KANSAS STATE UNIVERSITY

Kansas Fertilizer Research 2019

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Research and Extension

Kansas State University Agricultural Experiment Station and Cooperative Extension Service

Kansas Fertilizer Research 2019

Contents

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Precipitation Data

Month	Manhattan	SWREC Tribune	SEARC Parsons	ECK Exp. Field Ottawa	NWREC Colby
	----------	----------	in.	----------	----------
2017					
August	1.87	1.66	8.12	7.92	2.67
September	3.40	2.70	2.62	4.29	3.02
October	2.03	0.36	5.94	4.40	1.17
November	0.21	T	0.68	0.29	0.17
December	0.00	T	0.30	0.42	0.08
Total 2017	31.42	23.45	51.49	41.57	25.21
Departure from normal	-3.38	+5.55	+8.52	+4.95	+4.56
2018					
January	0.28	0.34	0.66	1.19	1.41
February	0.12	0.46	3.20	1.11	0.37
March	0.76	0.12	2.50	2.58	0.60
April	0.50	1.45	1.25	1.44	1.01
May	3.23	1.84	7.64	4.89	4.44
June	1.85	3.29	1.42	1.27	3.29
July	4.95	2.75	3.41	1.66	2.54
August	3.52	3.11	8.76	8.13	2.81
September	4.47	1.52	3.35	3.13	0.59

continued

Month	NCK Exp. Field Belleville	KRV Exp. Field Silver Lake	SCK Exp. Field Hutchinson	ARC-Hays	Ellsworth
	------------------------------------- in. -------------------------------------				
2017					
August	1.46	5.79	2.53	3.08	1.87
September	3.21	1.21	2.91	2.17	3.40
October	1.77	3.37	2.14	1.96	2.03
November	0.17	0.09	0.02	0.24	0.21
December	0.11	0.27	0.00	0.04	0.00
Total 2017	27.60	34.65	25.53	28.10	31.42
Departure from normal	-3.00	-0.99	-5.08	+4.60	+1.76
2018					
January	0.26	0.56	0.30	0.45	0.28
February	0.66	0.42	0.26	0.15	0.12
March	1.08	0.63	2.14	0.77	0.76
April	1.23	0.99	1.18	0.74	0.50
May	2.55	3.57	3.83	4.86	3.23
June	4.29	3.56	5.05	3.92	1.85
July	6.85	1.38	6.84	7.66	4.95
August	4.20	3.67	3.14	5.33	3.52
September	5.09	1.87	4.43	3.84	4.47

continued

Month	KRV Rossville	SWREC Garden City	NCK Exp. Field Scandia	McPherson
	----------	----------	in. ----------	----------
2017				
August	4.12	1.87	1.88	2.42
September	1.24	3.40	2.30	1.95
October	2.54	2.03	1.32	2.13
November	0.15	0.21	0.08	0.04
December	0.24	0.00	0.05	0.14
Total 2017	34.91	31.42	21.08	28.09
Departure from normal	-2.30	+12.27	-7.74	-4.70
2018				
January	0.49	0.28	0.16	0.37
February	0.38	0.12	0.27	0.32
March	0.75	0.76	0.99	1.42
April	1.39	0.50	0.77	1.42
May	4.55	3.23	2.12	7.13
June	5.94	1.85	6.83	3.05
July	2.18	4.95	2.59	4.77
August	3.99	3.52	4.49	4.48
September	2.62	4.47	4.08	2.84

continued

Month	Girard	Conway Springs	Ashland Bottoms
	---------------------------- in. ----------------------------		
2017			
August	9.83	1.02	6.09
September	3.29	2.62	0.81
October	5.86	4.73	3.66
November	0.61	0.15	0.09
December	0.05	0.00	0.11
Total 2017	55.33	29.87	29.37
Departure from normal	+9.61	-3.70	-3.18
2018			
January	1.14	0.14	0.40
February	4.35	0.21	0.40
March	2.67	0.76	0.69
April	1.37	1.29	1.71
May	7.10	4.99	3.28
June	1.37	5.63	2.15
July	2.29	8.49	2.86
August	9.98	2.14	6.65
September	1.06	4.16	5.02

SWREC = Southwest Research Extension-Center; SEARC = Southeast Agricultural Research Center; ECK = East Central Kansas; NCK = North Central Kansas; KRV = Kansas River Valley; SCK = South Central Kansas; ARC = Agricultural Research Center.

Nitrogen, Phosphorus, and Potassium Fertilization for Newly Established Tall Fescue

D.W. Sweeney, J.L. Moyer, and J.K. Farney

Summary
Tall fescue production was studied during a fourth year of continuous research at two locations. In 2016, the fescue at Site 1 was affected by nitrogen (N) and phosphorus (P) fertilization in the spring, but the response was less defined in the fall harvest. At Site 2 in 2017, fescue production was mainly affected by N rate, with marginal response to potassium (K) fertilization.

Introduction
Tall fescue is the major cool-season grass in southeastern Kansas. Perennial grass crops, as with annual row crops, rely on proper fertilization for optimum production; however, meadows and pastures are often under-fertilized and produce low quantities of low-quality forage. Even when new stands are established, this is often true. The objective of this study was to determine whether N, P, and K fertilization improves yields during the early years of a stand.

Experimental Procedures
The experiment was established on two adjacent sites in the fall of 2012 (Site 1) and 2013 (Site 2) at the Parsons Unit of the Kansas State University Southeast Agricultural Research Center. The soil at both sites was a Parsons silt loam soil with initial soil test values of 5.9 pH, 2.8% organic matter, 4.2 ppm P, 70 ppm K, 3.9 ppm NH_4-N, and 37.9 ppm NO_3-N in the top 6 inches at Site 1; and 6.5 pH, 2.2% organic matter, 6.7 ppm P, 58 ppm K, 6.8 ppm NH_4-N, and 12.3 ppm NO_3-N in the top 6 inches at Site 2. The experimental design was a split-plot arrangement of a randomized complete block. The six whole plots received combinations of P_2O_5 and K_2O fertilizer levels allowing for two separate analyses: 1) four levels of P_2O_5 consisting of 0, 25, and 50 lb/a each year and a fourth treatment of 100 lb/a only applied at the beginning of the study; and 2) a 2 × 2 factorial combination of two levels of P_2O_5 (0 and 50 lb/a) and two levels of K_2O (0 and 40 lb/a). Subplots were four levels of N fertilization consisting of 0, 50, 100, and 150 lb/a. Phosphorus and K fertilizers were broadcast applied in the fall as 0-46-0 (triple superphosphate) and 0-0-60 (potassium chloride). Nitrogen was broadcast applied in late winter as 46-0-0 (urea) solid. Fourth-year sampling and harvest dates from each site were as follows. Early growth yield as an estimate of grazing potential in early spring was taken at E2 (jointing) growth stage on April 22, 2016, at Site 1 and on April 19, 2017, at Site 2 from a subarea of each plot not used for later spring and fall harvests. Spring yield was measured at R4 (half bloom) on May 13, 2016, at Site 1 and on May 15, 2017, at Site 2. Fall harvest was taken on September 21, 2016, at Site 1 and on September 13, 2017, at Site 2.

Results and Discussion

Fourth-year production of tall fescue was measured at Site 1 in 2016 and at Site 2 in 2017. At site 1 in 2016, early yield at the E2 (jointing) growth stage, measured to estimate forage available if grazed early, was increased with 50 lb P_2O_5/a (Table 1), and was increased with N rates of 100 or 150 lb/a above yield with no N added. At the R4 stage of hay harvest in 2016, yield was increased by P fertilization, but with no difference between rates. Nitrogen fertilizer additions up to 150 lb/a increased R4 hay yield. Fall yields were unaffected by P fertilization. Apparent mineralization during the summer resulted greater fall yield with no N as compared to the 50 and 100 lb N/a rates applied in late winter. Total yield was maximized with P fertilization and N applied at 150 lb/a.

For the fourth year of production at Site 2 (2017), yield was mainly affected by N rate. Sampling at E2 and R4 and fall harvest yields were not affected by P fertilization (Table 2) and response to K fertilization was marginal (data not shown). Increasing N rates tended to increase yield at the E2 sampling, R4 hay harvest, and total (R4 + fall) yield, especially with K fertilization (data not shown), but response was less defined at the fall harvest (Table 2). Total yield averaged less than 3.5 ton/a, even at the 150 lb/a N rate.

Table 1. Fourth-year yield of newly established tall fescue in the spring and fall 2016 as affected by the interaction of P_2O_5 and nitrogen (N) fertilization rates at Site 1

	Yield			
	Spring			Total
P_2O_5	E2 (jointing)	R4 (half-bloom)	Fall harvest	(R4 + Fall)
lb/a	---------------------------- ton/a, 12% moisture ----------------------------			
0	0.19	0.93	1.25	2.18
25	0.21	1.14	1.34	2.48
50	0.28	1.19	1.38	2.57
100[1]	0.29	1.19	1.37	2.56
LSD (0.10)	0.07	0.16	NS	0.26
N				
lb/a				
0	0.10	0.18	1.40	1.58
50	0.12	0.89	1.12	2.01
100	0.34	1.53	1.23	2.76
150	0.42	1.84	1.60	3.44
LSD (0.05)	0.07	0.09	0.16	0.18

[1]The 100 lb P_2O_5/a rate was only applied at the beginning of the study (Fall 2012).

Table 2. Fourth-year yield of newly established tall fescue in the spring and fall 2017 as affected by P_2O_5 and nitrogen (N) fertilization rates at Site 2

	Yield			
	Spring			Total
P_2O_5	E2 (jointing)	R4 (half-bloom)	Fall harvest	(R4 + Fall)
lb/a	---------------------------- ton/a, 12% moisture ----------------------------			
0	0.28	0.67	0.76	1.43
25	0.26	0.62	0.73	1.34
50	0.30	0.74	0.78	1.52
100[1]	0.31	0.66	0.73	1.39
LSD (0.05)	NS	NS	NS	NS
N				
lb/a				
0	0.05	0.11	0.69	0.80
50	0.21	0.42	0.56	0.98
100	0.42	0.89	0.78	1.68
150	0.48	1.26	0.96	2.22
LSD (0.05)	0.08	0.13	0.08	0.18

[1]The 100 lb P_2O_5/a rate was only applied at the beginning of the study (Fall 2013).

Tillage and Nitrogen Placement Effects on Yields in a Short-Season Corn/Wheat/Double-Crop Soybean Rotation

D.W. Sweeney and D.A. Ruiz-Diaz

Summary
Under high-yielding conditions, corn yield in 2017 was not statistically affected by tillage. Applying nitrogen (N) fertilizer approximately doubled corn yield, but with no difference between N application methods.

Introduction
Many crop rotation systems are used in southeastern Kansas. This experiment was designed to determine the long-term effect of selected tillage and N fertilizer placement options on yields of short-season corn, wheat, and double-crop soybean in a rotation.

Experimental Procedures
A split-plot design with four replications was initiated in 1983 with tillage system as the whole plot and N treatment as the subplot. In 2005, the rotation was changed to begin a short-season corn/wheat/double-crop soybean sequence. Use of three tillage systems (conventional, reduced, and no-till) continued in the same areas used during the previous 22 years. The conventional system consisted of chiseling, disking, and field cultivation. Chisel operations occurred in the fall preceding corn or wheat crops. The reduced-tillage system consists of disking and field cultivation prior to planting. Glyphosate (Roundup) was applied to the no-till areas. The four N treatments for the crop were: no N (control), broadcast urea ammonium nitrate (UAN; 28% N) solution, dribble UAN solution, and knife UAN solution at a 4 in. depth. The N rate for the corn crop grown in odd years was 125 lb/a. Corn was planted on April 11, 2017.

Results and Discussion
Overall, yields were high in 2017. Tillage did not statistically affect corn yields (Figure 1). In general, adding N by any placement method approximately doubled the yield obtained without N. However, corn yield in 2017 was not affected by N placement method or by the interaction of tillage by N treatments.

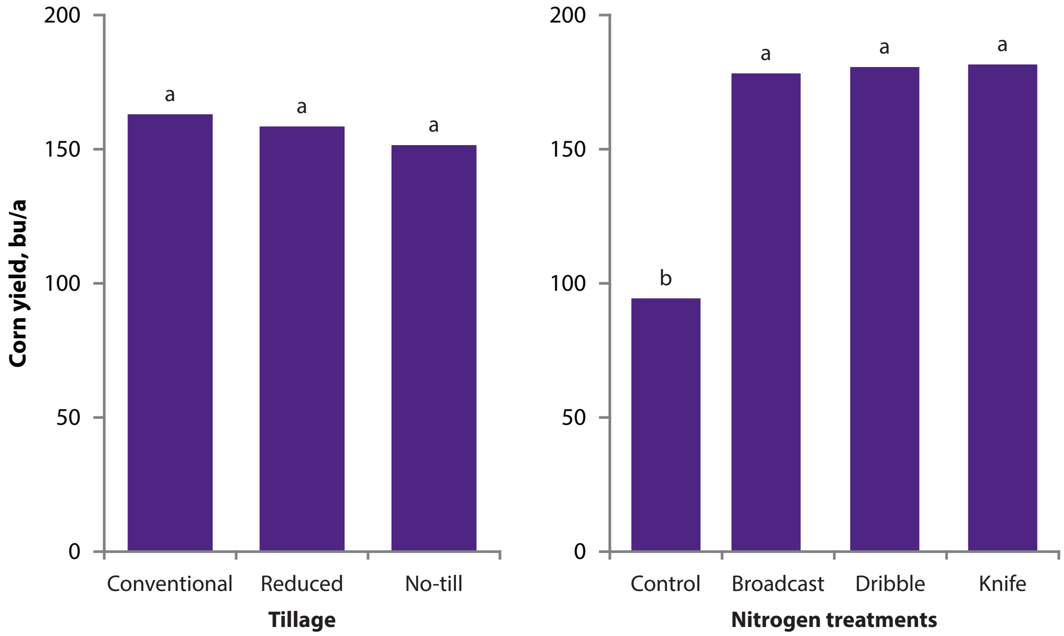

Figure 1. Effect of tillage and nitrogen placement on corn yield in 2017. Within a graph, bars with the same letter are not significantly different according to LSD (0.05).

