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KANSAS STATE UNIVERSITY Agronomy

KANSAS FIELD RESEARCH 2025

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KANSAS FIELD RESEARCH 2025

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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.

2024 Weather Information

2024 weather was closer to average for the area than generally observed for many measurements but did have a longer frost-free period. Precipitation during 2024 was 2.36 inches under the average, with 4 months having rainfall over the average (Table 1). The summer of 2024 had 39 days exceeding 90°F, with one exceeding 100°F, which is average for exceeding 90°F the last 5 years. There were 11 days with low temperatures in the single digits, compared to an average of 10.4 days in the previous 5 years. The last freezing temperature in the spring was April 5 (average, April 18), and the first killing frost in the fall was October 16 (average, October 21). There were 194 frost-free days, greater than the long-term average of 185.

Drier soils and warmer temperatures until the last week of April allowed for timely corn planting, but rainfall delayed soybean and grain sorghum planting until the end of May. There was generally adequate moisture to get the crops through the growing season without too much stress. The corn and grain sorghum hybrid trials did well, averaging 184 and 126 bu/a, respectively. Soybean yields were very respectable after getting some rain in August, with the soybean variety trial averaging 54.7 bu/a.

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

Month	2024	30-year avg. 1991-2022	Month	2024	30-year avg.
	---------------- in. ----------------			---------------- in. ----------------	
January	2.14	1.22	July	3.62	3.75
February	0.95	1.57	August	3.16	4.63
March	1.39	2.29	September	3.64	4.05
April	5.82	3.79	October	0.82	3.08
May	4.39	5.82	November	4.64	2.39
June	6.45	5.55	December	0.47	1.17
			Annual total	37.49	39.85

Kansas River Valley Experiment Field

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.

2024 Weather Information
The year was generally about average with some extremes mixed in, with rainfall 4-6 inches lower for the year and below average for four and five months of the six-month growing season at Paramore (Topeka) and Rossville, respectively. The frost-free season was 176 days at Rossville and 192 days at Paramore (average = 173 days), with 9 and 13 days in the single digits or lower at Rossville and Paramore, respectively. The last spring freeze was April 21 at Rossville and April 5 at Paramore (average = April 21), and the first fall freeze was October 14 (average = October 11). There were 46 and 39 days above 90°F, and one day above 100°F at Paramore and Rossville, respectively. Precipitation was below normal at both fields for 9 and 8 months at Rossville and Paramore, respectively. Irrigation for corn started June 11, much earlier than normal, up to 7.5 inches for the corn. Irrigation for soybeans started June 14, much earlier than normal with up to 5.8 inches from mid-June through mid-September.

The corn and soybean yields were some of the best seen at KRV in spite of the lack of rain and green snap in some corn at Rossville. The corn performance trials averaged 264 bu/a for the irrigated and 239 for the dryland. The soybean performance trials averaged 79.2 bu/a for the irrigated and 63.4 bu/a for the dryland. The sudden death syndrome foliar symptoms were first seen in early-August in most fields in 2024, causing yield loss in susceptible soybeans in both the irrigated and dryland trials due to the disease. The dryland soybean yields were reduced somewhat by the lack of moisture during the grain-fill period.

Table 1. Precipitation at the Kansas River Valley Experiment Field

	Rossville Unit		Paramore Unit	
Month	**2024**	**30-year avg. 1991-2022**	**2024**	**30-year avg. 1991-2022**
	-------------------- in. --------------------		-------------------- in. --------------------	
January	2.08	0.74	2.10	0.89
February	1.03	1.18	0.89	1.31
March	0.83	2.08	0.94	2.25
April	3.30	3.48	4.09	3.81
May	2.66	5.06	4.34	5.17
June	4.47	5.11	4.14	4.92
July	5.44	4.32	6.42	3.99
August	2.57	4.60	2.02	4.55
September	0.85	3.75	0.87	3.52
October	2.11	2.71	1.26	2.85
November	4.48	1.67	4.90	1.78
December	0.39	1.37	0.37	1.49
Total	30.21	36.07	32.34	36.53

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

Patrick W. Geier and Sarah H. Lancaster

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

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

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

Results and Discussion

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

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

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

Acknowledgments

Funding for this research was provided by Syngenta.

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

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

[1] PRE is preemergence, POST is postemergence.

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

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

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

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

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

continued

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

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

[1] PRE is preemergence, POST is postemergence.

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

Maverick Rates and Application Timings for Weed Control in Kansas Corn

Patrick W. Geier and Sarah H. Lancaster

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

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

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

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

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

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

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

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

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

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

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

continued

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

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

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

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

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

continued

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

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

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

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

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

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

Surtain Herbicide Programs for Weed Management in Corn

Patrick W. Geier and Sarah H. Lancaster

Summary

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

Introduction

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

Experimental Procedures

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

October 17, 2024, at Garden City by mechanically harvesting the center two rows of each plot and adjusting grain moistures to 15.5%.

Results and Discussion

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

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

Acknowledgments

Funding for this research was provided by BASF Corporation.

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

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

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

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

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

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

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

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

Intrava DX Tank Mixtures for Weed Control in Corn

Patrick W. Geier and Sarah H. Lancaster

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

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

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

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

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

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

Acknowledgments
Funding for this research was provided by UPL Limited.

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

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

[1] PRE is preemergence, POST is postemergence.

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

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

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

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

			AMAPA[3]		KCHSC[3]		AMAPA	KCHSC	SASKR[3]	SORHA[3]
Treatment[1]	Rate	Timing[2]	28 DA[4]	45 DB[4]	28 DA	45 DB	29 DA			
	oz/a		% visual				No./meter²			
Untreated	---	---	---	---	---	---	47	16	3	12
Intrava DX	21	PRE	100	94	96	96	1	1	0	1
Moccasin II Plus	21	PRE								
Glyphosate	36	PRE								
NIS	0.25%	PRE								
InterMoc	64	POST								
AMS	3.0 lb	POST								
Intrava DX	16	PRE	98	88	99	91	0	0	0	1
Motif	4.5	PRE								
Glyphosate	36	PRE								
NIS	0.25%	PRE								
InterMoc	64	POST								
AMS	3.0 lb	POST								
Intrava DX	16	PRE	100	95	100	100	0	0	0	0
Coyote	77	PRE								
Glyphosate	36	PRE								
NIS	0.25%	PRE								
InterMoc	64	POST								
AMS	3.0 lb	POST								
Acuron	48	PRE	93	90	100	100	2	0	0	1
Acuron	32	POST								
Liberty 280	32	POST								
AMS	3.0 lb	POST								
LSD (0.05)			2	6	3	3	13	2	2	6

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

Effect of Corn Row Spacing on Herbicide Effectiveness for Weed Control

Sarah Lancaster, Eric Adee, and Igor G. R. Lima

Summary

Cultural weed control practices, such as narrow row spacing, can be an essential component of successful weed management. In 2022 and 2023, experiments were conducted in the Kansas River Valley to evaluate the 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 in either year. However, at a site with a greater density of Palmer amaranth, Resicore + Acuron resulted in the greatest weed control, in either 15- or 30-inch row spacing. Degree + Callisto applied in 30-inch rows provided the best performance in both locations.

Introduction

The increased prevalence of herbicide-resistant weed populations has led to the need for more complex herbicide mixtures and multiple herbicide application periods throughout the year. Herbicide resistance has also led to the need for non-chemical means of weed control. Understanding how cultural or mechanical weed management practices and herbicides interact is important for maximizing weed control.

Light interception can be an effective practice to reduce competition, especially by reducing weed seed germination. Narrow row spacing has been shown to be an effective way to help control weeds in crops such as wheat and soybeans. However, little work has been done to evaluate the influence of corn row spacing on weed control. Unlike wheat or soybeans, which can be planted in rows as narrow as 7 inches, corn is limited in terms of row spacing by the harvesting equipment available. Currently, harvesting equipment for 15-inch rows is the narrowest available for corn. In addition, seeding rates for wheat and soybeans are much higher than for corn, as the wheat and soybeans can adjust to the seeding rate. Increasing the seeding rates of wheat or soybeans in narrower rows can promote earlier canopy development. Corn normally has a narrow range of seeding rates for specific environments due to plant architecture and seed cost; therefore, significant increases in maize seeding rates are not feasible.

The objective of this project was to evaluate weed control and corn yield response to commonly used herbicide programs applied to corn planted in 15- or 30-inch rows.

Experimental Procedures

Two studies were established under dryland (Topeka) or irrigated (Rossville) crop production in Shawnee County, KS, in 2023. 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 inches) and five herbicide programs plus a nontreated control (Table 1). Plots were 10 by 30 feet (7 by 15-inch rows, 4 by 30-inch rows). The field at Topeka, KS, was Eudora-Kimo complex soil, which had the soybean stubble inline subsoiled in the fall, then the field was cultivated prior to planting Pioneer 1413 AM corn at 28,000 seeds per acre. Rossville was Eudora silt loam that had the soybean stubble subsoiled in the fall and was vertical tilled before planting Pioneer 1572 AM at 33,000 seeds per acre. Both studies were planted with a Kinze 3000 planter on April 24, and the herbicides at planting were applied on April 25. 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. Just under 17 and 14 inches of rain were received at Topeka and Rossville, respectively, from April through August. The irrigated field received an extra 6.1 inches of water from June through August. Weed control was visually estimated throughout the summer until September 12. 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 13 and 15 (dryland and irrigated, respectively). Yields were converted to bushels per acre at 15.5% grain moisture.

Data were subjected to analysis of variance using a mixed effects model with row spacing, herbicide, and site-year as fixed effects and replication within site-year as a random effect. When appropriate, means were separated using Tukey's Honestly Significant Difference ($\alpha = 0.10$). In addition, yield response was assessed using preplanned orthogonal contrasts.

Results and Discussion

Weed control

Weed control 5 WAP (weeks after planting) in Rossville during 2022 was similar for all treatments and ranged from 24 to 68% (Figure 1). However, at harvest, Palmer amaranth control in 15-inch rows was 67% compared to 50% in 30-inch rows (Figure 2). During 2023, weed control 5 WAP differed among herbicide treatments included in the study. Control by Degree Xtra plus Callisto was greatest at 94% and was statistically comparable to all treatments except Harness Xtra and Bicep, which had 74% and 26% control, respectively (Figure 3). By 8 WAP, there was an interaction of herbicide and row spacing, with control ranging from 99% for Degree Xtra plus Callisto in 15-inch rows to 76% for Bicep in 30-inch rows (Figure 4 and 5). Weed control was not evaluated at harvest during 2023.

In Topeka during 2022, all treatments resulted in 100% weed control 5 WAP (Figure 6). Similarly, weed control at harvest (Figure 7) was statistically similar by all treatments, but ranged from 98% (Harness Xtra, 30-inch) to 65% (Bicep, 15-inch). At 5 WAP in 2023, weed control was affected by the interaction of herbicide and row spacing (Figure 8). Weed control in all treatments was 97% or greater, except Harness Xtra in 15-inch rows, which was 63%. By 8 WAP, there were no statistical differences among any treatments (Figure 9), with control ranging from 70% by Bicep in 15-inch rows to 99% for DegreeXtra plus Callisto in 15-inch rows, HarnessXtra in 15-inch rows, Acuron plus Resicore in 30-inch rows, Bicep plus Callisto in 30-inch rows, and DegreeXtra plus Callisto in 30-inch rows.

Weed populations at Topeka were less dense and more variable than populations at Rossville, which resulted in fewer statistical differences being detected. At Topeka, 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. At Rossville, the dominant weed species was Palmer amaranth.

Yield

During 2022, yields were similar between locations, despite the availability of irrigation at Rossville. This suggests that the Palmer amaranth infestation at Rossville may have resulted in yield loss that could not be overcome by irrigation. Yields were statistically similar across all herbicide treatments and both row spacings (Figures 10 and 12). The greatest yield was obtained in plots treated with DegreeXtra plus Callisto, which yielded 199 bushels per acre, and the lowest yield was 175 bushels per acre in the Bicep plus Callisto treatment. During 2023, yield was similar at both locations and was not influenced by herbicide or row spacing (Figures 11 and 13). The greatest yield of 203 bushels per acre was observed in the DegreeXtra plus Callisto treatment at Rossville. This yield was similar to the same treatment at Topeka, Acuron plus Resicore at Rossville and Topeka, Bicep plus Callisto at Rossville and Topeka, Harness Xtra plus Callisto at Rossville, and Bicep at Rossville. The lowest yield of 115 bushels per acre was from the nontreated check at Rossville.

Conclusion

In conclusion, this study investigated the interplay between herbicide programs, corn row spacings, weed control, and grain yield. While Resicore + Acuron consistently provided effective weed control, corn row spacing did not significantly influence weed management outcomes. However, site-specific factors such as weed species composition and density significantly impacted weed control efficacy. Notably, Palmer amaranth infestations required distinct management strategies compared to sites with lower weed densities. Additionally, herbicides applied at lower weed densities inadvertently affected corn yields due to plant injury. Certain herbicide treatments, particularly DegreeXtra plus Callisto, consistently produced higher corn yields across both years and locations, underscoring the importance of tailored weed management approaches for agricultural productivity.

Table 1. Herbicides and rates applied to corn planted in 15- and 30-inch rows at Rossville and Topeka, KS on April 25, 2023.

Treatment	Herbicides	Active Ingredients	Rate/a	Cost ($/unit)
1	Bicep II Magnum	atrazine + *S*-metolochlor	2.1 qt	48.10/gal
	Callisto	mesotrione	6 fl oz	2.50/fl oz
2	Degree Xtra	acetochlor	3 qt	51.10/gal
	Aatrex	atrazine	0.5 qt	60.00/gal
	Callisto	mesotrione	6 fl oz	2.50/fl oz
3	Harness Xtra	acetochlor	1.9 qt	57.35/gal
	Aatrex	atrazine	0.7 qt	60.00/gal
4	Acuron	*S*-metolachlor + atrazine + mesotrione + bicyclopyrone	1.5 pt	79.65/gal
	Bicep II Magnum	*S*-metolachlor + atrazine	1 pt	48.10/gal
5	Resicore	acetochlor + clopyralid + mesotrione	1.5 qt	72.65/gal
	Aatrex	atrazine	1 pt	60.00/gal

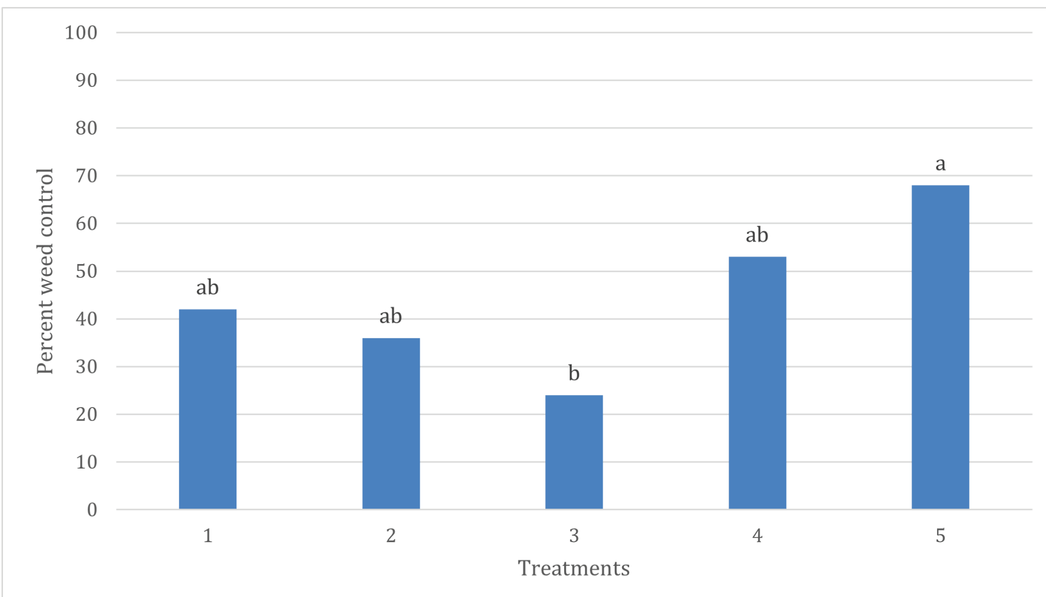

Figure 1. Weed control 5 weeks after corn planting at Rossville in 2022. Bars with similar letters are similar ($\alpha = 0.1$). Treatments correspond with information presented in Table 1.

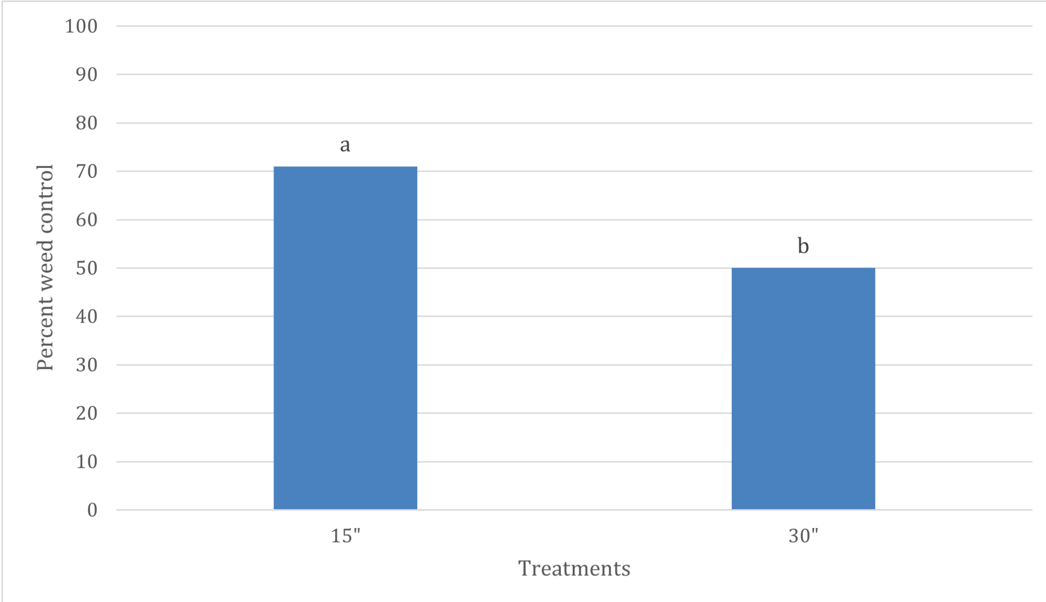

Figure 2. Weed control at corn harvest in Rossville in 2022. Bars with similar letters are similar ($\alpha = 0.1$).

