	9.0	PRE				
Atrazine	38	POST				
COC	1.0%	POST				
Moccasin II Plus	21	PRE	0	96	65	98
ImiFlex	6.0	POST				
Atrazine	38	POST				
COC	1.0%	POST				
UAN	2.5%	POST				
Moccasin II Plus	21	PRE	45	90	80	93
Atrazine	32	PRE				
ImiFlex	9.0	PRE				
Atrazine	32	POST				
COC	1.0%	POST				
UAN	2.5%	POST				
Moccasin II Plus	21	PRE	0	94	65	94
Atrazine	32	PRE				
ImiFlex	6.0	POST				
Atrazine	32	POST				
COC	1.0%	POST				
UAN	2.5%	POST				
Moccasin II Plus	21	PRE	33	90	78	90
ImiFlex	9.0	PRE				
Clarity	6.0	POST				
Atrazine	38	POST				
NIS	0.25%	POST				
UAN	2.5%	POST				
Moccasin II Plus	21	PRE	0	95	60	98
Atrazine	38	PRE				
ImiFlex	6.0	POST				
Clarity	6.0	POST				
NIS	0.25%	POST				
UAN	2.5%	POST				
LSD (0.05)			8	8	10	8

[1] COC = crop oil concentrate. UAN = 28% urea-ammonium nitrate. NIS = nonionic surfactant.

[2] PRE = preemergence. POST = postemergence.

[3] DA-B = days after the postemergence treatment.

Table 4. Palmer amaranth control with ImiFlex in forage sorghum, Manhattan, KS, 2022

Treatment	Rate	Timing[1]	28 DA-B[2]	56 DA-B
	oz/a		-------------- % Visual --------------	
Nontreated check	---	---	---	---
Moccasin II Plus	1.33 pt	PRE	95	87
Atrazine	32	PRE		
ImiFlex	6.0	POST		
Nonionic surfactant	0.5%	POST		
Urea-ammonium nitrate	1.0%	POST		
Moccasin II Plus	1.33 pt	PRE	97	87
Atrazine	32	PRE		
Huskie	16	POST		
Nonionic surfactant	0.5%	POST		
Urea-ammonium nitrate	1.0%	POST		
Moccasin II Plus	1.33 pt	PRE	91	89
Atrazine	32	PRE		
Huskie	16	POST		
ImiFlex	6.0	POST		
Nonionic surfactant	0.5%	POST		
Urea-ammonium nitrate	1.0%	POST		
Moccasin II Plus	1.33 pt	PRE	98	98
Atrazine	32	PRE		
Huskie	16	POST		
ImiFlex	6.0	POST		
Atrazine	16	POST		
Nonionic surfactant	0.5%	POST		
Urea-ammonium nitrate	1.0%	POST		
LSD (0.05)			NS	NS

[1] PRE = preemergence. POST = postemergence.

[2] DA-B = days after the postemergence treatments.

Table 5. Forage sorghum response to ImiFlex at Manhattan, KS, 2022

Treatment	Rate	Timing[1]	Injury		Height
			18 DA-B[2]	28 DA-B	28 DA-B
	oz/a		---------- % Visual ----------		Inches
Nontreated check	---	---	0	0	49
Moccasin II Plus	1.33 pt	PRE	0	1	46
Atrazine	32	PRE			
ImiFlex	6.0	POST			
Nonionic surfactant	0.5%	POST			
Urea-ammonium nitrate	1.0%	POST			
Moccasin II Plus	1.33 pt	PRE	1	0	45
Atrazine	32	PRE			
Huskie	16	POST			
Nonionic surfactant	0.5%	POST			
Urea-ammonium nitrate	1.0%	POST			
Moccasin II Plus	1.33 pt	PRE	0	1	48
Atrazine	32	PRE			
Huskie	16	POST			
ImiFlex	6.0	POST			
Nonionic surfactant	0.5%	POST			
Urea-ammonium nitrate	1.0%	POST			
Moccasin II Plus	1.33 pt	PRE	5	1	45
Atrazine	32	PRE			
Huskie	16	POST			
ImiFlex	6.0	POST			
Atrazine	16	POST			
Nonionic surfactant	0.5%	POST			
Urea-ammonium nitrate	1.0%	POST			
LSD (0.05)			4	NS	NS

[1] PRE = preemergence. POST = postemergence.

[2] DA-B = days after the postemergence treatments.

Previous Crop Impacts Winter Wheat Sowing Dates, Available Water at Sowing, and Grain Yield

L.M. Simão, A. Patrignani, S. Cominelli, and R.P. Lollato

Summary

Cropping systems choices can directly affect the sowing date for winter wheat, which is among the most important variables that determine attainable yields in the U.S. Central Great Plains. Our objective was to investigate the effect of the previous crop on winter wheat grain yield through the modulation of sowing date and its impact on plant available water at sowing, and temperatures during the critical period for yield determination. A no-tillage rainfed field experiment was established in 2019 at Ashland Bottoms, KS. Winter wheat was sown either after summer fallow, full-season soybean, double-cropped soybean, or corn—thus, resulting in a range in sowing dates of 270–326 days of the year (September 27 to November 22). The optimum sowing date for the site based on grain yield was estimated at day of year 296 ± 5 (October 18 to 28). Winter wheat after summer fallow and after a full-season soybean crop resulted in the greatest yields, whether sown at the optimum date or slightly later than optimum. Winter wheat yield was positively related to plant available water at sowing. Later sowing dates were most likely to reduce plant available water at sowing, and could delay wheat's development resulting in higher temperatures occurring during the critical period for yield determination (i.e., the days surrounding anthesis). Later sowing also shortened grain filling duration due to an overall later cycle and elevated temperatures. Thus, adjusting winter wheat sowing dates is the first step that determines the crop's yield potential through improved plant available water at sowing, and reduced temperatures during the critical period for yield determination. When following a summer crop, winter wheat should be sown as soon as the previous crop is harvested to try to mitigate these negative effects of late sowing.

Introduction

Winter wheat yields in the U.S. Great Plains have been stagnant for decades (Patrignani et al., 2014) at levels well below their potential (Lollato et al., 2017). As there is a large gap between potential and actual yields, improved management practices could help increase wheat yield and production in this region (e.g., Jaenisch et al., 2019, 2022; de Oliveira Silva et al., 2021, 2022; Lollato et al., 2019a). Crop rotation combined with no-tillage systems can boost crop grain yield and improve yield stability while broadening crop yield adaptability to varying yielding conditions (Simão et al., 2022). However, crop rotation can impact the winter wheat sowing date, which is crucial in determining attainable yields in the U.S. Central Great Plains (Jaenisch et al., 2021; Munaro et al., 2020). The optimum winter wheat sowing date is site-specific and impacts the crop's winter hardiness and water and temperature regimes.

The length of the fallow period preceding the wheat crop can impact the amount of water available at sowing (Lollato et al., 2016). Additionally, early sowing dates may result in excessive biomass production and increased soil water usage. While high fall biomass production is desired for dual-purpose winter wheat (i.e., grown for forage and grain; Lollato et al., 2019b), grain-only winter wheat yield may be compromised by lower soil water later in the spring if wheat is sown too early in the fall (Lollato et al., 2021). Conversely, a late sowing date can delay winter wheat's reproductive stages and reduce grain yield due to decreased grain numbers and shorter grain filling duration during high temperatures (Lollato et al., 2020). Our objective was to investigate the effect of the previous crop on sowing date for winter wheat and its impact on plant available water at sowing, and temperatures during the critical period for yield determination.

Procedures

Site Description and Agronomic Management

A rainfed field experiment was established in the fall of 2019 near Ashland Bottoms, KS, (10 miles south of Manhattan) in a Roxbury series soil (fine-silty, mixed, mesic Cumulic Haplustoll). Initial soil fertility levels based at 0- to 6-in. depth showed a soil pH = 6.0; and extractable phosphorus and potassium of 14.3 and 317 ppm, respectively, using the Mehlich-3 method. In this report, we combined data from the previous three growing seasons. Diammonium phosphate (DAP 18-46-0) starter fertilizer was applied to all plots at 50 lb/a. Winter wheat variety Zenda was sown at 7.5-in. row spacing by using a Great Plains 506 no-till drill on 2000 ft^2 plots (40 ft wide × 50 ft long). Seeding rate was adjusted according to sowing dates. When winter wheat was sowed early and late, seeding rate was adjusted to 120 lb/a; otherwise, seeding rate was 90 lb/a. Wheat was harvested on June 6 using a Massey Ferguson XP8 small-plot, self-propelled combine on the center of each plot (300 ft^2 area). Pests, weeds, and diseases were monitored regularly, so they were not limiting factors in this experiment.

Treatments and Analysis

Winter wheat was sown following four cropping systems, which resulted in a range of 270–326 day of the year (DOY; equivalent to September 27 to November 22) at sowing (Table 1). Relative grain yield was calculated as actual yield divided by annual maximum yield. Critical period was determined as beginning at 572°F before and lasting until 212°F after anthesis (Couëdel et al., 2021; Sadras et al., 2022). Mean temperature during this period was estimated using data from a nearby Kansas Mesonet station. Soil water was measured using a Diviner 2000 capacitance probe at 39.40-in. depth with 4-in. intervals. Plant available water at sowing (PAW) was estimated across all depths by subtracting the soil wilting point. The PAW was only evaluated for optimum and late sowing dates due to lack of sensors at early sowing dates plots.

Results

Winter wheat relative grain yield showed a quadratic relationship with day of the year at sowing (Figure 1) where yields increased as day of the year at sowing increased until reaching a peak, considered the optimum sowing date (OSD), after which date the winter wheat yields decreased. The OSD was defined as 296 ± 5 (October 18 to 28), and any sowing date earlier or later than that range can negatively affect winter wheat grain yield.

Winter wheat relative yield showed a positive linear relationship with PAW, meaning that as PAW at sowing increased, winter wheat grain yields also increased (Figure 2A).

Overall, the optimum sowing date resulted in greater PAW than late sowing (Figure 2B). Temperature at the critical period had a linear negative relationship with grain yield (Figure 3), suggesting that winter wheat grain yield decreases as temperature at the critical period for yield determination increases.

The greatest relative winter wheat yield was observed following summer fallow and full-season soybean at both optimum and late sowing dates (Figure 4). Following summer fallow, winter wheat relative yield was lower for the early sowing date, likely due to greater soil water usage during fall. Similarly, winter wheat following double-cropped soybean had similar relative yield as early sowing after summer-fallow, likely due to lower soil water after double-cropped soybean. Winter wheat relative yield after corn was the lowest compared to all other treatments, likely due to the extremely late sowing date (DOY = 326) and lower soil water after corn, which had a high soil water usage during the season.

Preliminary Conclusions

Overall, the sowing date of winter wheat impacted grain yield through its effects on soil available water at planting, and temperature during the critical period for grain yield determination. Later sowing dates resulted in an increased likelihood of lower soil water at planting and higher temperatures during critical period for yield determination, which negatively impacted grain yield. Since no differences were observed between optimum and late sowing date for winter wheat following summer fallow and full-season soybean, plant available water at sowing may be more limiting than temperature in reproductive stages, as winter wheat sowed late after double-cropped soybean had a lower yield than winter wheat sowed late after full-season soybean. A double-cropped soybean system (i.e., soybean following winter wheat) is likely to use more water than full-season soybean since it is a continuous cropping system that has no winter fallow period. Therefore, regardless of the cropping system adopted, if winter wheat is following a summer crop it must be sown as soon as possible after the summer crop is harvested, and sowing dates later than mid-November should be avoided.

Acknowledgments

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Table 1. Summary of previous crop and the respective day of the year at sowing for winter wheat

Previous crop	Day of the year at sowing
Summer fallow	270, 278, 289, and 312
Full-season soybean	295 and 312
Double-cropped soybean	312
Corn	326

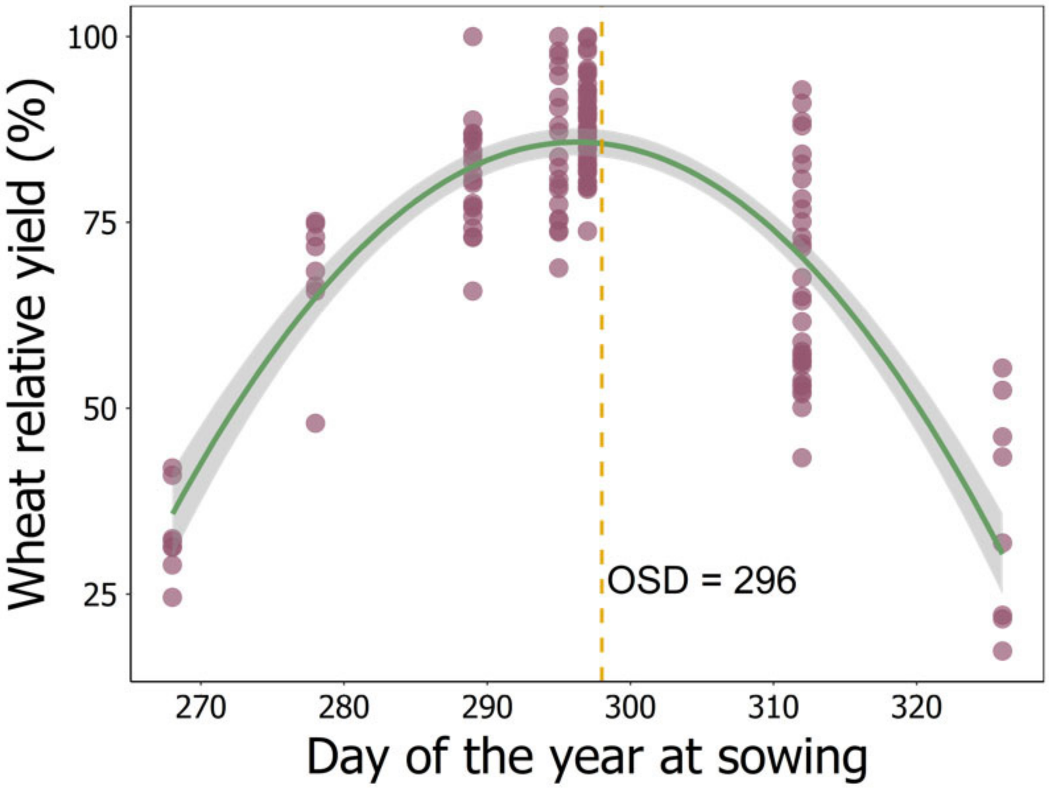

Figure 1. Quadratic relationship between winter yield relative yield and day of the year at sowing. The optimum sowing date (OSD) was estimated at 296 ± 5 (mid-October).