Timing of Side-Dress Applications of Nitrogen for Corn in Conventional and No-Till Systems

D.W. Sweeney, D. Shoup, and D.A. Ruiz-Diaz

Summary
Corn yield and yield components were affected by tillage and nitrogen (N) side-dress options in 2017. Corn yields were 14% greater with conventional tillage than with no-till. Yields were improved by either splitting N rate between pre-plant and side-dress or adding additional side-dress N as compared with applying 150 lb/a pre-plant. Side-dress applications of 50 lb N/a at V10 following 150 lb/a applied pre-plant resulted in greatest corn yield.

Introduction
Environmental conditions vary widely in the spring in southeastern Kansas. As a result, much of the N applied prior to corn planting may be lost before the time of maximum plant N uptake. Side-dress or split applications to provide N during rapid growth periods may improve N use efficiency while reducing potential losses to the environment. The objective of this study was to determine the effect of timing of side-dress N fertilization compared with pre-plant N applications for corn grown on a claypan soil.

Experimental Procedures
The experiment was established in spring 2015 on a Parsons silt loam soil at the Parsons unit of the Kansas State University Southeast Agricultural Research Center. The experiment was a split-plot arrangement of a randomized complete block design with four blocks (replications). Whole plot tillage treatments were conventional tillage (chisel, disk, and field cultivate) and no tillage. Sub-plot nitrogen treatments were six pre-plant/side-dress N application combinations that include 1) a no-N control, 2) 150 lb N/a applied pre-plant, 3) 100 lb N/a applied pre-plant with 50 lb N/a applied at the V6 (six-leaf) growth stage, 4) 100 lb N/a applied pre-plant with 50 lb N/a applied at the V10 (ten-leaf) growth stage, 5) 150 lb N/a applied pre-plant with 50 lb N/a applied at the V6 growth stage, and 6) 150 lb N/a applied pre-plant with 50 lb N/a applied at the V10 growth stage. The N source for all treatments was liquid urea-ammonium nitrate (28% N) fertilizer. Pre-plant N fertilizer was applied on March 16, 2017, side-dress N at V6 on May 25, 2017, and side-dress N at V10 on June 12, 2017, to appropriate plots. All N was broadcast applied with 7-stream pattern fertilizer nozzles. Corn was planted on April 11 and harvested on September 11, 2017.

Results and Discussion
In 2017, corn yielded 18 bu/a more with conventional tillage than with no-tillage, likely because of 16% greater stand (Table 1). Adding N fertilizer, generally, more than doubled yields obtained in the no-N control. Splitting the N fertilizer to apply 100 lb N/a preplant followed by 50 lb N/a at the V6 or V10 growth stages improved yields by more than 15 bu/a greater than all N applied pre-plant. Adding 50 lb N/a extra at the

V6 growth stage to a 150 lb N/a preplant application did not improve yields more than that obtained with 150 lb N/a applied split pre-plant and side-dress. However, delaying the extra 50 lb N/a side-dress application to the V10 stage improved yield by nearly 20 bu/a. These effects of N timing on corn yield in 2017 appeared to be related to the combined responses in kernel weight, ears/plant and kernels/ear.

Table 1. Tillage and nitrogen (N) side-dress application effects on yield and yield components of corn in 2017

Treatment	Yield	Stand	Kernel weight	Ears/plant	Kernels/ear
	bu/a	number/a	mg		
Tillage					
Conventional[1]	147.3	22300	225	0.93	789
No-till	129.0	19200	230	0.90	800
LSD (0.10)	16.6	1300	NS	NS	NS
N timing[2]					
No-N control	56.1	20900	178	0.82	483
150 PP	134.8	20900	220	0.92	814
100 PP/50 V6	152.0	20500	232	0.95	866
100 PP/50 V10	151.1	20600	240	0.92	850
150 PP/50 V6	157.8	20800	246	0.96	826
150 PP/50 V10	177.0	20900	250	0.94	929
LSD (0.05)	15.2	NS	19	0.08	80

[1]Conventional tillage: chisel, disk, and field cultivate.
[2]Nitrogen treatments: Control, no N fertilizer; 150 PP, 150 lb N/a applied pre-plant with no side-dress N;
100 PP/50 V6, 100 lb N/a applied pre-plant with 50 lb N/a side-dress applied at V6 (six-leaf) growth stage;
100 PP/50 V10, 100 lb N/a applied pre-plant with 50 lb N/a side-dress applied at V10 (ten-leaf) growth stage;
150 PP/50 V6, 150 lb N/a applied pre-plant with 50 lb N/a side-dress applied at V6 growth stage; and
150 PP/50 V10, 150 lb N/a applied pre-plant with 50 lb N/a side-dress applied at V10 growth stage.

Response of Soybean Grown on a Claypan Soil in Southeastern Kansas to the Residual of Different Plant Nutrient Sources and Tillage[1]

D.W. Sweeney, P. Barnes,[2] and G. Pierzynski

Summary

The residual from previous high-rate turkey litter applications, which were based on nitrogen (N) requirements of the previous grain sorghum crop, increased 2017 soybean yield more than that obtained from the residual of phosphorus (P)-based turkey litter applications (low rate), commercial fertilizer, or the control. Even though early soybean growth was marginally affected by residual treatments, the greatest dry matter production at the R6 growth stage was where the N-based litter had been applied and incorporated.

Introduction

Increased fertilizer prices in recent years, especially noticeable when the cost of phosphorus spiked in 2008, have led U.S. producers to consider other alternatives, including manure sources. The use of poultry litter as an alternative to fertilizer is of particular interest in southeastern Kansas because large amounts of poultry litter are imported from nearby confined animal feeding operations in Arkansas, Oklahoma, and Missouri. Annual application of turkey litter can affect the current crop, but information is lacking concerning any residual effects from several continuous years of poultry litter applications on a following crop. This is especially true for tilled soil compared with no-till because production of most annual cereal crops on the claypan soils of the region is often negatively affected by no-till planting. The objective of this study was to determine if the residual from fertilizer and poultry litter applications under tilled or no-till systems affects soybean yield and growth.

Experimental Procedures

A water quality experiment was conducted near Girard, KS, on the Greenbush Educational facility's grounds from spring 2011 through spring 2014. Fertilizer and turkey litter were applied prior to planting grain sorghum each spring. Individual plot size was 1 acre. The five treatments, replicated twice, were:

Control – no N or P fertilizer or turkey litter – no tillage;
Fertilizer only – commercial N and P fertilizer – chisel-disk tillage;
Turkey litter, N-based – no extra N or P fertilizer – no tillage;
Turkey litter, N-based – no extra N or P fertilizer – chisel-disk tillage; and
Turkey litter, P-based – supplemented with fertilizer N – chisel-disk tillage.

[1]Partially funded by U.S. Department of Agriculture Natural Resource Conservation Service Conservation Innovation Grant.

[2]Department of Biological and Agricultural Engineering, Kansas State University, Manhattan, KS.

Starting in 2014 after the previously-mentioned study, soybean was planted with no further application of turkey litter or fertilizer. Prior to planting soybean, tillage operations were done in appropriate plots as in previous years. A sub-area of 20 × 20 ft near the center of each 1-acre plot was designated for crop yield and growth measurements. Samples were taken for dry matter production at V3-V4 (approximately 3 weeks after planting), R2, R4, and R6 growth stages. Yield was determined from the center 4 rows (10 × 20 ft) of the sub-area designated for plant measurements in each plot.

Results and Discussion

In 2017, the residual effects of turkey litter and fertilizer amendments affected soybean yield, pods/plant, and seeds/pod (Table 1). The two treatments which had previously received a high application rate of turkey litter based on N requirements, regardless of tillage system, resulted in greater yields than from plots that had received low rates of turkey litter (P-based), commercial fertilizer, or no fertilizer N or P. The number of pods/plant and the number of seeds/pod were greater where N-based turkey litter had been applied than in the other residual treatments. Dry matter production was marginally affected by residual treatment through the R4 growth stage. However, at R6, dry matter production was greatest where turkey litter had previously been applied on an N-basis (high rate) and incorporated.

Table 1. Residual effect of turkey litter and fertilizer amendments on soybean yield, yield components, and dry matter production during 2017

Residual amendment[1]	Yield	Stand (× 1000)	Seed weight	Pods/ plant	Seeds/ pod	Dry matter V4	Dry matter R2	Dry matter R4	Dry matter R6
	bu/a	plants/a	mg			------------------- lb/a -------------------			
Control	22.7	122	143	30	2.0	440	1420	4130	3830
Fert-C	45.1	123	155	37	2.1	530	2360	5380	5760
TL-N	64.0	115	174	51	2.3	560	2920	5950	5540
TL-N-C	62.5	125	177	43	2.4	570	3300	5830	7650
TL-P-C	40.2	118	154	31	2.1	520	2290	4840	5460
LSD (0.05)	15.6	NS	NS	9	0.1	NS	1110	NS	1070

[1]Control, no turkey litter or N and P fertilizer with no tillage; TL-N, N-based turkey litter application with no tillage; TL-N-C, N-based turkey litter application incorporated with conventional tillage; TL-P-C, P-based turkey litter application and supplemental N application incorporated with conventional tillage; and Fert-C, commercial fertilizer incorporated with conventional tillage.

Long-Term Nitrogen, Phosphorus, and Potassium Fertilization of Irrigated Grain Sorghum

A.J. Schlegel and H.D. Bond

Summary
Long-term research shows that phosphorus (P) and nitrogen (N) fertilizer must be applied to optimize production of irrigated grain sorghum in western Kansas. In 2018, N applied alone increased yields 44 bu/a, whereas N and P applied together increased yields up to 67 bu/a. Averaged across the past 10 years, N and P fertilization increased sorghum yields up to 75 bu/a. Application of 80 lb/a N (with P) produced the maximum yield in 2018, which is slightly less than the 10-year average. Application of potassium (K) has had no effect on sorghum yield throughout the study period. Average grain N content reached a maximum of ~0.7 lb/bu while grain P content reached a maximum of 0.15 lb/bu (0.34 lb P_2O_5/bu) and grain K content reached a maximum of 0.19 lb/bu (0.23 lb K_2O/bu). At the highest N, P, and K rate, apparent fertilizer recovery in the grain was 31% for N, 65% for P, and 38% for K.

Introduction
This study was initiated in 1961 to determine responses of continuous grain sorghum grown under flood irrigation to N, P, and K fertilization. The study is conducted on a Ulysses silt loam soil with an inherently high K content. The irrigation system was changed from flood to sprinkler in 2001.

Procedures
This field study is conducted at the Tribune Unit of the Kansas State University Southwest Research-Extension Center. Fertilizer treatments initiated in 1961 are N rates of 0, 40, 80, 120, 160, and 200 lb/a N without P and K; with 40 lb/a P_2O_5 and zero K; and with 40 lb/a P_2O_5 and 40 lb/a K_2O. All fertilizers are broadcast by hand in the spring and incorporated before planting. The soil is a Ulysses silt loam. Grain sorghum (Pioneer 85G46 in 2009–2011, Pioneer 84G62 in 2012-2014, Pioneer 86G32 in 2015, Pioneer 84G62 in 2016–2017, and Pioneer 85P44 in 2018) was planted in late May or early June. Irrigation is used to minimize water stress. Sprinkler irrigation has been used since 2001. The center two rows of each plot are machine harvested after physiological maturity. Grain yields are adjusted to 12.5% moisture. Grain samples were collected at harvest, dried, ground, and analyzed for N, P, and K concentrations. Grain N, P, and K content (lb/bu) and removal (lb/a) were calculated. Apparent fertilizer N recovery in the grain ($AFNR_g$) was calculated as N uptake in treatments receiving N fertilizer minus N uptake in the unfertilized control divided by N rate. The same approach was used to calculate apparent fertilizer P recovery in the grain ($AFPR_g$) and apparent fertilizer K recovery ($AFKR_g$).

Results

Grain sorghum yields in 2018 were 5% lower than the 10-year average (Table 1). Nitrogen alone increased yields 44 bu/a, while P alone increased yields less than 10 bu/a. However, N and P applied together increased yields up to 67 bu/a. Averaged across the past 10 years, N and P applied together increased yields up to 75 bu/a. In 2018, 40 lb/a N (with P) produced about 88% of maximum yield, which is greater than the 10-year average of 85%. The 10-year average for 80 lb/a N (with P) and 120 lb/a N (with P) was 94 and 95% of maximum yield, respectively. Sorghum yields were not affected by K fertilization, which has been the case throughout the study period.

The 10-year average grain N concentration (%) increased with N rates but tended to decrease when P was also applied, presumably because of higher grain yields diluting N content (Table 2). Grain N content reached a maximum of ~0.7 lb/bu. Maximum N removal (lb/a) was obtained with 160 lb N/a or greater with P. Similar to N, average P concentration increased with P application but decreased with higher N rates. Grain P content (lb/bu) of ~0.15 lb P/bu (0.34 lb P_2O_5/bu) was similar for all N rates when P was applied. Grain P removal was similar for all N rates of 40 lb/a or greater with P removal ranging from 19 to 22 lb/a. Average K concentration (%) and content (lb/bu) tended to decrease with increased N rates. Similar to P, K removal was similar for all N rates of 40 lb/a or greater plus K ranging from 22 to 26 lb/a. At the highest N, P, and K rate, apparent fertilizer recovery in the grain was 31% for N, 65% for P, and 38% for K.

Acknowledgment

The International Plant Nutrition Institute partially supported this research project.