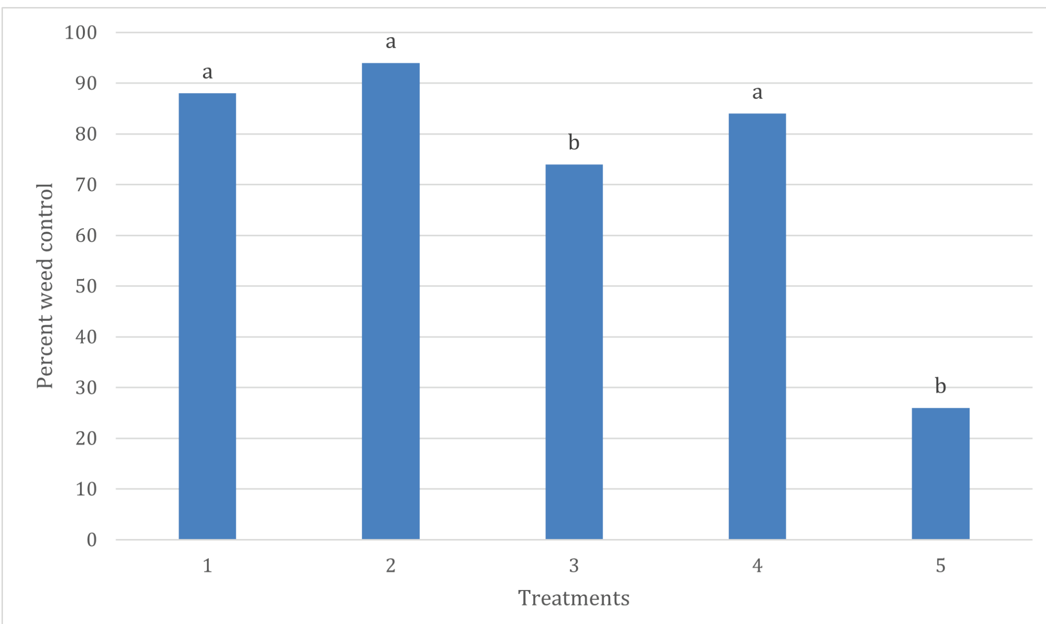

Figure 3. Weed control 5 weeks after corn planting at Rossville in 2023. Bars with similar letters are similar ($\alpha = 0.1$). Treatments correspond with information presented in Table 1.

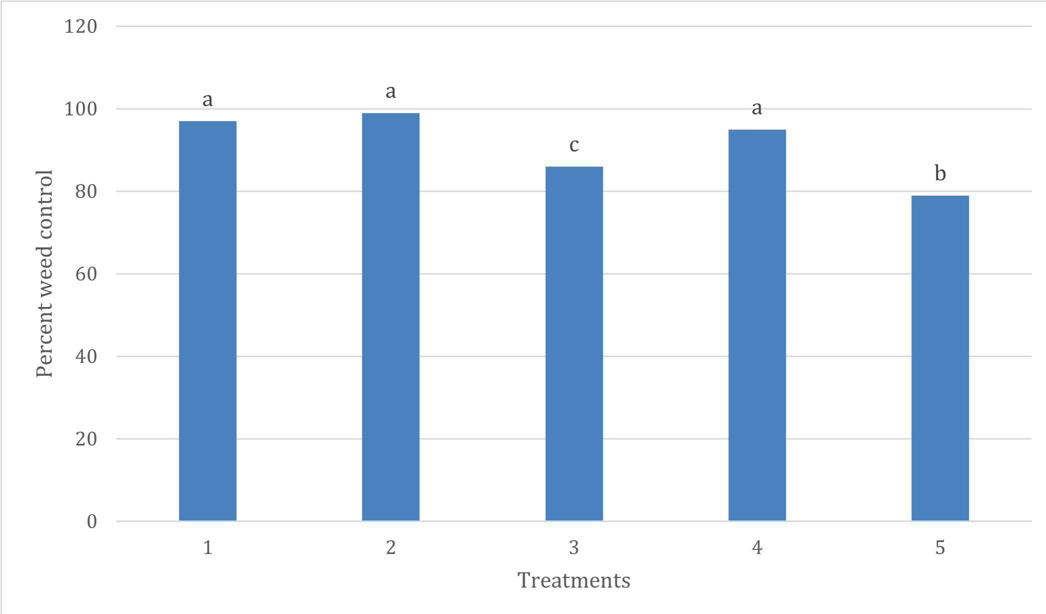

Figure 4. Weed control at corn harvest in Rossville during 2023. Bars with similar letters are similar ($\alpha = 0.1$). Treatments correspond with information presented in Table 1.

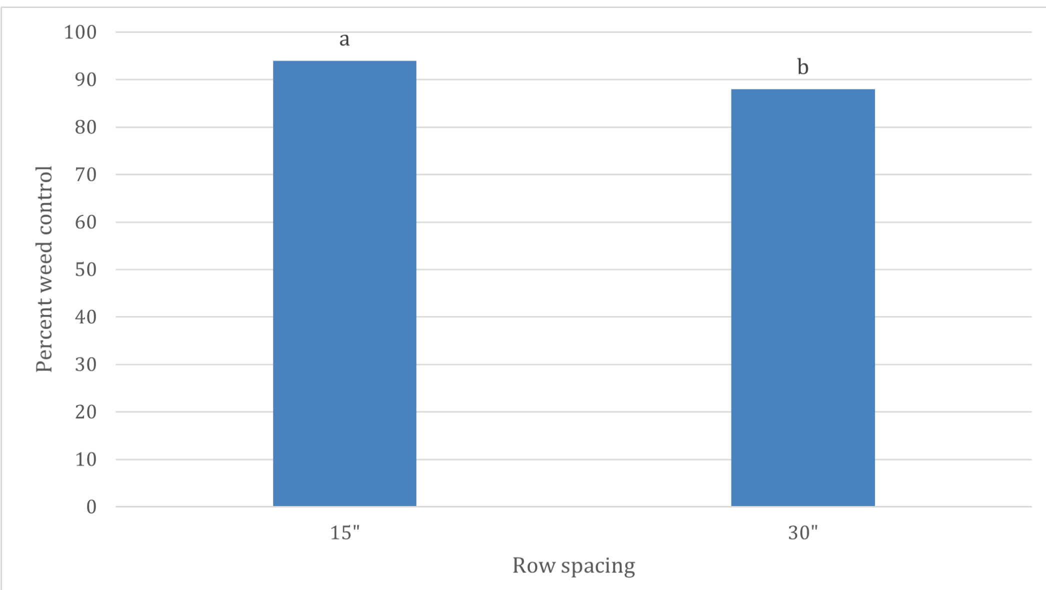

Figure 5. Weed control at corn harvest in Rossville during 2023. Bars with similar letters are similar ($\alpha = 0.1$).

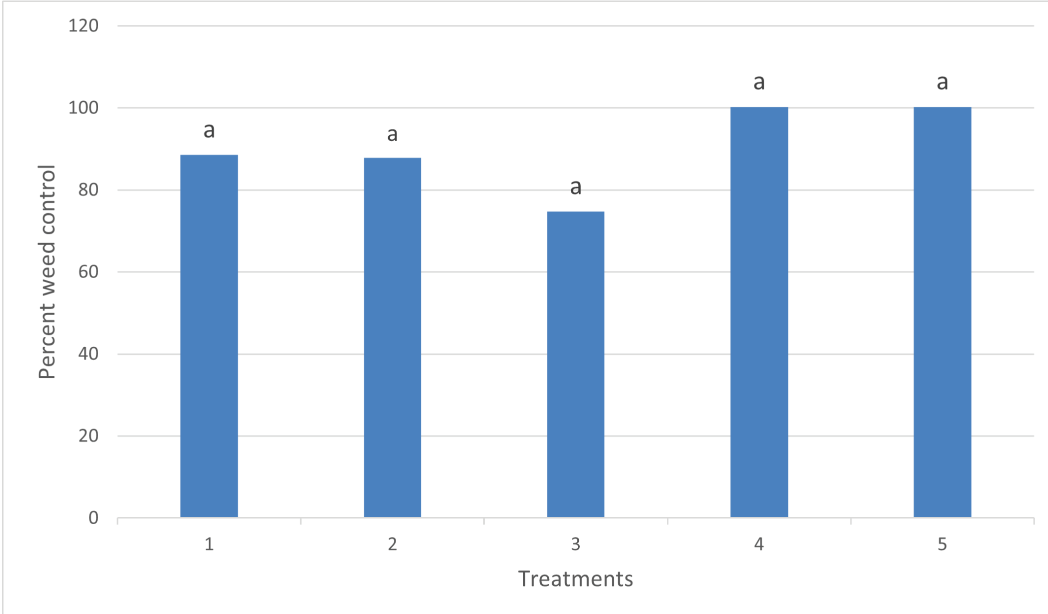

Figure 6. Weed control five weeks after corn planting at Topeka in 2022. Bars with similar letters are similar ($\alpha = 0.1$). Treatments correspond with information presented in Table 1.

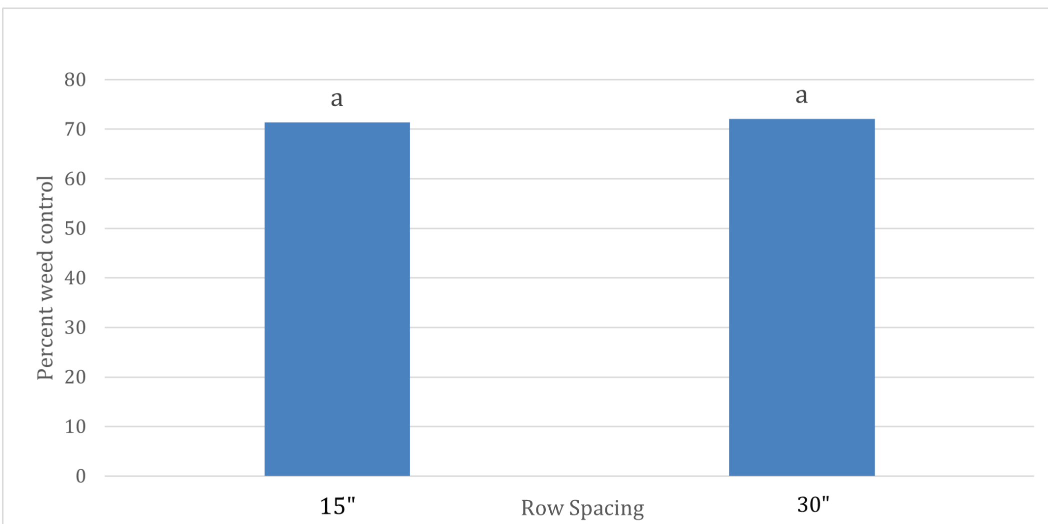

Figure 7. Weed control at corn harvest in Topeka during 2022. Bars with similar letters are similar ($\alpha = 0.1$).

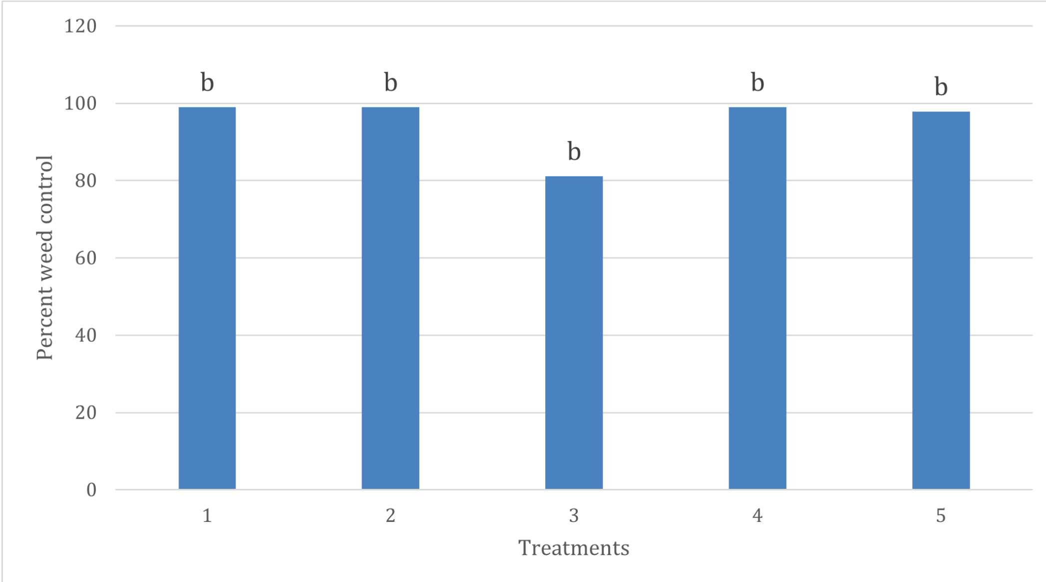

Figure 8. Weed control five weeks after corn planting at Topeka in 2023. Bars with similar letters are similar ($\alpha = 0.1$). Treatments correspond with information presented in Table 1.

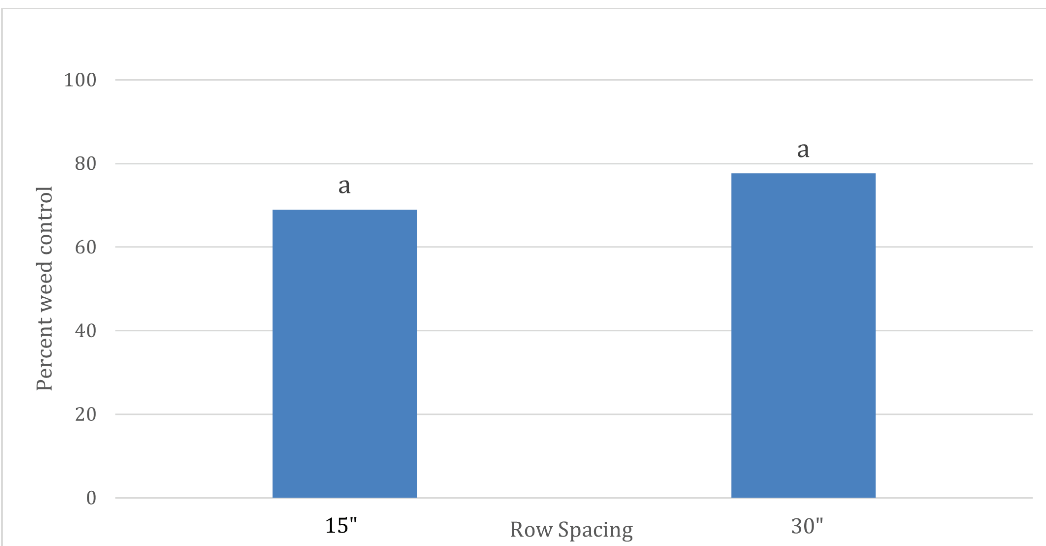

Figure 9. Weed control at corn harvest in Topeka during 2023. Bars with similar letters are similar ($\alpha = 0.1$).

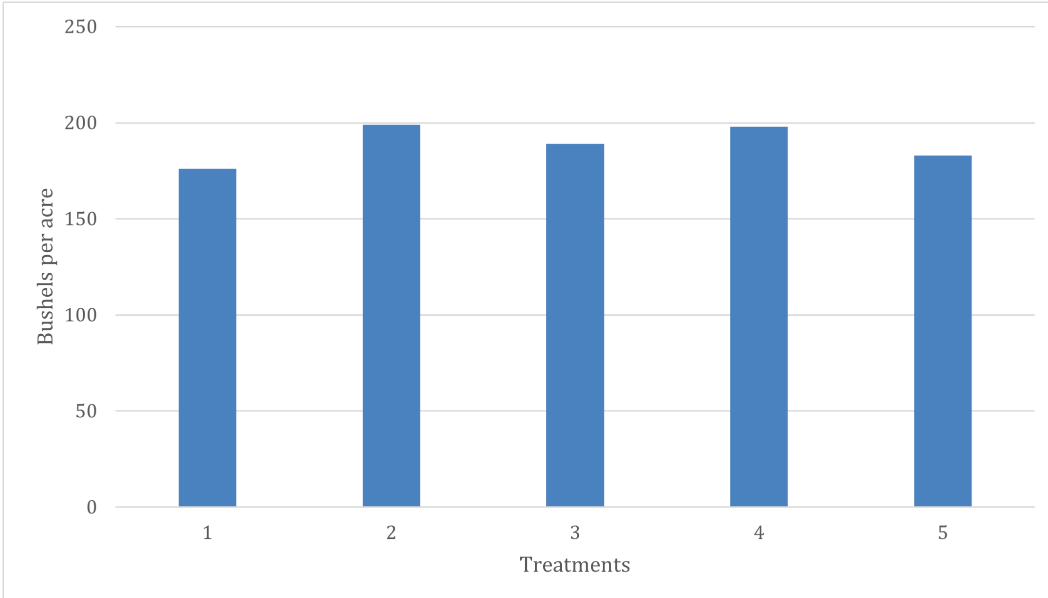

Figure 10. Corn grain yield (adjusted to 15.5% moisture) at Rossville in 2022. No statistical differences were observed among herbicides or row spacings. Treatments correspond with information presented in Table 1.