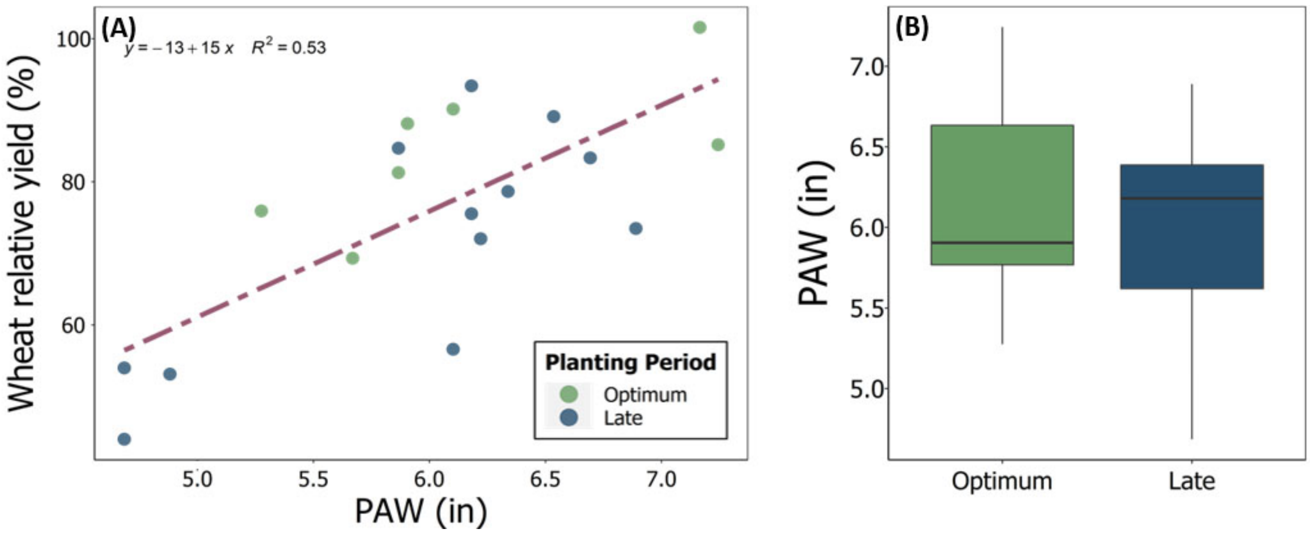

Figure 2. Linear positive relationship between winter wheat relative yields and plant available water at sowing (PAW) (A); and PAW at different sowing dates (B).

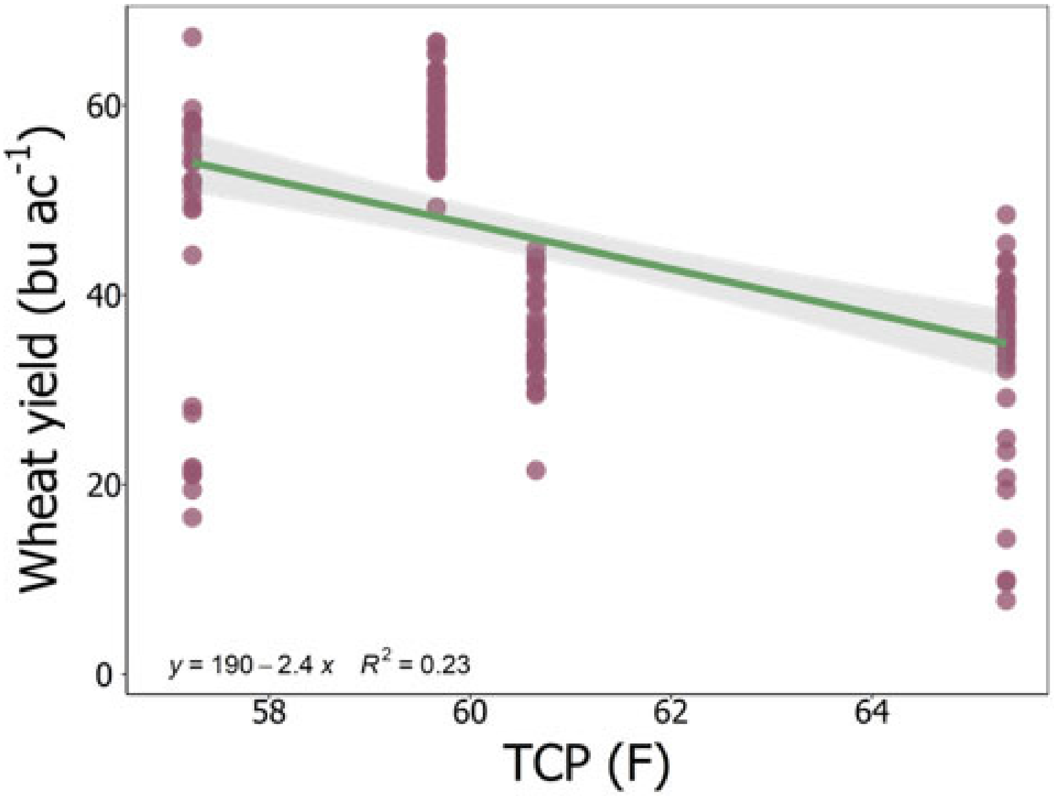

Figure 3. Winter wheat grain yield as affected by temperature during the critical period (TCP) for yield determination.

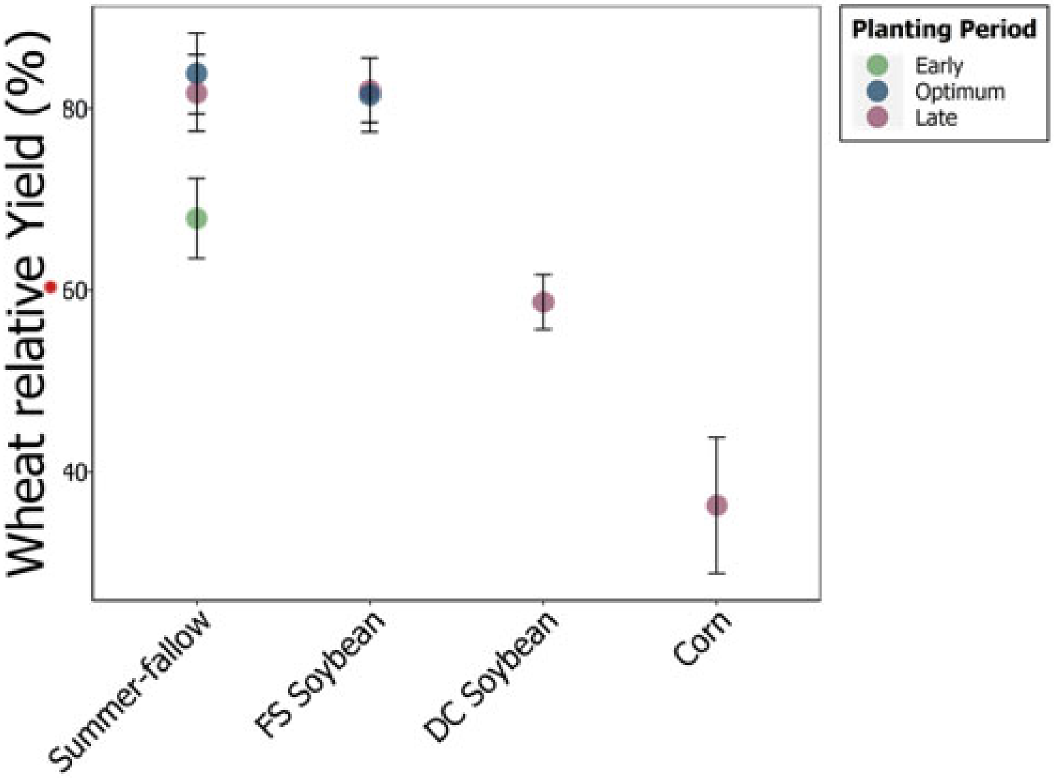

Figure 4. Winter wheat relative yield at three sowing periods (early, optimum, and late) following summer fallow, full-season soybean (FS Soybean), double-cropped soybean (DC Soybean), and corn.

Previous Crop Impacts on Wheat Variety Performance in Central Kansas During the 2021–2022 Growing Season

L. Simão, A. Patrignani, J. Grané, L. Pradella, N. Giordano, J.A. Romero Soler, and R.P. Lollato

Summary

The effect of a previous crop and its residue left on the field before the next crop is a consequence of soil water usage and residue quality. We evaluated the grain yield of forty winter wheat varieties, as well as soil bulk density, soil water content, and previous crop's residue C:N ratio in three neighboring fields near Solomon, KS. Wherein these three fields, winter wheat was no-tilled following a previous crop of either 1) soybean; 2) cover crop mix (legume and cereal); or 3) winter wheat. The mix of cover crops consisted of pearl millet, sorghum sudan, and sunn hemp. Soil samples were taken in October during winter wheat sowing. Four replications of soil measurements for bulk density and water content were taken from the 0- to 16-in. depth at 8-in. intervals. Six replications of 10.8-ft^2 quadrats of residue biomass were sampled and evaluated for total nitrogen (N) and carbon (C). There were no significant differences in winter wheat grain yield among the varieties nor among the sites, although yield following soybeans was slightly lower than yield following wheat or cover crops (41 vs. 46 bu/a). Soil bulk density and residue C:N ratio were the lowest when following soybean (i.e., greater soil porosity and faster residue decay), although soil water content was also the lowest. Soil water content at sowing was the greatest when following winter wheat, likely as there were no actively growing summer crops to use precipitation water prior to wheat sowing. Soil water content increased at deeper layers (0–8 in. compared to 8–16 in.) when winter wheat was sown following a cover crop mix or a previous winter wheat crop, but it decreased when following soybean. Preliminary results from this on-farm experiment suggest that winter wheat variety performance was similar across previous crops despite measured differences in residue and soil characteristics. These results may help farmers to decide the benefits of each crop residue based on their cropping system needs.

Introduction

A previous crop can impact the yield of the following crop (Munaro et al., 2020; Jaenisch et al., 2021; Simão et al., 2023). This impact may result from modification of soil characteristics—such as soil bulk density through different root systems, and soil water content by the soil water usage of the previous cash or cover crop—and length of the fallow period preceding wheat sowing (Lollato et al., 2016). Different wheat varieties are adapted to specific environmental conditions (Lollato et al., 2020, 2021). Researching the effects of previous crops to help producers choose wheat varieties improve the yield and reduce yield gaps in the U.S. Great Plains (Lollato et al., 2017, 2019; Jaenisch et al., 2019, 2022).

Decisions at the cropping systems level can impact a number of environmental indicators that later may relate to crop performance. For example, soil bulk density is a crucial factor that impacts soil health and productivity. It refers to the weight of soil per unit volume and is often used as an indicator of soil compaction (NRCS, 2012). When soil is compacted (i.e., greater bulk density), it becomes denser and less porous, which makes it difficult for water and air to penetrate the soil. As a result, plant roots are unable to access the nutrients they need to grow, and the soil becomes less productive. The availability of water in the soil is essential for plant growth, as it is required for the uptake of nutrients and the maintenance of turgor pressure in plant cells (Troch et al., 2009). Thus, soil water content is an important measurement to consider when sowing the next crop. Likewise, the crop residue's C:N ratio is a measure of the relative amounts of carbon and nitrogen in plant material left on the soil surface after a crop is harvested. This ratio is important because it impacts the rate at which plant residues decompose and release nutrients back into the soil. If the C:N ratio is too high (i.e., greater than approximately 25:1), the decomposition process can be slow, and the nitrogen in the residues may not be readily available for plant uptake. In fact, nitrogen can be immobilized if the C:N ratio is too high because bacteria that decompose plant residue also consume nitrogen. If this nitrogen is not available from the residue due to low nitrogen content, the bacteria will use nitrogen from the soil surroundings (Robertson and Groffman, 2007). If the C:N ratio is too low, the carbon in the residues may be rapidly decomposed, which can result in a loss of soil organic matter (Stella et al., 2019). By managing the C:N ratio of crop residues, farmers can improve nutrient cycling, reduce fertilizer costs, and maintain soil health. Our objective was to quantify the grain yield of 40 winter wheat varieties and characterize previous crop residue quality (C:N ratio), soil bulk density, and soil water content after soybean, a cover crops mix, and winter wheat.

Procedures

On-farm data collection was done in October of 2021 at winter wheat sowing at three different neighboring fields near Solomon, KS. Each field had a different previous crop, including: 1) soybean; 2) cover crop mix; or 3) winter wheat. In each site, forty winter wheat varieties were sown in four replications at a 105 lb/a seeding rate, using 6- × 30-ft plots with rows spaced 7.5 in. apart. Winter wheat was sown on October 19 when following a previous wheat crop or cover crops, and on October 21 when following soybeans. The site with previous crops of wheat and cover crops had Irwin silty clay loam soil. The site with a previous crop of soybeans had Solomon silty clay soil. The previous wheat and soybean crops consisted of commercially available varieties, while the cover crop mix consisted of 9 lb/a of pearl millet, 4 lb/a of sorghum sudan, and 2 lb/a of sunn hemp, chemically terminated a few days prior to wheat planting. All trials received 50 pounds of DAP (18-46-0) per acre in furrow at planting, and fertilizer management was done by the cooperator. Grain yield and moisture content were measured at physiological maturity by harvesting the entire plot area using a self-propelled small plot combine (Massey Ferguson XP8).

Each soil measurement had four replications in each site. Soil bulk density was measured using the cylindrical core method, and soil water content was measured as gravimetric water content (mass of water per mass of dry soil). Six random and representative 10.8 ft^2 areas were selected in each site for aboveground residue biomass collection. Biomass was weighed, ground, and sent to the Kansas State University Soil Fertility Laboratory for a dry combustion with a Perkin-Elmer CHNS/O Analyser

2400 for nitrogen and carbon quantification. Two-way analysis of variance (ANOVA) at the alpha = 0.05 significance level for grain yield response was performed with winter wheat variety, site, and their interaction as the fixed effects and replication within site as random effect.

Results

Yield

Winter wheat grain yield ranged from 39–51 bu/a across all sites (Figure 1A). There was no significant effect of winter wheat variety, site, or their interaction on grain yield. Winter wheat varieties showed similar grain yield, regardless of the site (i.e., previous crop). Winter wheat grain yield average across varieties was greater following the cover crop mix and winter wheat (approximately 45–46 bu/a) than when following soybean (41 bu/a).

Soil

Figure 2 shows soil bulk density and soil water content for each site. Soil bulk density was lower after soybean (average 1.31 g cm^{-3}) than after the cover crop mix (average 1.41 g cm^{-3}) and winter wheat (average 1.52 g cm^{-3}) at both depths (0–8 and 8–16 in.), with the greatest value for winter wheat in both depths. Soil water content was greater after winter wheat (average of 25.7%) than after the cover crop mix (average 18.2%) and soybean (average 12.8%) at both depths, with the lowest value for soybean at both depths.

Residue

Figure 3 depicts residue characteristics for each site. Soybean had the greatest aboveground biomass production (8407 lb/a), followed by cover crop mix (7110 lb/a) and winter wheat (2775 lb/a). It is important to highlight that winter wheat residue data was collected after 3 months of winter wheat harvest, whereas soybean biomass was collected as soon as soybean was harvested, and cover crop mix biomass was collected a few days after cover crop termination. The different time intervals between crop harvest and leftover residue sampling at wheat planting could explain some of these differences. The C:N ratio was lowest for soybean (27:1) followed by cover crop mix (50:1) and winter wheat (60:1), suggesting that while soybeans had the highest residue, it would also likely decompose faster. Soybean also left higher amount of nitrogen in the residue compared to cover crop mix and winter wheat, likely due to greater amount of biomass present and nitrogen concentration in the residue.