Table 1. Nitrogen (N), phosphorus (P), and potassium (K) fertilizers on irrigated grain sorghum yields, Tribune, KS, 2009-2018

Fertilizer			Grain sorghum yield										
N	P_2O_5	K_2O	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Mean
---------- lb/a ----------			---------- bu/a ----------										
0	0	0	64	51	75	78	62	90	89	80	70	77	74
0	40	0	70	51	83	90	77	94	102	91	79	87	83
0	40	40	76	55	88	93	72	96	97	91	80	83	83
40	0	0	84	66	106	115	94	115	122	106	87	93	99
40	40	0	118	77	121	140	114	144	160	142	120	126	126
40	40	40	109	73	125	132	110	142	155	137	118	131	123
80	0	0	115	73	117	132	102	120	133	120	104	103	112
80	40	0	136	86	140	163	136	151	173	154	123	144	141
80	40	40	108	84	138	161	133	164	178	160	129	140	140
120	0	0	113	70	116	130	100	116	127	108	93	91	106
120	40	0	130	88	145	172	137	162	177	164	121	128	142
120	40	40	136	90	147	175	142	170	178	170	131	143	148
160	0	0	108	74	124	149	117	139	150	135	120	107	122
160	40	0	128	92	152	178	146	171	181	173	137	134	149
160	40	40	140	88	151	174	143	176	179	161	131	139	148
200	0	0	110	78	128	147	119	139	155	151	123	121	127
200	40	0	139	84	141	171	136	165	177	167	131	134	145
200	40	40	129	87	152	175	138	170	179	170	131	130	146

continued

Table 1. Nitrogen (N), phosphorus (P), and potassium (K) fertilizers on irrigated grain sorghum yields, Tribune, KS, 2009-2018

Fertilizer	Grain sorghum yield										
N P_2O_5 K_2O	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Mean
---------- lb/a ----------	---------- bu/a ----------										
ANOVA (P>F)											
Nitrogen	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Linear	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Quadratic	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
P-K	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Zero P vs. P	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
P vs. P-K	0.324	0.892	0.278	0.826	0.644	0.117	0.806	0.943	0.727	0.549	0.833
N × P-K	0.053	0.229	0.542	0.186	0.079	0.012	0.002	0.001	0.084	0.003	0.007
MEANS											
Nitrogen, lb/a											
0	70 c	52 c	82 d	87 d	70 d	94 e	96 d	87 d	76 d	82 c	80 d
40	104 b	72 b	117 c	129 c	106 c	134 d	146 c	129 c	108 c	117 b	116 c
80	120 a	81 a	132 b	152 b	124 b	145 c	161 b	145 b	119 b	129 a	131 b
120	126 a	82 a	136 ab	159 ab	126 b	149 bc	161 b	147 b	115 bc	121 ab	132 b
160	125 a	84 a	142 a	167 a	135 a	162 a	170 a	156 a	129 a	127 a	140 a
200	126 a	83 a	141 a	165 a	131 ab	158 ab	170 a	163 a	129 a	128 a	139 a
$LSD_{(0.05)}$	11	5	8	9	8	9	8	8	9	9	6
P_2O_5-K_2O, lb/a											
0 - 0	99 b	68 b	111 b	125 b	99 b	120 b	129 b	117 b	99 b	99 b	107 b
40 - 0	120 a	80 a	130 a	152 a	124 a	148 a	162 a	149 a	119 a	126 a	131 a
40 - 40	116 a	79 a	133 a	152 a	123 a	153 a	161 a	148 a	120 a	128 a	131 a
$LSD_{(0.05)}$	7	4	6	6	5	6	5	6	6	6	4

ANOVA = analysis of variance.
LSD = least significant difference.

Table 2. Nitrogen (N), phosphorus (P), and potassium (K) fertilizers on grain N, P, and K content of irrigated grain sorghum, Tribune, KS, 2009-2018

Fertilizer			Grain						Grain removal					
N	P_2O_5	K_2O	N	P	K	N	P	K	N	P	K	*AFNRg	*AFPRg	*AFKRg
------------ lb/a ------------			--------------- % ---------------			------------- lb/bu -------------			-------------- lb/a --------------			-------------------- % --------------------		
0	0	0	1.05	0.256	0.358	0.51	0.125	0.176	38	9	13	- - -	- - -	- - -
0	40	0	1.04	0.311	0.382	0.51	0.152	0.187	42	13	15	- - -	20	- - -
0	40	40	1.04	0.310	0.382	0.51	0.152	0.187	42	13	16	- - -	20	8
40	0	0	1.15	0.233	0.346	0.57	0.114	0.170	55	11	17	44	- - -	- - -
40	40	0	1.12	0.314	0.371	0.55	0.154	0.182	69	19	23	78	59	- - -
40	40	40	1.12	0.309	0.370	0.55	0.152	0.181	67	19	22	73	55	29
80	0	0	1.35	0.218	0.340	0.66	0.107	0.167	73	12	19	45	- - -	- - -
80	40	0	1.23	0.295	0.358	0.60	0.145	0.175	84	20	25	58	64	- - -
80	40	40	1.20	0.304	0.359	0.59	0.149	0.176	81	21	25	55	67	35
120	0	0	1.41	0.204	0.337	0.69	0.100	0.165	73	11	17	29	- - -	- - -
120	40	0	1.32	0.283	0.355	0.65	0.139	0.174	92	20	25	45	60	- - -
120	40	40	1.32	0.302	0.357	0.65	0.148	0.175	96	22	26	48	73	39
160	0	0	1.41	0.228	0.345	0.69	0.112	0.169	84	14	21	29	- - -	- - -
160	40	0	1.39	0.304	0.360	0.68	0.149	0.177	101	22	26	40	75	- - -
160	40	40	1.36	0.280	0.353	0.67	0.137	0.173	98	20	26	38	63	38
200	0	0	1.43	0.234	0.349	0.70	0.115	0.171	88	15	22	25	- - -	- - -
200	40	0	1.39	0.281	0.358	0.68	0.138	0.175	98	20	25	30	61	- - -
200	40	40	1.40	0.288	0.359	0.68	0.141	0.176	99	20	26	31	65	38

continued

Table 2. Nitrogen (N), phosphorus (P), and potassium (K) fertilizers on grain N, P, and K content of irrigated grain sorghum, Tribune, KS, 2009-2018

Fertilizer	Grain						Grain removal					
N / P_2O_5 / K_2O	N	P	K	N	P	K	N	P	K	*AFNRg	*AFPRg	*AFKRg
lb/a	%			lb/bu			lb/a			%		
ANOVA (P>F)												
Nitrogen	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Linear	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Quadratic	0.001	0.011	0.001	0.001	0.011	0.001	0.001	0.001	0.001	0.042	0.001	0.001
P-K	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.819	---
Zero P vs. P	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	---	---	---
P vs. P-K	0.477	0.846	0.726	0.477	0.846	0.726	0.813	0.843	0.962	---	---	---
N × P-K	0.236	0.013	0.347	0.236	0.013	0.347	0.147	0.001	0.005	0.019	0.110	---
MEANS												
Nitrogen, lb/a												
0	1.04 e	0.292 a	0.374 a	0.51 e	0.143 a	0.183 a	40 e	11 c	15 d	---	20 c	8 c
40	1.13 d	0.286 a	0.362 b	0.55 d	0.140 a	0.178 b	63 d	16 b	21 c	65 a	57 b	29 b
80	1.26 c	0.272 b	0.353 c	0.62 c	0.133 b	0.173 c	80 c	18 ab	23 b	53 b	65 ab	35 a
120	1.35 b	0.263 b	0.350 c	0.66 b	0.129 b	0.172 c	87 b	17 ab	23 b	41 c	66 a	39 a
160	1.39 ab	0.271 b	0.353 c	0.68 ab	0.133 b	0.173 c	95 a	19 a	24 a	36 c	69 a	38 a
200	1.41 a	0.268 b	0.355 c	0.69 a	0.131 b	0.174 c	95 a	18 a	24 a	29 d	63 ab	38 a
$LSD_{(0.05)}$	0.04	0.012	0.006	0.02	0.006	0.003	5	1	1	6	8	5
P_2O_5-K_2O, lb/a												
0 - 0	1.30 a	0.229 b	0.346 b	0.64 a	0.112 b	0.170 b	69 b	12 b	18 b	35 b	---	---
40 - 0	1.25 b	0.298 a	0.364 a	0.61 b	0.146 a	0.178 a	81 a	19 a	23 a	50 a	56	---
40 - 40	1.24 b	0.299 a	0.363 a	0.61 b	0.146 a	0.178 a	81 a	19 a	23 a	49 a	57	---
$LSD_{(0.05)}$	0.03	0.009	0.004	0.01	0.004	0.002	3	1	1	5	5	---

*$AFNR_g$, $AFPR_g$, and $AFKR_g$ =Apparent Fertilizer N Recovery (grain), Apparent Fertilizer P Recovery (grain), and Apparent Fertilizer K Recovery (grain).
ANOVA = analysis of variance.
LSD = least significant difference.

Long-Term Nitrogen and Phosphorus Fertilization of Irrigated Corn

A.J. Schlegel and H.D. Bond

Summary

Long-term research shows that phosphorus (P) and nitrogen (N) fertilizer must be applied to optimize production of irrigated corn in western Kansas. In 2018, N applied alone increased yields by 76 bu/a, whereas P applied alone increased yields up to 17 bu/a. Nitrogen and P applied together increased yields up to 169 bu/a which is 26 bu/a more than the 10-year average of 143 bu/a. Application of 120 lb/a N (with highest P rate) produced 97% of maximum yield in 2018, which is slightly greater than the 10-year average. Application of 80 instead of 40 lb P_2O_5/a increased average yields 9 bu/a. Average grain N content reached a maximum of 0.6 lb/bu while grain P content reached a maximum of 0.15 lb/bu (0.34 lb P_2O_5/bu). At the highest N and P rate, apparent fertilizer nitrogen recovery in the grain ($AFNR_g$) was 43% and apparent fertilizer phosphorus recovery in the grain ($AFPR_g$) was 62%.

Introduction

This study was initiated in 1961 to determine responses of continuous corn and grain sorghum grown under flood irrigation to N, P, and potassium (K) fertilization. The study is conducted on a Ulysses silt loam soil with an inherently high K content. No yield benefit to corn from K fertilization was observed in 30 years, and soil K levels remained high, so the K treatment was discontinued in 1992 and replaced with a higher P rate.

Procedures

This field study is conducted at the Tribune Unit of the Kansas State University Southwest Research-Extension Center. Fertilizer treatments initiated in 1961 are N rates of 0, 40, 80, 120, 160, and 200 lb/a without P and K; with 40 lb/a P_2O_5 and zero K; and with 40 lb/a P_2O_5 and 40 lb/a K_2O. The treatments were changed in 1992; the K variable was replaced by a higher rate of P (80 lb/a P_2O_5). All fertilizers were broadcast by hand in the spring and incorporated before planting. The soil is a Ulysses silt loam. The corn hybrids [DeKalb 61-69 (2009), Pioneer 1173H (2010), Pioneer 1151XR (2011), Pioneer 0832 (2012-2013), Pioneer 1186AM (2014), Pioneer 35F48 AM1 (2015), Pioneer 1197 (2016), and Pioneer 0801 (2017-2018)] were planted at about 32,000 seeds/a in late April or early May. Hail damaged the 2008, 2010, and 2017 crops. The corn is irrigated to minimize water stress. Sprinkler irrigation has been used since 2001. The center two rows of each plot are machine harvested after physiological maturity. Grain yields are adjusted to 15.5% moisture. Grain samples were collected at harvest, dried, ground, and analyzed for N and P concentrations. Grain N and P content (lb/bu) and removal (lb/a) were calculated. Apparent fertilizer N recovery in the grain ($AFNR_g$) was calculated as N uptake in treatments receiving N fertilizer minus N uptake in the unfertilized control divided by N rate. The same approach was used to calculate apparent fertilizer P recovery in the grain ($AFPR_g$). Grasshoppers were treated by aerial application of insecticide.

Results

Corn yields in 2018 were 15% higher than the 10-year average (Table 1). Nitrogen alone increased yields 76 bu/a, whereas P alone increased yields 17 bu/a. However, N and P applied together increased corn yields up to 169 bu/a. Maximum yield was obtained with 160 lb/a N with 80 lb/a P_2O_5. Corn yields in 2018 (averaged across all N rates) were 9 bu/a greater with 80 than with 40 lb/a P_2O_5.

The 10-year average grain N concentration (%) increased with N rates but tended to decrease when P was also applied, presumably because of higher grain yields diluting N content (Table 2). Grain N content reached a maximum of 0.6 lb/bu. N removal (lb/a) was greater at the higher yield levels. Maximum N removal (lb/a), was attained with 200 lb N and 80 lb P_2O_5/a. At the highest N and P rate, $AFNR_g$ was 43% and $AFPR_g$ was 62%. Similar to N, average P concentration increased with increased P rates but decreased with higher N rates. Grain P content (lb/bu) of about 0.15 lb P/bu (0.34 lb P_2O_5/bu) was greater at the highest P rate with low N rates. Grain P removal averaged 27 lb P/a at the highest yields.

Acknowledgment

The International Plant Nutrition Institute partially supported this research project.

Table 1. Nitrogen (N) and phosphorus (P) fertilization on irrigated corn yields, Tribune, KS, 2009-2018

Fertilizer		Yield										
N	P_2O_5	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Mean
------ lb/a ------		------ bu/a ------										
0	0	85	20	92	86	70	86	92	74	44	82	73
0	40	110	21	111	85	80	95	103	78	47	93	82
0	80	106	28	105	94	91	98	104	86	52	99	86
40	0	108	23	114	109	97	106	113	105	60	110	94
40	40	148	67	195	138	125	153	164	145	92	160	139
40	80	159	61	194	135	126	149	162	135	90	159	137
80	0	123	34	136	128	112	117	131	118	70	117	109
80	40	179	85	212	197	170	187	195	196	132	212	176
80	80	181	90	220	194	149	179	193	193	129	207	173
120	0	117	28	119	134	114	115	124	109	62	102	102
120	40	202	90	222	213	204	213	212	212	142	218	193
120	80	215	105	225	211	194	216	216	223	162	243	201
160	0	139	49	157	158	122	128	144	142	84	139	126
160	40	210	95	229	227	199	211	215	226	154	230	200
160	80	223	95	226	239	217	233	216	238	165	251	210
200	0	155	65	179	170	139	144	162	159	114	158	146
200	40	207	97	218	225	198	204	214	216	148	231	196
200	80	236	104	231	260	220	238	221	235	174	243	216

continued

Table 1. Nitrogen (N) and phosphorus (P) fertilization on irrigated corn yields, Tribune, KS, 2009-2018

Fertilizer		Yield										
N	P_2O_5	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Mean
------ lb/a ------		bu/a										
ANOVA (P>F)												
Nitrogen		0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Linear		0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Quadratic		0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Phosphorus		0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Linear		0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Quadratic		0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
N × P		0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
MEANS												
Nitrogen, lb/a												
0		100 e	23 e	103 d	88 f	80 e	93 e	100 e	79 e	48 e	91 d	81 e
40		138 d	50 d	167 c	127 e	116 d	136 d	146 d	129 d	81 d	143 c	123 d
80		161 c	70 c	189 b	173 d	143 c	161 c	173 c	169 c	110 c	179 b	153 c
120		178 b	74 bc	189 b	186 c	171 b	181 b	184 b	182 b	122 b	188 b	165 b
160		191 a	80 ab	204 a	208 b	179 ab	190 ab	192 ab	202 a	134 a	207 a	179 a
200		199 a	89 a	209 a	218 a	186 a	196 a	199 a	203 a	145 a	211 a	186 a
$LSD_{(0.05)}$		12	9	13	10	10	10	9	10	11	13	8
P_2O_5, lb/a												
0		121 c	36 b	133 b	131 c	109 b	116 c	128 b	118 b	72 c	118 c	108 c
40		176 b	76 a	198 a	181 b	163 a	177 b	184 a	179 a	119 b	191 b	164 b
80		187 a	81 a	200 a	189 a	166 a	186 a	185 a	185 a	129 a	200 a	171 a
$LSD_{(0.05)}$		9	7	9	7	7	7	6	7	8	9	6

*Note: Hail events on 7/23/10, 5/28/15, and 8/18/17.
ANOVA = analysis of variance.
LSD = least significant difference.