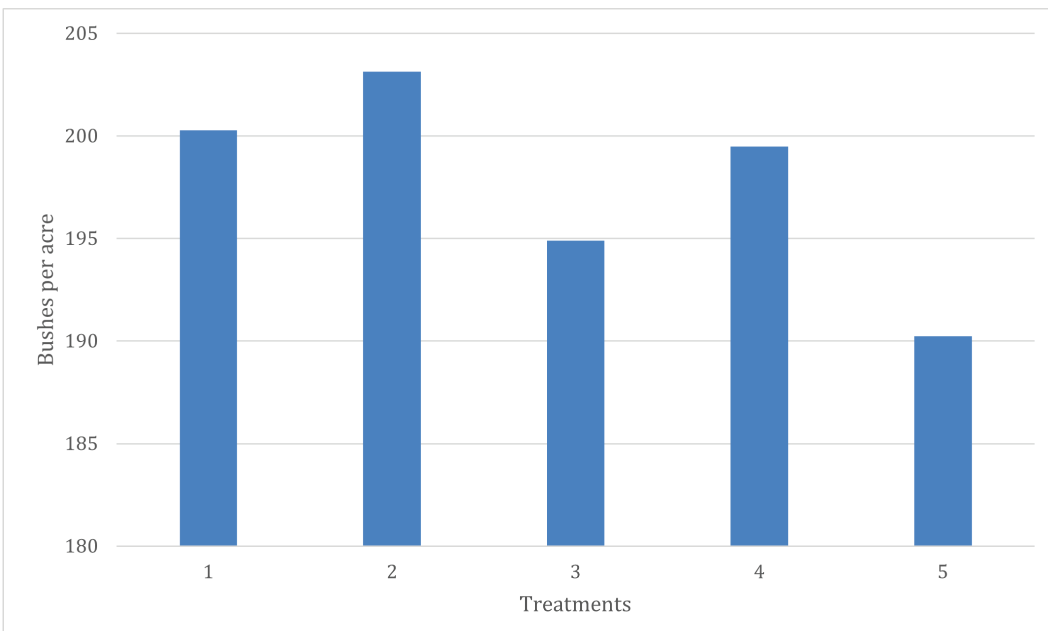

Figure 11. Corn grain yield (adjusted to 15.5% moisture) at Rossville in 2023. No statistical differences were observed among herbicides and row spacings. Treatments correspond with information presented in Table 1.

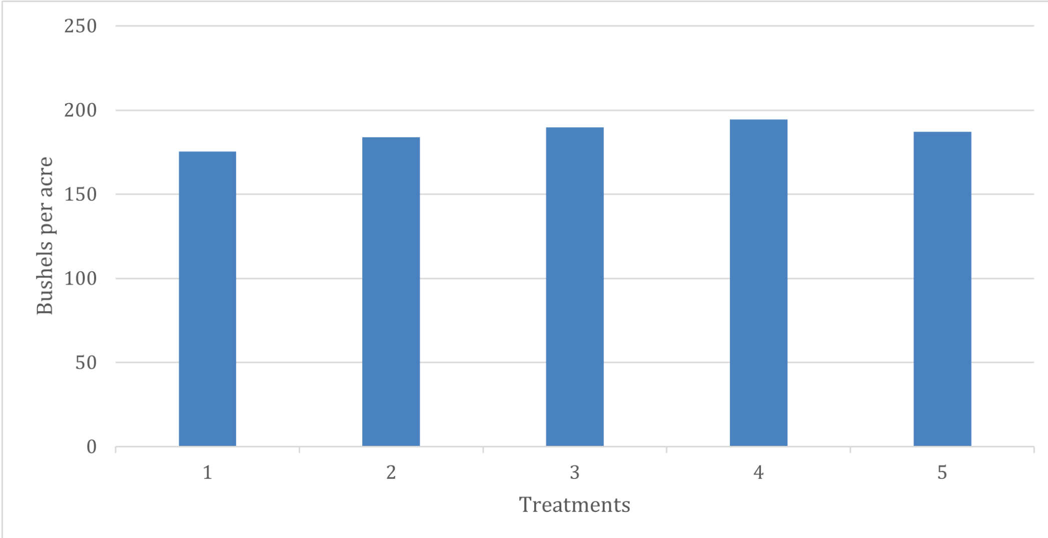

Figure 12. Corn grain yield (adjusted to 15.5% moisture) at Topeka in 2022. No statistical differences were observed among herbicides and row spacings. Treatments correspond with information presented in Table 1.

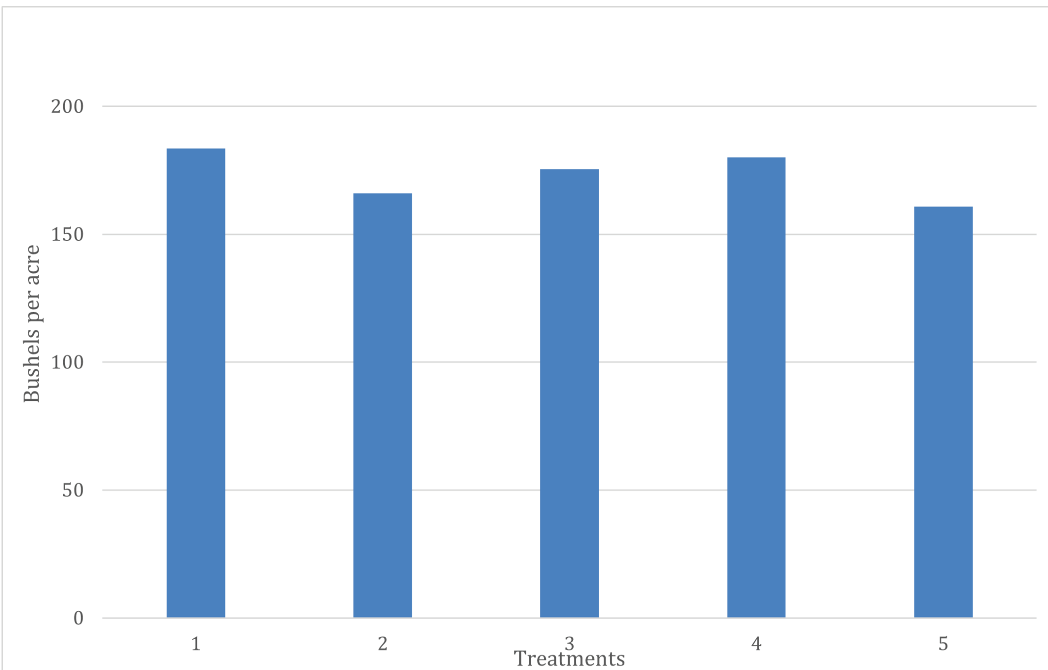

Figure 13. Corn grain yield (adjusted to 15.5% moisture) at Topeka in 2023. No statistical differences were observed among herbicides and row spacings. Treatments correspond with information presented in Table 1.

Macronutrient Fertility on Irrigated Corn/ Soybean in Rotation

E. A. Adee

Summary

Effects of nitrogen (N), phosphorus (P), and potassium (K) fertilization on a corn/soybean cropping sequence were evaluated from 2015 to 2023 (corn planted in odd years) from a study initiated in 1983. Corn yields responded most to N, followed by P fertilization, and soybean yields were most influenced by P fertilization. The highest return on fertilizer investment averaged over both crops was when N, P, and K were more closely meeting the needs of the crops.

Introduction

A study was initiated in 1972 at the Topeka Unit of the Kansas River Valley Experiment Field to evaluate the effects of N, P, and K on furrow-irrigated soybeans. In 1983, the study was changed to a corn/soybean rotation with corn planted and fertilizer treatments applied in odd years, and in 2000, sprinkler irrigation was initiated. The study objectives were to evaluate the effects of N, P, and K applications to a corn crop on grain yield of corn, yield of the following soybean crop, and soil test values.

Procedures

The initial soil test in March 1972 on this silt loam soil was 47 lb/a available P and 312 lb/a exchangeable K in the top 6 inches of the soil profile. All fertilizer treatments were applied pre-plant before corn planting and incorporated. Nitrogen rates included a factorial arrangement of 0, 120, and 160 lb/a of N (with single treatments of 80 and 200 lb/a N). Three rates of P were 0, 30 and 60 lb/a of P_2O_5, and K treatments were 0 and 150 lb/a of K_2O.

Planting dates averaged April 21 for corn for the last five corn crops and May 16 for soybeans for the last three soybean crops, with herbicides applied preplant and postemergence herbicides each year. Plots were sprinkler-irrigated with a linear move irrigation system. A plot combine was used for harvesting grain yields from the middle two rows of 15 (6 rows) by 30-foot plots.

As the yield potential of hybrids and varieties improve over years, the fertility needs for the crops increase. For this reason, yield data from both crops for the last several rotation sequences are presented here to give a picture of the current yield level. Prior to 2020, the soybean varieties were susceptible to Sudden Death Syndrome (SDS), therefore, were not included in this analysis with the yield data of SDS tolerant varieties with seed treatment for control of SDS.

The income from fertilizer was calculated for each treatment in a crop rotation sequence. Average yields of corn and soybeans were multiplied by current grain price (January 2025) at $4.65 for corn and $10.07 for soybeans. Fertilizer cost was calculated using the following prices, N at $0.445/lb, phosphorus (P_2O_5) at $0.611/lb, and potassium chloride (KCl) at $0.375/lb. The fertilizer cost of each treatment was subtracted from the gross income of a rotation of corn and soybeans since the fertilizer was applied only before corn. For additional comparison of fertilizer treatments, the gross income of the check plot with no fertilizer was subtracted from each treatment in each replication for each year.

Results

Average yield response of corn and soybean yields from 2015 to 2023 and 2020 to 2024, respectively, to the fertilizer treatments applied prior to corn planting are shown in Table 1. There were differences between the treatments for both crops. The factorial analysis at the bottom of the table helps sort out each crop's response to each nutrient.

All three macro-nutrients increased corn yield, with corn responding most to N and P (Table 1). Nitrogen rate had the greatest influence on corn yield, as also demonstrated in Figure 1, especially to the first 120 lbs of N. The yield response curve begins to flatten as the N rate increases above 120 lbs. When P and K were more adequate, the optimum N rate would probably be over 160 lbs. This study will be modified for the 2025 season and beyond to have five N rates with 60 lbs of P and 150 lbs of K, which this study has shown would more closely meet the needs of the higher-yielding crops.

Similarly, the first 30 lbs of P_2O_5 resulted in the greatest yield increase (26 bu/a) for corn, and continued to increase (14 bu/a) with an additional 30 lbs of P_2O_5 (Table 1). The addition of 150 lbs of KCl increased the corn yield by 3.3 bu/a.

Soybean yields showed a significant response to the P left over after the corn, with a 14 bu/a increase for the first 30 lbs of P_2O_5, with an additional increase of 10.3 bu/acre at the 60 lb rate. Across all N and P rates, average yield increased by 2.8 bu/a of soybeans with the application of 150 lb of K_2O. There was a 4.7 bu/a increase in soybeans following the N applied to corn.

The highest return on fertilizer investment over a corn/soybean rotation was with the 160-60-150 treatment (Table 1). The treatments that had more balanced fertility that more closely met the needs of the crops had the highest incomes (Table 1).

As corn yields increased with higher N rates, more P and K were removed from the soil, as shown by the soil test data (Table 2). As a result, corn showed a greater increase in yield with N when the P and K were closer to meeting the crop's needs. (Figure 1, Table 2).

The soil P ppm has been dropping from the initial sampling when the study began as a corn/soybean rotation in 1983, with a study average of 55 ppm then compared to 44 ppm in 2022 with 60 lb/a P_2O_5 and 16 ppm with 30 lb/a P_2O_5, averaged across N and K rates. Soil K ppm has dropped from 320 to 307 K ppm, averaged across N and P rates, for the same time period.

The P and K removed by both crops in a corn/soybean rotation averaging 225 bu/acre corn and 72 bu/acre soybeans would be 132 and 158 lbs/acre, respectively.

Summary

As well documented for years, the data from a long-term study showed that N is the most critical fertilizer for corn. Phosphorus follows closely behind as a critical fertilizer for both crops. However, the addition of K allowed for corn yield to respond more as N rates increased. The best return for fertilizer investment is a balanced program that meets the needs of both crops in the rotation, and over the long term helps maintain or build fertility levels as needed.

Table 1. Average yield response of corn and soybean yields from 2015 to 2023 and 2020 to 2024, respectively, to the fertilizer treatments applied prior to corn planting.

Fertilizer[1]			Corn yield		Soybean yield		2 year Income return over	2 Year net income over
N	P_2O_5[2]	K_2O	2015-2023		2020-2024		fertilizer cost[4]	check (0-0-0)
------------ lb/a ------------			---------- bu/a ----------				---------- $/acre ----------	
0	0	0	95.8	h[3]	38.9	i	838	0
0	0	150	97.6	h	43.7	hi	838	0
0	30	0	120.6	f	58.5	ef	1132	294
0	30	150	101.2	gh	58.9	ef	989	151
0	60	0	112.0	fg	69.2	ab	1181	343
0	60	150	114.0	fg	74.5	a	1187	350
120	0	0	157.1	e	50.6	ed	1186	348
120	0	150	165.5	de	53.1	gh	1195	357
120	30	0	181.7	c	59.2	def	1369	531
120	30	150	201.2	b	66.9	bc	1481	643
120	60	0	204.9	b	69.2	ab	1559	722
120	60	150	206.7	b	71.5	a	1535	697
160	0	0	170.8	cde	47.5	gh	1202	364
160	0	150	168.5	cde	48.3	gh	1142	304
160	30	0	202.5	b	60.9	cde	1465	628
160	30	150	206.0	b	61.4	cde	1430	593
160	60	0	209.7	b	71.0	ab	1583	745
160	60	150	223.8	a	72.1	ab	1603	765
80	30	150	175.3	cd	58.0	ef	1289	451
200	30	150	209.3	b	65.6	bcd	1470	632
Prob>F			<0.0001		<0.0001			

continued

Table 1. Average yield response of corn and soybean yields from 2015 to 2023 and 2020 to 2024, respectively, to the fertilizer treatments applied prior to corn planting.

Fertilizer[1]			Corn yield	Soybean yield	2 year Income return over	2 Year net income over
N	P_2O_5[2]	K_2O	2015-2023	2020-2024	fertilizer cost [4]	check (0-0-0)
------------ lb/a ------------			----------------- bu/a ----------------		---------------- $/acre ----------------	
Nitrogen means						
0			106.9 c	57.3 b		
120			186.2 b	61.7 a		
160			196.9 a	60.2 a		
Prob>F			<0.0001	0.008		
Phosphorus means						
	0		142.6 c	47.0 c		
	30		168.9 b	60.9 b		
	60		178.5 a	71.2 a		
Prob>F			<0.0001	<0.0001		
Potassium means						
		0	161.7	58.3 b		
		150	165.0	61.1 a		
Prob>F			0.17	0.02		

[1] Fertilizer applied to corn in odd years from 1983 to 2023.
[2] P treatments not applied in 1997. Starter fertilizer of 10 gal/a of 10-34-0 was applied to all treatments in 1997 and 1998 (corn and soybean). N and K treatments were applied to corn in 1997.
[3] Numbers followed by different letters are different at Prob. = 0.05.
[4] 2 year income calculated using corn at $4.65, soybeans at $10.07, N at $0.445/lb, P_2O_5 at $0.611/lb, KCl at $0.375/lb.

Table 2. Interaction of nitrogen, phosphorous and potassium fertilizer applied before corn in a corn-soybean rotation on soil fertility, corn and soybean yield at Kansas River Valley Experiment Field-Topeka.[1]

Nutrient			2022 soil test		2015-2023 corn yield average	2020-2024 soybean yield average
N	P_2O_5	K_2O	P ppm	K ppm		
lb/a			0-6 inch depth		bu/a	
0	0	0	12	193	95.8	38.9
0	0	150	12	330	97.6	43.7
0	30	0	22	187	120.6	58.5
0	30	150	22	300	101.2	58.9
0	60	0	55	178	112.0	69.2
0	60	150	58	306	114.0	74.5
120	0	0	5	176	157.1	50.6
120	0	150	7	310	165.5	53.1
120	30	0	18	169	181.7	59.2
120	30	150	12	296	201.2	66.9
120	60	0	39	170	204.9	69.2
120	60	150	49	297	206.7	71.5
160	0	0	5	191	170.8	47.5
160	0	150	5	331	168.5	48.3
160	30	0	12	158	202.5	60.9
160	30	150	9	304	206.0	61.4
160	60	0	34	160	209.7	71.0
160	60	150	32	289	223.8	72.1
80	30	150	12	309	175.3	58.0
200	30	150	9	294	209.3	65.6

[1] Fertilizer applied to corn in odd years from 1983 to 2023.