Preliminary Conclusions

Overall, winter wheat varieties showed similar grain yield response to location and, in this case, a confounded effect of previous crop. Ideally, future work would test winter wheat varieties in a research trial explicitly designed to test the effects of a previous crop on wheat variety performance, thus overcoming the confounding effects of location on the results. Previous soybean crop resulted in lower soil bulk density (though this may be a function of the soil type at the experimental location) and lower residue C:N ratio than cover crop mix; however, it depleted more soil water. Average grain yield was lower after soybean than after cover crop mix and winter wheat; therefore, soil water content at sowing may have limited the subsequent winter wheat grain yield after soybean. Winter wheat as previous crop resulted in the greatest soil water content at sowing, likely due to the 3-month fallow period preceding wheat sowing. Thus, for the circumstances of this study, a previous crop of soybean was a better option than the evaluated cover crop mix when considering residual nitrogen in the field and soil bulk density. When water availability was the most limiting issue, a previous winter wheat crop followed by a short summer fallow provided greater soil moisture at sowing to the following crop.

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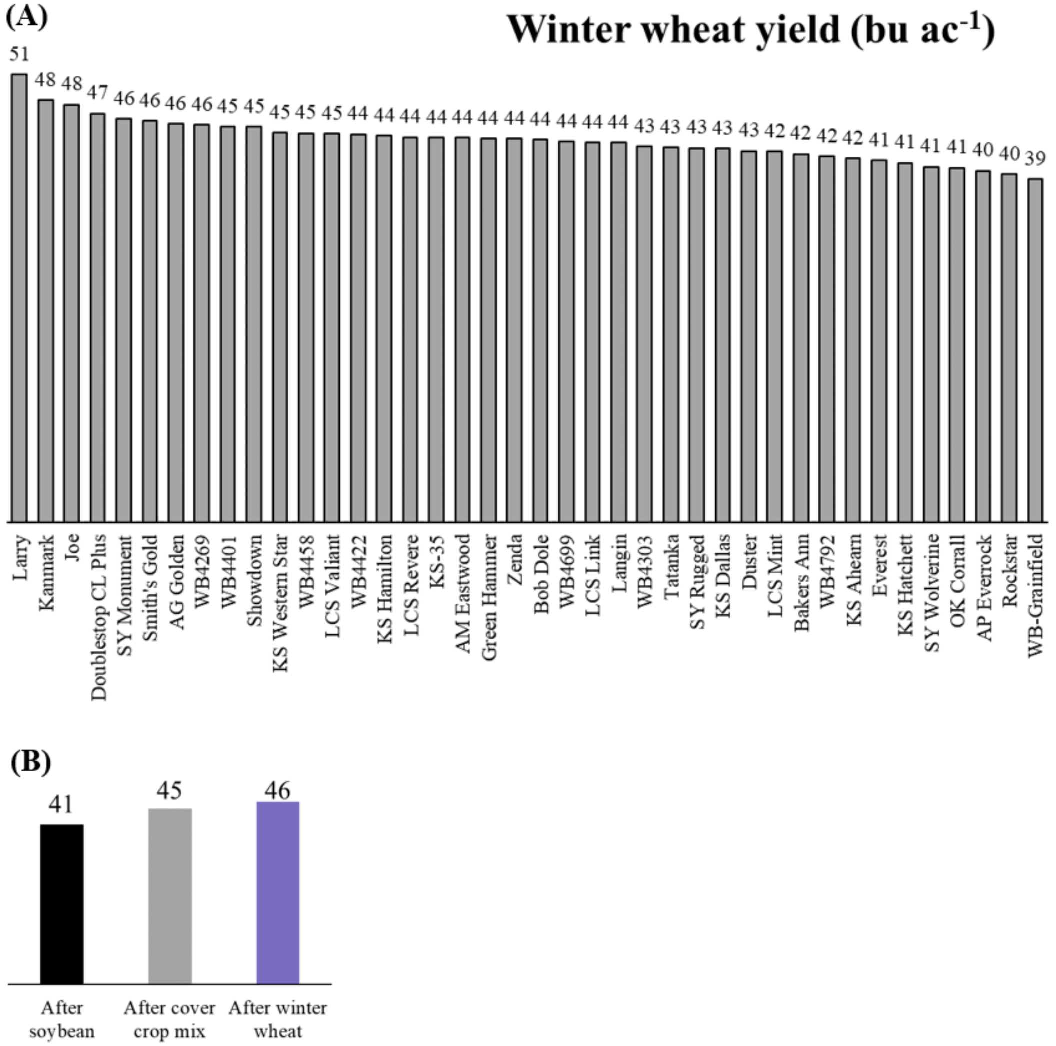

Figure 1. Winter wheat grain yield by variety (A) and by site (B) (i.e., after soybean, cover crop mix (legume + cereal), or winter wheat) in an on-farm experiment near Solomon, KS.

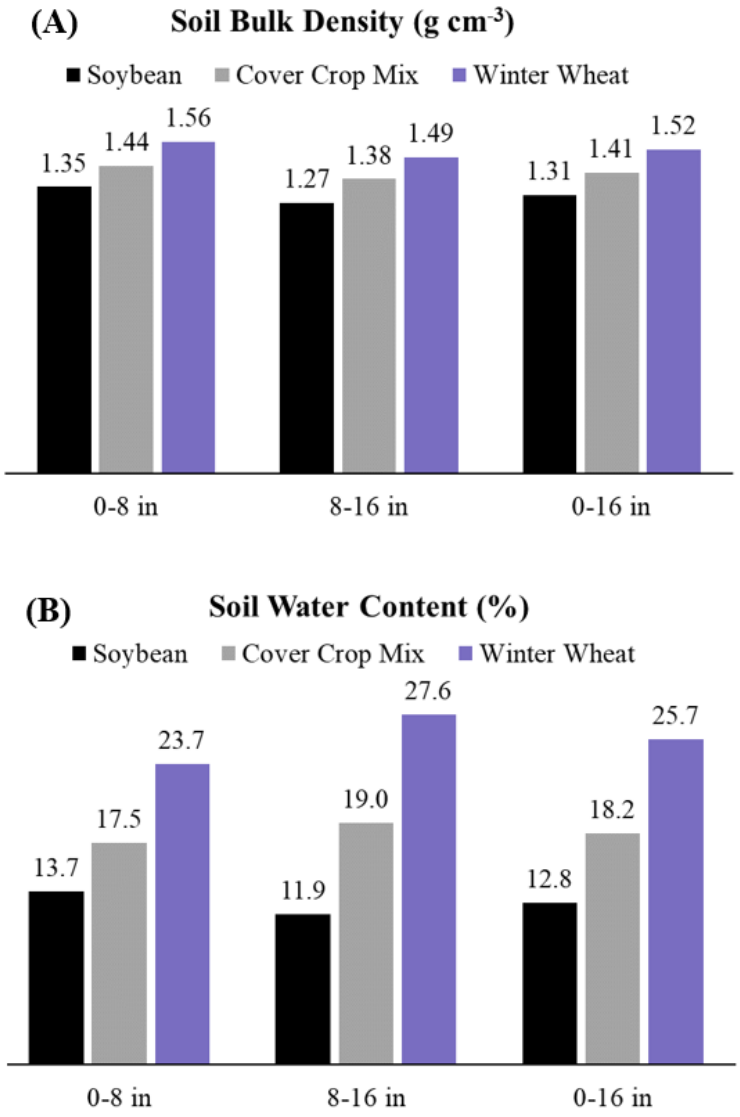

Figure 2. Soil bulk density (A) and soil water content (B) at two depths (0–8 in. and 8–16 in.) and average between depths (0–16 in.) after soybean, cover crop mix (legume + cereal), and winter wheat in an on-farm experiment near Solomon, KS.

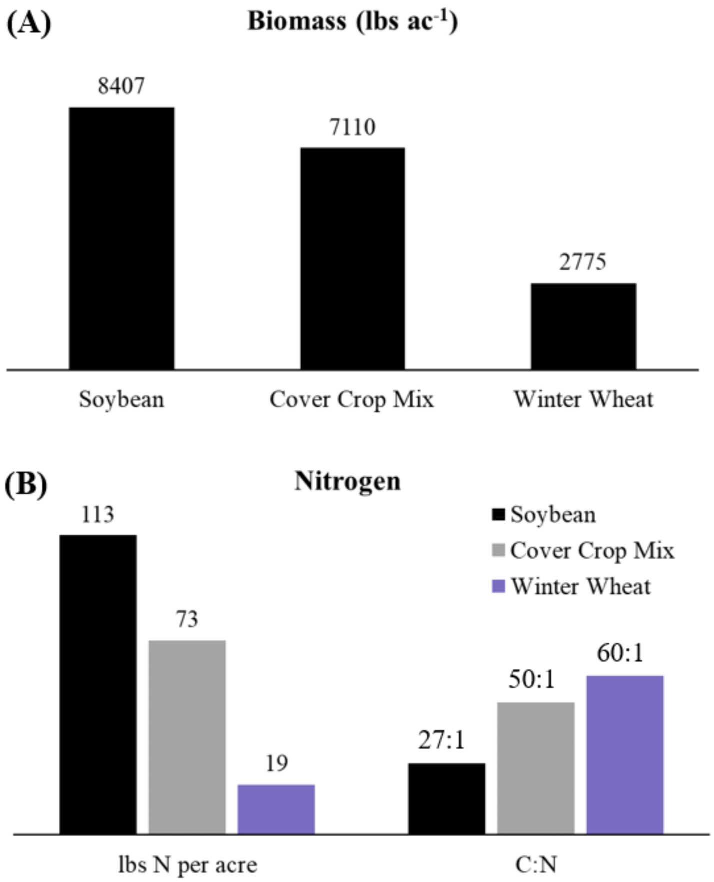

Figure 3. Aboveground biomass (A); total nitrogen (B, left); and C:N ratio (B, right) of soybean, cover crop mix (legume + cereal), and winter wheat residue in an on-farm experiment near Solomon, KS.

Does Winter Wheat Yield Response to Fungicide Application Depend on Nitrogen Management?

J.A. Romero Soler, L.O. Pradella, N. Giordano, G. Cruppe,[1] and R.P. Lollato

Summary

Nitrogen and fungicide are among the more important management tools to increase wheat (*Triticum aestivum* L.) grain yield in Kansas. However, there is limited information on whether hard red winter wheat grain yield is impacted by the interaction of nitrogen rates and foliar fungicide application. Thus, our objective was to evaluate the effects of different N rates with or without a fungicide application at Feekes 10.5 on grain yield of two winter wheat genotypes with contrasting disease resistances to leaf and stripe rust. Eleven field experiments were established across Kansas using a factorial structure of two fungicide management options (either no fungicide or 13 fl oz of Nexicor per acre), five N rates (0, 30, 60, 90, and 120 pounds of N per acre), and two genotypes (Larry and Zenda) in a split-split plot design during the 2021–2022 growing season. There was a significant interaction between genotype and environment where Larry out-yielded Zenda in anywhere from 3.1 to 15 bu/a. There was a significant interaction between N rate and environment, likely due to the initial soil NO_3-N and yield potential, as grain yield ranged from less than 34 to more than 81 bu/a. Increases in fractions of canopy cover in response to N fertilization and fungicide application explained about 29% and 15% of the increases in grain yield, respectively. There was a slightly greater crop yield response to foliar fungicide application as the N supply increased, from a nearly null difference at low N supply to as much as 5.9% for total N supply greater than 160.7 lb of N/a. In dry conditions with minimal disease incidence, winter wheat response to N availability differed in each environment, but there was only a marginal response to foliar fungicide.

Introduction

There is a large yield gap for winter wheat in Kansas, where the current farmer yields are considerably lower than their attainable potential (Patrignani et al., 2014; Lollato et al, 2017). Within this context, in-season management decisions can largely improve grain yields, narrowing the yield gap (Jaenisch et al., 2019, 2022; de Oliveira Silva et al., 2021, 2022). Among the many practices that growers can manage, nitrogen management and foliar fungicide applications seem to be the largest drivers of wheat yield in this region (Cruppe et al., 2017, 2022; Jaenisch et al., 2021; Lollato et al., 2019a; Munaro et al., 2020). Thus, more research is needed on agronomic management of nitrogen, fungicide, and potentially of their interaction to increase winter wheat yield in the region.

Some evidence suggested an interaction between N management and foliar fungicide application in other regions and for other wheat classes (Brinkman et al., 2014). Nitrogen can increase disease pressure by promoting lush growth, which creates a moist microclimate within the canopy and keeps leaves green longer. (Salgado et al., 2017). Likewise, with applications of foliar fungicide, the crop may have higher yield potential,

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and N requirements are linked to the crop's yield potential (Salgado et al., 2017; Lollato et al., 2019b, 2021).

Although this information on N × fungicide interactions is available in other regions, there is limited information on whether hard red winter wheat yield is impacted by this interaction in the U.S. central Great Plains region. Therefore, our objectives were to evaluate the effects of different N rates with or without a foliar fungicide application at heading on the grain yield of two winter wheat genotypes with contrasting disease resistances to leaf and stripe rust.

Procedures

This study was conducted at eleven rainfed locations across the state of Kansas during the 2021-2022 winter wheat growing season (Ashland Bottoms, Belleville after fallow; Belleville after soybeans; Great Bend, Hays, and Hutchinson with sowing dates around the early, optimum, and late side of the sowing window; and Leoti, Manhattan, and Solomon). Sowing dates for these locations are provided in Table 1.

The field experiment was established using a factorial structure arranged in a split-split plot design, where the fungicide application constituted the whole plot, N rates the sub-plot, and the genotype constituted the sub-sub-plot. The fungicide management was either no fungicide or 13 oz of Nexicor per acre at heading; the five nitrogen rates were 0, 30, 60, 90, and 120 pounds of N per acre; and the two winter wheat varieties used across locations were Larry (susceptible to leaf rust) and Zenda (susceptible to stripe rust).

Winter wheat varieties were sown at 90 pounds of seeds per acre, in combination with 50 pounds of diammonium phosphate applied in furrow at sowing. Nitrogen was applied as urea (46-0-0) by hand broadcast at Feekes 3, and fungicide was applied using flat fan nozzles mounted on a CO_2 backpack sprayer at Feekes 10.5. The fields had adequate weed control using commercially available herbicides to ensure weeds were not a limiting factor. Plots were harvested using a Massey Ferguson 8 XP small plot combine.