Table 2. Nitrogen (N) and phosphorus (P) fertilization on grain N and P content of irrigated corn, Tribune, KS, 2009-2018

Fertilizer		Grain				Grain removal			
N	P_2O_5	N	P	N	P	N	P	*$AFNR_g$	*$AFPR_g$
--------- lb/a ---------		---------- -% ----------		-------- lb/bu --------		--------- lb/a ---------		---------- % ----------	
0	0	0.98	0.226	0.46	0.107	33	8	---	---
0	40	0.94	0.304	0.44	0.144	36	12	---	23
0	80	0.94	0.317	0.45	0.150	37	13	---	15
40	0	1.16	0.181	0.55	0.086	51	8	45	---
40	40	0.96	0.299	0.45	0.141	62	20	73	67
40	80	0.97	0.318	0.46	0.151	62	21	72	37
80	0	1.26	0.177	0.59	0.084	63	9	38	---
80	40	1.04	0.251	0.49	0.119	86	21	67	73
80	80	1.01	0.305	0.48	0.145	82	25	61	49
120	0	1.27	0.171	0.60	0.081	61	8	23	---
120	40	1.13	0.225	0.53	0.107	102	20	58	71
120	80	1.09	0.295	0.52	0.139	103	28	58	57
160	0	1.25	0.175	0.59	0.083	74	10	25	---
160	40	1.17	0.240	0.55	0.114	110	22	48	83
160	80	1.15	0.276	0.55	0.131	114	27	51	55
200	0	1.22	0.188	0.58	0.089	83	13	25	---
200	40	1.18	0.235	0.56	0.111	108	22	38	79
200	80	1.17	0.291	0.55	0.138	119	30	43	62

continued

Table 2. Nitrogen (N) and phosphorus (P) fertilization on grain N and P content of irrigated corn, Tribune, KS, 2009-2018

Fertilizer		Grain				Grain removal			
N	P_2O_5	N	P	N	P	N	P	*$AFNR_g$	*$AFPR_g$
--------- lb/a ---------		---------- -% ----------		-------- lb/bu --------		--------- lb/a ---------		---------- % ----------	
ANOVA (P>F)									
Nitrogen		0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Linear		0.001	0.001	0.001	0.001	0.001	0.001	- - -	0.001
Quadratic		0.001	0.001	0.001	0.001	0.001	0.001	- - -	0.001
Phosphorus		0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Linear		0.001	0.001	0.001	0.001	0.001	0.001	0.001	- - -
Quadratic		0.001	0.001	0.001	0.001	0.001	0.001	0.001	- - -
N × P		0.001	0.001	0.001	0.001	0.001	0.001	0.043	0.094
MEANS									
Nitrogen, lb/a									
0		0.95 e	0.282 a	0.45 e	0.134 a	35 e	11 e	---	19 d
40		1.03 d	0.266 b	0.49 d	0.126 b	58 d	16 d	63 a	52 c
80		1.10 c	0.244 c	0.52 c	0.116 c	77 c	18 c	55 b	61 b
120		1.16 b	0.230 d	0.55 b	0.109 d	88 b	19 bc	46 c	64 ab
160		1.19 a	0.231 d	0.56 a	0.109 d	99 a	20 ab	41 c	69 ab
200		1.19 a	0.238 cd	0.56 a	0.113 cd	103 a	21 a	35 d	70 a
$LSD_{(0.05)}$		0.02	0.011	0.01	0.005	4	1	5	9
P_2O_5, lb/a									
0		1.19 a	0.186 c	0.56 a	0.088 c	61 b	9 c	31 b	---
40		1.07 b	0.259 b	0.51 b	0.123 b	84 a	19 b	57 a	66 a
80		1.05 b	0.300 a	0.50 b	0.142 a	86 a	24 a	57 a	46 b
$LSD_{(0.05)}$		0.01	0.008	0.01	0.004	3	1	4	5

*$AFNR_g$ and $AFPR_g$ = Apparent Fertilizer N Recovery (grain) and Apparent Fertilizer P Recovery (grain).
ANOVA = analysis of variance.
LSD = least significant difference.

Occasional Tillage and Nitrogen Application Effects on Winter Wheat and Grain Sorghum Yield

A.K. Obour, J.D. Holman, and A.J. Schlegel

Summary

Occasional tillage ahead of winter wheat planting could alleviate herbicide-resistant weeds, redistribute soil acidification, and improve seedbed at wheat planting. The objective of this study is to determine occasional tillage and nitrogen (N) fertilizer application effects on winter wheat, and grain sorghum yields and soil quality in a wheat-sorghum-fallow cropping system. Treatments were three tillage practices: 1) continuous no-tillage (NT); 2) continuous reduced-tillage (RT); and 3) single tillage operation every 3 years (June-July) ahead of winter wheat planting [occasional tillage (OT)]. The sub-plot treatments were assigned to four N fertilizer rates (0, 40, 80 and 120 lb/a of N). Preliminary results showed tillage had no effect on winter wheat grain yield. Applying N fertilizer increased wheat yield, ranging from 21 bu/a with no N fertilizer to 29 bu/a when N fertilizer was applied at 120 lb/a of N. Tillage and N fertilizer effects on grain sorghum yield varied over the 2 years of the study. Grain sorghum yields in 2017 decreased with RT but tillage had no effect on sorghum yields in 2018. Averaged across tillage and years, sorghum grain yield was 54 bu/a with no N fertilizer and 84 bu/a when N was applied at 120 lb/a of N. Both sorghum and winter wheat grain yields obtained with 80 lb/a of N were not different from those with 120 lb/a of N, suggesting 80 lb/a of N may be adequate for both crops.

Introduction

Adoption of NT practices during fallow by many producers in the central Great Plains (CGP) has increased the quantity of residues retained on the soil surface, and soil moisture storage. This has allowed for cropping intensification in dryland systems in the CGP from winter wheat-fallow to winter wheat-summer crop-fallow or a more intensified cropping system with no fallow depending on soil water availability. The benefits of NT include reduction in soil erosion, increased soil organic matter accumulation, improved soil structure, and increased soil water storage.

Despite these benefits, stratification of soil nutrients, organic matter, and pH tend to develop near the soil surface in long-term continuous NT systems. In addition, the lack of effective herbicides for perennial grass weeds—such as three-awn grass (*Aristida purpurea* Nutt.) and tumble windmill grass (*Chloris verticillata* Nutt.) —and the emergence of glyphosate-resistant weeds pose challenges in NT crop production. Also in drier years, the upper layer (0-2 inches) of soils in NT tends to be "hard" and presents a challenge to placing seed in subsoil moisture at the time of wheat planting. This may cause poor plant establishment and reduce winter wheat yields. Occasional tillage of NT soils may be necessary to alleviate herbicide-resistant weed issues, redistribute soil acidity, and improve seedbed at wheat planting. Research objectives are to determine the impacts of OT and N application on crop yields and soil water availability, and long-term effects of OT on soil health and herbicide-resistant weeds.

Procedures

Field experiments were initiated in spring 2017 at the Kansas State University Agricultural Research Center near Hays, KS, to address the previously mentioned objectives. Study design is a split-split-plot with three replications in a randomized complete block design. Main plots were three crop phases of a wheat-sorghum-fallow, sub-plot treatments were three tillage practices: 1) continuous NT; 2) continuous RT; and 3) single tillage operation every 3 years (June-July) ahead of winter wheat planting (OT). The sub-sub-plots were assigned to four N fertilizer application rates (0, 40, 80, and 120 lb/a of N). The reduced tillage treatments had two to three tillage operations during fallow ahead of wheat planting and one tillage operation prior to sorghum planting. All tillage operations were done with a sweep-plow to a depth of 4– to 6–inches. Each phase of the crop rotation, tillage, and N fertilizer treatment is implemented in each year of the study. Winter wheat and sorghum grain yields were determined by harvesting a 5 × 80 ft area from the center of each plot using a small plot combine. Statistical analysis with the PROC MIXED procedure in SAS version 9.4 (SAS Inst., Cary, NC) was used to examine winter wheat and grain sorghum yields as a function of tillage and N fertilizer application.

Results

Winter Wheat Grain Yield

Winter wheat grain yield in 2018 was not affected by tillage (Figure 1a). Averaged across N rates, wheat grain yield was 25 bu/a with NT or OT, and 23 bu/a with RT. Applying N fertilizer did increase wheat grain yield. Across tillage treatments, grain yield ranged from 21 bu/a with no N fertilizer to 29 bu/a when N fertilizer was applied at 120 lb/a of N. However, wheat grain yield was not different when N was applied at 80 lb/a of N or 120 lb/a of N (Figure 1b).

Tillage effects on sorghum grain yield varied over the 2 years. In 2017, sorghum grain yields with NT or OT were not different. However, RT operations reduced sorghum grain yield compared to the other tillage treatments (Figure 2). Tillage had no effect on grain sorghum yields in 2018, possibly due to abundant precipitation during the sorghum growing season in 2018. Similarly, sorghum response to N fertilizer application differed over the 2 years. Application of N fertilizer increased sorghum yields in 2017, but grain yields produced with 40 lb/a of N were similar to that achieved with greater N rates. In the 2018 growing season, applying N fertilizer resulted in a linear increase in sorghum grain yield. Averaged across tillage treatments, sorghum grain yield ranged from 52 bu/a with no N fertilizer application to 91 bu/a when 120 lb/a of N was applied (Figure 3). The differences in N response between 2017 and 2018 growing seasons were because of the differences in precipitation amount in the 2 years that affected amount of available soil water for sorghum production. Across the 2 years and tillage treatments, applying N fertilizer increased grain yield from 54 bu/a with the check treatment (no N applied) to 84 bu/a with 120 lb/a of N. However, grain yield with 80 lb/a of N (79 bu/a) was not different from that obtained with the highest N rate of 120 lb/a of N.

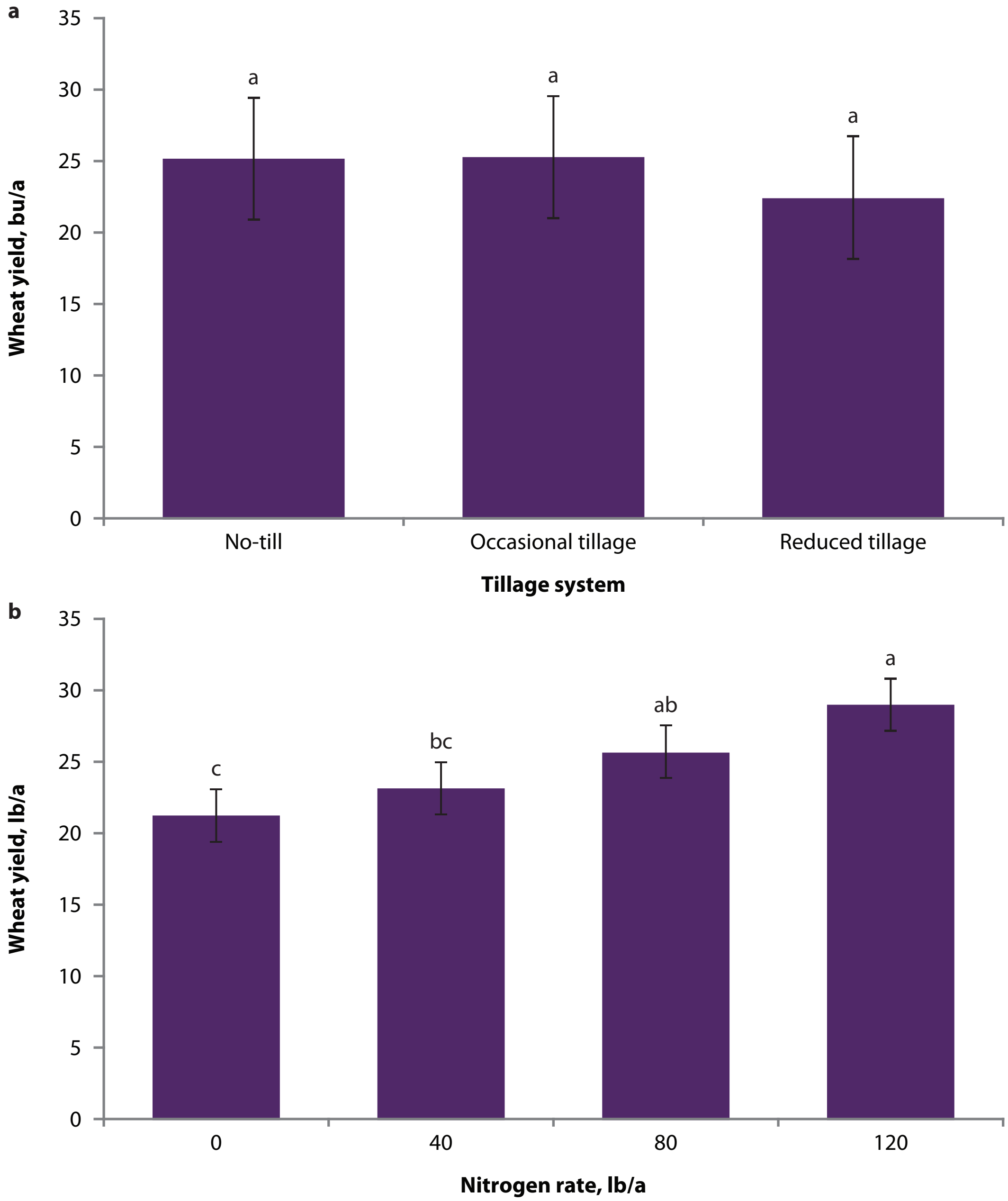

Figure 1. Winter wheat grain yield as affected by tillage (a) and N fertilizer application rate (b) in 2018 growing season at Hays, KS. Data for tillage effects are averaged across four N rates and three replications (n = 12), and data for N rate effects are averaged across three tillage treatments and three replications (n = 9). Means followed by same lower case letter(s) are not significantly different ($P > 0.05$).