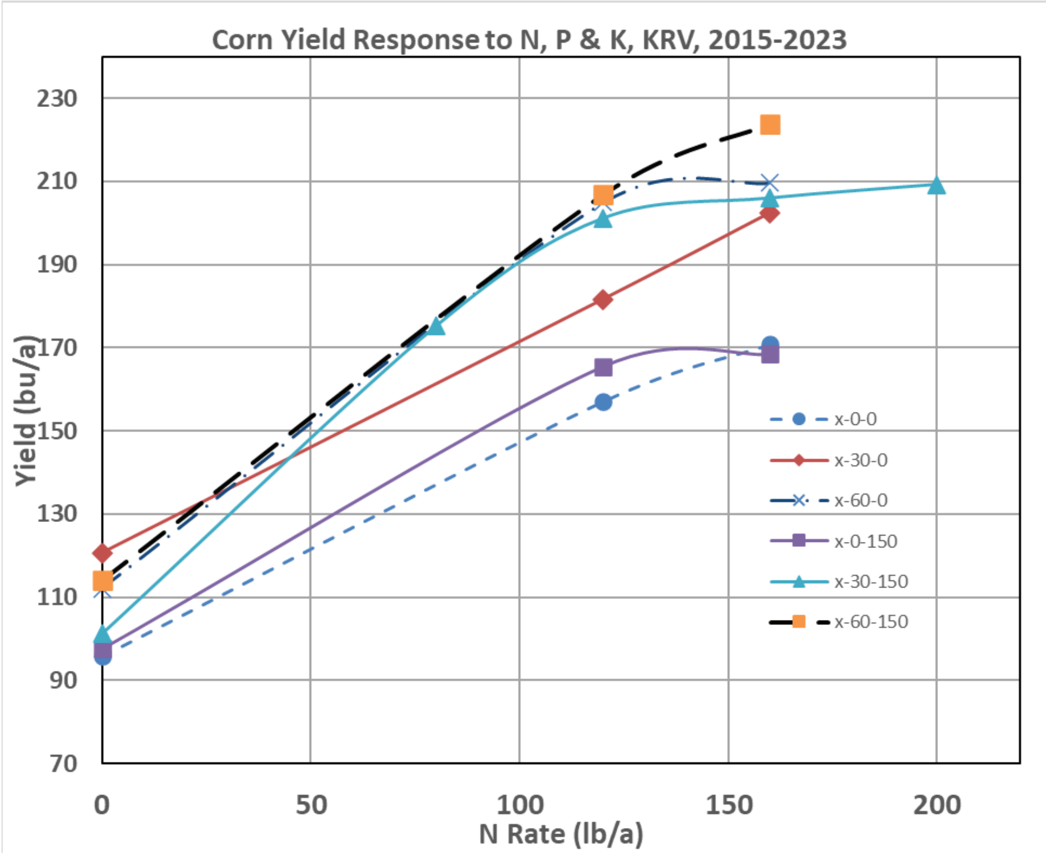

Figure 1. Corn yield response to N at different levels of P and K from corn planted in annual rotation with soybeans from 2015-2023 at Kansas River Valley Experiment Field. The "x" = N rate in legend, followed by P and K rates.

Effect of Early Planting on Soybean Yield: 2021-2024 at Kansas River Valley

Eric Adee, Scott Dooley, Udit Debangshi, and Gaurav Jha

Summary
To increase soybean yield potential, early planting dates have been promoted as a management practice that can increase the 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 study's 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 seeds when emergence is slowed due to cool and wet conditions, early planting may be a viable option. Over the four years this study has been conducted at the Kansas River Valley Experiment Field, the early planting dates in late March/early April have shown soybean yields as either stable or increased when planting in late March/early April compared to planting in mid-to-late April and early-to-mid May. This study also shows the increased yield potential compared to more traditional planting dates later in May.

Procedures
Early soybean planting studies were conducted in 2021-2024 at Kansas State University experiment field, Kansas River Valley (Topeka). Reports of results from individual years, 2021-2023 from Topeka and North Central Experiment Field have been published in previous Field Research Reports (Vol. 8, Iss. 4 2022; Vol. 9, Iss. 4 2023: Vol. 10, Iss. 3 2024). The experiment at Topeka in 2024 was irrigated, receiving 5.75 inches of water from July 29 to September 16. 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 Pioneer 37A18E (Maturity Group MG 3.7) and Pioneer 42A84E (MG 4.2), and they were treated with ILeVO (BASF, Florham Park, NH) and Lumigen (Corteva Agriscience, Indianapolis, IN). The 2024 planting dates at Topeka were March 29, April 15, and May 1. Soybeans were planted in four 30-inch row plots at 10 ft wide × 40 long. The experimental design utilized 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 average days to emerge for the planting dates for the four years of the study decreased from 20 days for the first planting date at the end of March to just under 12 days for the third date at the beginning of May (Table 1). The difference between the emergence dates of the first and third planting dates was not as great as the difference in the planting dates, 25.6 days versus 34 days, respectively. The planting and emergence dates, days to emerge and growing degree days (GDD) for the four years and average of four years of the study are listed in Table 1.

The canopy dates between the first (July 10) and last (July 15) planting dates had shortened to a difference of 5.4 days (Table 1) compared to the 34-day difference between the same planting dates. By the end of the season, the maturity dates were only 3.2 days different between the first and third planting dates (Sept 25 and 28, respectively). This demonstrates the ability of the soybean plant to "hurry up" through the season in response to changes in day length as soybean is not as influenced by calendar date as other crops.

A low level of foliar symptoms of Sudden Death Syndrome (SDS) was observed, with the highest level being on the variety that did not have ILEVO seed treatment to protect against SDS in 2023 (Table 1). As reported previously and again this year, there were no significant differences in the severity of SDS between the planting dates for any years of the study.

There was more than a 4 bushel per acre (bu/a) (>5%) increase with yields from the late March and mid-April planting dates compared to the early May planting date during the four years of the study (Table 1). For individual years, the highest yield could be either the end of March or mid-April planting dates.

The earlier maturity group (MG) (3.7) soybeans tended to canopy and mature a few days earlier than the later MG soybeans (average MG 4.1) (Table 1). Over the four years of the study, the MG 3.7 varieties matured just under 4 days before the varieties averaging MG 4.1. There was no interaction between planting date and varieties for canopy and maturity dates.

Over the four years of the study, the MG 3.7 varieties yielded almost 2 bu/a better than the MG 4.1 varieties (Table 1). This may be in part due to the lack of ILEVO seed treatment and increased SDS on the MG 4.2 in 2023, and to the specific varieties selected. There was no interaction between planting date and varieties for yield.

Seeding rate was not a significant factor for any of the data collected in this study over the four years.

There has not been a killing frost experienced during this study for the four years. A chart for first and last frost dates for Topeka, KS put out by the National Gardeners Association (not shown) gives an idea of the risk associated with soybean emergence earlier in the season. According to this chart, there is a 10% chance of 28° on April 16, and 10% chance of 32° on May 3. The average emergence date for the late March planting date was April 20, with the earliest being April 15. The temperatures that soybeans can survive are influenced by several factors including the soil type, moisture and residue cover, but the general thought is soybeans can tolerate 28° for several hours.

Combining the data with a previous study (Vol 5, Iss. 6 2019) conducted in 2015-2018 at the same location that looked at soybean planting dates from early May to mid-June may give a more complete picture of the effect of soybean planting date on yield. The MG 3.7 variety tolerant to SDS and with ILeVO seed treatment averaged almost the same yield when planted on May 4 as the varieties planted in this study planted on May 4. The yield of subsequent planting dates every two to three weeks later continued to decline, with a sharp decline in yield when planted after the first week of

June (Fig. 1). The SDS susceptible variety in this study did not show an increased yield response when planted earlier than the first week of June due to the yield limiting effect of increased SDS with the earlier planting dates.

Based on these data, growing soybeans in East Central Kansas under irrigation show the best yield potential when planted mid-April or earlier. Selection of a variety with good tolerance to SDS and a good seed treatment package would be necessary to ensure good stands with the slower emergence through the cooler soils. Dryland soybean production offers other challenges, such as lack of rainfall later in the season, which may limit yield response to the earlier planting dates.

With the improvement of varieties and seed treatments, there is an opportunity to increase soybean production with earlier planting dates when the soil conditions are favorable than when soybeans have been traditionally planted. If moisture is not a limiting factor during the season, lengthening the growing season allows for increased yield potential of soybeans. Also, early planting date may spread out the risk of suffering through planting delays if a rainy period starts in May.

Table 1. Effect of early planting date and variety maturity group on soybean emergence, canopy closure, maturity date and yield at Kansas River Valley Experiment Field-Topeka, 2021-2024

	Planting day	Emergence	Days to emerge	GDD	Canopy date	Maturity date	SDS (R6)	Yield
pl date	**2021**							
1	30-Mar	19-Apr	20	156	.	263.0	.	72.7
2	15-Apr	2-May	17	174	.	267.3	.	70.6
3	4-May	19-May	15	180	.	268.4	.	65.7
	2022							
1	4-Apr	25-Apr	21	198	196.5	274.5	4.2	79.9
2	21-Apr	4-May	13	161	197.0	274.5	5.6	78.6
3	9-May	16-May	7	246	198.9	276.6	4.3	76.4
	2023							
1	29-Mar	20-Apr	22	280	188.8	266.6	24.7	71.2
2	13-Apr	28-Apr	15	167	187.0	266.8	23.1	76.3
3	1-May	11-May	10	188	191.4	269.2	11.9	72.9
	2024							
1	29-Mar	15-Apr	17	215	187.1	267.8	5.6	82.3
2	15-Apr	29-Apr	14	180	189.4	270.3	7.2	82.0
3	1-May	16-May	15	207	198.4	270.8	4.2	74.7
4 year Average								
1	31-Mar	Ap 20	20	212	190.8	268.1	11.5	76.5
2	Ap 16	1-May	14.75	171	191.1	269.7	12.0	76.9
3	May 4	16-May	11.75	205	196.2	271.3	6.8	72.4
	Pr>F			<0.0001	<0.0001	<0.0001	0.0198	<0.0001
Variety	**Maturity Group**							
	2021							
1	3.7				.	265.6	.	71.2
2	4				.	266.8	.	68.1
	2022							
1	3.7				197.5	275.1	4.5	78.8
2	3.9				197.4	275.7	4.8	77.8
	2023							
1	3.7				187.3	264.2	0.5	74.0
2	4.2	no ILEVO			190.8	270.9	39.3	73.0
	2024							
1	3.7				190.0	266.5	3.8	80.7
2	4.2				193.2	272.8	7.5	78.6
4 year Average								
	3.7				191.6	267.8	2.9	76.17
	4.1				193.8	271.5	17.2	74.39
	Pr>F				0.001	<0.0001	<0.0001	0.03

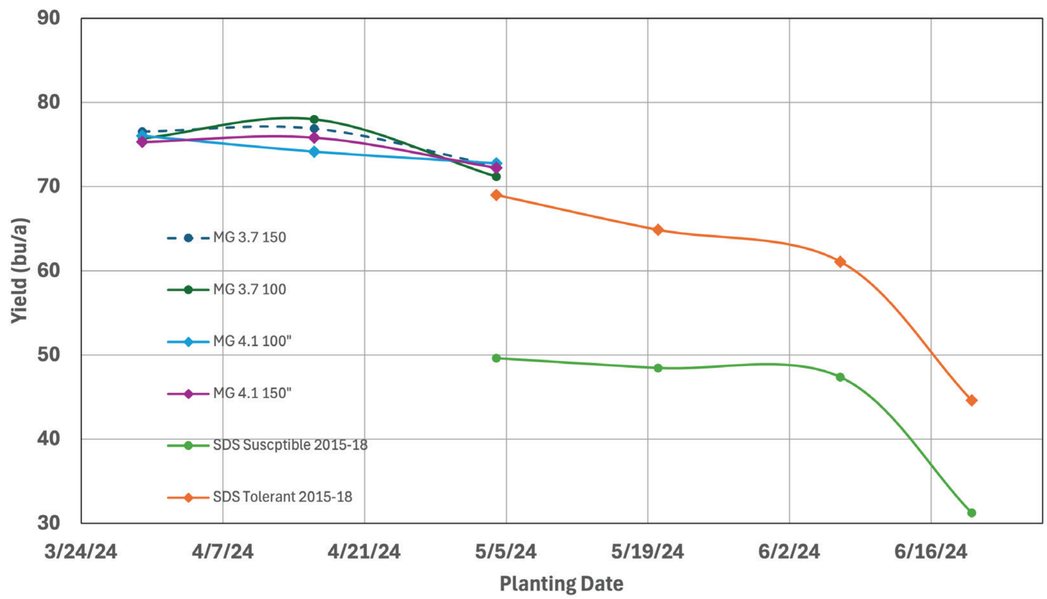

Figure 1. Effect of planting date on soybean yield under irrigation, KRV 2015-18, 2021-24

Sustainable Intensification of Winter Wheat for Improved Yield

Aastha Gautam, Luiz O. Pradella, Nicolas Giordano, Jorge Romero Soler, Jazmin Gastaldi, and Romulo P. Lollato

Summary

Preliminary evidence suggests that the current wheat grain yield of Kansas farmers is well below the yield potential of current varieties under the typical weather conditions experienced in the region. Consequently, this large yield gap is due to the conservative management of producers. To address whether current yields can be improved via intensive management, and whether such improvement is dependent on variety, we conducted a field study in a complete factorial treatment structure established in a split-plot design across six environments during the 2023–2024 growing season evaluating 10 winter wheat varieties (sub-plot) under two management practices (whole plots), namely intensive and standard. Intensive management included increased seed rate, seed treatment, fungicide application, and enhanced fertilization as compared to standard. Environmental conditions significantly influenced average grain yield, which ranged from 6.6 bushels per acre in Hays to 80.3 bushels per acre in Leoti. There were significant variety by environment and management by environment interactions, suggesting that variety performance and management effectiveness were location-dependent. Here, KS Bill Snyder performed best in Leoti (89.4 bushels per acre) and Phillipsburg (87.7 bushels per acre), while KS Providence excelled in McPherson (66.2 bu/a) and Manhattan (68.1 bu/a). Intensive management boosted average yield in Manhattan (30%), Phillipsburg (12%), and McPherson (11.2%) though the latter was only numerical. These findings emphasize that wheat yield improvement requires site-specific variety selection and management practices, reinforcing the importance of adaptive agronomic strategies to minimize the wheat yield gap in Kansas.

Introduction

Wheat is a cornerstone of food and nutritional security in the world, providing ~20% of all human dietary protein and calories (Shewry and Hey, 2015). In the US, Kansas leads as the nation's largest winter wheat-producing state, producing ~330,000,000 bushels of wheat per year with a 10-yr average yield of 42.9 bushels per acre (USDA, 2023). This yield level, however, falls well behind its potential yield, which is estimated between 74 and 83 bu/a (Couedel et al., 2025; Patrignani et al., 2013; Lollato et al., 2015, 2017, 2019). This significant yield gap (i.e., the difference between actual yield, Ya, and potential yield limited by water, Yw) is critical and can be narrowed with improved wheat management (e.g., Jaenisch et al., 2019, 2022; Raj et al., 2023). The environment to which the crop is exposed — including precipitation amount and distribution, temperatures, and solar radiation — in combination with crop genetics dictate the crop's Yw, while the management adopted by each grower in each field (e.g., crop sequence, sowing dates, in-season management) defines Ya (de Oliveira Silva et al., 2021; Jaenisch et al., 2022; Lollato et al., 2021; Sciarresi et al., 2019).

Kansas has a considerable exploitable yield gap that can be economically reduced through effective management practices. Beres et al. (2020) emphasized the need for innovative management strategies, advocating for the genetics × environment × management (G×E×M) framework to optimize productivity and reduce the yield gap. Adopting improved agronomic practices has contributed to enhancing the actual yield of wheat, thereby slowly narrowing the yield gap (Fischer et al., 2015). In Kansas commercial wheat fields, agronomic management practices that have shown widescale potential to narrow yield gaps include nitrogen (N) management and foliar fungicides (Jaenisch et al., 2021). Furthermore, improved population density (Bastos et al., 2020; Jaenisch et al., 2019; Lollato et al., 2024) and interactions with in-furrow fertilizer applications (Maeoka et al., 2020) and seed treatments (Pinto et al, 2019), could help to narrow the yield gap. The benefits of improved management, however, can be variety-specific (de Oliveira Silva et al., 2020). For example, Giordano et al., (2024) demonstrated that variety-specific N management may be warranted under high-yielding conditions but not under harsh environments. Pradella & Lollato (2023) suggested the need for variety-specific seeding rates. Jaenisch et al. (2019, 2020, 2021) suggested that different varieties may respond differently to the interaction between N and sulfur (S) rates.

The primary objective of the experiment was to determine the yield gains resulting from management intensification using a combination of currently adopted practices, such as seed treatment, fungicide application, fertilization, etc., in ten commercial wheat varieties in field experiments across the state of Kansas.

Procedures

Field experiments were conducted in six environments (E) (Hays, McPherson, Leoti, Manhattan, Phillipsburg, and Hoisington) during the 2023-2024 winter wheat growing seasons in a complete factorial combination of 10 varieties (G) (sub-plot) and two management levels (M) (whole plot) in a split-plot design with three and four replicates depending upon the environment. The winter wheat varieties were Bob Dole, KS Ahearn, KS Big Bow, KS Hamilton, KS Hatchett, KS Providence, KS Territory, KS Mako, KS Bill Snyder, and WB4699, under two wildly divergent management levels, identified as standard and intensive.

The management levels were designed to test technologies already adopted by wheat growers in their commercial fields. Thus, we used the survey data collected by Jaenisch et al. (2021) to develop combinations of management practices that reflected the average Kansas wheat farmer management, and a level of intensification that reflected the 80th percentile grain yield level among the ~700 wheat fields surveyed. Standard management involved a seeding rate of 1 million seeds per acre, no seed treatment, no flag leaf fungicide application, and a nitrogen rate of 80 pounds of N per acre applied as urea during spring green-up. In contrast, the intensive management utilized a higher seed rate of 1.4 million seeds per acre together with 50 pounds of diammonium phosphate (DAP) per acre applied in furrow, fungicide and insecticide seed treatment (Sedaxane, Difenoconazole, Mefenoxam, and Thiamethoxam at 0.03, 0.16, 0.04, and 0.47 oz ai per acre respectively), and flag leaf fungicide application (Benzovindiflupyr, Azoxystrobin, and Propiconazole at 5.0, 2.9, and 2.2 oz ai per acre respectively). Ammonium-sulfate was added to provide 20 pounds of S per acre and reduce the chances that S availability limited grain yield. Total nitrogen rate, including that as applied as ammonium-sulfate plus urea, was 130 pounds of N per acre. A detailed description of the combination of treatment for both management practices is provided in Table 1.

The treatments were implemented either through the manual application of fertilizers or via a CO_2-pressurized backpack sprayer for applying foliar fungicides (Table 1). Plots were harvested using a Massey Ferguson 8XP small plot, self-propelled combine. Parameters such as grain weight, test weight, and moisture content were automatically measured during harvest using the on-board HarvestMaster GrainGage system. Grain yield was adjusted to 13% moisture content. Statistical analysis was conducted employing a three-way analysis of variance with varieties, management, environments, and their interactions treated as fixed effects, and block nested within the environment and management nested within block as random effects. Mean values were distinguished at the significance level of alpha = 0.05 ($p<0.05$).