Soil samples were collected at each location before sowing from 0 to 6 in. and from 6 to 18 in., depths (Table 1). For each depth, soil fertility and texture were analyzed. Downward facing images were collected at a height of 5 feet above the ground through the season at Feekes 3, 6, 10.5, 11, and 11.4, and the fraction of green canopy cover was estimated with the Canopeo app (Pratignani and Ochsner, 2015). Delta (changes) in yield and delta in canopy cover were calculated based on all possible comparisons between genotype, environment, and fungicide management. The associations were analyzed with linear and non-linear regressions. Plots were 6 × 30 ft, and yield was measured by combine harvesting the entire experimental unit at maturity. Four-way ANOVA evaluated the main effects of N rate, fungicide, genotype, and environment, as well as their interactions.

Results

Genotype by Location Interaction

A significant interaction between genotype and environment suggested that the yield differences among genotypes depended on the environment (Table 2). Grain yield ranged from 30.75 to 90.31 bu/a, and the variety Larry out-yielded Zenda from 1.64 to 12.64 bu/a in seven locations. There was no difference between genotypes in the remaining four locations.

Nitrogen Rate by Location

There was a significant interaction between N rate and environment, likely due to the different initial soil NO_3-N contents and yield potential (Figure 1). Mean grain yield ranged from less than 34.1 bu/a in Manhattan to more than 83 bu/a in Belleville. Grain yield increased with increases in N rate in Hays, Ashland Bottoms, Belleville, and Manhattan. It was neutral in Hutchinson (with an early, optimum, and late planting date), Leoti, Great Bend, and Solomon. Grain yield also decreased with increases of N rate in Belleville with an optimum planting date.

Nitrogen by Fungicide

There was a trend of slightly greater crop yield response to foliar fungicide application as N supply increased (Figure 2), from a nearly null difference at low N supply to as much as 5.9% for total N supply greater than 160.7 lb/a.

Simultaneous Modulation of Green Canopy Cover and Grain Yield

Increases in green canopy coverage in response to N fertilization explained about 29% of the increases in grain yield, with steeper increases at low levels (Figure 3a). Differences in green canopy cover due to foliar fungicide application explained about 15% of the differences in grain yield (Figure 3b). Negative values in Figure 3b may be functions of the dry environments evaluated, and may reflect the environment-specific impacts of foliar fungicides.

Preliminary Conclusions

In a dry growing season, with minimal disease incidence, winter wheat grain yield responded to genotype and to N availability differently in each environment, and showed a global response to foliar fungicide. Grain yield responses to nitrogen and fungicide additions were partially explained by greater canopy cover at anthesis and the soft dough stage of grain development, respectively. We note, however, that foliar fungicide decreased grain yield in some of these dry environments. A continuation of this research should explore responses in more moist years where increased disease pressure may result in interaction among the studied factors.

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Table 1. Initial soil fertility measured at winter wheat sowing during the 2021–2022 growing season for eleven environments in Kansas

Location	Sowing date	Depth	pH	NO_3-N	P-M	K	S	OM	Sand	Silt	Clay
		in.		ppm				%			
Ashland Bottoms	10/12/2021	0-6	5.80	26.7	54.6	256	8.2	1.7	38	54	8
		6-18	7.20	5.6	31.2	156	2.3	0.8	35	53	12
Belleville, O	10/7/2021	0-6	4.9	41.8	56.5	409	8.1	2.7	16	52	32
		6-18	6.1	25.1	15.8	484.8	5.4	2.3	18	42	40
Belleville	10/7/2021	0-6	5.1	17.5	75.5	571.9	6.8	2.7	20	56	24
		6-18	6	8.6	57.1	730	5.4	2.8	10	54	36
Great Bend	10/20/2021	0-6	5.7	21.9	164.1	618.9	8.6	1.9	20	54	26
		6-18	7.2	12.9	57	557.9	9.4	1.3	20	40	40
Hays		0-6	6	26.4	76.4	709.3	5.7	1.8	18	52	30
	9/28/2021	6-18	6.4	18.7	45.5	614.2	4.7	2	22	42	36
Hutchinson, E	9/21/2021	0-6	5.4	47	61.2	324.5	8.7	2.5	28	48	24
		6-18	7	43.5	36.1	295.9	8.4	2.7	34	39	27
Hutchinson, L	10/21/2021	0-6	5.6	34.5	84.6	434.7	8	3.3	34	38	28
		6-18	5.9	21.2	51.6	386	6.4	2.3	26	44	30
Hutchinson, O	8/8/2021	0-6	6.7	37.7	46.9	214	7.1	1.6	38	42	20
		6-18	7.5	34.4	24.4	216.6	5.7	1.7	36	40	24
Leoti	9/25/2021	0-6	6.8	28.8	74.7	692.3	6.8	1.7	26	46	28
		6-18	7.4	20.9	32.7	677.3	6.1	1.8	26	43	31
Manhattan	10/18/2021	0-6	6.6	10.4	23.1	243.2	3.5	2.3	22	50	28
		6-18	7.2	7.5	13.4	260.3	4	3	22	46	32
Solomon	10/21/2021	0-6	7.4	11.8	42.8	349.8	4.7	2.9	20	44	36
		6-18	7.2	9.8	18.5	325.5	4.5	2.5	20	41	39

O = optimum. E = early. L = late.

Table 2. Grain yield of two winter wheat genotypes at eleven locations in Kansas during the 2021–2022 growing season

	Genotype		
	Larry	Zenda	Mean
Location	Grain yield, bu/a		
Ashland Bottoms	57.04 a	55.4 a	56.22
Belleville, O	90.31 a	78.72 b	84.51
Belleville	84.66 a	72.04 b	78.35
Great Bend	38.77 a	34.61 b	36.69
Hays	56.89 a	50.06 b	53.47
Hutchinson, E	54.51 a	46.04 a	50.28
Hutchinson, L	34.31 a	30.75 b	32.53
Hutchinson, O	57.93 a	52.58 a	55.25
Leoti	59.56 a	44.56 b	52.06
Manhattan	58.22 a	45.9 b	52.06
Solomon	40.85 a	39.66 a	40.25

Means of each variety followed by the same letter are not statistically different at $P < 0.001$.
O = optimum. E = early. L = late.

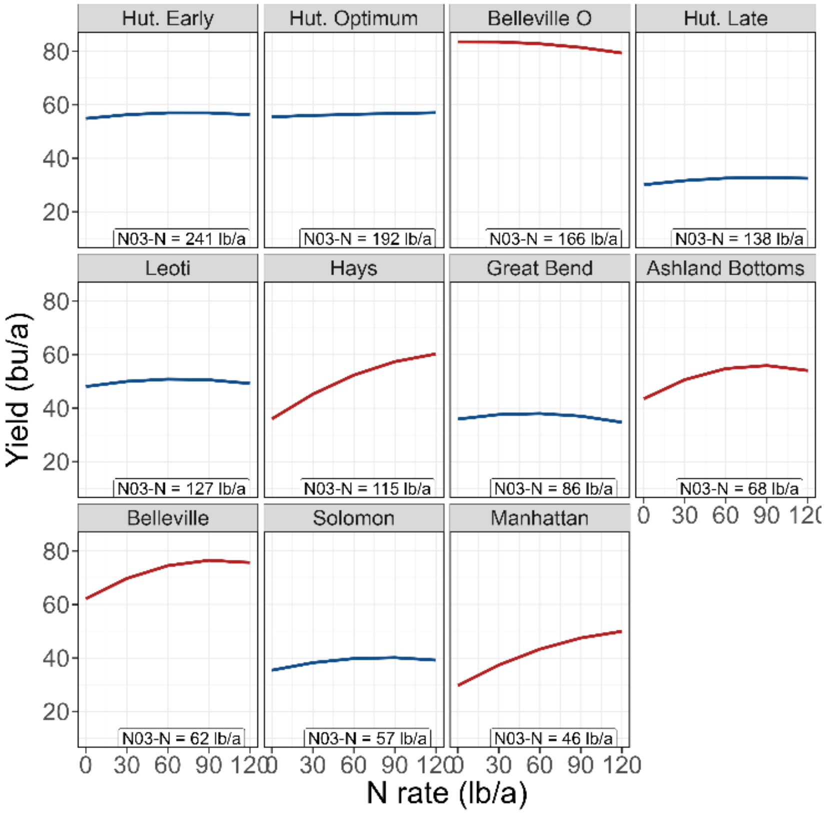

Figure 1. Winter wheat grain yield as function of nitrogen rate and its interactions with environment during the 2021–2022 growing season in 11 locations across Kansas. Initial soil NO_3-N contents for each location are presented in the lower panels. Red lines indicate significant relationship while blue lines indicate no significant relationship.

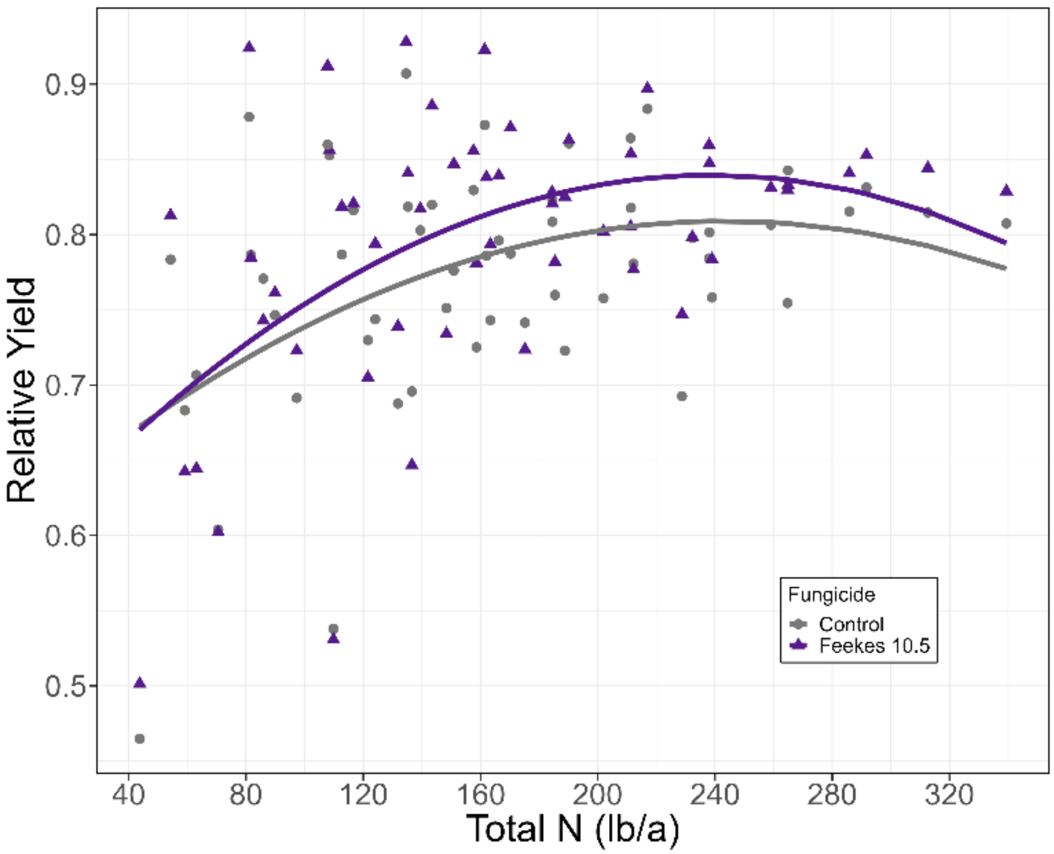

Figure 2. Relative wheat grain yield in response to total nitrogen available (soil NO_3-N at sowing in the top 18-in. profile plus applied N rate) for crops with (purple) and without (grey) foliar fungicide applied at Feekes 10.5 during the 2021–2022 growing season in Kansas.

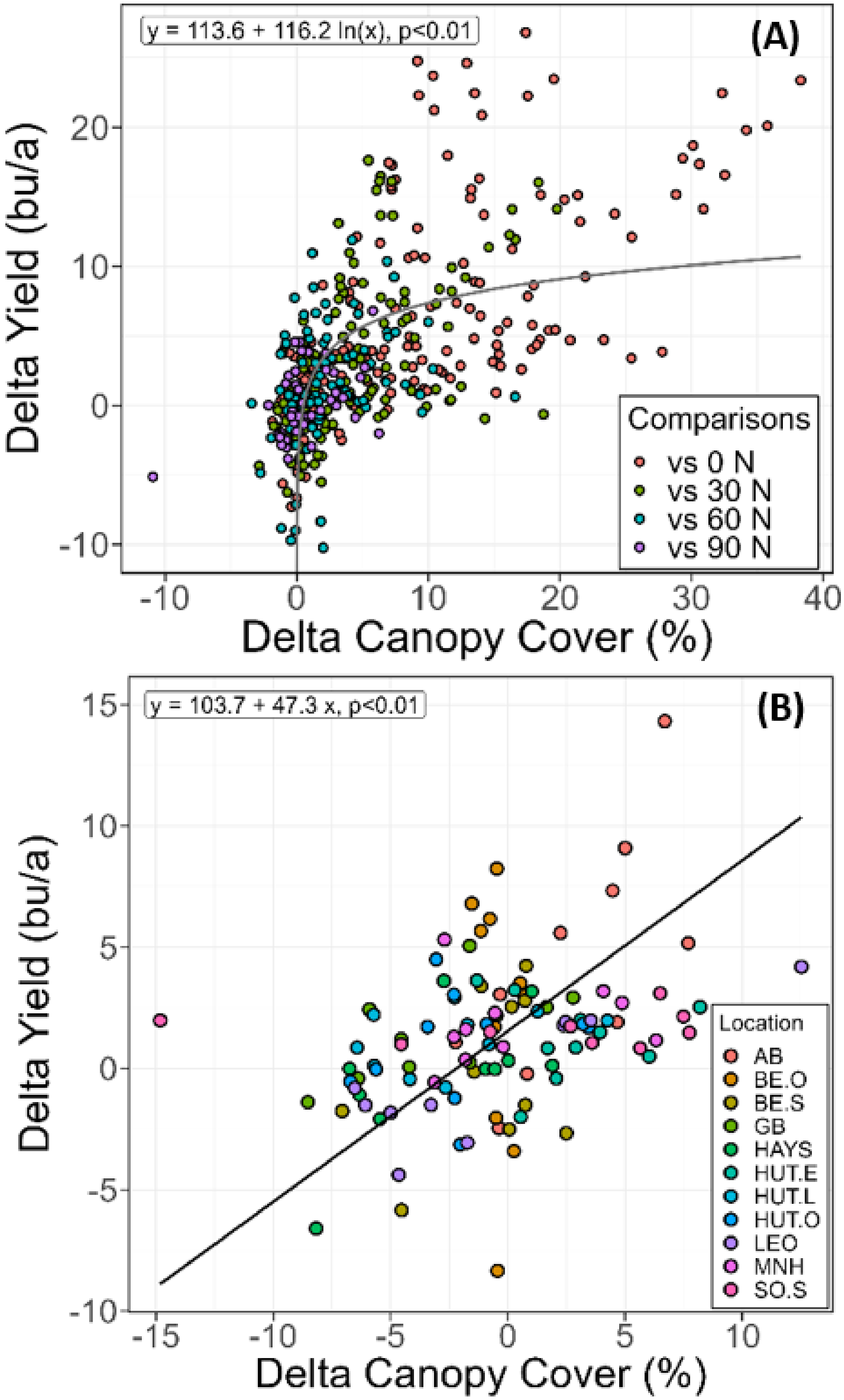

Figure 3. (a) Relation between winter wheat delta canopy cover at Feekes 10.5 and delta yield for all possible comparisons among location, fungicide management, and genotype as function of N addition. (b) Relation between delta canopy cover at Feekes 11 and delta grain yield for all possible comparisons within the location, nitrogen rate, and genotype as function of foliar fungicide application at Feekes 10.5 during the 2021–2022 growing season in Kansas.