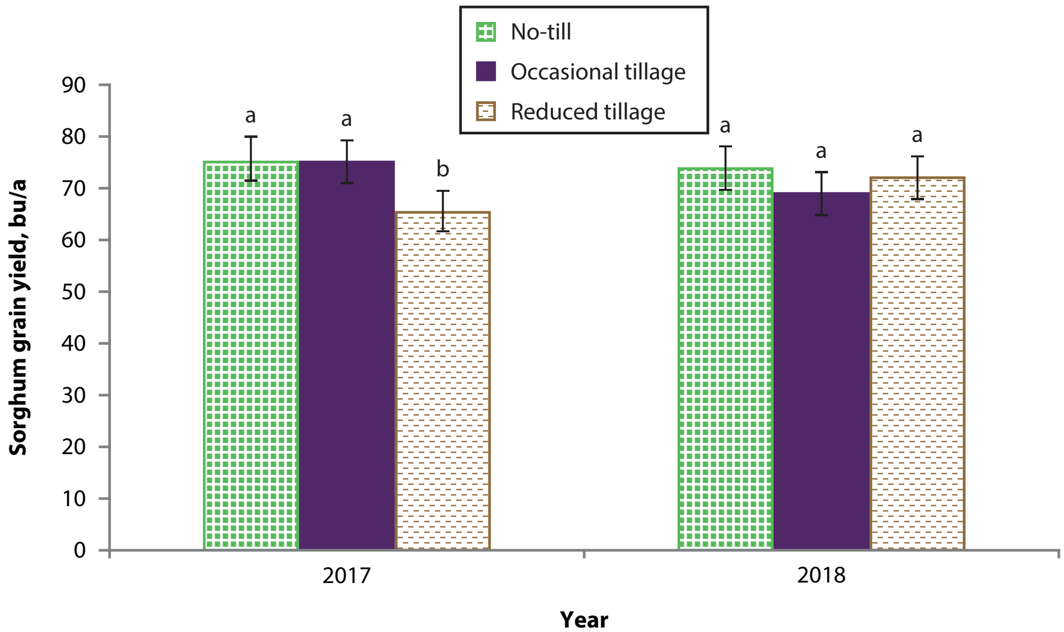

Figure 2. Grain sorghum grain yield as affected by tillage system in 2017 and 2018 growing seasons at Hays, KS. Data are averaged across four N treatments and three replications (n = 12). Means followed by same lower case letter(s) within a year are not significantly different (*P* > 0.05).

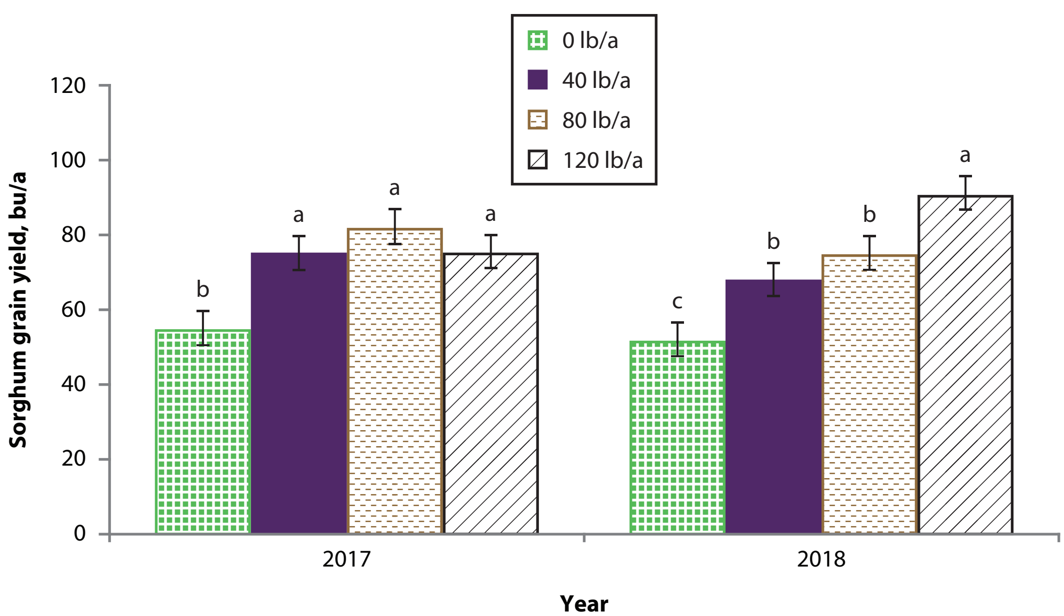

Figure 3. Grain sorghum grain yield as affected by nitrogen fertilizer application rates in 2017 and 2018 growing seasons at Hays, KS. Data are averaged across three tillage treatments and three replications (n = 9). Means followed by same lower case letter(s) within a year are not significantly different (*P* > 0.05).

Strategic Tillage in Dryland No-Tillage Crop Production Systems

A.K. Obour, J.D. Holman, and A.J. Schlegel

Summary

Emerging challenges in continuous no-till (NT) systems require developing flexible management strategies that will minimize the impacts of herbicide resistant (HR) weeds and nutrient stratification on soil and crop productivity. This study evaluated the effectiveness of strategic tillage (ST) operations as an option to redistribute soil nutrients and acidity, control perennial grass and HR weeds, and improve crop yields following tillage of an otherwise long-term NT soil. Treatments were five crop rotations: 1) continuous winter wheat (WW); 2) wheat-fallow (WF); 3) wheat-sorghum-fallow (WSF); 4) continuous sorghum (SS); and 5) sorghum-fallow (SF) as main plots. Subplots were reduced tilled (RT), continuous NT, and ST of long-term NT. Grass and herbicide resistant weeds were reduced with tillage. Irrespective of crop rotation, soil water content at wheat planting was significantly less with RT treatments compared to NT or ST. Soil water content with NT was not different from that of ST under cropping systems with fallow (WF or WSF). Tillage (ST or RT) reduced soil water content at wheat planting in WW system. Winter wheat grain yields decreased with increasing cropping intensity, WF (26-48 bu/a) > WSF (22-33 bu/a) > WW (15-19 bu/a). Averaged across years and crop rotations, wheat yield with ST was 30 bu/a, which was greater than the NT (23 bu/a) or RT (28 bu/a) systems, mostly due to better weed control and increased nutrient availability. Sorghum grain yield over the 2 years with ST (63 bu/a) was not different from that of NT (61 bu/a), but were both greater than that of RT (54 bu/a). Increasing cropping intensity reduced sorghum grain yield, average grain yield with SF was 73 bu/a, similar to WSF (68 bu/a), but greater than SS (38 bu/a). Tillage had no effect on soil bulk density. However, increasing cropping intensity lowered the bulk density measured in the upper 0 to 2 in. of the soil. Tillage and crop rotation effects on soil organic matter (SOM), pH, and nutrient concentrations occurred only in the top 0- to 2-in. depth. The SOM, iron (Fe), and manganese (MN) concentrations were greater in soils under WW compared to WF or WSF. Soil pH and potassium (K) were least in soils under WW. The SOM concentration in the top 0 to 2 in. with NT was 3.34%, which was similar to that of soil under ST (3.02%) but both were greater than RT (2.65%). Nitrate-N concentration increased with ST but ammonium-N concentration was greatest in soils under NT. Our results suggest ST could provide a mitigation option for HR weeds in NT crop production with little impact on crop yields and soil chemical properties.

Introduction

No-tillage (NT) systems provide several benefits to dryland crop production in the semiarid central Great Plains (CGP). These include improvements to soil health, reduced wind erosion, fewer energy inputs, increased retention of soil moisture, and improved crop yields. Despite these benefits, maintaining continuous NT and the associated soil conservation benefits are at risk due to a lack of effective control of HR weeds, as well as issues of compaction and stratification of soil pH and nutrients. Stratification of soil nutrients and soil acidity could reduce nutrient availability and uptake by crops and increase the chances of nitrogen and phosphorus losses in surface runoff.

In addition, the lack of effective herbicides to control perennial grass weeds such as three-awn grass (*Aristida purpurea* Nutt.) and tumble windmill grass (*Chloris verticillata* Nutt.), and the advent of herbicide resistant weeds such as kochia (*Kochia scoparia* L.) and Palmer amaranth (*Amaranthus palmeri* S. Watson) pose challenges in NT crop production. With low grain prices and the high cost of controlling HR weeds, some producers are returning to tillage as a strategic management tool.

Strategic tillage (ST) with a sweep plow timed when soil erosion risk is low in an otherwise NT cropping system could help manage HR weed populations and reduce stratification of soil properties. After the one-time tillage operation, the field goes back to NT production. This ST approach could increase productivity and profitability of dryland cropping systems in the region. However, the soil health impacts of ST are unclear particularly in water-limited environments of the CGP where susceptibility to wind erosion can be high.

Few studies have investigated the effects of ST on soils that have been in continuous NT (> 40 years) in dryland conditions in the CGP. Our objectives were to determine the effects of ST in long-term NT systems on 1) soil water content at winter wheat planting; 2) winter wheat and grain sorghum yields; 3) effectiveness of ST to redistribute soil nutrients, reduce soil acidity, and control perennial grass and herbicide resistant weeds; and 4) determine soil quality following tillage of an otherwise long-term NT soil.

Procedures

This study was conducted using long-term tillage and crop rotation experiment plots established in 1976 at the Kansas State University Agricultural Research Center near Hays, KS. The experimental design was a randomized complete block with three replications in a split-plot treatment structure. Main plots were five crop rotations [continuous winter wheat (WW), wheat-fallow (WF), wheat-sorghum-fallow (WSF), continuous sorghum (SS), and sorghum-fallow (SF)] and two tillage treatments (RT and NT) as sub-plots. Every phase of each crop rotation and tillage system combination was present in each replication for each year of the study. The study was modified in the summer of 2016 to three tillage treatments [RT, continuous NT, and strategic tillage (ST) of NT] by splitting the long-term NT plots into two equal plots of 20-ft wide by 80-ft long. One half was left in continuous NT and the other half was tilled. The ST plots were tilled twice, first with a sweep plow to a 3-in. depth followed by a second tillage operation 3 days later to 6-in. depth, also with a sweep plow. All tillage operations in the wheat rotations were performed in July prior to winter wheat planting in October. For crop rotations involving sorghum, tillage operations were done in May before sorghum planting in June. Tillage in the RT treatments were accomplished with the same tillage implement to 6- to 8-in. depth. Two to three tillage operations were usually done in the RT plots over the fallow period.

Soil water content at winter wheat planting was determined gravimetrically to 4 ft, in 6-in. depth increments in 2016 and 2017. Two soil cores were taken from each plot and data averaged for a single soil water content measurement. Winter wheat and sorghum grain yields were determined by harvesting a 5 × 80 ft area from the center of each plot using a small plot combine. Soil samples were taken from 0 to 2, 2 to 6, 6 to 12 in. soil depths after tillage operations in 2017 only. These samples were analyzed for changes in bulk density, soil organic carbon (SOC), dry aggregate size distribution, and soil nutrients. The SOC was multiplied by a factor of 2 (because no calibrated conversion factor is available for this soil) and reported as SOM concentration.

Results

Weeds, Soil Water Content, and Bulk Density

In general, broadleaf and grass weeds were significantly less with RT and ST compared to the NT treatments (data not shown). Tillage × crop rotation interaction had a significant effect on soil water content measured at winter wheat planting. Regardless of crop rotation, soil water content with NT was similar to that of ST but were both greater than that measured with RT in crop rotation systems that had fallow (Figure 1). However, with WW system, tillage operation as either ST or RT reduced soil water at winter wheat planting compared to NT (Figure 1). Averaged across crop rotations, profile soil water content was 13.4 in. with NT or ST, and 12.6 in. with RT over the 2 years. In general, water content decreased with increasing cropping intensity, mostly due to increased crop water use. Averaged across the 2 years and tillage treatments, profile soil water content with WF was 13.7 inches, which was greater than WSF (13.2 inches) or WW (12.4 inches).

Soil bulk density measured within the top 12 in. of the soil was not different among tillage systems. Across crop rotations and sampling depth, bulk density averaged 1.16 g cm^{-3} with NT and 1.13 g cm^{-3} with ST or RT. However, crop rotation × depth interaction had a significant effect on bulk density. In general, bulk density within the top 0 to 6 inches decreased with increasing cropping intensity. The continuous wheat treatment had the lowest bulk density at 0 to 2 in., and 2 to 6 in. depth (Table 1), possibly due to greater contribution of plant residue input onto the soil surface. Bulk density was no different among the crop rotation systems beyond the 6-in. depth.

Soil pH and Nutrient Concentrations

Tillage system had no effect on soil pH, which averaged 5.5 for NT, 5.6 with ST, and 5.7 with RT at the upper 0 to 2 in. soil depth. Crop rotation × sampling depth interaction had a significant effect on soil pH. Regardless of crop rotation system, pH at the upper 0 to 2 in. was markedly lower than that measured in the subsurface. Averaged across tillage treatments, soil pH at the 0 to 2 in. depth was lowest in the WW production system (Table 1), possibly because of annual N fertilizer application and mineralization of SOM in this treatment. Soil pH measured below 2 in. depth was not different among crop rotations. The SOM concentration was significantly affected by crop rotation and tillage, but mostly within the top 0 to 2 in. Across tillage, SOM measured in the upper surface was 2.72% for WF, 2.74% for WSF, and 3.55% for WW. The differences were due to differences in crop residue addition that affected SOM accretion in the surface soil. When averaged across crop rotations, SOM concentration measured in the upper soil surface with ST was 3.02%, which was similar to 3.34% measured in soil under long-term continuous NT but were both greater than that with RT (Table 2). Tillage system had no effect on SOM concentration beyond the top 0 to 2 in. soil depth.

Tillage or crop rotation effects on soil nutrient concentrations were limited to the upper 0 to 2 in. of the soil. Soil K concentration in the upper surface decreased with WW compared to WF or WSF system. However, soil Fe and Mn concentrations increased with WW production system. Greater Mn and Fe concentration in soils under WW is possibly explained by the decrease in soil pH associated with the WW system that caused increased solubility of these cations. Soil P and Zn concentrations were not affected by tillage or crop rotation. Nitrate-N concentration measured in the upper soil surface increased under ST compared to NT or RT. This was possibly because of increased mineralization associated with tillage of the long-term NT soil. Expectedly, ammonium-N concentration was significantly greater in soils under NT (Table 2). However, soil K concentration increased in soils under RT compared to NT or ST system.