Results

The locations studied had very contrasting weather conditions, especially considering in-season precipitation that ranged from 11.1 to 27.6 inches. This range in precipitation drove large differences in grain yield among locations. The highest average grain yield was observed in Leoti (80.3 bushels per acre) followed by Philipsburg (74.4 bushels per acre), Manhattan (60.9 bushels per acre), McPherson (59.1 bushels per acre), Hoisington (15.2 bushels per acre), and lastly Hays (6.6 bushels per acre) (Table 2). The low yields measured in Hays and Hoisington were due to a combination of factors including primarily extreme season-long drought conditions and potential cold injury at stem elongation.

There were significant interactions between varieties and environment (G×E), and between environment and management (E×M), suggesting that the performance of different varieties was influenced by environmental conditions, and the effectiveness of management practices was also location-dependent. The variety by location interaction was likely due to all varieties performing similarly in Hays, Hoisington, and Manhattan, but performing differently in McPherson, Leoti, and Phillipsburg. The variety KS Bill Snyder had the greatest yield in Leoti and Phillipsburg, while KS Providence outperformed other varieties in McPherson (Table 2). The interaction between management and environment was portrayed by the intensive management increasing grain yield in Manhattan (21.6 bushels per acre or 30% yield gain) and in Phillipsburg (9.6 bushels per acre or 12% yield gain). However, despite the numerical yield increase in McPherson (6.9 bushels per acre or 11% yield gain), no significant difference in grain yield was noticed for management practices across other locations. We note that there were no significant three-way interactions among varieties, environment, and management (G×E×M).

Conclusion

Environmental conditions were the primary drivers of yield variations, but variety and management also played crucial roles. The significant G × E and E × M interactions indicated variety selection and management strategies should be tailored to specific environments for optimal grain yield. Intensive management improved yields only in specific locations, reinforcing the need for site-specific recommendations to address the yield gap in wheat production.

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Table 1. Combinations of management practices adopted in winter wheat fields based on different yields.

	Across Locations	
Management Practices	**Standard**	**Intensive**
Seeding rate (seeds/a)	1,000,000	1,400,000
Seed treatment	No	Yes
DAP (lb/a)	No	50
N rate (lb N/a)	80	130
S rate (lb S/a)	0	20
Fungicide (Trivapro) (oz/a)	No	13.7
Flag leaf fungicide	No	Yes

Table 2. Grain yield as determined by the interaction between variety and environment, and management and environment.

	Grain Yield (bushels per acre)					
Treatments	Environments					
Varieties	**Hays**	**Hoisington**	**McPherson**	**Leoti**	**Manhattan**	**Phillipsburg**
Bob Dole	6.5	17.8	60.1[ab]	67.8[c]	68.9	63.4[d]
KS Ahearn	6.8	16.1	55.4[ab]	80.7[abc]	60.6	63.2[d]
KS Big Bow	8.3	16.5	62.9[ab]	84.2[ab]	64.9	86.2[a]
KS Bill Snyder	4.6	14.3	60.2[ab]	89.4[a]	54.6	87.7[a]
KS Hamilton	6.0	15.3	55.3[ab]	81.2[ab]	57.5	72.2[bcd]
KS Hatchett	5.6	14.2	53.5[ab]	76.4[abc]	54.8	74.9[abcd]
KS Mako	6.0	16.5	65.1[ab]	83.5[ab]	65.6	80.4[ab]
KS Providence	8.3	15.1	66.2[a]	85.5[ab]	68.2	70.2[bcd]
KS Territory	7.9	13.3	59.9[ab]	73.1[bc]	58.7	79.3[abc]
WB4699	5.6	12.5	52.7[b]	81.1[abc]	55.4	66.7[cd]
Management Practices						
Intensive	7.2	12.4	62.6	79.8	71.7[a]	79.2[a]
Standard	5.9	18.0	55.7	80.8	50.1[b]	69.6[b]

*Letters denote significance at the 0.05 probability level.

Wheat Yield Response to Fungicide Application and Nitrogen Management in Kansas during 2023-2024

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Summary

Nitrogen (N) 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. Seven field experiments were established in Kansas using a factorial structure of two fungicide management (either absence of fungicide or 13 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 2023-2024 growing season. Depending on the environment, grain yield varied from less than 18 bushels per acre to more than 88 bushels per acre, likely due to differences in initial soil NO_3-N levels and in-season precipitation. A significant interaction was observed between fungicide application and location, with mean yields ranging from 14.0 bushels per acre in Hoisington (with fungicide) to 87.9 bushels per acre in Leoti (without fungicide). Fungicide had a significant effect in half of the locations, with the greatest yield response observed in Ashland Bottoms (8.6 bushels per acre), which also received the highest precipitation during the growing season. Nitrogen rate increased the yield of variety Zenda from 55.1 bushels per acre at the zero nitrogen rate, to 62.5 bushels per acre at the highest rate, and of the wheat variety Larry from 51 to 54 bushels per acre. Results suggested that the management of nitrogen and fungicide were variety- and environment-specific, respectively, supporting the notion of adaptive management based on seasonal conditions.

Introduction

There is a large yield gap for winter wheat in Kansas, where the current farmer yields are considerably lower than their attainable potential (Couedel et al., 2025; 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., 2020, 2021). 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, 2021; 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.

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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, and N requirements are linked to the crop's yield potential (Salgado et al., 2017; Lollato et al., 2019b, 2021). Further, different wheat varieties may have different yield potentials (Lollato et al., 2020; Raj et al., 2023), also affecting nitrogen requirements – especially in high-yield environments where N is not limiting (Giordano et al., 2024). Although 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 Kansas. 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 varieties with contrasting disease resistances to leaf and stripe rust.

Procedures

This study was conducted at seven rainfed locations across the state of Kansas during the 2023-2024 winter wheat growing season (Ashland Bottoms, Hays, Hoisington, Hutchinson, McPherson, Leoti, and Phillipsburg). Initial soil fertility conditions 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 subplot, 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 spring green-up (Feekes 3-4), and foliar 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 from 0 to 6 inches and from 6 to 18 inches depth at each location before sowing (Table 1). For each depth, soil fertility and texture were analyzed. 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

This report does not include the grain yield data from Hays due to the low emergence and poor stand establishment caused by the dry conditions at the time of seeding.

Grain yield showed a significant variability as function of environment, likely due to the different initial soil NO_3-N contents (Table 1) and the amount of precipitation during the growing season (Figure 1). Precipitation from planting to the harvest ranged from 10.9 to 25.3 inches, with low precipitation amounts recorded in Hoisington, Hutchinson, and Leoti; particularly at the end of the winter and the beginning of the spring. On average, grain yield ranged from 14 to 83.1 bushels per acre, with the highest yields recorded in Leoti and Phillipsburg while the lowest yields were recorded in Hoisington (Figure 2).

There was a significant interaction between fungicide application and the environment with a positive effect on grain yield for the variety Larry in McPherson, Ashland Bottoms, and Phillipsburg. At these locations, fungicides increased the grain yield of wheat by 5.0, 10.3, and 4.4 bushels per acre, respectively. No differences were found between plots receiving fungicide or not for the variety Larry in Hoisington and Hutchinson, while there was a reduction of 9.2 (bushels per acre) in Leoti (Figure 3). Yield reductions due to fungicides in dry environments are not uncommon and can relate to increased crop water usage due to a prolonged green canopy (Cruppe et al., 2021). For the variety Zenda, foliar fungicide applications increased grain yield in Phillipsburg and Ashland Bottoms (Figure 3).

Across sources of variation, grain yield of the variety Larry increased slightly but significantly, from 51 bushels per acre at 30 pounds of N per acre to 54.2 bushels per acre at 120 pounds of nitrogen per acre. Yield gains of the variety Zenda due to nitrogen were also small but significant, with yields ranging from 55.1 bushels per acre at the zero nitrogen rate to 62.5 bushels per acre with the highest N rate (Figure 4).

Conclusions

The grain yield responses to fungicide and to nitrogen were variety- and environment-specific, likely attributed to the different amounts and timing of precipitation, as well as the varying initial soil NO_3-N contents. The genotype Larry responded to fungicide application in four environments while Zenda significantly increased grain yield when fungicide was applied in two environments. Both varieties showed small but positive responses to increased nitrogen rates across environments. Fungicide had a significant effect in half of the locations, with greater yield responses in environments with higher precipitation, which are conditions that favor the incidence of diseases such as stripe and leaf rust (DeWolf et al., 2023).

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Table 1. Initial soil fertility, for winter wheat sowing during the 2023-2024 growing season for seven environments in Kansas

Location	Depth	OM	pH	NO_3-N	P-M	K	Sand	Silt	Clay
	in.	%		------------	ppm	------------	--------------	%	-------------
Ashland Bottoms (AB)	0 to 6	1.7	6.1	24.4	65	198	35	53	12
	6 to 24	1.4	7.7	5.4	34	154	35	53	12
Hays	0 to 6	2.4	5.2	53.2	39	441	9	70	21
	6 to 24	2.1	6.6	33.5	17	298	16	67	17
Hoisington (HOI)	0 to 6	2.1	7.2	43	28	177	31	46	23
	6 to 24	1.9	8	31	17	147	32	40	28
Hutchinson (HUT.O)	0 to 6	2.1	6.6	1.9	34	510	17	50	33
	6 to 24	1.9	7	1.7	39	469	17	47	36
Leoti (LEO)	0 to 6	1.9	7.1	14.1	87	623	24	52	24
	6 to 24	2	7.8	14.5	59	577	22	50	28
McPherson (MCP)	0 to 6	2.9	6.5	9.4	36	330	16	49	35
	6 to 18	2.4	6.8	10.7	19	319	15	45	40
Phillipsburg (PHB)	0 to 6	2.5	6.1	40.6	97	651	20	56	24
	6 to 24	2	6.9	31.4	110.0	702.0	18	53	29

Abbreviations: OM, organic matter; pH, soil pH; NO_3-N, soil nitrate nitrogen; P, phosphorus; K, potassium; CEC, cation exchange capacity, Cl, chloride.

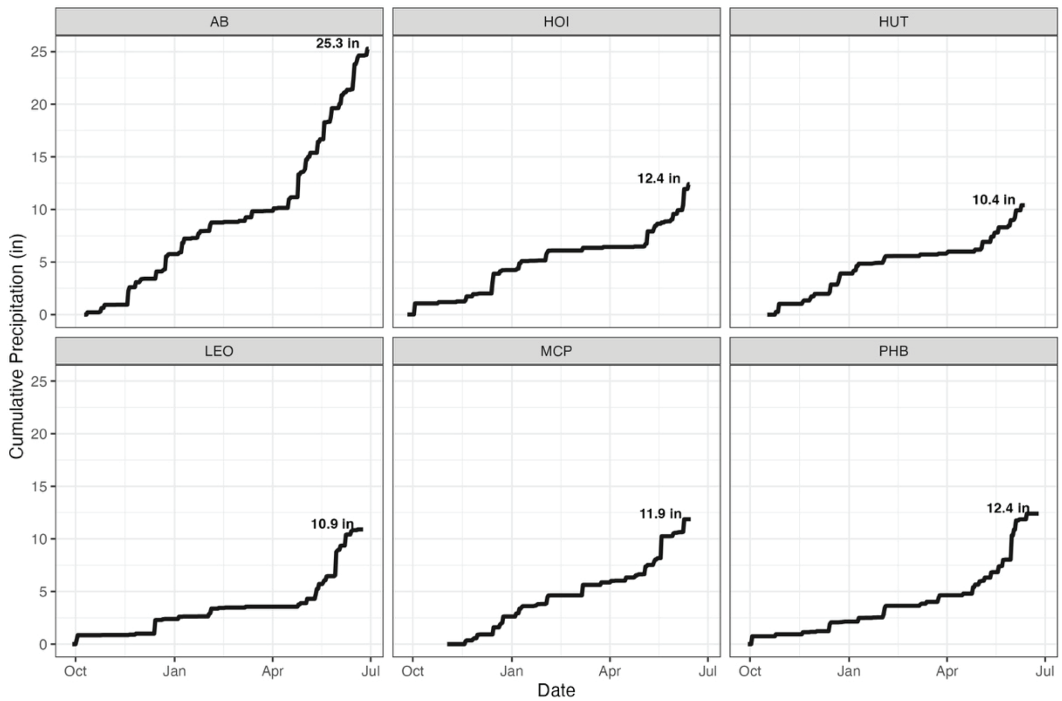

Figure 1. Cumulative precipitation from planting to harvest in the 6 locations during the 2023-2024 growing seasons in Kansas.

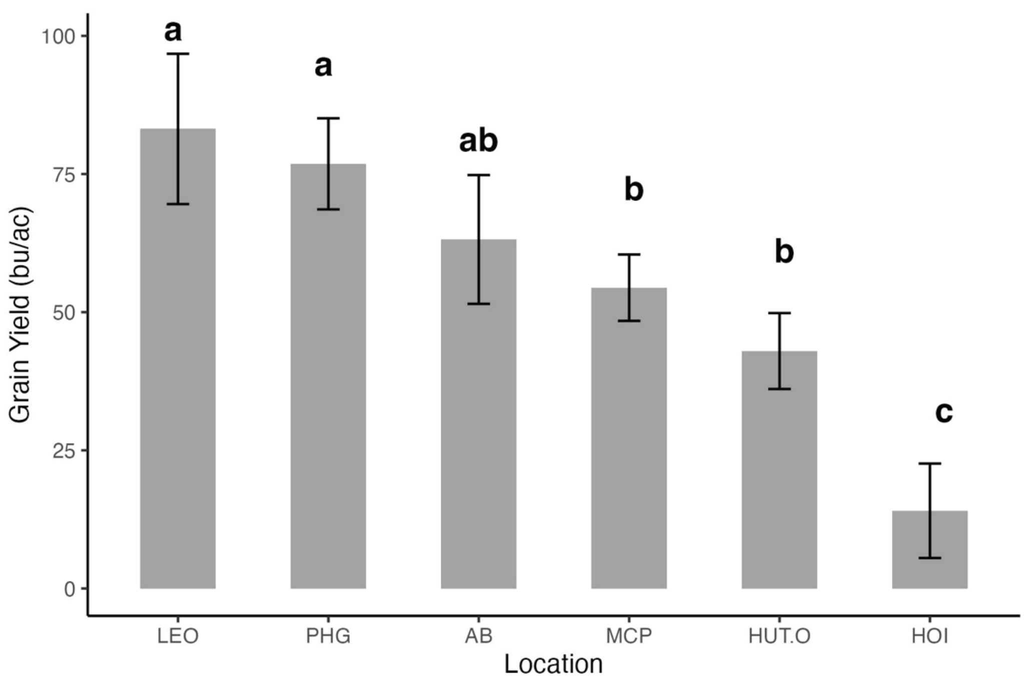

Figure 2. Wheat grain yield at 6 locations during the 2023-2024 wheat growing seasons in Kansas. Letters indicate significant differences with p-value < 0.05.

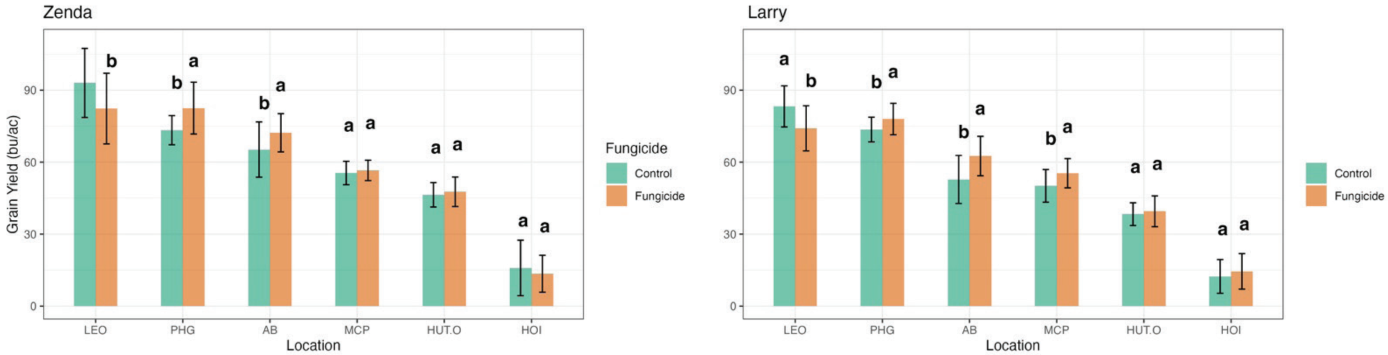

Figure 3. Winter wheat grain yield response to foliar fungicide application at heading in six locations for the varieties Zenda (left panel) and Larry (right panel) during the 2023-2024 growing season in Kansas.

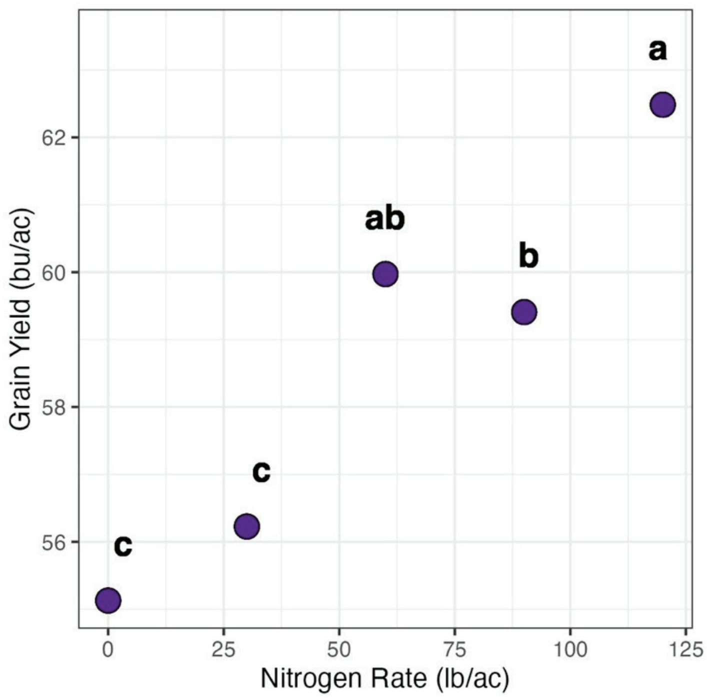

Figure 4. Wheat grain yield of the variety Zenda in response to five nitrogen rates across six locations during the 2023-2024 wheat growing season in Kansas.