Tillering Potential and Stability of Winter Wheat Varieties Commonly Grown in Kansas

L.O. Pradella and R.P. Lollato

Summary

The tillering potential and stability of winter wheat (*Triticum aestivum* L.) can be positive traits by conferring adaptation to distinct production environments. The literature demonstrates a high correlation between the tillering potential and many yield components. However, the actual impact of tillering potential on grain yield is not clear. Our goal was to quantify the tillering potential and stability of a range of winter wheat varieties. Field experiments were conducted in six locations in the state of Kansas during the 2021–2022 season. A complete factorial treatment structure of twenty-five winter wheat varieties by two seeding rates (400,000 seeds per acre and 1.2 million seeds per acre) was established in a randomized complete block design with three or four blocks. We measured the stand count (twenty days after sowing) and the number of stems at the growth stage Feekes 6 in 3 ¼ row-feet in each plot. Tillers per plant were modeled as a function of plants per square feet by replication within the environment using non-linear models. Overall, fall precipitation and temperature accumulation partially regulated tiller production, but the major determinant of tillers per plant was the number of plants per area. Different seeding rates led to large differences in population and tiller components, which in compensation only resulted in modest grain yield changes. With few exceptions, varieties tended to be stable in their ranking as a function of the environment; thus, varieties with high tillering potential can be an option to reduce seed costs.

Introduction

Winter wheat responses to seeding rate are inconsistent (Bastos et al., 2020; Evans and Fischer, 1999; Jaenisch et al., 2022; Lollato et al., 2019a). Some studies suggest that grain yield responses to population depend on environmental yield potential, which ultimately would occur due to resource availability (Bastos et al., 2020). Wheat yield and its relationships with population were measured in a dataset of commercial fields entered in the Kansas Wheat Yield Contest. The results suggested that populations as low as 400,000 plants per acre were sufficient to maximize yields, as long as fields had substantial resources (Lollato et al., 2019b). Environmental resources (including moisture and temperature) needed to ensure proper wheat tiller production and maintenance during the fall may not always be available in areas with highly variable weather such as Kansas (Lollato and Edwards, 2015; Lollato et al., 2017, 2020; Sciarresi et al., 2019). When wheat sowing dates are delayed to follow a summer crop, low wheat populations can be challenging (Munaro et al., 2020; Jaenisch et al., 2021).

In addition, the literature demonstrates a high correlation between the tillering production and many yield components (Bastos et al., 2020; Jaenisch et al., 2022; Sadras and Rebetzke, 2013). The number of tillers usually associates with the number of spikes; thus, the higher tiller production can help maximize wheat yields when seeding rates are reduced (Bastos et al., 2020). This indicates that winter wheat tillering potential and stability can be positive traits by conferring adaptation to distinct production environments. However, a trait's actual impact on grain yield is not clear, requiring a better understanding of the correlation between grain yield, environments, and varieties.

We used the concept of tillering potential (TP, the number of tillers developed per plant) and tillering stability (i.e., the genotype's ability to produce a predetermined phenotype) to explore genotype by environment interactions. The objective of this work was to quantify the tillering potential and stability of a range of winter wheat varieties.

Procedures

Treatments, Experimental Design, and Management

Six field experiments were conducted in the state of Kansas. Sites were near Belleville, Great Bend, Hays, Leoti, and there were two experiments with contrasting sowing dates near Hutchinson. This research was conducted during the winter wheat seasons of 2021–2022. Across locations, the different cropping systems ensured different tillering potentials resulting from planting dates and conditions. For example, cropping systems ranged from wheat sown at the optimal time after a fallow period, to wheat sown late following the harvest of a summer crop. These different planting times allow us to explore the effects of fall weather on early crop growth. Seeds were treated with thiamethoxam, difenoconazole, and mefenoxam for protection against early-season diseases and insects. Diammonium phosphate (DAP 18-46-0) was used as starter fertilizer at a rate of 50 lb/a. Management factors such as foliar fungicide (Cruppe et al., 2017, 2021), topdressing fertilizer (Lollato et al., 2019c, 2021), weed management, and insect control were carried out to ensure that these were not limiting factors to wheat yield at all sites by using prophylactic pesticide applications.

Treatments were arranged in a randomized complete block design (RCBD). Each block received twenty-five winter wheat varieties which were sown in two seeding rates: either 400,000 seeds per acre, or 1,200,000 seeds per acre. These sowing rates were considered as treatments of lower and higher seeding rate, respectively. The rates were defined based on preliminary data suggesting that optimum grain yields could be attained at 400,000 seeds per acre (Lollato et al., 2019b). Thus, the trial had a total of 50 treatments.

We demarked a 3.28-ft row to measure stand count (SC) between 3 and 4 weeks after sowing, and the tiller number (TN) after the winter when the plants were around the jointing stage of development (Feekes 6). Finally, grain yield was measured at physiological maturity by harvesting the entire plot and adjusting for 13% moisture.

The Kansas Mesonet system was used to provide weather data, including precipitation, and maximum and minimum temperature.

Statistical Analyses

The number of tillers per plant was correlated by a linear model with fall cumulative precipitation and fall growing degrees per day. The main response variables of population, tillers per area, tillers per plant, and grain yield were grouped by Tukey's test at $P <$ 0.05 within location to explore effects of the treatments. A non-linear regression model was fitted to tillers per plant as a function of plants per area by replication within the environment. The residuals of the above relation were ordered by location to show the response of varieties within the environment. The lowest and highest tillering production environments were selected to illustrate and simplify the interpretation of the results.

Results

Fall Weather Conditions

Tillers per plant tended ($P < 0.32$) to increase with increases in precipitation and growing degree days accumulated from the sowing date until December 31st across the six locations studied (Figure 1). Growing degree days had a greater impact ($r^2 = 0.51$) than precipitation ($r^2 = 0.23$) on tillers per plant.

Grain Yield

Increasing seeding rates increased the plants per area two-fold and tillers per area by 15% while reducing tillers per plant by 43% (Table 1). Increases in grain yield were significant but modest (mean: 6%). Interestingly, the reduced crop density increased the tillering production and decreased the number of tillers per area. In spite of the buffer effect from the tillering production, the grain yield was reduced as well. TThis aligns with previous findings (Jaenisch et al., 2022; Lloveras et al., 2004), however here exploring a larger quantity of varieties and environments.

Tillering Potential

Tillers per plant decreased exponentially with increases in the plants per area (Figure 2). The wheat varieties evaluated had different tillering potentials (Table 2). While a few varieties switched ranking between environments markedly, the majority of the varieties maintained their ranking tendency (above or below average). Interestingly, the hierarchical order which was established for the lowest tillering production environments appears to be pretty similar to that resulting from the highest tillering production environments (Table 2). This demonstrates a predominance of the genotype's response to the environment in the tillering potential trait in most of the varieties. Grouping the tillering potential values by Tukey's test at $P < 0.05$ resulted in only two main groups, and in all environments more than 80% of the varieties belonged to the same group. This fact can indicate a difficulty and/or issues in classifying winter wheat varieties by a precise scale by means of their tillering potential traits.

Preliminary Conclusions

This study identified that precipitation and temperature accumulation between sowing and the onset of winter partially regulated tiller production, but the major determinant of tillers per plant was the plant density (plants per area). Different seeding rates led to large differences in population and tiller components, which in compensation only resulted in modest yield changes.

With few exceptions, varieties tended to be stable in their ranking regarding tillering potential as a function of the environment. Thus, varieties with high tillering potential may be an option to reduce seed costs across environments.

Acknowledgments

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Table 1. Mean population, tillers produced per area, tillers produced per plant, and grain yield across varieties for the different environments and plant populations studied

		Population mean (per square ft)		Tillers mean (per square ft)		Tillers per plant		Grain yield mean (bu/a)	
Location	**Environ.**	**Target 400,000 seeds/a**	**Target 1,200,000 seeds/a**	**Target 400,000 seeds/a**	**Target 1,200,000 seeds/a**	**Target 400,000 seeds/a**	**Target 1,200,000 seeds/a**	**Target 400,000 seeds/a**	**Target 1,200,000 seeds/a**
Belleville	BES	11.5b	28.1a	63.6a	65.4a	5.7a	2.4b	77.3b	83.3a
Great Bend	GB	11.0b	24.0a	75.6b	98.4a	7.1a	4.4b	34.2b	35.7a
Hays	HAY	8.4b	18.0a	77.2b	94.7a	9.7a	5.6b	41.6b	44.6a
Hutchinson	HUT-LAT	10.4b	20.1a	50.4b	62.9a	5.3a	3.5b	35.7b	38.7a
Hutchinson	HUT-OPT	6.8b	13.0a	105.4a	110.6a	17.1a	9.3b	58.0b	62.5a
Leoti	LEO	9.1b	17.9a	111.6b	123.5a	13.0a	7.3b	50.6b	55.0a
Mean		9.3b	19.7a	81.6b	93.5a	9.9a	5.6b	49.1b	52.0a

Different letters suggest that means were not similar by Tukey's test at $P < 0.05$.

Table 2. Order of varieties per location in terms of tillering potential

Tillering potential	Belleville	Great Bend	Hays	Hutchinson Late	Hutchinson Optimum	Leoti
	---------- Variety Name ----------					
High	WB4699	WB4699	WB4699	WB4699	WB4699	WB4595
	WB4595	WB4303	WB4269	DoubleStop CL Plus	KS Hamilton	WB4269
	KS Western Star	KS Hamilton	WB4595	WB4269	Larry	Joe
	KS Hamilton	Joe	SY Monument	KS Hatchett	Joe	Larry
	WB4269	Duster	Duster	Duster	KS Hatchett	WB4699
	DoubleStop CL Plus	WB4595	KS Hamilton	SY Wolverine	WB4595	SY Wolverine
	KS Ahearn	WB4269	Joe	Joe	KS Ahearn	Kanmark
	Duster	Showdown	KS Hatchett	Larry	SY Wolverine	KS Hatchett
	WB4792	DoubleStop CL Plus	KS Ahearn	SY Monument	WB4792	KS Providence
	SY Wolverine	KS Ahearn	KS Western Star	KS Ahearn	Duster	SY Monument
	Joe	KS Hatchett	Showdown	KS Hamilton	DoubleStop CL Plus	Showdown
	Bakers Ann	SY Monument	WB4792	WB4595	WB4269	KS Hamilton
Median	Zenda	Zenda	Zenda	Bakers Ann	Zenda	KS Ahearn
	KS Hatchett	WB4401	Larry	WB4792	WB4303	WB4792
	Larry	Bob Dole	SY Wolverine	Showdown	KS Dallas	WB4401
	OK Corral	OK Corral	OK Corral	Zenda	Bob Dole	Duster
	WB4401	KS Providence	Kanmark	Bob Dole	Bakers Ann	Bob Dole
	SY Monument	KS Dallas	Bob Dole	WB4303	KS Western Star	DoubleStop CL Plus
	Smith’s Gold	SY Wolverine	KS Providence	KS Dallas	OK Corral	KS Western Star
	KS Dallas	KS Western Star	Bakers Ann	KS Western Star	KS Providence	WB4303
	KS Providence	WB4792	Smith’s Gold	KS Providence	SY Monument	Zenda
	WB4303	Larry	WB4303	WB4401	WB4401	OK Corral
	Bob Dole	Smith’s Gold	DoubleStop CL Plus	Smith’s Gold	Showdown	KS Dallas
	Showdown	Bakers Ann	WB4401	OK Corral	Smith’s Gold	Bakers Ann
Low	Kanmark	Kanmark	KS Dallas	Kanmark	Kanmark	Smith’s Gold

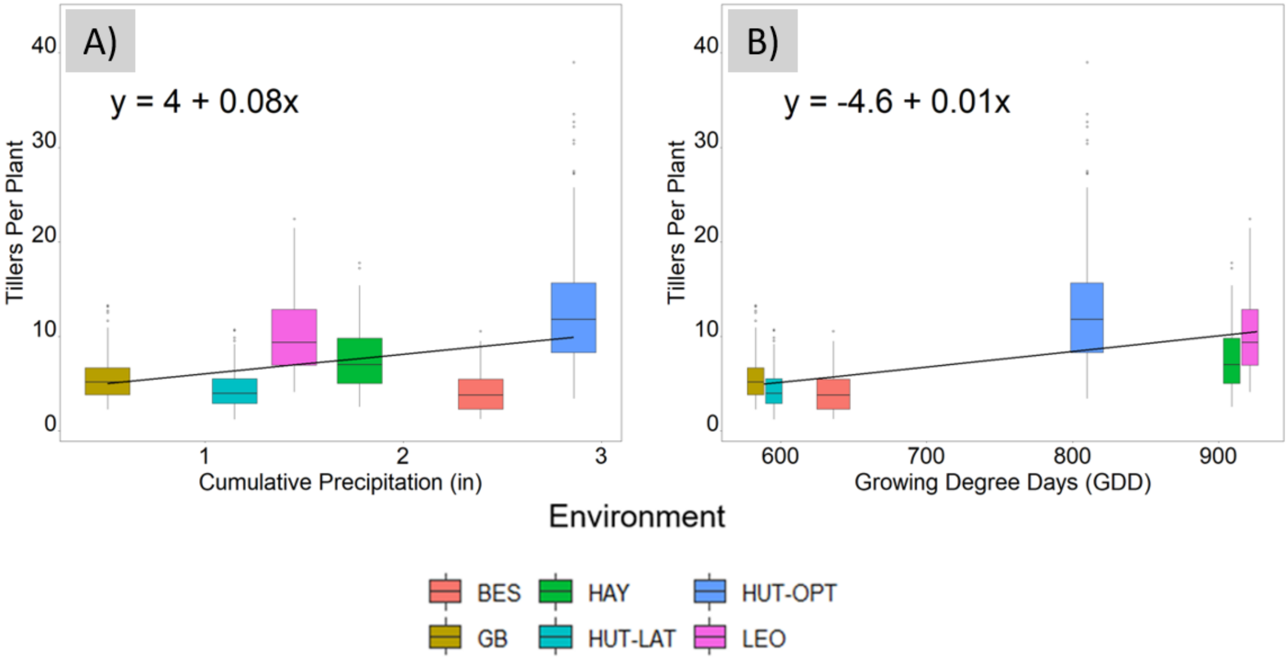

Figure 1. Tillers per plant tended to increase as function of precipitation (A) and growing degree days (B) accumulated from the sowing date until December 31 ("Fall") across the six environments evaluated.