Winter Wheat and Grain Sorghum Yield

Winter wheat grain yield differed over the two years of the study. Crop rotation × year interaction had effect on winter wheat grain yield. Regardless of crop rotation, winter wheat grain yield in 2018 was significantly less than that achieved in 2017 (Figure 2). Averaged across tillage and crop rotation, wheat yield averaged 33.3 bu/a in 2017 and 20.7 bu/a in 2018. The differences were due to spring drought conditions in 2018. Winter wheat grain yields decreased with increasing cropping intensity, WF (26-48 bu/a) > WSF (22-33 bu/a) > WW (15-19 bu/a), which was expected due to decreased soil water availability for crop production when cropping intensity increased.

Similarly, tillage intensity had significant ($P = 0.0006$) effect on wheat grain yield. Across the 2 years and crop rotations, winter wheat yield with NT was 23 bu/a, which was less than the 30 bu/a obtained with ST or 28 bu/a with RT (Figure 3a). This is possibly due to improved grass weed control with tillage operations that reduced weed competition and improved plant establishment. It is also plausible that tillage operations of long-term NT increased nutrient availability, particularly N (Table 1) in the ST plots compared to continuous NT or RT treatments.

Average sorghum grain yield in 2017 was 47 bu/a, less than the 72 bu/a in 2018. Grain yields were significantly affected by crop rotation ($P = 0.0001$) and tillage ($P = 0.006$). Sorghum grain yield with ST was not different from that of NT, but were both greater than that of RT (Figure 3b). Similar to winter wheat, increasing cropping intensity reduced sorghum grain yield. Average grain yield of SF was 73 bu/a, similar to WSF (68 bu/a) but greater than SS (38.1 bu/a).

Table 1. Soil bulk density, organic matter, pH, potassium, iron, manganese, and copper concentration as affected by crop rotation and soil sampling depth

Crop rotation	0 to 2 inches	2 to 6 inches	6 to 12 inches	0 to 2 inches	2 to 6 inches	6 to 12 inches	0 to 2 inches	2 to 6 inches	6 to 12 inches	0 to 2 inches	2 to 6 inches	6 to 12 inches
	Bulk density, g cm^{-3}			Soil organic matter, %			Soil pH			Potassium, ppm		
Wheat-fallow	1.14 a	1.22 ab	1.21 a	2.72 b	2.27 a	1.79 a	5.7 a†	6.2 a	6.9 a	558 a	559 a	545 a
Wheat-sorghum-fallow	1.02 b	1.25 a	1.17 a	2.74 b	2.23 a	1.84 a	5.9 a	6.3 a	6.9 a	539 a	511 b	524 a
Continuous wheat	0.89 c	1.17 b	1.18 a	3.55 a	2.45 a	1.99 a	5.3 b	6.1 a	7.0 a	516 b	528 b	544 a
	Iron, ppm			Manganese, ppm			Phosphorus, ppm			Zinc, ppm		
Wheat-fallow	53 b	39 ab	22 a	27 b	21 b	12 a	41.2 a	19.8 a	8.2 a	0.64 a	0.43 a	0.25 a
Wheat-sorghum-fallow	47 b	35 b	22 a	26 b	21 b	12 a	37.7 a	13.8 a	6.0 a	0.76 a	0.37 a	0.27 a
Continuous wheat	77 a	46 a	22 a	43 a	25 b	12 a	44.1 a	16.5 a	4.6 a	0.75 a	0.39 a	0.39 a

†Means followed by same lower case letter(s) within a site-year are not significantly different. Upper case letter(s) denotes comparisons between site-years.

Table 2. Soil organic matter, nitrogen (N), and potassium concentrations as affected by tillage operation and soil sampling depth

Tillage system	0 to 2 inches	2 to 6 inches	6 to 12 inches	0 to 2 inches	2 to 6 inches	6 to 12 inches	0 to 2 inches	2 to 6 inches	6 to 12 inches	0 to 2 inches	2 to 6 inches	6 to 12 inches
	Soil organic matter, %			Nitrate-N, ppm			Ammonium-N, ppm			Potassium, ppm		
No-tillage	3.34 a	2.35 a	1.84 a	33.2 ab	16.3 a	7.6 a	13.2 a	3.3 a	2.6 a	516 b	538 a	543 a
Strategic tillage	3.02 a	2.40 a	1.97 a	37.4 a	16.9 a	9.9 a	8.3 b	3.2 a	2.6 a	515 b	517 a	535 a
Reduced tillage	2.65 b	2.21 a	1.81 a	30.7 b	15.8 a	11.2 a	4.4 c	2.7 a	2.5 a	582 a	543 a	535 a

†Means followed by same lower case letter(s) within a soil sampling depth are not significantly different. Upper case letter(s) denotes comparisons between site-years.

Figure 1. Soil water content at winter wheat planting as affected tillage in each crop rotation system. Data are averaged across 2 year and three replications (n = 6).

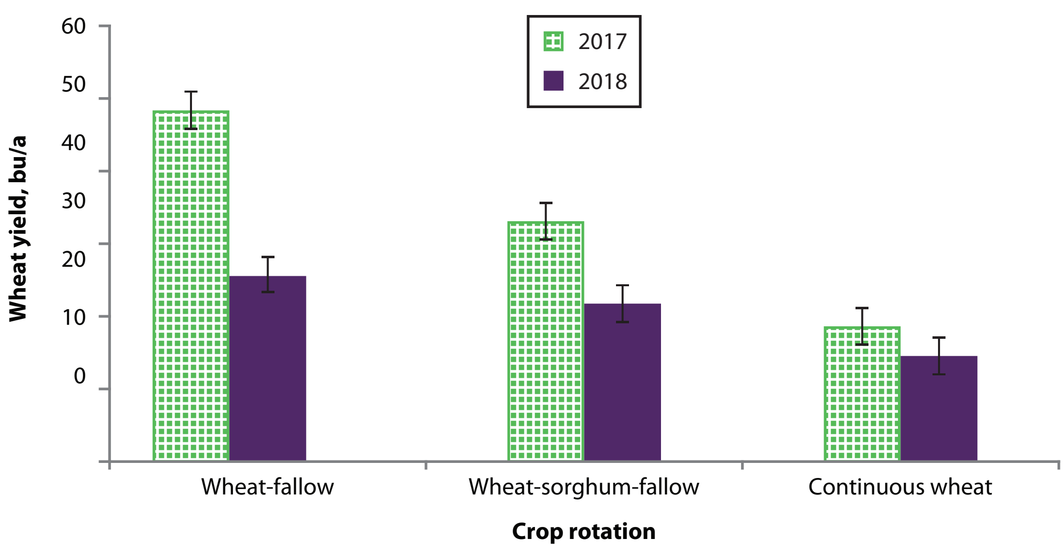

Figure 2. Winter wheat grain yield as affected by crop rotation system in 2017 and 2018 growing seasons at Hays, KS. Data are averaged across three tillage systems and three replications (n = 9).

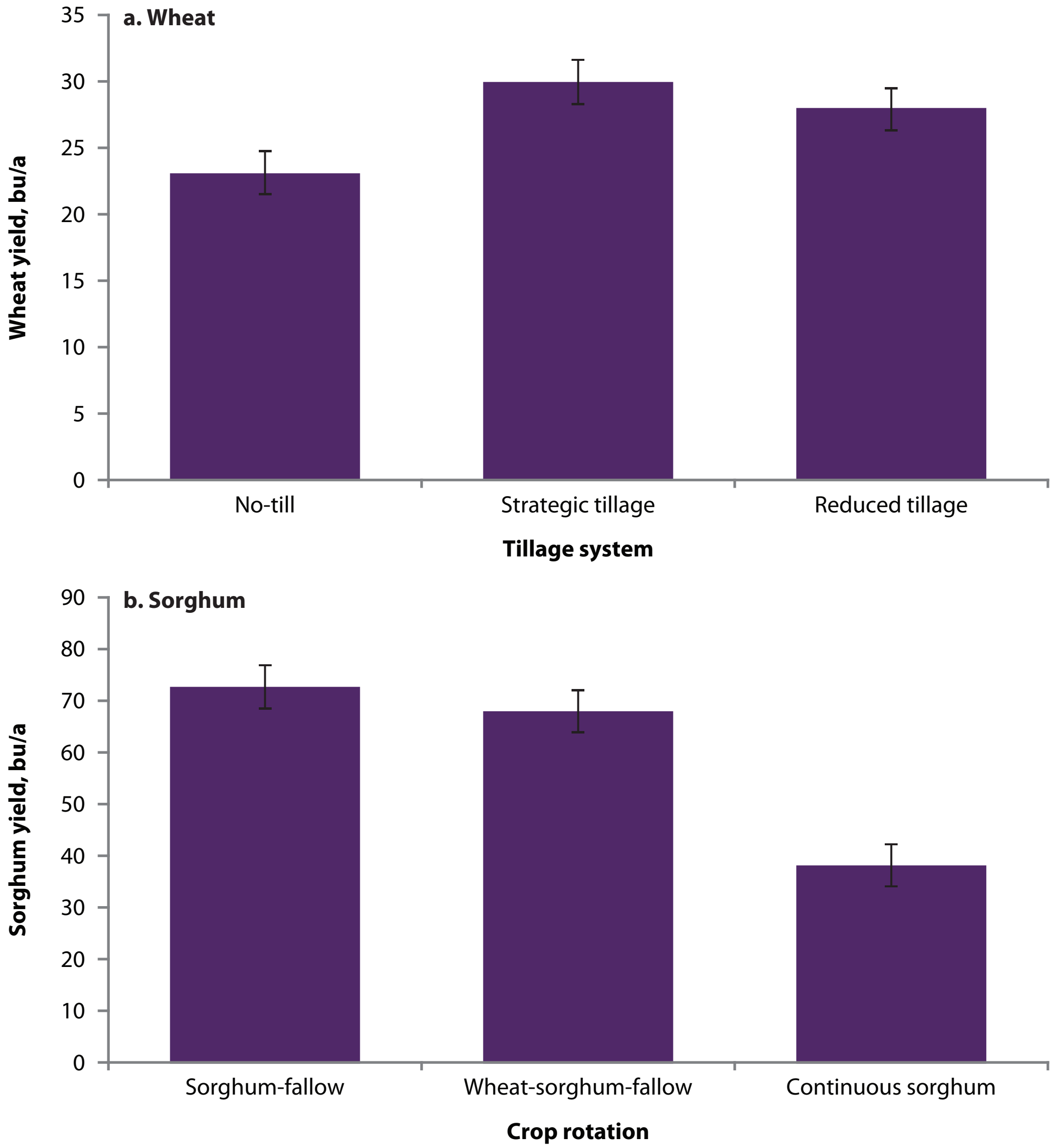

Figure 3. Winter wheat (a) and grain sorghum (b) grain yield as affected tillage system. Data are averaged across three crop rotations, 2 years, and three replications (n = 18).

Wheat Grain Yield and Protein Response to Nitrogen and Sulfur Rates

B.R. Jaenisch and R.P. Lollato

Abstract
Winter wheat is often double-cropped after soybeans in no-tillage systems. The soybean crop removes large quantities of sulfur (S), which might unbalance ratios of nitrogen (N) to S for the following wheat crop. Our objective was to evaluate the responses of two wheat varieties to three N and four S rates representing a range of N:S ratios. The experiment was arranged as a complete factorial with a split-split-plot design. Variety was the whole-plot, N the sub-plot, and S the sub-sub plot. Nitrogen rates were 50, 100, and 150% of the recommended rate for 60 bu/a, which corresponded to ~45, 87, and 130 lb N/a. Sulfur rates were 0, 10, 20, and 40 lb S. The two locations (Manhattan and Belleville) were conducted under no-till and data were pooled for the statistical analysis. Nitrogen by S interactions occurred for grain yield and protein. The 45 lb N/a with 0, 10, or 40 lb S yielded similarly, while 20 lb S reduced yield by 4 bu/a. The 87 lb N/a increased yield by 9 bu/a from the 45 lb N/a with all S rates yielding similarly. The 130 lb N/a increased yield by 18 bu/a from the 45 lb N/a with 10 lb S resulting in the lowest yield, with 0 and 20 lb S yielding the highest. Zero and 40 lb S resulted in similar yields across all N rates. The 45 and 130 lb N/a with 10 lb S produced protein of 10.9% and 11.9%, respectively. However, 130 lb N/a with 0 or 10 lb S increased protein to 12.6–12.8%. This research will be continued for two more years at three locations per year to better explore the interactive effects of N, S, and variety.

Introduction
Sulfur plays many roles within the plant, from the synthesis of amino acids to formation of chlorophyll. Sulfur is supplied to plants through rainfall, soil organic matter and crop residue mineralization, or as part of organic or mineral fertilizers. Wheat takes up approximately 80% of the S before anthesis. Winter wheat planted after soybeans has become the preferred crop rotation in recent years for many producers in north-central Kansas. Due to the high removal of S by soybeans, lower organic matter mineralization in the spring, and the declining S deposition in the rainfall, symptoms of S deficiency are increasingly common in north-central Kansas. Requirements of S for wheat are generally low (80 bu/a crop removes 7 lb of S in the grain and another 15 lb of S in the straw). However, soybeans remove approximately 25 lb of S in the grain and stover in a 60 bu/a grain crop. Research is needed to determine the effects of S on wheat yield and grain quality in Kansas soils.

Proper N fertilization increases probability of higher tiller number and grain yield (Jaenisch et al., 2019; Lollato et al., 2019). Winter wheat is generally sink limited, and kernels per foot is a coarse regulator of increasing wheat grain yield. Potential kernels per meter are determined by Feekes 6 in the winter wheat growing season, and N deficiency at this time will result in decreased yield potential. Thus, matching N application with this critical growth stage is important for maximizing kernels per foot. Likewise, N concentration within the plant changes throughout the growing season according to biomass levels; therefore, N dilution curves help determine N deficiencies in crops. Research is needed to determine the optimal N concentration and N:S ratios in plant tissue to maximize grain yield and quality in Kansas.

Procedures

The experiment was established in the fall of 2017 at the Kansas State University North Central Experiment Field in Belleville (moderately well-drained Crete silt loam, 0–1% slopes) and Agronomy North Farm in Manhattan (Kahola silt loam, rarely flooded, 0–1% slopes). No-till has occurred for 11 and 6 years in Manhattan and Belleville, respectively. Both locations were grown under rainfed conditions and were chosen as no-till wheat, which is commonly sown into soybean stubble at these locations in Kansas.