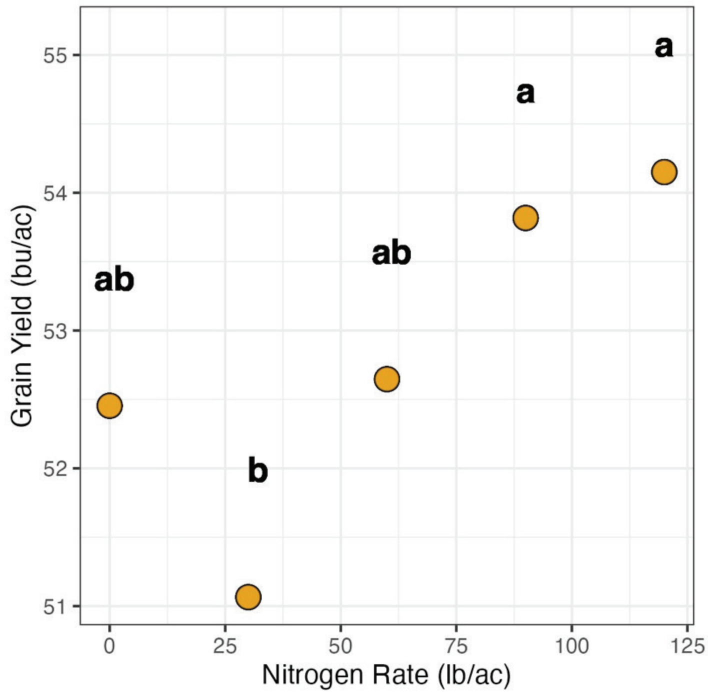

Figure 5. Wheat grain yield of the variety Larry in response to five nitrogen rates across six locations during the 2023-2024 wheat growing season in Kansas.

Wheat Grain Yield Response to Seeding Rate in 2023-2024

Romulo P. Lollato, Nicolas Giordano, Jazmin Gastaldi, Jorge Romero Soler, and Luiz Otavio Pradella

Summary
Wheat response to seeding rate varies 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. The wheat varieties tested were WB4792, Langin, WB4422, and KS Big Bow in the trial conducted in Leoti (western KS), and all but Langin in the trial conducted in Belleville (north central KS). The trial included five seeding rates increasing exponentially from 100,000 to 1,600,000 seeds per acre. The trials were established after a long summer fallow in sorghum residue during late September 2023. Growing season total precipitation ranged from 11.1 to 15.4 inches. There were significant effects of seeding rate on final stand count, with greater rates resulting in greater stand counts; however, final stand count was closer to the target in lower seeding rates. At both locations, grain yield was affected independently by seeding rate and by variety, but not by their interaction, suggesting that varieties performed similarly as a function of seeding rate. In Belleville, yields ranged from 53.4 to 85.6 bushels per acre as a function of seeding rate, whereas in Leoti the range was 66.7 to 92.7 bushels per acre. At both sites, grain yield increased from the lowest seeding rate to 800,000 seeds per acre, plateauing thereafter. The variety KS Big Bow was the highest-yielding variety across sites. In Belleville, the highest yield of KS Big Bow could be attributed to the presence of wheat streak mosaic virus in the study site. Results here suggest that wheat yield varied as a function of variety and seed rate separately, highlighting opportunities to manage both variables independently.

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, 2024). 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 evidence suggested that wheat responses to seeding rate were dependent on the level of resource availability in 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; Lollato et al., 2024) 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; Lollato et al., 2024). 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 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 (Couedel et al., 2025; 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

Field experiments were conducted in two locations during the 2023-2024 winter wheat growing season: a commercial wheat field near Leoti, KS; and the Kansas State University North Central Experiment Field near Belleville, KS. The research plots were sown on September 28 and 29, 2023 at Belleville and Leoti, and comprised seven 7.5-inch 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., WB4792, Langin, WB4422, and KS Big Bow) and five seeding rates (100,000, 200,000, 400,000, 800,000, and 1,600,000 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. In Leoti, wheat was the second crop after manure application (5 tons per acre, providing about 150 pounds of nitrogen and phosphorus). In-furrow diammonium phosphate was applied with the seed at 50 pounds of product per acre both locations. 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 in early July 2024.

A total of 15 individual soil cores (0- to 24-inch depth) were collected from each location and divided into 0- to 6-inch and 6- to 24-inch 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. Linear and non-linear regression analysis was used to test the population and grain yield responses to seeding rate.

Results

Weather conditions

The 2023-2024 growing season was extremely variable in terms of weather patterns, in particular of precipitation amount and distribution. In the context of this study, total in-season precipitation was 11.1 inches in Belleville and 15.3 inches in Leoti (Table 2). The fall had 2.4 to 3.5 inches of precipitation and the winter, 1.2 to 2.9 inches (Table 2). The spring had 7.5 and 8.8 inches, respectively. Temperature ranges were comparable across locations. This limited amount of water in the growing season is typical of the study region, which is characterized by a high likelihood of water, temperature, and combined stresses (Couedel 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 in both locations (Table 3). Stand count ranged from 347,491 to 683,773 plants per acre in Belleville and from 257,521 to 969,022 plants per acre in Leoti. Overall, increases in seeding rate resulted in greater stand count, as expected, although there was some variability in the response at Belleville (Table 4). We note that final populations were closer to the target population at lower seeding rates as compared to higher seeding rates. In Leoti, there was also a variety effect on final stand establishment, where KS Big Bow had greater final population than WB4792 and Langin (638,227 versus ~490,000 plants per acre) (Table 4).

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). At both locations, grain yield increased from the lowest seeding rate to the highest seeding rate, with the peak occurring at the 800,000 seeds per acre seeding rate (Table 5). In Belleville, yields increased from 53.4 bushels per acre at the lowest rate to 85.6 bushels per acre at the peak, while at Leoti grain yield increased from 66.7 bushels per acre at the lowest rate to 96.9 bushels per acre at the highest rate (Table 5). There was also a significant effect of wheat variety on grain yield at both locations, with the variety KS Big Bow consistently outyielding the other varieties. In Belleville, KS Big Bow averaged 92.1 bushels per acre as compared to ~63 bushels per acre for the other tested varieties (Table 5). This large difference may likely be associated with the incidence of wheat streak mosaic virus in this trial coupled with the improved genetic resistance of this variety to the disease; or potentially to the low soil pH at the studied sites (Table 1). In Leoti, yields were more comparable, with KS Big Bow averaging 93.1 bushels per acre with the other varieties ranging from 75.3 to 85.1 bushels per acre (Table 5).

Preliminary Conclusions

This trial provided information about the yield response of different wheat varieties to a large range of seeding rates, suggesting that 800,000 seeds per acre were sufficient to maximize yield in two separate locations. While there were significant differences in grain yield among varieties, with KS Big Bow yielding more than the other varieties at both locations, multiple site-years of data are needed for proper variety comparison.

The lack of variety by seeding rate interaction in the data also suggested that varieties responded similarly to seeding rate, potentially precluding the need for variety-specific seeding rates.

Acknowledgments

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Table 1. Initial soil fertility measured at wheat sowing during the 2023-2024 growing season for the trials conducted near Belleville and Leoti, KS

		Belleville		Leoti	
Variable	**Unit**	**0-6 in.**	**6-24 in.**	**0-6 in.**	**6-24 in.**
O.M.	%	2.8	2.9	1.9	2
pH	---	4.8	5.3	7.1	7.8
NO_3-N	ppm	45	40	14	15
P	ppm	55	42	87	59
K	ppm	357	311	623	577
S	ppm	7.3	5.4	4.1	4.9
Ca	ppm	2163	2520	2502	4967
Mg	ppm	320	358	336	446
CECS	meq/100g	26	27	17	30
Sand	%	18	18	24	22
Silt	%	53	49	52	50
Clay	%	29	33	24	28

Variables include, respectively, soil organic matter, pH, nitrate-N, Mehlich III phosphorus, potassium, sulfur, calcium, magnesium, 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 near Belleville and Leoti, KS, during the 2023–2024 growing season

Timeframe	Variable	Unit	Belleville	Leoti
Season	Precipitation	Inch	11.1	15.33
	Tmax	°F	63.4	61.0
	Tmin	°F	34.8	36.1
Fall	Precipitation	°F	2.4	3.6
	Tmax	°F	60.5	58.0
	Tmin	°F	32.0	33.6
Winter	Precipitation	°F	1.2	2.9
	Tmax	°F	50.8	47.0
	Tmin	°F	23.1	23.6
Spring	Precipitation	°F	7.5	8.8
	Tmax	°F	79.5	78.6
	Tmin	°F	49.7	51.6

*Fall: September 28 - December 31. Winter: January 1 - March 31. Spring: April 1 - July 1.

Table 3. Results from the two-way analyses of variance for wheat stand count and grain yield for the main effects variety and seeding rate, as well as their interaction, in trials conducted near Belleville and Leoti, KS, during the 2023-2024 growing season

Source of variation	Belleville		Leoti	
	Stand count	Grain yield	Stand count	Grain yield
	------------------- *P* -------------------			
Variety (V)	0.006	< 0.001	< 0.001	< 0.001
Seeding rate (SR)	0.31	< 0.001	< 0.001	< 0.001
V × SR	0.77	0.94	0.64	0.65

Table 4. Mean stand count of winter wheat as a function of seeding rate or variety for trials conducted near Belleville and Leoti during the 2023-2024 growing season

Treatment	Belleville		Leoti	
Seeding rate (seeds/acre)	------------ Stand count (plants per acre) ------------			
100,000	347491	B*	257521	D
200,000	414747	AB	330530	D
400,000	369910	B	463272	C
800,000	669024	A	702209	B
1,600,000	683773	A	969022	A
Variety				
WB4792	536281		485308	B
WB4422	415927		562829	AB
KS Big Bow	538759		638227	A
Langin	---		491679	B

*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.

Table 5. Mean grain yield of winter wheat as a function of seeding rate or variety for trials conducted near Belleville and Leoti during the 2023-2024 growing season

Treatment	Belleville		Leoti	
Seeding rate (seeds/acre)	------------ Grain yield (bushels per acre) ------------			
100,000	53.4	D*	66.7	D
200,000	64.1	C	77.7	C
400,000	76.1	B	88.7	B
800,000	85.6	A	96.9	A
1,600,000	83.6	A	92.7	AB
Variety				
WB4792	62.4	B	85.1	B
WB4422	63.1	B	75.3	C
KS Big Bow	92.1	A	93.1	A
Langin	---		84.6	B

*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.

Do Wheat Grain Yield and Grain Protein Concentration Responses to Nitrogen Rate Depend on Variety-Specific Agronomic Traits?

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Abstract

Nitrogen (N) management and genotype selection play crucial roles in optimizing winter wheat (*Triticum aestivum* L.) yield in Kansas. This study evaluated whether wheat cultivars with different agronomic traits would require differential nitrogen management. Eight cultivars were selected to represent high- and low-grain yield stability, above- and below-grain protein deviation for a given yield level, and early and late maturity. These cultivars were exposed to seven nitrogen rates ranging from 0 to 180 pounds of N per acre in seven rainfed locations in Kansas during the 2023–2024 growing season. Results suggested significant N rate by environment interactions and cultivar agronomic trait by environment interactions for grain yield and grain protein concentration. Still, there were no agronomic trait by N rate interactions. Overall, in specific environments, less stable cultivars outyielded more stable cultivars, and early maturity cultivars outyielded late maturity cultivars. These yield advantages were often associated with lower protein concentration. The agronomic trait of grain protein deviation did not result in yield advantages but had higher protein concentrations at all locations. These results emphasize the importance of understanding cultivar traits and their interaction with the environment when making variety selection, and the crop's overall response to N management as a function of environmental conditions. Still, results suggested no differences in how N should be managed according to a cultivar's specific agronomic traits.

Introduction

Nitrogen is a key limiting factor for winter wheat (*Triticum aestivum* L.) yield in Kansas (Lollato et al., 2019a, 2021; Jaenisch et al., 2021). Accurately managing this macronutrient is essential to maximize yields while avoiding over- and under-application, which can lead to waste and environmental pollution, or result in larger yield gaps and below-optimal grain quality (Cruppe et al., 2017; Lollato et al., 2019b; Giordano et al., 2023). Since wheat in this region is already characterized by large yield gaps, in other words, current yields are well below their potential (Couedel et al., 2025; Lollato et al., 2017; Jaenisch et al., 2021), management practices to narrow yield gaps are warranted since they can be profitable.

At question here is whether wheat variety selection should be considered when making N recommendations since the interaction between genotype and environment (G × E) can be significant (Beres et al., 2020), nitrogen rate can change the yield-environment (Giordano et al., 2024), and varieties may interact with management to drive wheat yield (Jaenisch et al., 2022; Raj et al., 2023). Giordano et al. (2024) provided some initial evidence highlighting the interaction between genotype and nitrogen (G × N) on wheat yield in Kansas. The authors suggested that more stable (or less plastic) varieties had similar grain yield to those less stable in environments with low yield, but stable varieties failed to capture the higher yield potential of higher-yielding environments — specifically when N was not limiting. This behavior — a more conservative yield of stable cultivars under high-yielding conditions — had previously been reported in eastern Kansas (Lollato et al., 2020). Consequently, cultivar grain yield stability may influence a wheat cultivar's response to nitrogen. Likewise, traits such as protein concentration and maturity can affect the crop's nitrogen use efficiency (Lollato et al., 2021). Thus, our aim was to quantify how varieties with more or less stable grain yield, below- or above-average protein for a given yield level, and early- or late-maturity, respond to nitrogen rates across a range of locations and environmental conditions in Kansas.

Procedures

Treatments, experimental design, and management

Rainfed field experiments were conducted during the 2023-2024 winter wheat season in seven locations across Kansas: Ashland Bottoms, Belleville, Hays, Hoisington, McPherson, Manhattan, and Phillipsburg. A split-plot design was used to evaluate a combination of seven nitrogen rates (whole plot) and eight winter wheat varieties (subplot) with three or four repetitions.

The N rates (0, 30, 60, 90, 120, 150, and 180 lb N/a) were applied as granulated urea (46-0-0) at spring green up or around the Feekes 3-4 growth stage. At the N application time, all the experiments received 15 pounds per acre of sulfur (S) as gypsum to avoid S deficiency and interaction with N availability (Jaenisch et al., 2019, 2020, 2021). The eight varieties were selected based on three traits: grain yield stability based on long-term trials (Munaro et al., 2020), grain protein deviation (GPD, the deviation in grain protein for a given yield level), and maturity. All combinations of traits occurred so that direct comparisons of a given trait could be made while other traits were constant, resulting in a balanced presence/absence of traits. The varieties selected for this study and their classification in terms of stability, GPD, and maturity are shown in Table 1.

Wheat was sown from late September through October 2023 with a Great Plains 606 no-till drill with a row spacing of 7.5 inches. Plots were seven rows wide and about 30 ft long. At sowing, soil samples were collected at each location from 0 to 6 and 6 to 24 inches deep (Table 1). Foliar fungicide was applied once in each trial between flag leaf and anthesis (Feekes 9-10.5) to avoid the confounding effects of variety-specific disease resistances (Cruppe et al., 2021, de Oliveira Silva et al., 2020). Grain weight and moisture were measured with a Massey Ferguson 8XP small plot combine. A moisture basis of 13% was used to adjust grain yield. Grain protein concentration was adjusted to a dry basis measured by NIR spectroscopy.

Statistical Analysis

Statistical analysis was performed with R Studio. Linear mixed-effects models were used to assess the impact of the different agronomic traits of the studied cultivars across different environments, as well as the effect of N rates on grain yield and grain protein concentration. The model structure included fixed effects for cultivar groups (either high- and low-stability, protein deviation, or maturity), environment, N rate, and their interactions. Random effects included cultivars nested within the agronomic trait group, N rate nested with repetition, and repetition nested within the environment. The groups of cultivars used in the analyses always consisted of four cultivars contrasting for the trait of interest and balanced for the other two traits.

Results

There was a wide range in grain yields across the experiments. The highest yield was measured in Phillipsburg (72.9 bushels per acre) followed by Ashland Bottoms (67.5 bushels per acre), sites that received more in-season precipitation (Figure 1). Hays (8.3 bushels per acre) and Hoisington (15.3 bushels per acre) had the lowest yields, which may be due to a dry soil profile at sowing coupled with low precipitation during the growing season, resulting in severe water stress. Across sources of variation, grain protein concentration ranged from 8.7% to 22.5%, averaging 13.8%.

Statistical analysis of grain yield and grain protein concentration across E, N rates, and agronomic traits suggested that there were significant N × E interactions and, for most cases, agronomic trait × E interactions, except for grain yield as a function of the trait GPD (Table 2). Overall, there were no agronomic trait × N interactions or three-way interactions (Table 2), suggesting that the response of the different varieties to N rate were similar, irrespective of the agronomic trait considered.

The interaction between N rate and E on wheat grain yield is shown in Figure 1. There were significant responses to N in four out of seven environments (i.e., Ashland Bottoms, Belleville, Manhattan, and Phillipsburg). The remaining sites were unresponsive, either due to extreme drought (Hays, Hoisington), or due to high soil NO_3-N at sowing (McPherson) (Table 1). Additionally, the interaction between N and E significantly affected grain protein concentration (Table 2). This interaction resulted from Hoisington showing no response in grain protein concentration to N rate, two sites showing a linear increase in protein as a function of N rate, three sites portraying a quadratic protein response to N rate, and Phillipsburg portraying a cubic response of protein to N rate (Figure 2), which is biologically explained (Giordano et al., 2024).