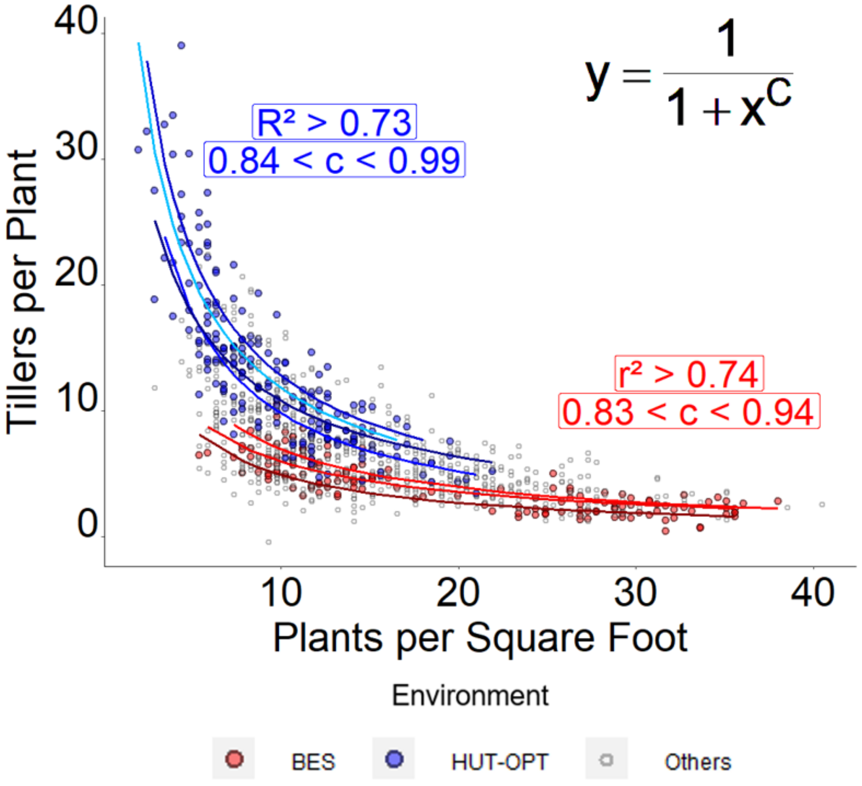

Figure 2. Tillers per plant decreased exponentially with increases in plants per area. Lines show regressions for each block in blue for the highest tillering environment (Hutchinson sown at the optimum time) and red for the lowest tillering environment (Belleville sown late after soybeans).

Allelopathic Potential of Winter Wheat Varieties for Weed Suppression

C. Bott, A. Dille, A. Mohammad,[1] L. Simão, L.O. Pradella, and R.P. Lollato

Summary

Summer weeds are an expensive economic and environmental problem during the fallow period following the harvest of a wheat crop. Anecdotal evidence suggests that different wheat varieties impact the need for weed control in the subsequent fallow period differently, with reasons ranging from residue amount and quality to the allelopathic potential of such residue. Thus, our objectives were to compare the allelopathic effects of different winter wheat varieties on weed and crop germination suppression. We collected the residue left after harvest of 25 varieties grown in a randomized complete block design in two Kansas locations (Hays and Great Bend) during 2022. The residue of the different varieties were combined (replications within location), dried, ground, and used to create extracts with 5% concentration that were later used in a growth chamber study. A total of 50 seeds for weed species Palmer amaranth (*Amaranthus palmeri*) and giant foxtail (*Setaria faberi*), and 25 seeds for grain sorghum (*Sorghum bicolor*), were added to petri dishes in combination with 5 mL of each extract in four replicates. Petri dishes were sealed with Parafilm and placed in a dark growth chamber set to 84/75°F day/night temperatures. Seed germination was counted after 5 days. There were significant location by variety interactions in the control of both weed species, with greater weed control resulting from the residue derived from Great Bend (6–100% control) than from Hays (-10 to 69%). The difference among varieties was also large, and depending on weed species and location, ranged from as little as 26% to as much as 90% (these differences reflected contrasts between the varieties with minimum versus those with maximum control). All wheat varieties significantly reduced seed germination of Palmer amaranth and giant foxtail, but varieties differed in their germination suppression potential. The allelopathic effects of wheat varieties could be additional targets of breeding programs for reduced weed pressure. Meanwhile, grain sorghum germination was minimally impacted by allelopathic effects of wheat residue.

Introduction

Winter wheat is the predominant crop in the U.S. Central Great Plains due to its broad adaptability (Lollato et al., 2020a) and good match between crop demand for water and precipitation distribution (Couëdel et al., 2021; Lollato et al., 2017, 2020b; Sciarresi et al., 2019). About half of the wheat acreage is grown after a short summer fallow in the central portion of Kansas, and about 75% of the acreage is grown after a long (11 to 14 months) fallow in western Kansas (Jaenisch et al., 2021). Summer weeds on fallow ground following wheat harvest are a costly problem for Kansas growers. These include both economical costs associated with weed control, and environmental costs associated with weeds' consumption of water and nutrients.

After harvest, the wheat crop leaves a large amount of residue in the ground that can impact moisture retention and yield of the subsequent crop (Simão et al., 2021, 2023)

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as well as management of summer weeds (Simão et al., 2020). Similarly to grain yield (e.g., Munaro et al., 2020), wheat varieties differ in the amount and quality of residue left behind. Growers report that weed pressure can vary in different fields depending on which wheat variety was grown in the preceding season, but evidence is anecdotal. A potential explanation for different weed pressures include the amount and quality of biomass residue left after harvest. Another potential explanation, which was the focus of this study, is whether wheat varieties' residues differ in allelopathic effects, potentially suppressing weed germination. Thus, the objective of this study was to compare the allelopathic effects of different winter wheat varieties on weed and crop germination suppression.

Procedures

We collected winter wheat residue left on the field immediately after harvest from a study evaluating 25 winter wheat varieties. The study was conducted in a randomized complete block design with four replicates in Great Bend and Hays, KS. Sharper, a broadleaf herbicide, was applied at 2 fl oz/a four days prior to harvest at Great Bend as a pre-harvest weed control strategy.

Within location, wheat residue was collected from all replicates for a given variety and combined into a homogenous sample. Samples were dried at 140°F for 48 h and ground to form a fine powder, which was steeped in deionized (DI) water for 44 hours to generate extracts with 5% concentration.

To evaluate the potential allelopathic effect of the extract of different wheat varieties' residue on crop and weed germination, seeds of two weed species and one summer crop species were placed on top of filter paper in Petri dishes. A total of 50 seeds were used for weed species Palmer amaranth (*Amaranthus palmeri*) and giant foxtail (*Setaria faberi*), and 25 seeds were used for grain sorghum (*Sorghum bicolor*). Then, we added 5 ml of each extract into petri dishes in four replicates of each of the three seed species.

For each species, the growth chamber study was established as a two-way factorial (location × variety) plus control. The control consisted of de-ionized water for baseline germination estimate. Petri dishes were sealed with Parafilm and placed in a dark growth chamber set to 84/75°F day/night temperatures. Seed germination was counted after 5 days (Figure 1). Seed germination for each treatment was calculated as percentage of control. This dataset was then subjected to two-way analysis of variance (ANOVA) using variety, location, and their interaction as fixed factors, and replication nested within location as random factor.

Results

Wheat varieties differed in allelopathic effects on weed germination, holding a potential for use as biological weed control (Tables 1 and 2).

The ANOVA evaluation of percent reduction in giant foxtail seed germination suggested that the interaction between location and variety was significant (P = 0.0007, Figure 2). There was a greater percent reduction in foxtail germination in Great Bend (72–100%) than in Hays (-10 to 69%). Wheat varieties differed in their suppression of germination, with a larger variety-induced range in germination reduction in Hays (range of ~79% from minimum to maximum control) than in Great Bend (range: 28%).

The ANOVA for Palmer amaranth seed germination relative to the control also suggested a significant interaction between location and variety ($P < 0.0001$, Figure 3). There was a greater Palmer amaranth germination reduction in Great Bend (6–96%) as compared to Hays (20–46%). Varieties differed in their germination suppression potential, with a greater range in germination reduction potential in Great Bend (range of 90% between minimum and maximum control) than in Hays (range: 26%).

Given that the overall weed suppression control was greater in Great Bend than in Hays, we believe that the pre-harvest application of Sharpen herbicide may have contributed to the greater reduction in weed seed germination measured in this location.

Regarding reduction in grain sorghum germination, the variety × location interaction was not significant, but varieties impacted grain sorghum germination ($P = 0.047$; Figure 4). We note that while grain sorghum germination was significantly reduced by the presence of wheat extract as compared to the control, this germination suppression only ranged from 2–14%, which was considerably lower than for weeds (range: 6–100%).

Preliminary Conclusions

All wheat varieties significantly reduced seed germination of Palmer amaranth and giant foxtail, but varieties differed in their germination suppression potential. The allelopathic effects of wheat varieties could be additional targets of breeding programs for reduced weed pressure. Future studies could also focus on other weed-controlling traits such as canopy architecture and light interception, residue amount, and carbon-to-nitrogen ratio.

Locations played an important role on wheat's allelopathic effects, perhaps due to pre-harvest application of Sharper herbicide. Grain sorghum germination was minimally impacted by allelopathic effects of wheat residue.

Acknowledgments

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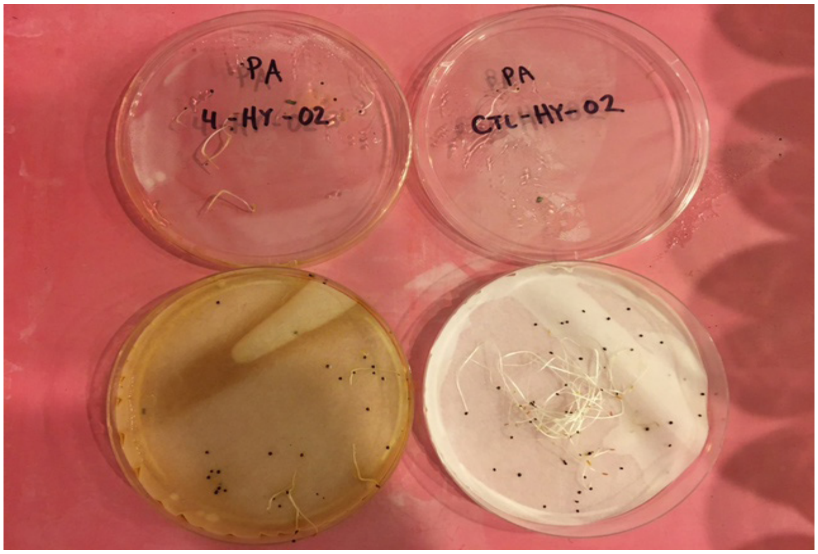
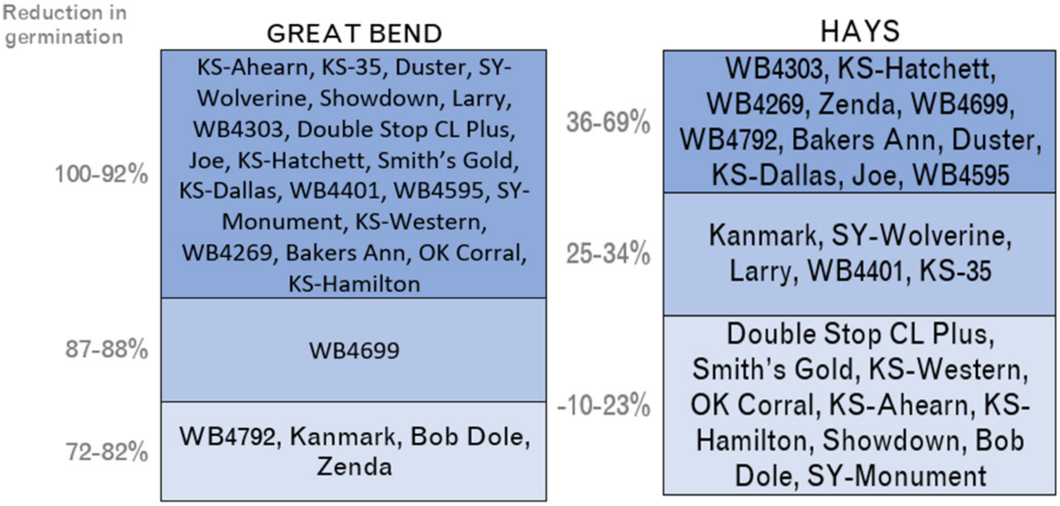


Figure 1. Palmer amaranth seed germination after 5 days for the wheat variety Duster (left) versus the de-ionized water control (right).



GREAT BEND

Reduction in germination	
100-92%	KS-Ahearn, KS-35, Duster, SY-Wolverine, Showdown, Larry, WB4303, Double Stop CL Plus, Joe, KS-Hatchett, Smith's Gold, KS-Dallas, WB4401, WB4595, SY-Monument, KS-Western, WB4269, Bakers Ann, OK Corral, KS-Hamilton
87-88%	WB4699
72-82%	WB4792, Kanmark, Bob Dole, Zenda

HAYS

Reduction in germination	
36-69%	WB4303, KS-Hatchett, WB4269, Zenda, WB4699, WB4792, Bakers Ann, Duster, KS-Dallas, Joe, WB4595
25-34%	Kanmark, SY-Wolverine, Larry, WB4401, KS-35
-10-23%	Double Stop CL Plus, Smith's Gold, KS-Western, OK Corral, KS-Ahearn, KS-Hamilton, Showdown, Bob Dole, SY-Monument

Figure 2. Percent reduction in giant foxtail seed germination relative to the control as impacted by the significant interaction between 25 winter wheat varieties and two locations (Great Bend, left; and Hays, right) following the 2022 winter wheat growing season. Wheat varieties placed within the highest or the lowest groups did not differ statistically from each other according to the Tukey's test at *P* < 0.05.

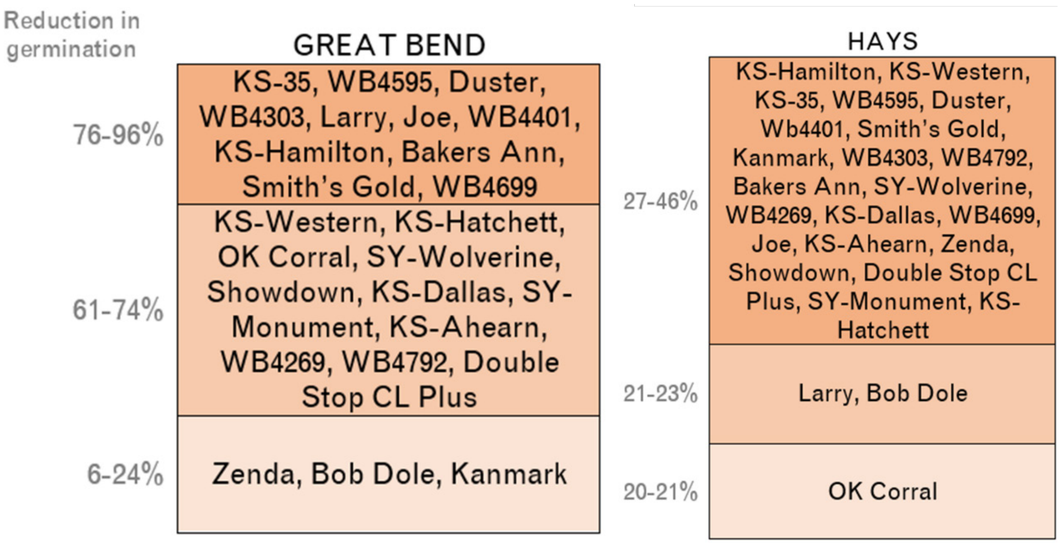


Figure 3. Percent reduction in Palmer amaranth seed germination relative to the control as impacted by the significant interaction between 25 winter wheat varieties and two locations (Great Bend, left; and Hays, right) following the 2022 winter wheat growing season. Wheat varieties placed within the highest or the lowest groups did not differ statistically from each other according to the Tukey's test at *P* < 0.05.