Treatments included four S rates (0, 10, 20, and 40 lb S) and three N rates (50, 100, and 150% of K-State recommendations for a 60 bu/a yield) which were applied to two wheat varieties (SY Monument and LCS Mint) in a 2 × 3 × 4 (variety × N rate × S rate) complete factorial structure. The experiment was arranged in a split-split-plot design with four replications. The varieties SY Monument and LCS Mint were selected for their differences in N uptake and N use efficiency. Nitrogen was applied as urea ammonium nitrate (28-0-0) and S was applied as ammonium thiosulfate (12-0-0-26S) using a pressurized CO_2 back sprayer with a three-nozzle spray boom. The specific streamer nozzles (SJ3-02-VP - SJ3-05-VP) varied due to the change in N and S rates. The N and S were applied in combination for specific treatments and application occurred at Feekes 4.

Wheat was sown no-till into soybean stubble directly after harvest with a Great Plains 506 no-till drill (7 rows spaced at 7.5 inches) with plot dimensions of 4.375-ft wide × 30-ft long at all locations. Seed was treated with 5 oz Sativa IMF Max across the whole study so fungicide or insecticide was not a limiting factor. Likewise, both varieties were sown at 1.5 million seeds due to the later planting date.

In 2017, soil samples were taken at sowing at each location for soil nutrient analysis. Samples were taken by a hand push probe at two depths, 0–6 and 6–24 in., and a total of 15 cores were pulled per depth and combined to represent a composed sample at each location. Weeds were controlled to ensure they were not limiting factors by a pre- and post-emergence herbicide application. Insect pressure was not experienced in 2018.

Results

Weather

The 2017–18 wheat growing season can be classified as a cold and dry winter, to a cold and dry early spring, to a hot and dry late spring/early summer. The drought and cool temperatures kept the wheat crop dormant until late April. Likewise, the reduced rainfall in the spring reduced spring tillering and fertilizer incorporation, thus decreasing spikes per foot. For the season, 60 and 49% of the annual rainfall was received for Belleville and Manhattan, respectively. Temperatures were above normal for May and June, accelerating crop development and decreasing the grain filling period. Wheat yields ranged from 64–76 bu/a in Belleville and Manhattan.

Wheat Grain Yield

Across locations, increasing N rate increased wheat grain yield (Figure 1) and the N by S rate interaction was measured. The 45 lb N/a with 0, 10, or 40 lb S resulted in the highest grain yield of 67 bu/a and the addition of 20 lb S decreased yield to 64 bu/a. The 87 lb N/a and all S rates yielded similarly to 73 bu/a. At the highest N rate (137 lb N/a), 0 or 20 lb N/a resulted in the highest grain yield of 79 bu/a; however, 10 or 40 lb S/a reduced grain yield to 76 bu/a.

Grain Protein

Following the same trend as grain yield, an increasing N rate increased grain protein. Likewise, the S rate also increased protein but did not follow a linear trend as compared to N rate (Figure 2). The N by S rate interaction for protein concentration was measured. The 45 lb N/a with 10 lb S resulted in the highest protein concentration of 10.9%, and the addition of 0, 20, or 40 lb S decreased protein concentration to 10.6%, perhaps as a dilution effect from slightly higher grain yield. The 87 lb N/a with 10 lb S resulted in the highest protein concentration of 11.9%, and the addition of 0, 20, or 40 lb S decreased protein concentration to 11.6%. The highest N rate of 137 lb N/a with 0, 10, or 40 lb S resulted in the highest protein concentration of 12.6-12.8%; however, 20 lb S reduced protein concentration to 12.5%, again, perhaps due to increased yield in this treatment.

Preliminary Conclusions

Due to limitations of sites and years, it is difficult to make strong conclusions. However, with significant N by S rate interactions for both grain yield and protein concentration, the preliminary data suggest that a balanced nutrition is needed for both nutrients to maximize yield and protein. One existing trend was that increasing N increased grain yield and protein concentration, suggesting that N rate could have been further increased to maximize yield in the studied sites. However, Staggenborg et al. (2003) measured grain yield to plateau at 75 lb N/a in wheat planted after summer crops. Therefore, this warrants additional research to understand whether further increasing N is economically viable, and to better characterize N × S × variety interactions.

Acknowledgments

We thank Andrew Esser, Keith Thompson, and Dustin Ridder for helping us with project establishment, management, and harvest at the experiment fields. We also thank the Kansas Wheat Commission for the funding to allow us to conduct this research. We also acknowledge the Kansas State University Winter Wheat Production Program staff for their hard work and assistance in the project.

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Table 1. Treatment description for the trials established at Manhattan and Belleville, KS, in 2018

Winter wheat varieties	Nitrogen rate, lb N/a	Sulfur rate, lb S/a
SY Monument	45	0
LCS Mint	87	10
	130	20
		40

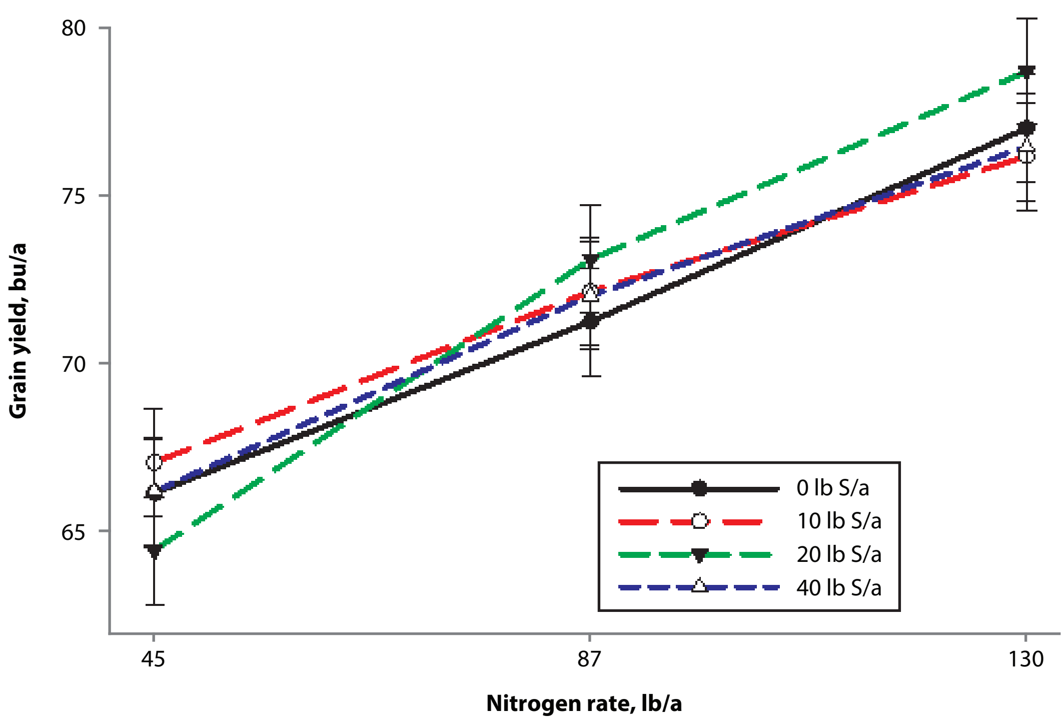

Figure 1. Average wheat grain yield (bu/a) response to three N rates (45, 87, and 130 lb N/a) and four S rates (0, 10, 20, and 40 lb S/a) across both winter wheat varieties for combined locations of Belleville and Manhattan, KS, in 2018.

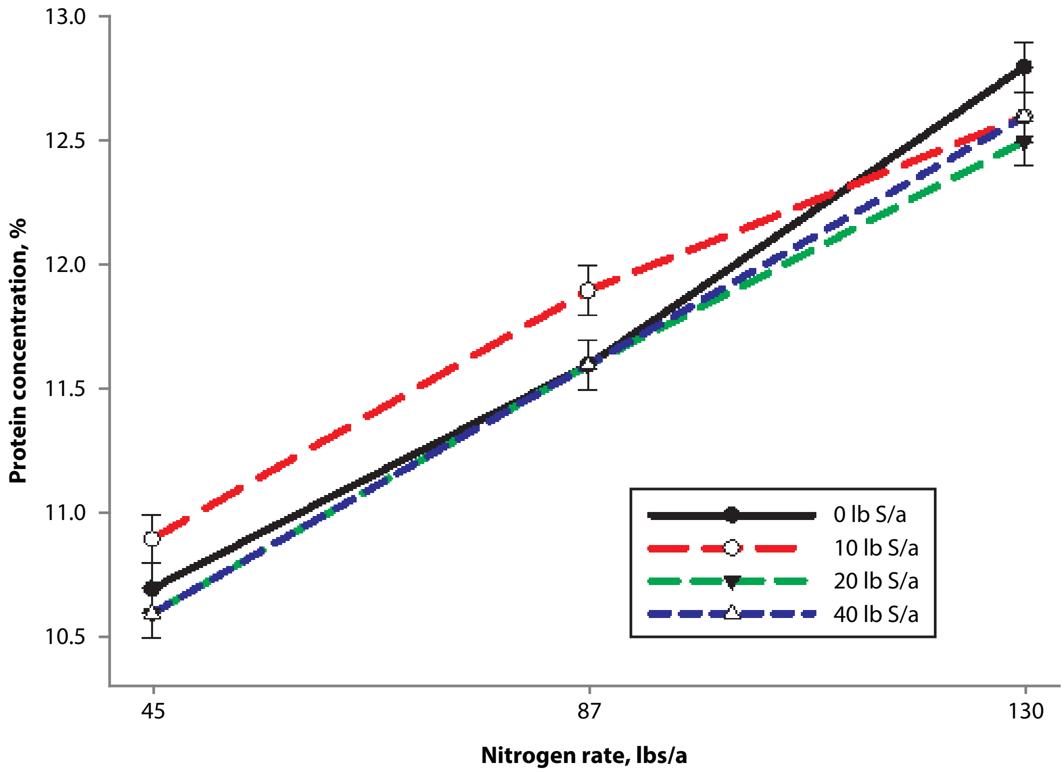

Figure 2. Average wheat grain protein concentration (%) response three N rates (45, 87, and 130 lb N/a) and four S rates (0, 10, 20, and 40 lb S/a) across both winter wheat varieties for combined locations of Belleville and Manhattan, KS, in 2018.

Changes in Soil Nitrate and Ammonium During the Corn Growing Season as Affected by Nitrification Inhibitors

F.D. Hansel and D.A. Ruiz Diaz

Summary

Nitrification inhibitors (NI) are used to delay the nitrification process, increasing nitrogen fertilization efficiency. The objective of this study was to evaluate the effect of NI on soil nitrate (NO_3-N) and ammonium (NH_4-N) content throughout the growing season for corn. The study was conducted at four locations (Manhattan, Scandia, Rossville, and Ashland, KS) during the 2017 and 2018 crop seasons. Most of the NI effects on soil NH_4-N and NO_3-N were observed early in the season and when the higher nitrogen (N) fertilizer rate was used. An increase in NO_3-N soil content was observed during the season with a posterior decrease at the end. At the V8 corn growth stage, we observed the peak of NO_3-N soil content at 0- to 12-in. sampling depth with an additional increase at 12- to 24-in. depth in the treatment without NI, suggesting NO_3-N movement to the lower soil layer or uptake by the corn crop.

Introduction

Nitrogen is an essential element for optimum corn yields. After applied as fertilizer to the soil, N changes its chemical form and can be subject to potential loss. Nitrification is an important step in the N cycle and is promoted by the biological oxidation of ammonium to nitrite and nitrate. Conversion of NH_4^+-N to NO_3^--N increases the potential for nitrogen leaching due to the mobility of nitrate in the soil and can be readily lost from the plant rooting zone (Wiederholt and Johnson, 2005). The nitrification process can occur rapidly in warm, moist, well-aerated soils.

Nitrification inhibitors are chemicals that slow down or delay the nitrification process, thereby decreasing the possibility of large N losses before the fertilizer nitrogen is taken up by plants (Nelson and Huber, 2001). The objective of this study was to evaluate the effect of NI on soil nitrate and ammonium content in the soil throughout the corn growing season.

Procedures

This study was conducted in four locations (Manhattan, Scandia, Rossville, and Ashland, KS) during the 2017 and 2018 crop seasons. Treatments were: 1) N fertilizer without nitrification inhibitor (control), and 2) N fertilizer treated with nitrification inhibitor. Anhydrous ammonia was applied at four rates 0, 100, 150, and 200 lb/a in early spring. Soil samples were taken at the V2, V4, V8, V12, R1, and R6 corn growth stages at two soil depths (0–12 and 12–24 in.). Soil samples were submitted to the K-State Research and Extension Soil Testing Laboratory on the same day for NO_3^--N and NH_4^+-N soil test. The experimental design is in randomized complete blocks with 4 repetitions. Experimental plots were 10-ft wide × 60-ft long.

Results

Changes in NO_3-N and NH_4-N

The form of N in the soil was dependent on soil type (moisture and texture) and climate (temperature and precipitation) characteristics. In general, NH_4-N content in the soil was greater at the initial corn growth stages and decreased during the season. Consequently, NO_3-N content increases as a result of the nitrification process (Figure 1).

The use of NI contributed to maintain greater NH_4-N content early in the season in the 0–12 in. depth but no changes in the 12–24 in. depth for any of the corn growth stages (Figure 2). However, the soil NO_3-N content was greater for most sampling times in the 0–12 in. depth when the nitrification inhibitor was used. At the 12–24 in. depth, soil NO_3-N content showed an increase at the V8 corn growth stage for the treatment without nitrification inhibitor. This increase matches with a peak observed at the same corn growth stage at the 0–12 in. soil layer suggesting a leaching process of NO_3-N from the top to the deeper soil layer (Figure 2).

The increase of N fertilizer rates promotes a consequent increase in soil N. However, the NH_4-N fraction was generally low with soil sampling during the growing season, suggesting a low sensitivity of the NH_4-N fraction for soil sampling/testing (Figure 3). On the other hand soil NO_3-N concentration was generally greater, and with significant differences with the use of nitrification inhibitor at the 200 lb N/a rate suggesting a reduction in the nitrification process in the soil at this point in the season (Figure 3).