The interactions between agronomic trait and environment on grain yields are shown in Table 3. Varieties with lower yield stability were higher yielding than their stable counterparts in Ashland Bottoms, Belleville, Manhattan, and Phillipsburg, yielding similarly in the remaining environments. The trait GPD did not interact with environment on grain yield. Finally, earlier maturing varieties yielded more than their later counterparts in Ashland Bottoms, Belleville, Hoisington, McPherson, and Phillipsburg, yielding similarly in the other environments.

Regarding the interactions between agronomic trait and environment on grain protein concentration (Table 4), more yield-stable varieties had greater protein concentration than their less stable counterparts in five out of seven locations. Varieties with the trait high GPD had greater protein than their counterparts in all environments, and late maturing varieties had greater grain protein concentration than early maturing varieties in three out of seven environments. Greater protein concentration as a function of later variety maturity may relate to these varieties being more exposed to the harsher environmental conditions that are typical later in the calendar year as the crop progresses into the summer (Zhao et al., 2022).

Preliminary Conclusions

The interaction between N rates and the environment influenced grain yield and grain protein, highlighting the complex nature of crop response to nitrogen availability and its management. The interaction between cultivars with contrasting agronomic traits and environment also highlighted the need for cultivar-specific and environment-specific knowledge when selecting wheat varieties for a given farm. However, the lack of interaction between agronomic trait and N rate suggests that cultivar-specific N management recommendations may not be warranted for the cultivars and traits evaluated.

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Table 1. Agronomic traits of the different winter wheat varieties evaluated in this study.

Variety	Yield stability	GPD	Maturity
Bob Dole	Stable	High	Early
LCS Chrome	Stable	High	Late
LCS Julep	Not stable	High	Late
SY Monument	Stable	Low	Late
SY Wolverine	Not stable	High	Early
WB4269	Stable	Low	Early
WB4401	Not stable	Low	Early
WB4699	Not stable	Low	Late

Table 2. Soil characteristics for the 0 to 6 and for the 6 to 18-inch or 6 to 24-inch depth layers at each study location during 2023-2024 growing season

Location	Depth	OM	pH	NO_3-N	P	K	CEC	Cl	Sand	Silt	Clay
	in.	%	---------------- ppm			----------------	meq/100 g	ppm	------------ %		------------
Ashland Bottoms	0 to 6	1.7	6.1	24.4	65	198	8	5.6	35	53	12
Ashland Bottoms	6 to 24	1.4	7.7	5.4	34	154	11.8	2.8	35	53	12
Belleville	0 to 6	3.2	5	14.7	54	478	21.5	4.6	16	61	23
Belleville	6 to 24	2.9	5.7	5.3	35	435	26.2	5.1	17	48	35
Hays	0 to 6	2.4	5.2	53.2	39	441	18.2	12.3	9	70	21
Hays	6 to 24	2.1	6.6	33.5	17	298	19.4	6.1	16	67	17
Hoisington	0 to 6	2.1	7.2	43	28	177	23.8	5.6	31	46	23
Hoisington	6 to 24	1.9	8	31	17	147	30	4.7	32	40	28
McPherson	0 to 6	2.9	6.5	9.4	36	330	25.5	21.6	16	49	35
McPherson	6 to 18	2.4	6.8	10.7	19	319	29.3	9.6	15	45	40
Manhattan	0 to 6	4.6	6.8	9.4	27	234	29.3	6.1	16	56	28
Manhattan	6 to 12	3.7	7.2	6.2	13	218	30.5	6.4	14	53	33
Phillipsburg	0 to 6	2.5	6.1	40.6	97	651	17.7	4.6	20	56	24
Phillipsburg	6 to 24	2	6.9	31.4	110.0	702.0	18.30	5.2	18	53	29

Abbreviations: OM, organic matter; pH, soil pH; NO_3-N, soil nitrate nitrogen; P, phosphorus; K, potassium; CEC, cation exchange capacity, Cl, chloride.

Table 3. Analyses of variance of wheat grain yield and grain protein concentration (GPC) as affected by agronomic traits (yield stability, grain protein deviation [GPD], and maturity) and N rates at seven locations during the 2023–2024 growing season

		Yield stability		GPD		Maturity	
Source of variance	df	Grain yield	GPC	Grain yield	GPC	Grain yield	GPC
Environment (E)	6	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Nitrogen rate (N)	6	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Agron. trait (AT)	1	<0.001	<0.001	0.17	<0.001	<0.001	0.06
E × N	36	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
E × AT	6	0.001	<0.001	0.67	<0.001	0.06	0.05
N × AT	6	0.73	0.16	0.96	0.41	0.77	0.99
E × N × AT	36	0.99	0.99	0.99	0.77	0.98	0.99

Abbreviation: df, degrees of freedom.

Table 4. Grain yield (bushels per acre) as a function of the interaction between environment and the agronomic traits yield stability, GPD, and maturity, across seven Kansas locations during the 2023-2024 growing season

	Grain yield (bushels per acre)					
	Yield stability		GPD		Maturity	
Environment	Low	High	Low	High	Early	Late
Ashland Bottoms	**59.5**	57.5	35.6	35.5	**59.3**	57.6
Belleville	**51.3**	46.6	40.7	40.5	**50.7**	47.3
Hays	7.6	6.8	41.3	40.1	8.3	6.1
Hoisington	13.2	13.2	42.5	42.6	**15.2**	11.2
McPherson	52.5	52.9	44.6	44.0	**54.2**	51.3
Manhattan	**49.7**	47.7	44.4	43.0	48.4	49.0
Phillipsburg	**65.2**	60.9	45.2	44.7	**64.3**	61.8

Values in bold indicate that means of the two agronomic trait groups are significantly different within environment. ($\alpha = 0.05$). Abbreviation: GPD, grain protein deviation.

Table 5. Grain protein concentration (percent) as function of the interaction between environment and the agronomic traits yield stability, GPD, and maturity, across seven Kansas locations during the 2023-2024 growing season

	Protein (%)					
	Yield stability		GPD		Maturity	
Environment	Low	High	Low	High	Early	Late
Ashland Bottoms	12.2	**12.8**	12.2	**12.8**	**12.6**	12.4
Belleville	12.6	**13.3**	12.7	**13.2**	13.0	12.9
Hays	12.8	**13.1**	12.4	**13.6**	12.9	13.0
Hoisington	18.7	18.3	17.8	**19.1**	18.4	**18.6**
McPherson	14.2	14.9	13.8	**15.3**	14.2	**14.8**
Manhattan	11.7	**12.3**	11.6	**12.4**	11.9	**12.1**
Phillipsburg	12.2	**12.8**	12.2	**12.7**	12.5	12.5

Values in bold indicate that means of the two agronomic trait groups are significantly different within environment. ($\alpha = 0.05$). Abbreviation: GPD, grain protein deviation.

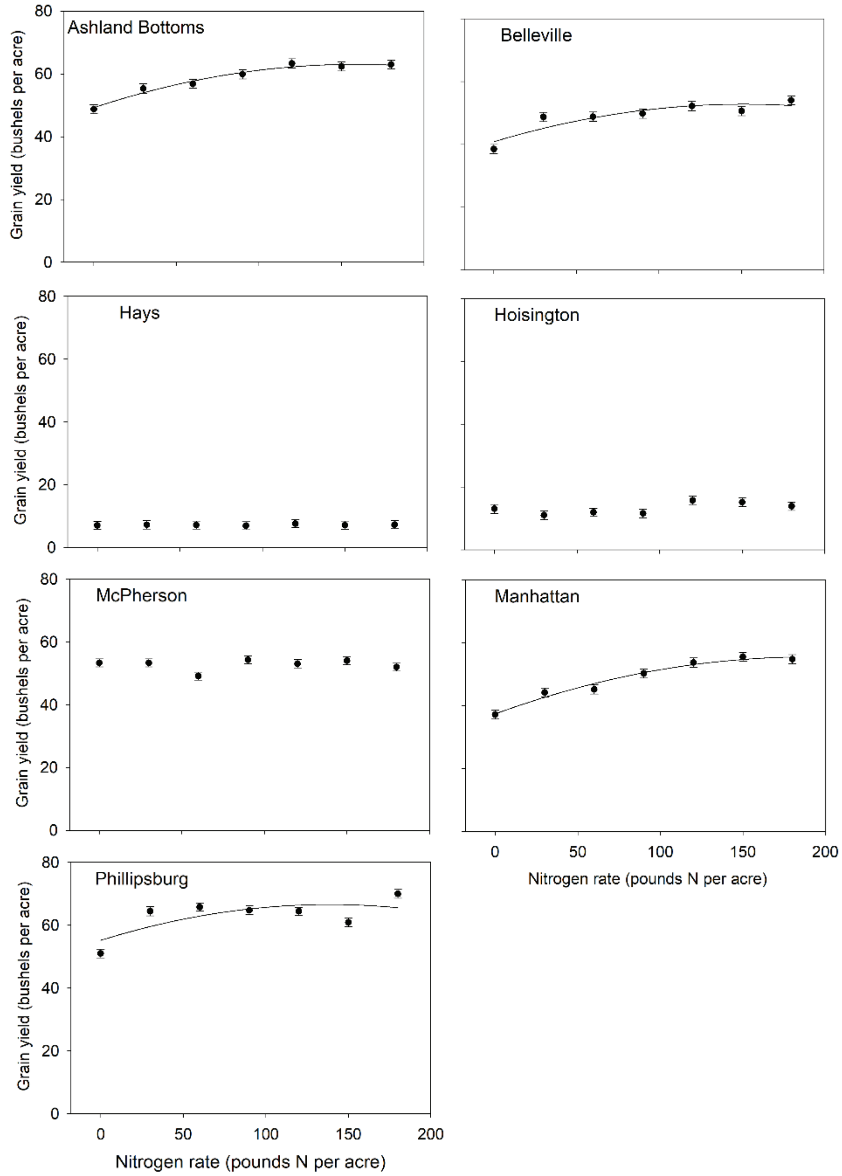

Figure 1. Winter wheat grain yield as a function of the interaction between nitrogen rate and environment at seven Kansas locations during the 2023-2024 growing season. Lines portray statistically significant quadratic regressions.

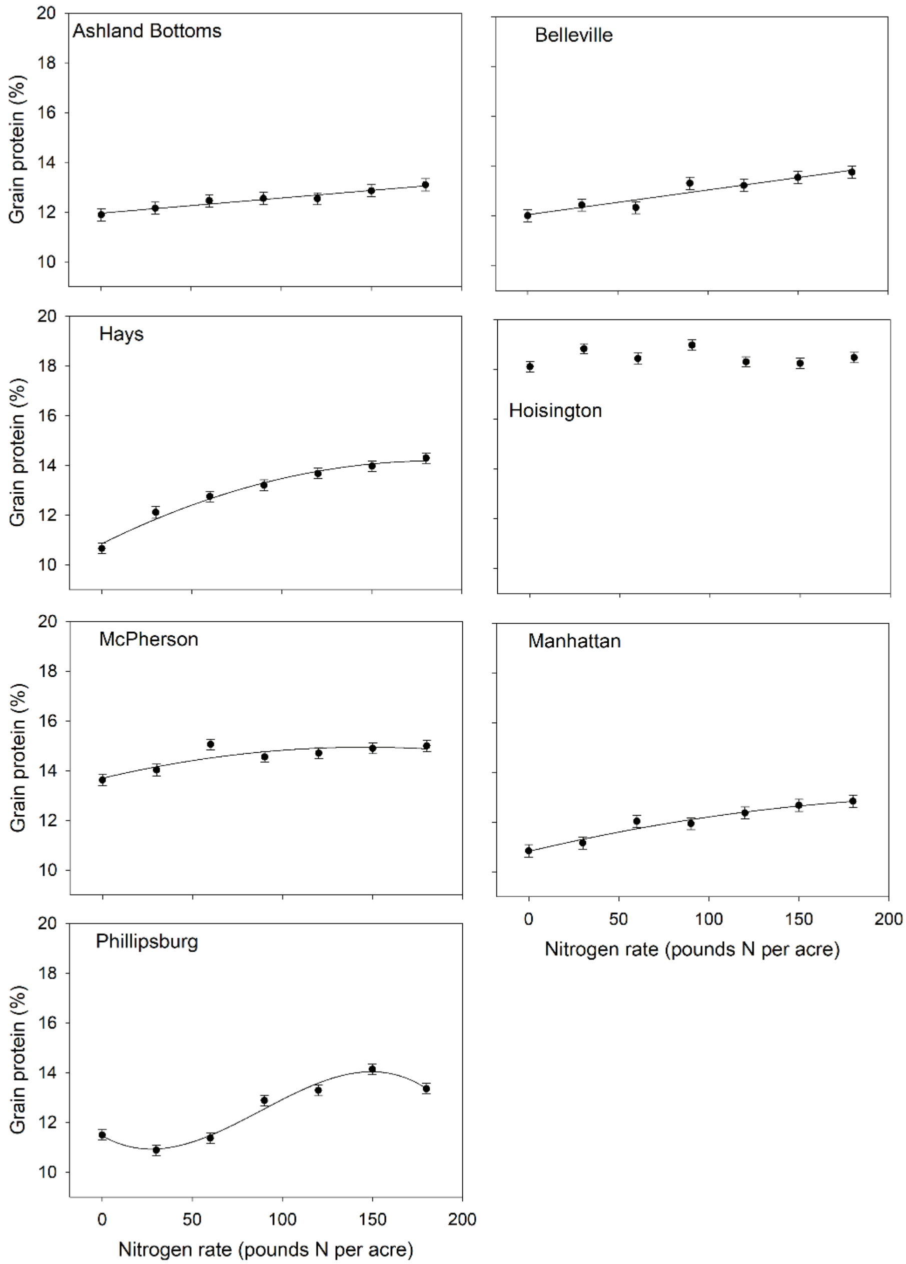

Figure 2. Winter wheat grain protein concentration as a function of the interaction between nitrogen rate and environment at seven Kansas locations during the 2023-2024 growing season. Lines portray statistically significant polynomial regressions.

Effect of Defoliation at Different Stages on Grain Sorghum Yield and Yield Components in 2024

Kraig L. Roozeboom

Summary
A third year of 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 2024. 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 also delayed heading. Yield reductions were greatest when leaf area was lost at flag leaf appearance or half bloom. Leaf area loss of 60% or greater at these stages caused yield losses of 30% to 70%. Leaf area losses approaching 100% at the early hard dough stage caused yield reductions approaching 30%. Yield losses were associated with different combinations of reductions in head size and seed size depending on timing of leaf loss.

Introduction
Although dry matter is translocated from the stem to grain during grain filling, leaves are the primary source of energy for growth and grain filling in grain sorghum. Of several possible causes, 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. Leaves that emerge after 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 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 because most of the leaf area has already emerged, and little grain fill has occurred. These responses for modern sorghum hybrids in contemporary production systems have not been characterized. 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 soil. Sorghum hybrid P84P72 was planted on June 10, 2024, at 75,000 seeds per acre using a White 9000 series planter with Precision Planting seed meters and a 20|20 seed monitoring system. Fertilizer was applied before planting as a mix of 28% UAN and ammonium polyphosphate to supply 150 pounds of nitrogen and 55 pounds of P_2O_5 per acre. A

mix of burndown and residual herbicides was applied before crop emergence on May 10. Plots were harvested on October 16–19 after reaching physiological maturity.

Treatments and Experimental Design

Treatments consisted of four levels of defoliation imposed at four developmental stages. Target defoliation levels of 0, 33, 66, and 100% were imposed using a hedge trimmer plus hand trimming the 100% treatment as needed. The sorghum stages when defoliations were imposed were 5 leaves fully emerged (S2), flag leaf visible in whorl (S4), half bloom (S6), and early hard dough (S8). 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. Leaf area was determined using a LiCor LI3100C area meter. Actual defoliation rate was calculated as the leaf area remaining as a percent of the 0% defoliation plot in each replication. Leaf area index (LAI) was calculated by dividing the sample leaf area by the sample soil surface area. 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 heads per plant was determined by dividing the number of heads by the number of plants counted in the harvest area. 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. The effect of defoliation was characterized by regressing the response parameters on measured defoliation rate separately for each developmental stage. Pearson correlation coefficients were calculated for all combinations of variables to characterize relationships among variables.

Results

Growing Season Conditions

Growing conditions were generally favorable for sorghum growth during the 2024 growing season (Figure 1). Temperatures were close to normal until planting. Although temperatures averaged near normal for the rest of the growing season, they tended to swing from above to below normal every several days. Cumulative precipitation was above normal until late August. Although there was minimal precipitation during the grain filling period, no visual drought response symptoms were observed.

Effect of Defoliation on Remaining Leaf Area, Bloom Date, and Plant Height

Increasing rates of defoliation were significantly negatively correlated with LAI across all developmental stages and within each stage when defoliation was imposed (Table 1). Increasing rates of defoliation at S2 and S4 delayed half bloom, defoliations imposed at S6 and S8 had no effect on half bloom (Table 1, Figure 2). Plant height was not influenced by defoliation at S2, S6, and S8, but was reduced as S4 defoliation rate increased (Table 1, Figure 3).

Effect of Defoliation on Yield Components and Yield

Defoliation affected yield components differently depending on the developmental stage when the defoliation was imposed. Plant density differences due to defoliation were substantially less than differences due to non-uniform stands (Figure 4), which were not large enough to influence yield (Table 1). The number of heads per plant responded minimally to defoliation at any growth stage (Table 1). As with plant density, differences in heads per plant due to defoliation were within the range of variation across all rates of defoliation imposed at any growth stage (Figure 5). The lack of tillering response might be explained in part by the late planting date because sorghum tends to produce fewer productive tillers when temperatures are warmer during early vegetative stages. Head size was the yield component most responsive to defoliation, with fewer seeds per head with greater defoliation rates at S4, S6, and S8 (Table 1, Figure 6), although the decrease in head size for defoliations imposed at S8 were minimal. Defoliation rates approaching 100% at S4 and S6 resulted in head size reductions of 50% and 35%, respectively. Increasing rates of defoliation at S4, S6, and S8 were strongly associated with decreased seed size (Table 1). Seed size was reduced by 10% to 20% with maximum defoliation imposed at S4 and S8 but was reduced by 50% with maximum defoliation at S6 (Figure 7). Increasing rates of defoliation were strongly negatively correlated with grain yield regardless of when the defoliation was imposed (Table 1). Complete defoliation at S6 resulted in the most severe yield reduction of almost 70%, followed by S4, which had a yield reduction of 40% to 60% (Figure 8). Only the most severe defoliation at S2 affected yield, with yield reductions between 10% and 20%. The 10% reduction in head size and 20% reduction in seed size resulting from 100% defoliation at S8 translated into a nearly 30% reduction in yield.