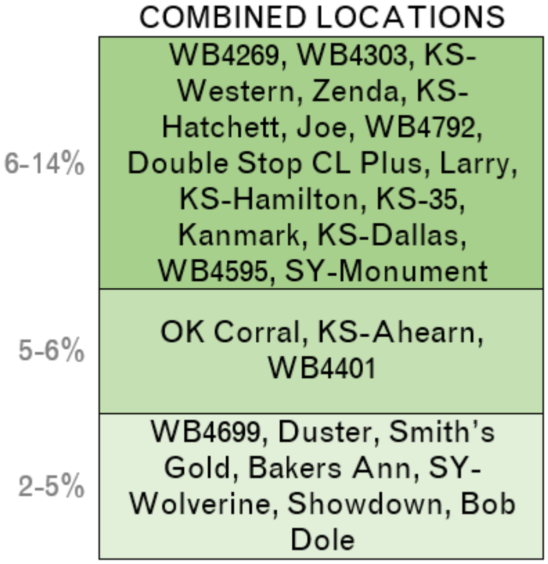


Figure 4. Percent reduction in grain sorghum seed germination relative to the control as impacted by the main effect of 25 winter wheat varieties combined across two locations (Great Bend and Hays) following the 2022 winter wheat growing season. Wheat varieties placed within the highest or the lowest groups did not differ statistically from each other according to the Tukey's test at *P* < 0.05.

Increasing Winter Wheat Grain Yield by Replicating the Management Adopted in High-Yielding Commercial Fields in Kansas during 2021–2022

L. Ryan, L. Haag, J. Holman, and R.P. Lollato

Summary

Large winter wheat (*Triticum aestivum*) yield gaps between actual yields from farmers and yield potential in the U.S. Great Plains indicate the need to improve recommendations of best management strategies to profitably bridge these gaps. Many studies have compared individual management factors pre-determined by the individual researcher, but we are not aware of studies comparing combination of practices that producers are currently using, which would be more relevant for real-world scenarios. Our objective was to determine the yield gains resulting from management intensification using the combination of practices currently adopted in commercial wheat fields. Four management intensities (i.e., low, average, high, and top) were derived from a survey of 656 commercial wheat fields, and replicated in trials conducted in six western Kansas locations (cultivated after a sorghum-fallow period) and six central Kansas locations (directly no-tilled following soybean) during the 2021–2022 growing season. Management intensities were tested factorially on two adapted varieties which differed between central and western sites. Grain yield in central Kansas ranged from 37.1 bu/a in the low management intensity to 47.3 bu/a in the top intensity, with increases in yield of 14%, 6%, and 5% from the low to average, average to high, and high to top management intensities, respectively. The variety WB4269 outyielded Zenda (44.6 and 41.3 bu/a) across central environments. In western Kansas, there was a significant management effect, where wheat yield increased from the low intensity to the high and top intensities (from 45.9 to 60.1–61.4 bu/a); though WB-Grainfield and KS Dallas varieties had similar yields. Using similar management practices as the high yielding producers in central and western Kansas increased yields from the low- or average-management intensities, while further increases in management intensification sometimes resulted in no yield increases. Variety selection played an important role to increase attained yields in central Kansas but was dependent on location in western Kansas.

Introduction

The adoption of conservative farming practices has led to large (c.a., 55% or more) hard red winter wheat (*Triticum aestivum L.*) yield gaps between actual and potential yields in Kansas and most of the U.S. central Great Plains (Jaenisch et al., 2021; Lollato et al., 2017; Patrignani et al., 2014). While part of this conservative management is justified due to harsh weather (Couëdel et al., 2021; Lollato et al., 2020a; Sciarresi et al., 2019), evidence suggests that the highest yielding growers (i.e., those that competed in state and national yield contests) were able to narrow this yield gap to less than 15% (Lollato et al., 2019a). Thus, efforts to improve management practices to narrow this yield gap profitably and effectively are warranted to sustainably increase food production.

Among the most important management practices that can potentially narrow the wheat yield gap in this region are fertilization practices (Lollato et al., 2019b, 2021) and foliar fungicides (Cruppe et al., 2017, 2021; Jaenisch et al., 2019, 2022), as quantified by de Oliveira Silva et al. (2020). We note, though, that other practices such as crop rotation and sowing date (Munaro et al., 2020; Simão et al., 2023), seeding rate (Bastos et al., 2020), fungicide and insecticide seed treatments (Pinto et al., 2019), in-furrow fertilizer (Maeoka et al., 2020), and liming (Lollato et al., 2013; 2019c) have also benefited the wheat yields in this region.

Many studies evaluating strategies to narrow the yield gap have treatments originally designed by the researcher him/herself (e.g., de Oliveira Silva et al., 2020; Jaenisch et al., 2019, 2022). While these studies can provide valuable information, they usually do not quantitatively reflect practices currently adopted by growers. To our knowledge, there are no studies where the practices (or combination of practices) tested have been quantitatively determined by practices that producers are already using in commercial fields. Still, we argue that using field experiments to replicate the different management intensities adopted in commercial wheat fields can help identify avenues to increase yields while maintaining treatment parsimony and connection to reality. Thus, our objective was to quantify the gain in wheat grain yield resulting from adopting the same management practices of those adopted by top commercial wheat growers, as compared to the average- and low-yielding fields, using Kansas as a case study.

Procedures

Two experiments were conducted in a number of locations in the state of Kansas, one representing growers in the central region and one in the western region of the state. All central Kansas locations were conducted immediately after the harvest of a previous soybean crop, and included Ashland Bottoms (Belvue silt loam), Belleville (Crete silt loam), Hutchinson (Funmar-Taver loams), Manhattan (Kahola silt loam), Great Bend (Taver loam), and Solomon (Detroit silty clay loam). Western Kansas locations were conducted following a previous sorghum crop and a fallow period after the sorghum crop, and included Belleville (Crete silt loam), Colby (Keith silt loam), Garden City (Satanta silt loam), Hays (Harney silt loam), Leoti (Richfield silt loam), and Norcatur (Holdrege silt loam). Belleville was included in both east and western studies by differing the cropping system evaluated, and this is justified as this is a transitional region. The study was set up in a two-way factorial experiment in a split-plot design with management intensity as the whole plot, and wheat variety as the sub-plot. Management intensities were based on a survey of management practices adopted in 656 wheat fields (Jaenisch et al., 2021). Fields were categorized by grain yield into low (bottom 30% yielding fields), average, high (upper 30% yielding fields), and top (upper 5% yielding fields) categories. The frequency of adoption of different management practices was quantified for each group and replicated as treatments. A listing of management practices used in each treatment is provided in Table 1. Two hard red winter wheat varieties were planted at each location, including Zenda and WB4269 in the central locations, and KS Dallas and WB-Grainfield in the western locations. Central locations were sown following harvest of a preceding soybean crop while western locations followed a period of fallow, as was regionally common according to the survey of adopted practices. We also note that these differences in fallow period (western Kansas) versus continuous cropping (central Kansas) can result in vastly different available water at wheat sowing (Lollato et al., 2016), likely decreasing yield potential in the central locations.

Treatments were established according to Table 1, either by hand spreading fertilizers or by using a CO_2-pressurized backpack sprayer for application of foliar fungicides. Plots were harvested with a Massey Ferguson 8XP small plot, self-propelled combine. Grain weight, test weight, and moisture content were measured at harvest with an on-board HarvestMaster GrainGage system. Grain yield was calculated with an adjustment to 13% moisture content. Statistical analysis was completed using RStudio v. 2022.12.0. Two-way analysis of variance was used with environments as the random effect, which detected the effects of the fixed effects variety, management, and their interaction. Means were separated at the alpha = 0.05 level.

Results

Central Kansas

The main effects of management and variety both influenced grain yield in the central Kansas experiment, however with no significant interaction. The fields with 'Low' management yielded on average 37.1 bu/a across environments and varieties (Table 2). Increasing inputs to average management increased yield by 14.3% to 42.4 bu/a. High management resulted in a grain yield of 45.1 bu/a, an increase of 6.4% compared to the average level. Further increases in inputs to the top intensity significantly increased yield by an additional 4.9% as compared to high management. Half of the central Kansas trials saw increases in yield as management intensified, while the other half did not. Great Bend, Hutchinson, and Solomon had observed yields that were statistically similar across all management intensities. The Ashland Bottoms and Belleville trials had similar effects of treatments, where the increase from low to average and from average to high input levels produced increases in grain yield. Both of these trials did not see further statistical increases in yield at the top input level but did observe numerical increases. The Manhattan location was the only site where the top intensity statistically increased yield, where there was a 10.0% increase.

Across all levels of management intensity, WB4269 produced 8.0% greater grain yield than Zenda (44.6 vs. 41.3 bu/a). WB4269 variety yielded statistically higher than Zenda in two locations (Belleville and Hutchinson) but exhibited higher numerical yields at all locations (Table 2). The differences in yield potential between these varieties may relate to their protein production potential (Lollato et al., 2020b).

Different management practices were changed simultaneously when evaluating management intensification, thus, we cannot differentiate the effect of each practice individually. However, we can discuss the potential contribution of each. For example, seeding rate may be among the most impactful for increasing grain yield in central Kansas due to the previous crop of soybean, which pushed sowing dates to the later side of the window. Higher seeding rates are needed in lower yielding environments (Bastos et al., 2020), which often occur when winter wheat is planted following the summer crop harvest to compensate for later planting dates (Lollato et al., 2019a; Staggenborg et al., 2003). Consistent with findings from Lollato et al. (2019b), optimum nitrogen rates to maximize grain yield are about 100 lb of N/a; two of the three sites that saw input-related yield increases maximized the yield when increasing nitrogen from 80 to 120 lb of N/a. Low disease levels due to dry weather make it unlikely that application of fungicide at jointing played a significant role, a practice that has been found to be dependent on cultivar and environment (Watson et al., 2020). This points to increases in fertility as the driving factor of yield increases at the top intensity level.

Western Kansas

In the western Kansas experiments, there was only a significant effect of management on grain yield. General yield trends showed no significant increases in grain yield were observed between the low and the average management intensities, which ranged from 54.9–56.7 bu/a.

As inputs were increased to the high and top levels of management, grain yield significantly increased to 60.1–61.4 bu/a. Across all locations, increasing management intensity from the High to the Top level did not further increase grain yield. When breaking down the impact of management intensity by location (Table 2), Hays was the only location that had significant effects when management intensity increased between the low and average levels, where a 16.9% increase was observed. Colby and Hays both maximized yield when increasing from average to high input intensity, while Norcatur required the additional inputs at the top level to maximize yield. The Belleville, Garden City, and Leoti locations did not have any significant differences in grain yield between treatments. None of the western locations experienced increases in yield between the high and the top management intensities.

Varieties were not statistically different at yields of 58.2 and 58.3 bu/a. Varietal effects varied by location, with both varieties being favored in different sites (Table 2). WB-Grainfield produced higher yields in Belleville and Colby, and KS Dallas had higher yields in Hays and Norcatur, while no differences were observed in Garden City and Leoti.

Although seeding rate increased between low and average management, there was no collective increase in yield, in part due to wheat being planted at the optimal timing following fallow. This was also observed by Lollato et al. (2019a) where wheat yield was unaffected by increasing the seeding rate when planted at the optimal timing. The result also aligns with the findings of Bastos et al. (2020) where wheat yield was less responsive to seeding rates at high yielding environments. The increase of management intensity to high input levels is where we see the largest overall increase of input levels with the addition of several factors, which resulted in an increase in grain yield compared with the low management. One factor was the addition of sulfur fertilizer, which is documented to increase the plant's ability to respond to nitrogen applications. Fungicide likely had little impact on grain yields this year due to the low disease presence, which has been observed to increase yield in the presence of disease pressure (Cruppe et al., 2021; Jaenisch et al., 2019; Lollato et al, 2019c).

Conclusions

In both central and western Kansas, using similar management practices as the top 30% of producers in these regions increases grain yield, but any further increase in management intensity did not consistently result in yield increases. Variety impacted grain yield in both regions, but the yields often depended on the location.

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Table 1. Combinations of management practices adopted in 656 commercial winter wheat fields based on different yield levels in the central and western environments

	Central Kansas (Sub-Humid) Previous crop: Soybean				Western Kansas (Semi-Arid) Previous crop: Fallow			
Practice	**Low**	**Average**	**High**	**Top**	**Low**	**Average**	**High**	**Top**
Yield goal (bu/a)	35	55	75	95	35	55	80	95
Seeding rate (seeds/a)	1,000,000	1,200,000	1,450,000	1,450,000	750,000	900,000	1,050,000	1,050,000
Nitrogen (lb N/a)	40	80	120	160	40	80	120	180
Phosphorus (lb P/a)	-	20	30	35	-	-	30	30
Sulfur (lb S/a)	-	10	10	20	-	-	10	20
Chloride (lb KCl/a)	-	15	15	15	-	-	-	-
Seed treatment	-	Yes	Yes	Yes	-	-	Yes	Yes
Split N application	-	-	Yes	Yes	-	-	Yes	Yes
Flag leaf fungicide	-	-	Yes	Yes	-	-	Yes	Yes
Jointing fungicide	-	-	-	Yes	-	-	-	Yes
Micronutrients	-	-	-	Yes	-	-	-	Yes

Table 2. Grain yield by management intensity, variety, and location for the central and western Kansas experiments

	Central Kansas grain yield (bu/a)						
Management intensity	**Ashland Bottoms**	**Belleville**	**Great Bend**	**Hutchinson**	**Manhattan**	**Solomon**	**Sites combined**
Low	40.0 c	54.5 c	30.5 a	30.3 a	29.6 d	37.8 a	37.1 d
Average	48.9 b	65.9 b	32.0 a	32.0 a	39.0 c	36.4 a	42.4 c
High	53.1 a	72.3 a	29.0 a	30.6 a	47.2 b	38.3 a	45.1 b
Top	55.7 a	75.3 a	31.1 a	32.7 a	51.9 a	37.3 a	47.3 a
Variety							
WB4269	49.9 a	71.6 a	32.2 a	34.1 a	42.0 a	37.8 a	44.6 a
Zenda	48.9 a	62.5 b	29.1 a	28.6 b	41.9 a	37.1 a	41.3 b

	Western Kansas grain yield (bu/a)						
Management intensity	**Belleville**	**Colby**	**Garden City**	**Hays**	**Leoti**	**Norcatur**	**Sites combined**
Low	80.5 a	38.0 b	52.4 a	48.0 c	56.5 a	54.2 b	54.9 c
Average	75.3 a	38.0 b	57.6 a	56.1 b	58.5 a	54.9 b	56.7 bc
High	76.9 a	50.0 a	51.2 a	62.4 a	60.0 a	60.2 ab	60.1 ab
Top	76.8 a	45.8 a	52.9 a	64.7 a	59.4 a	69.0 a	61.4 a
Variety							
WB Grainfield	81.2 a	45.5 a	53.4 a	55.5 b	58.6 a	55.3 b	58.2 a
KS Dallas	73.6 b	40.4 b	53.6 a	60.2 a	58.6 a	63.9 a	58.3 a

Letters denote significance at the 0.05 probability level.