Relationships Among Sorghum Response Variables

Plant density was strongly negatively correlated with number of heads per plant but was not related to differences in yield (Table 1), illustrating sorghum's ability to compensate for non-uniform stands. The number of heads per plant was unrelated to other yield components. It was positively correlated with yield only when defoliations were imposed at S4. Correlations of days to half bloom with plant height and LAI when defoliations were imposed at S2 and S4 were likely mediated by defoliation rate.

Head size and seed size displayed no correlation with other parameters with defoliations imposed at S2. However, at S4, head size and seed size were correlated with plant height, LAI, and yield. At S6 and S8, head size and seed size were strongly correlated with each other and with LAI, and yield.

Yield was strongly correlated with LAI at the time of defoliation for all defoliation timings, but relationships between yield and yield components varied with timing of defoliation (Table 1). For defoliations at S2 and S4, yield was negatively correlated with days to bloom. Yield had strong correlations with heads per plant, head size, and seed size with defoliation at S4, but only head size and seed size were strongly correlated with yield when defoliations were imposed at S6 or S8.

Conclusion

Defoliation tended to reduce yield, but the degree of yield reduction varied with timing and extent of defoliation. Light to moderate defoliations at S2 resulted in minimal yield reduction, likely because the plants could add leaf area and additional productive heads when defoliated at this stage. Severe defoliation at S2 delayed heading and reduced yield by 10% to 20%. Yield reductions of 30% from severe defoliation at S8 were associated with reductions in seed size and with reductions in head size, likely due to kernel abortion. Severe defoliations at S4 and S6 resulted in smaller heads and seeds that reduced yield by 60% to 70%.

Acknowledgments

National Crop Insurance Services provided funding and guidance on experimental design. Carter Keesecker assisted with imposing the treatments and data collection.

Table 1. Pearson correlation coefficients for defoliation of grain sorghum at Manhattan, KS, 2024; bold values indicate 95% confidence in significant correlation

	Defoliation	Days bloom	Plant height	Plant density	Heads/ plant	Head size	Seed size	LAI[1]	Yield
				↓ stage 4 (flag leaf appearance, upper right) ↓					
Defoliation		**0.65**	**-0.65**	0.03	-0.00	**-0.82**	**-0.53**	**-1.00**	**-0.86**
Days bloom	**0.97**		**-0.56**	-0.16	0.02	-0.41	-0.36	**-0.65**	**-0.59**
Plant height	-0.19	-0.16		0.08	-0.09	**0.50**	0.13	**0.65**	**0.59**
Plant density	-0.19	-0.24	0.36		**-0.82**	-0.36	-0.05	-0.03	-0.22
Heads/plant	0.04	0.10	-0.19	**-0.66**		0.24	0.11	0.00	**0.23**
Head size	-0.01	0.10	0.35	-0.09	-0.04		0.39	**0.82**	**0.88**
Seed size	-0.41	-0.39	0.10	-0.04	-0.25	-0.12		**0.52**	**0.57**
LAI	**-1.00**	**-0.96**	0.17	0.18	-0.03	0.00	0.39		**0.86**
Yield	**-0.60**	**-0.56**	0.24	0.03	0.41	0.13	0.03	**0.57**	
				↑ stage 2 (five leaves emerged, lower left) ↑					
				↓ stage 8 (hard dough, upper right) ↓					
Defoliation		-0.29	-0.10	0.26	-0.13	**-0.68**	**-0.87**	**-1.00**	**-0.87**
Days bloom	-0.08		0.14	0.33	-0.28	0.20	0.06	0.27	0.16
Plant height	-0.18	-0.41		0.04	0.06	-0.14	0.07	0.10	0.14
Plant density	0.23	-0.19	-0.18		**-0.79**	**-0.55**	-0.41	-0.29	-0.27
Heads/plant	-0.14	0.07	-0.30	**-0.76**		0.39	0.25	0.14	0.32
Head size	**-0.78**	-0.01	0.39	-0.25	0.08		**0.51**	**0.70**	**0.67**
Seed size	**-0.90**	-0.03	0.30	-0.30	0.15	**0.76**		**0.88**	**0.84**
LAI	**-0.99**	0.12	0.13	-0.15	0.07	**0.75**	**0.89**		**0.88**
Yield	**-0.90**	-0.04	0.24	-0.22	0.17	**0.85**	**0.95**	**0.89**	
				↑ stage 6 (half bloom, lower left) ↑					
				↓ over all stages (upper right) ↓					
Defoliation		**0.41**	**-0.30**	0.05	-0.02	**-0.54**	**-0.61**	**-0.71**	**-0.73**
Days bloom			**-0.25**	**-0.23**	0.15	0.06	-0.02	**-0.42**	-0.05
Plant height				0.12	**-0.24**	**0.42**	0.16	**0.25**	**0.36**
Plant density					**-0.73**	**-0.25**	-0.18	0.02	-0.18
Heads/plant						0.04	0.08	-0.05	0.15
Head size							**0.44**	**0.31**	0.79
Seed size								**0.49**	**0.76**
LAI									**0.48**

[1]LAI = leaf area index.

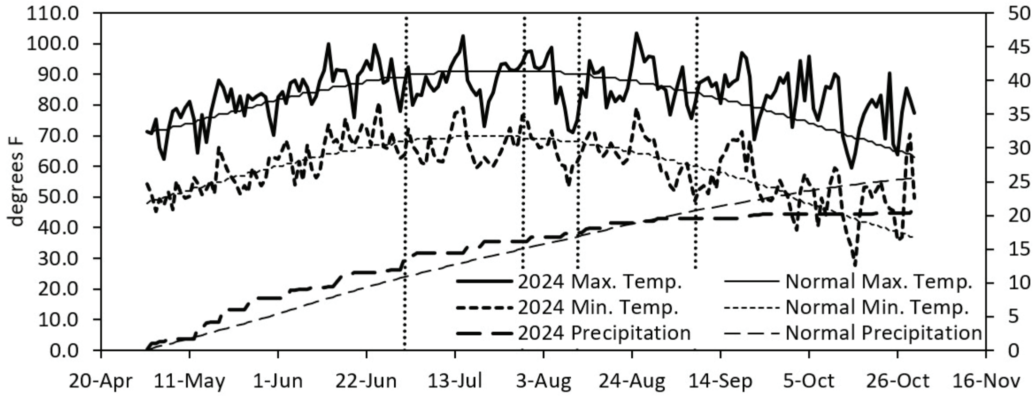

Figure 1. Daily maximum and minimum temperatures and cumulative precipitation for 2024 and 30-year normals for Manhattan, KS. Vertical dotted lines represent defoliation events.

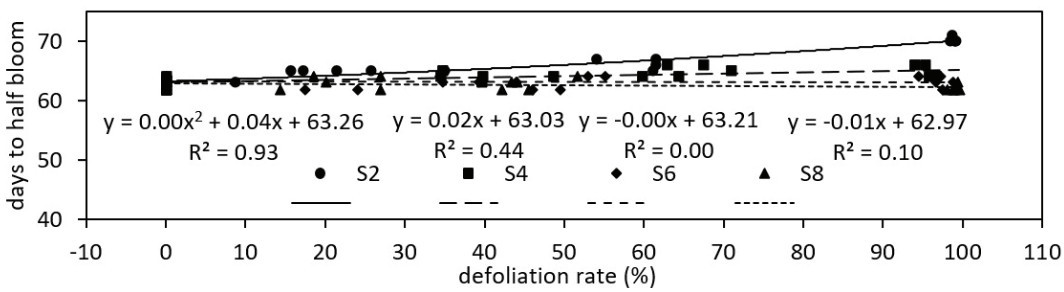

Figure 2. Effect of defoliation at four grain sorghum developmental stages on days to half bloom at Manhattan, KS, in 2024.

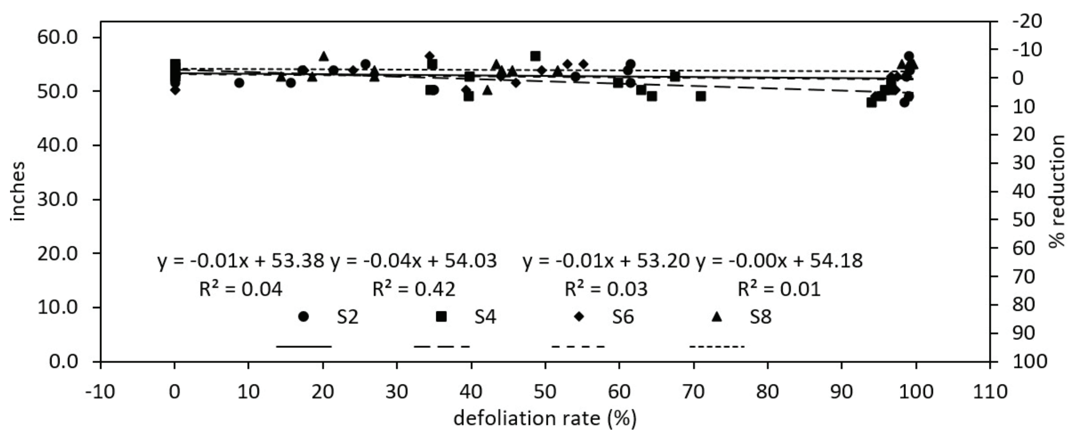

Figure 3. Effect of defoliation at four grain sorghum developmental stages on plant height at Manhattan, KS, in 2024.

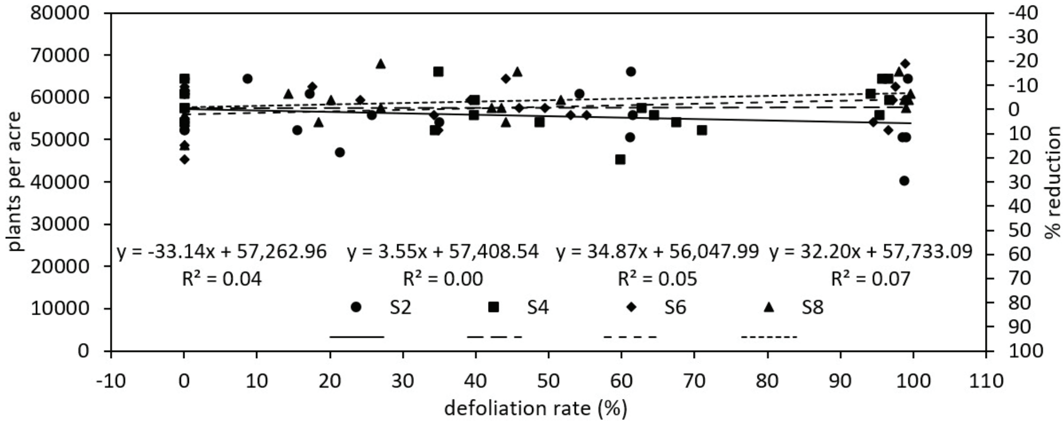

Figure 4. Effect of defoliation at four grain sorghum developmental stages on plant density at Manhattan, KS, in 2024.

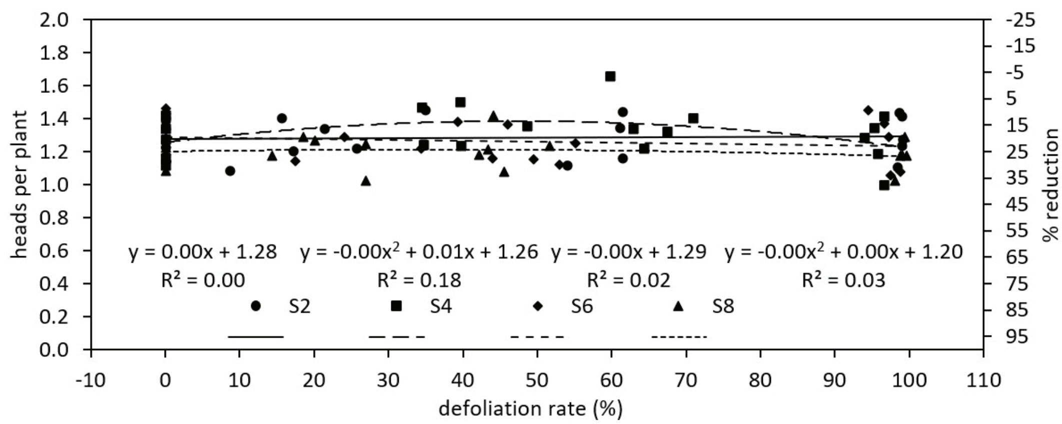

Figure 5. Effect of defoliation at four grain sorghum developmental stages on number of heads per plant at Manhattan, KS, in 2024.

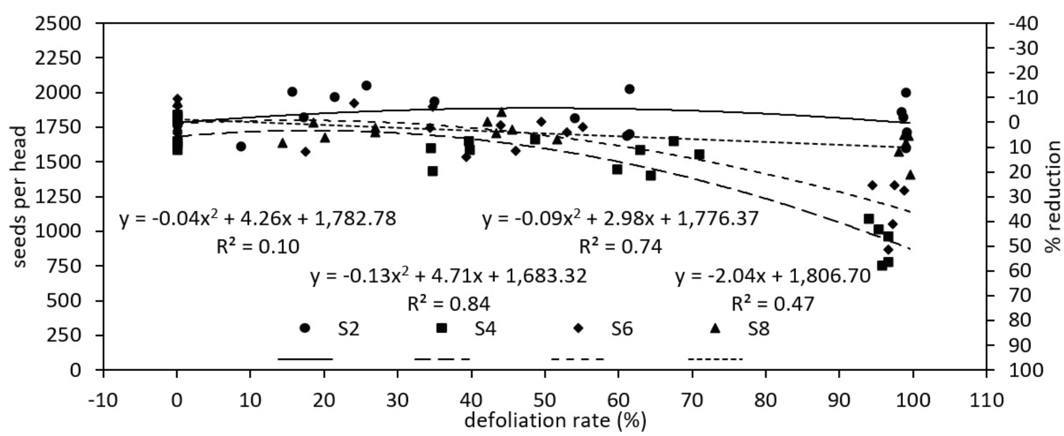

Figure 6. Effect of defoliation at four grain sorghum developmental stages on head size at Manhattan, KS, in 2024.

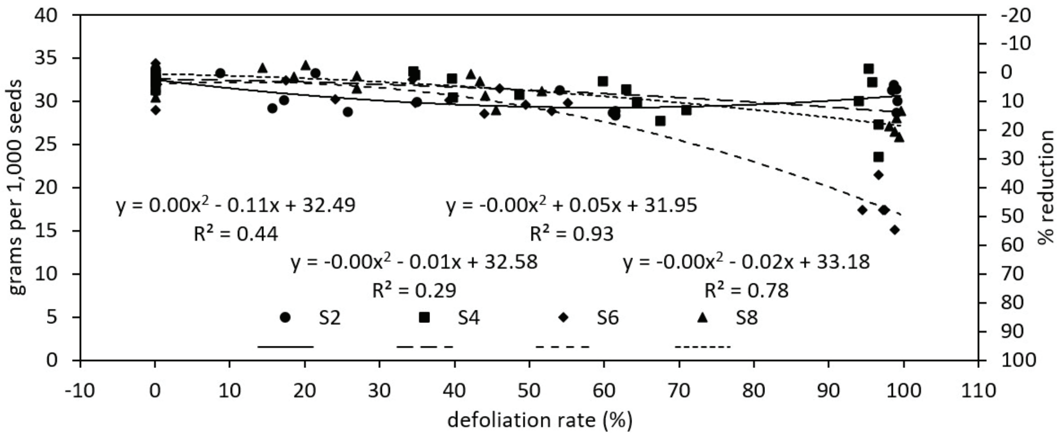

Figure 7. Effect of defoliation at four grain sorghum developmental stages on seed size at Manhattan, KS, in 2024.

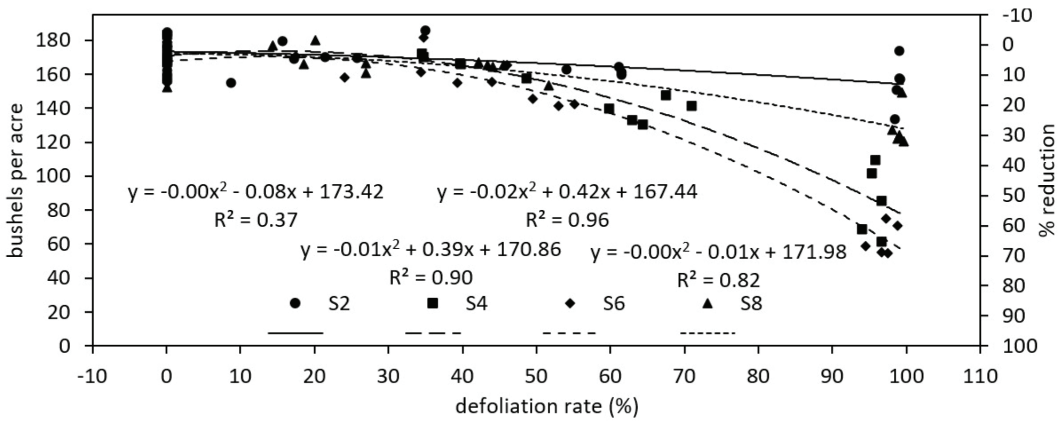

Figure 8. Effect of defoliation at four grain sorghum developmental stages on grain yield at Manhattan, KS, in 2024.

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