Wheat Variety-Specific Response to Seeding Rate Under Intensive Management Conditions in Western Kansas in 2021–2022

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Summary

Wheat response to seeding rate is variable and depends on resource availability during the growing season (e.g., fertility, moisture, and temperature). Our objective was to evaluate winter wheat population and grain yield responses to seeding rate and its interaction with variety in a highly-managed production system where manageable stresses were limited. This study was established to evaluate the response of the wheat varieties Joe, WB-Grainfield, Langin, and LCS Revere to five seeding rates ranging from 200,000 to 1,000,000 seeds per acre. The site was managed by growers who consistently win state and national wheat yield contests near Leoti, KS. The trial was established on September 25, 2021, after a long summer fallow in sorghum residue. A total of 0.75-in. rainfall surrounding sowing ensured good stand establishment. The entire growing season was dry, limiting grain yield to the 40 to 66 bu/a range, depending on treatment. There were significant effects of seeding rate and variety on stand count, with no interaction. Main effects suggested that the stand count increased with increases in the seeding rate (from 205,795 to 658,544 plants per acre), with the 800,000 and 1,000,000 seeds/a rates attaining the highest stands. WB-Grainfield had the greatest population (522,586 plants per acre), which was statistically greater than that of Langin (412,121 plants per acre) but similar to the other two varieties with intermediate population. Final populations were closer to the target population at lower seeding rates as compared to higher seeding rates. Grain yield also depended primarily on variety and on seeding rate, with no interaction between both effects. Grain yield ranged between 56.9 and 58.2 bu/a acre for the seeding rates ranging between 600,000 and 1,000,000 seeds/a, and from 49.3 to 55.0 bu/a for lower seeding rates. Langin and WB-Grainfield were the highest yielding varieties (57.6 bu/a), and LCS Revere and Joe had the lowest yield (53.1 bu/a). These results suggest that wheat grain yield responses to seeding rate were not dependent on variety, with optimum seeding rates as low as 600,000 seeds/a. We note that increasing seeding rates beyond 600,000 seeds/a led to numerical but not statistical increases in yield.

Introduction

Wheat responses to seeding rate are inconsistent, ranging from quadratic to positive linear, quadratic-plateau, plateau-negative linear, and even inexistent (Jaenisch et al., 2019, 2022; Fischer et al., 2019; Lollato et al., 2019). The quadratic response suggests that there is an optimum population to optimize yields. In this case, populations below the optimum may limit crop yields due to sub-optimum stands, and populations above the optimum may limit crop yields due to increased disease pressure, insects, lodging, or insufficient resources such as fertility. Recently, some Kansas yield results provided evidence suggesting that wheat responses to seeding rate were dependent on the level of resource availability of the environment (Bastos et al., 2020). In high-yielding environments (greater than 90 bu/a) where the crop is not limited by resources (including fertility levels, and optimal temperatures and moisture for tillering), crop yield was unresponsive to plant population. Similar results were derived from the Kansas Wheat Yield Contest (Lollato et al., 2019) and from studies with intensively managed wheat in Kansas (Jaenisch et al., 2019) and in Mexico (Fischer et al., 2019). Meanwhile, in average (65 bu/a average) and low (45 bu/a average) yielding environments, wheat responded to increases in plant population up until about 25 to 31 plants per square foot (approximately 1.1 to 1.35 million plants per acre), leveling out at greater populations (Bastos et al., 2020). The optimum plant population might also depend on the variety's tillering potential (Bastos et al., 2020), as varieties with greater tillering potential might require less population to maximize yields when compared to varieties with lower tillering potential (Jaenisch et al., 2022).

The majority of the studies evaluating wheat yield response to seeding rate were performed under standard management conditions, not excessively high fertility levels, or other management factors (e.g., Whaley et al., 2000; Lloveras et al, 2004; Bastos et al., 2020). Thus, in this study we aimed to understand wheat response to seeding rate in a scenario with highly-available resources. This is relevant in a context in which the increases in food production are needed to feed an increasing global population, especially in regions characterized by actual yields well below the potential yields, such as in Kansas and neighboring states (Jaenisch et al., 2021; Lollato and Edwards, 2015; Lollato et al., 2017; 2019; Patrignani et al., 2014). Since resource availability and variety-specific tillering capacity seem to govern wheat yield response to plant population, our objective was to evaluate the grain yield response of different winter wheat varieties to seeding rate, including extremely low seeding rates, in a highly-managed commercial field in western Kansas.

Procedures

A field experiment was conducted during the 2021–2022 winter wheat growing season in a commercial wheat field near Leoti, KS. The research plots were sown on September 25, 2021, and comprised of seven 7.5-in. spaced rows wide and were 30-ft long. A two-way factorial treatment structure was established in a completely randomized block design and included four commercial wheat varieties (i.e., Joe, Langin, WB-Grainfield, and LCS Revere) and five seeding rates (200,000, 400,000, 600,000, 800,000, and 1,000,000 seeds/a). All seeds were treated with insecticide and fungicide seed treatment to avoid potential stand losses due to pests (Pinto et al., 2020). The experiments were sown after a long summer fallow in sorghum residue; wheat was the second crop after manure application (5 tons per acre, providing about 150 pounds of N and P). In-furrow diammonium phosphate was applied with the seed at 50 pounds of product per acre. Management of the field consisted of 40 pounds of N per acre, with 3.5 ounces per acre Rave herbicide in February, 180 pounds of N per acre as urea on March 10, and 13 ounces per acre of Nexicor fungicide at heading. Combined with the soil fertility available at sowing, all the manageable stresses were likely reduced. Harvest occurred using a Massey Ferguson XP8 small-plot, self-propelled combine on July 5, 2022.

A total of 15 individual soil cores (0- to 24-in. depth) were collected from each location and divided into 0- to 6-in. and 6- to 24-in. increments for initial fertility analysis. The individual cores were mixed to form one composite sample, which was later analyzed for base fertility levels (Table 1). In-season measurements included stand count (measured about 20–30 days after sowing) and grain yield at harvest maturity (corrected for 13% moisture content). Statistical analysis of the data collected in this experiment was performed using a two-way ANOVA in PROC GLIMMIX procedure in SAS v. 9.4. Non-linear regression analysis was used to test the grain yield response to plant population, and the residuals from this relationship were subjected to one-way ANOVA to test the effect of wheat variety.

Results

Weather Conditions

The 2021-2022 growing season was extremely dry. There was only 1.5 inches of precipitation in the fall, and the winter only received 0.4 inch, with water supply only representing 10% of crop water demand (Table 2). The spring had 4.3 inches of precipitation, which only represented 20% of crop water demand (Table 2). This water limitation restricted grain yields, which ranged from 40 to 66 bu/a. These dry conditions are typical of the study region, which is characterized by high likelihood of water and temperature stresses (Couëdel et al., 2021; Lollato et al., 2020; Sciarresi et al., 2019; Zhao et al., 2022).

Seeding Rate and Variety Effects on Stand Establishment and Grain Yield

There was a significant seeding rate effect on final stand establishment (Table 3). Overall, increases in seeding rate resulted in greater stand count, as expected. However, we note that final populations were closer to the target population at lower seeding rates as compared to higher seeding rates. For instance, the target population of 200,000 plants/a resulted in 205,795 plants per acre; while the target of 1,000,000 plants/a resulted in 658,544 plants per acre. This is usually observed in seeding rate studies (Bastos et al., 2020). There was also a variety effect on final stand establishment, where WB-Grainfield resulted in more plants per acre than Langin, but both were not statistically different than LCS Revere or Joe (Table 3).

Grain yield was affected by seeding rate and by variety independently, with no variety × seeding rate interaction, suggesting that varieties responded similarly to seeding rate (Table 3). Overall, there was a linear-plateau grain yield response to seeding rate, increasing from 49.3 bu/a in the 200,000 seeds/a rate, to anywhere from 56.9 to 58.2 bu/a in the seeding rates ranging from 600,000 to 1,000,000 seeds/a, with no significant statistical differences among the higher seeding rates. The varieties Langin and WB-Grainfield had the highest grain yield (57.6 bu/a), followed by LCS Revere and Joe (53.1 bu/a).

The overall relationship between plant population and grain yield is shown in Figure 1a. Grain yield showed a quadratic relationship as a function of plant population, with the highest yields visually observed between the populations of 550,000 and 720,000 plants per acre. Analysis of the residuals of this relationship as affected by wheat variety indicated a significant variety effect (Figure 1b). This analysis evaluates the effect of variety on grain yield when the effect of plant population is accounted for. Langin and WB-Grainfield out-yielded the expected yield for a given population by 1.4 to 3.9 bu/a, while Joe and LCS Revere were 1.7 to 2.1 bu/a below the expected yield for a given population.

Preliminary Conclusions

This trial provided information on wheat response to seeding rate within a highly managed scenario, during a dry growing season. At yield levels ranging between 40 and 66 bu/a, wheat response to seeding rate was independent of variety, and yield was maximized at 600,000 seeds per acre. The increases in yield reported for seeding rates beyond 600,000 seeds/a were not statistically significant.

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Table 1. Initial soil fertility measured at wheat sowing during the 2021–2022 growing season for the trial conducted near Leoti, KS

Depth	pH	NO_3-N	P	K	Ca	Mg	S	OM	CEC	Sand	Silt	Clay
inch	------------------------------- ppm -------------------------------							%	meq/100 g	----------- % -----------		
0 to 6	6.8	28.8	74.7	692.3	2767.9	390.3	6.8	1.7	19.01	26	46	28
6 to 18	7.4	20.9	32.7	677.3	4048.7	499.6	6.1	1.8	26.31	26	43	31

Variables include, respectively, soil pH, nitrate-N, Mehlich phosphorus, potassium, calcium, magnesium, sulfur, organic matter, cation exchange capacity, and soil texture (sand, silt, and clay percent).

Table 2. Weather conditions including average maximum (Tmax) and minimum (Tmin) air temperatures, and cumulative precipitation and reference evapotranspiration (ETo) near Leoti, KS, during the 2020–2021 growing season

Season*	Tmax	Tmin	Precipitation	ETo	WS:WD**
	°F		inch		
Fall	64.4	32.3	1.5	12.8	0.1
Winter	48.5	19.2	0.4	8.3	0.1
Spring	78.9	47.2	4.3	20.0	0.2

*Fall: September 25 to December 31. Winter: January 1 to March 31. Spring: April 1 to July 5.

**Water supply (WS) to water deficit (WD) ratio.

Table 3. Stand count and grain yield of four winter wheat varieties (WB-Grainfield, Joe, LCS Revere, and Langin) as affected by seeding rate ranging from 200,000 to 1,000,000 seeds/a

Factor	Plant population		Grain yield	
	plants/a		bu/a	
Seeding rate (seeds/a)				
200,000	205,795	b	49.3	c
400,000	387,691	b	55.0	b
600,000	503,202	b	56.9	ab
800,000	622,695	a	57.3	ab
1,000,000	658,544	a	58.2	a
Variety	522,586	a	57.5	a
WB-Grainfield				
Joe	487,535	ab	53.0	a
LCS Revere	480,099	ab	53.1	b
Langin	412,121	b	57.7	b
Test of fixed effects				
SRATE	<0.001		<0.001	
VAR	0.003		<0.001	
SRATE × VAR	0.37		0.89	

SRATE = seeding rate. VAR = variety.

*Significance of fixed effects resulting from the ANOVA as well as post-hoc mean grouping. Means followed by the same letter are not significantly different at $P = 0.05$.

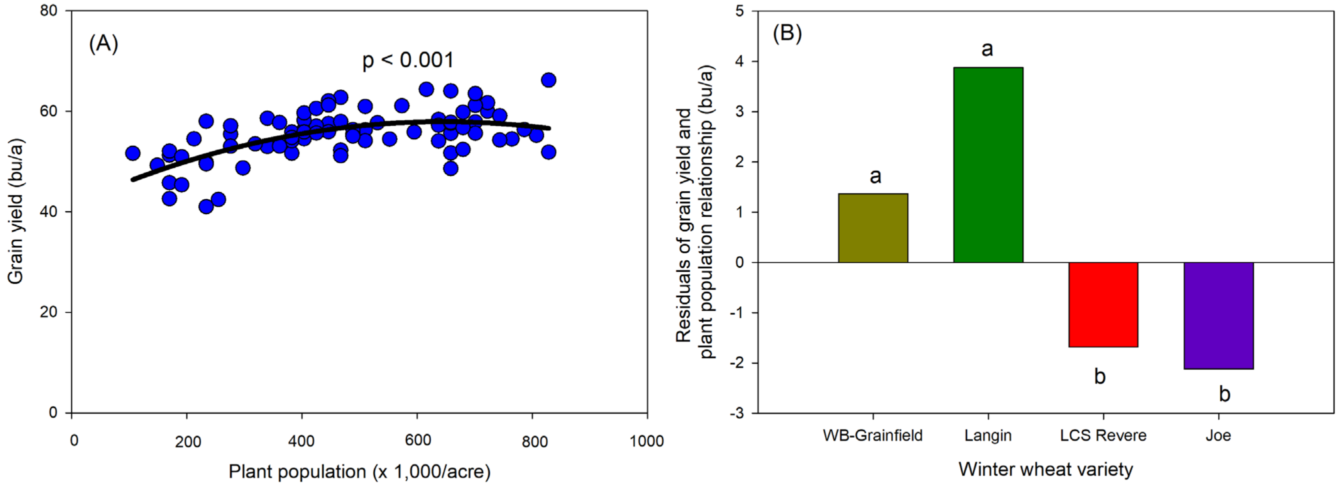

Figure 1. (A) Winter wheat grain yield as function of plant population across all varieties and seeding rates evaluated, and (B) analysis of variance of the residuals of the relationship of grain yield by plant population as affected by winter wheat variety. Data represent one location near Leoti, KS, during the 2021–2022 growing season.

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