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Table 1. Levels of significance for soil nitrate (NO_3-N) and ammonia (NH_4-N) affected by treatments, corn growth stages, and soil depth

Factors	NO_3	NH_4
	---------- P > F ----------	
Treatment (T)	0.182	0.063
Stage (S)	<0.001	<0.001
Depth (D)	<0.001	<0.001
T × S	0.949	0.007
T × D	0.135	0.058
S × D	<0.001	<0.001
T × S × D	0.909	0.024
Treatment	0.758	0.803
Nitrogen (N) rate	<0.001	0.012
T × N	0.329	0.005

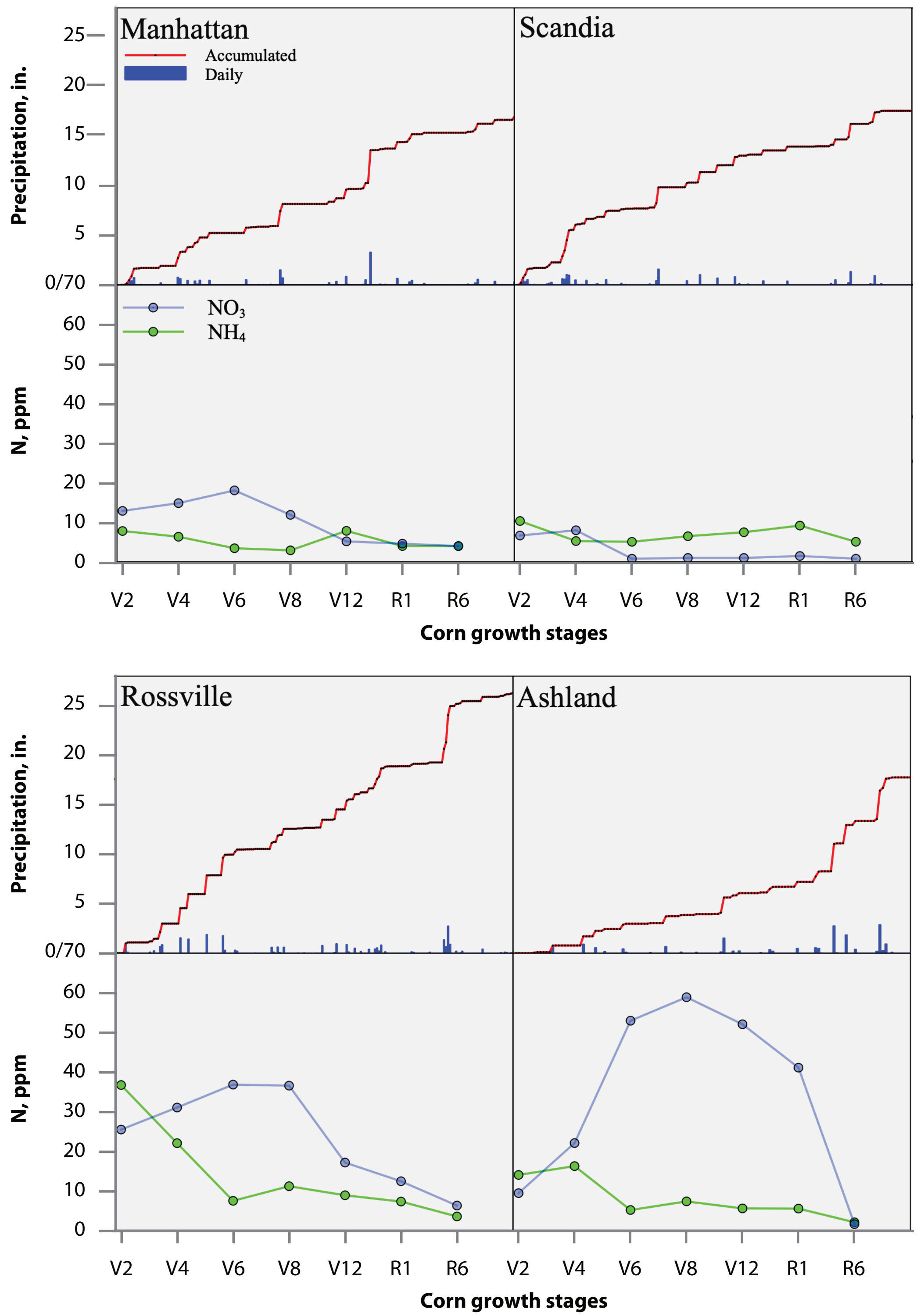

Figure 1. Average soil nitrate (NO_3-N) and ammonia (NH_4-N) content throughout the growing season in Manhattan (2017), Scandia (2017), Rossville (2018), and Ashland (2018), KS, and the respective daily/accumulated precipitation during the study.

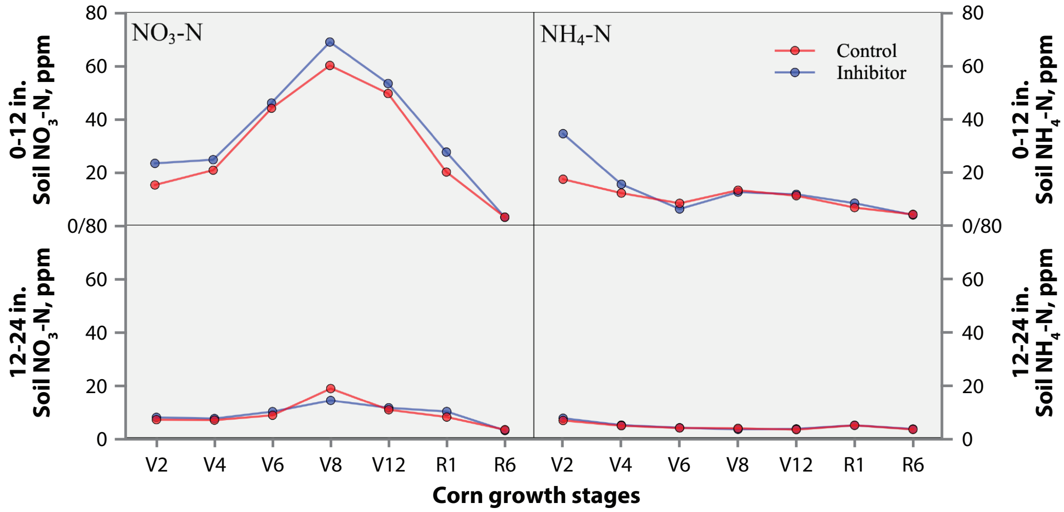

Figure 2. Average soil nitrate (NO_3-N) and ammonium (NH_4-N) content throughout the growing season as affected by the use of nitrification inhibitor in the 0–12 in. and 12–24 in. soil depth. Averaged across locations.

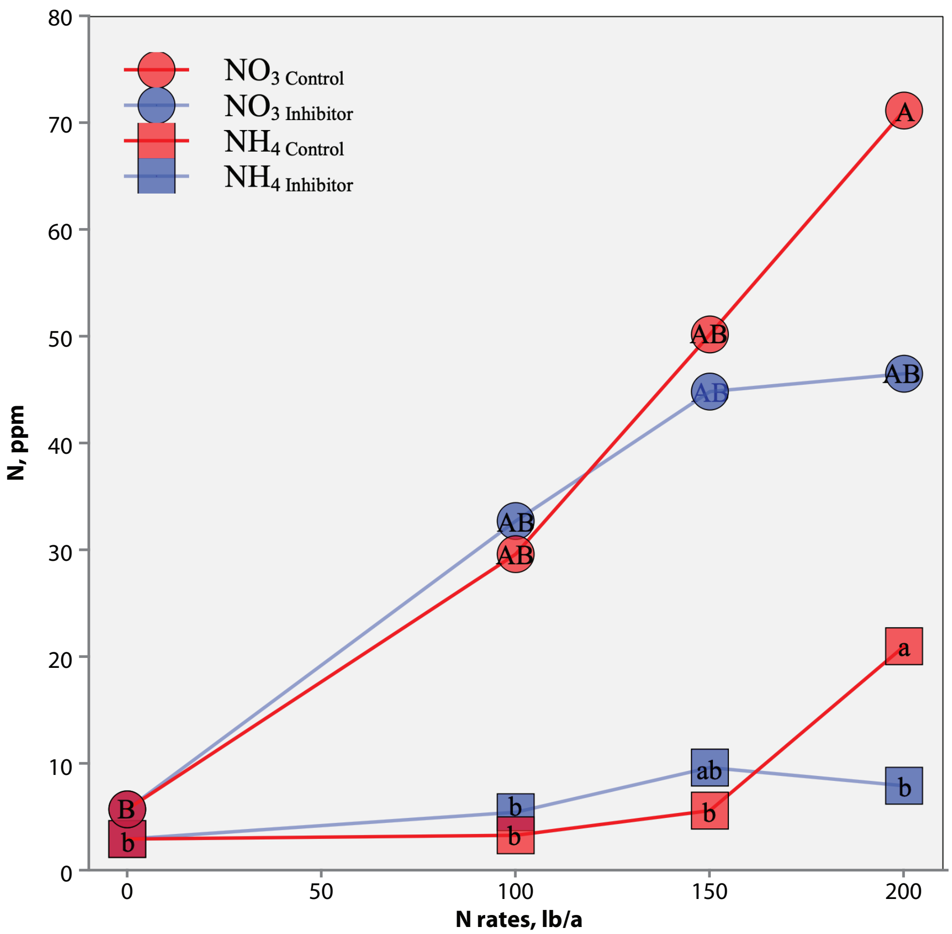

Figure 3. Soil nitrate (NO_3-N) and ammonium (NH_4-N) content as affected by N rates. Samples were collected at the V8 corn growth stage. Uppercase letters are used to compare NO_3-N content in the soil as affected by N rates. Lowercase letters are used to compare NH_4-N content in the soil as affected by N rates.

Correlation Between Mehlich-3 and Ammonium Acetate Extractable Potassium in Kansas Soils

B. Rutter and D.A. Ruiz Diaz

Summary

The K-State Research and Extension Soil Testing Laboratory has been using Mehlich-3 soil test procedures for phosphorus (P) extraction, and ammonium acetate extraction for potassium (K). Previous research in other states has shown a strong correlation between these two tests for K, but data correlating the two in Kansas soils have been limited. A study was performed on soils from across the state to investigate the relationship between these two methods. A strong positive correlation was observed ($r = 0.99$) across the wide range of soil types, pH, and fertility conditions represented in the sample set. Linear regression suggests a near 1:1 relationship and strong fit between Mehlich-3 and ammonium acetate extractable K (slope = 0.97, $R^2 = 0.98$). Based on these results the Mehlich-3 procedure for soil K analysis is a suitable for Kansas soils.

Introduction

Potassium is an essential plant nutrient and is the third most common yield-limiting nutrient in agricultural production. The bioavailability (solubility) of soil-K is governed by equilibrium reactions between three main pools: nonexchangeable-K (K_{non}), exchangeable-K (K_{ex}), and soluble-K (K_{sol}). In many soils, the vast majority of total soil-K exists in the K_{non} pool, where K is either trapped between clay platelets or fixed in the crystalline structures of various minerals (e.g. orthoclase and feldspars). Exchangeable-K is associated with cation exchange sites and may enter the soil solution via displacement from soil colloid surfaces. Soluble-K consists of K^+ ions in the soil solution, which is immediately available for plant uptake but is also the smallest soil-K pool. Even though K_{non} is typically much larger than both K_{ex} and K_{sol} combined, the latter are of particular importance to agriculture, as they represent the bulk of soil-K available for plant uptake over a given growing season. As such, most soil tests for K target the K_{ex} and K_{sol} pools, and are used in combination with fertilizer response curves to make K fertilizer recommendations.

Several soil tests for K are currently employed by laboratories across the U.S.; however, ammonium acetate (NH_4OAc) and Mehlich-3 (M3) are currently the most popular. The KSRE soil testing lab uses M3 for soil phosphorus, but continued using NH_4OAc for soil tests for K. While there are some contrasting chemical characteristics between these two solutions (e.g. pH), the primary mechanisms for K extraction are similar in theory. Primarily this should occur through displacement of K^+ from the cation exchange complex by NH_4^+. As both solutions contain NH_4^+ and have similar reaction times (shake times), the amount of K^+ extracted should be similar for a given soil. Researchers in other states have demonstrated a near 1:1 correlation between measurements made from these two procedures, however, data correlating the two methods have been limited in Kansas soils. The objectives of this study were to investigate the relationship between NH_4OAc and M3 extractable K, and determine whether M3-K can directly replace NH_4OAc-K in K fertilizer application rate calculations for crops grown in Kansas soils.

Procedures

Laboratory Analysis

Soil samples were randomly selected from soils submitted to the KSRE soil testing lab by farmers and homeowners during 2016-2017 year. Each sample was dried at 40°C and ground to pass a #10 sieve (2 mm). Samples were measured into extraction vessels using 2 g standard soil scoops (NCR) and extracted according to the procedures described in the NCERA 013 *Recommended Chemical Soil Test Procedures* handbook. Briefly, extractions were performed using a 1:10 soil-extractant suspensions of either M3 (0.2 M CH_3COOH, 0.25 M NH_4NO_3, 0.015 M NH_4F, 0.013 M NHO_3, 0.001 M EDTA; pH = 2.5 0.1) or NH_4OAc (1.0 M NH_4OAc; pH 7.0 0.1), with a reaction time of 5 minutes. Extracts were filtered using Ahlstrom 642 filter paper and analyzed using a PerkinElmer Aanalyst 200 Atomic Absorption Spectrometer. The relationship between Mehlich-3 and NH_4OAc extractable K was investigated using linear regression procedures.

Results

A total of 776 samples from 46 different counties in Kansas were included in the study (Table 1). A strong positive correlation was observed between NH_4OAc-K and M3-K over the entire data set (r = 0.99) (Table 2), values for which ranged from 50 to 960 ppm and 41 to 991 ppm, respectively. The near 1:1 relationship (Figure 1) and standard error of the linear regression model (0.97 and 0.005, respectively) suggest that M3-K values could be used as direct replacements of NH_4OAc-K values when calculating fertilizer recommendations without recalibration.

Table 1. General summary of samples used in the study, soils from 46 Kansas counties were used in the study, and covered a wide range of soil pH, Mehlich-3 K (M3K) and ammonium acetate-K (AAK)

Value	pH	M3K	AAK
		---------------- soil ppm, mg/kg	----------------
Minimum	4.0	41.0	50.0
Mean	6.6	238.3	237.2
Maximum	8.5	991.0	960.0

Table 2. Regression analysis results indicate a strong relationship between Mehlich-3 K (M3K) and ammonium acetate-K across the range of soil type, pH, and fertility conditions of samples included in the study

	Estimate	Standard error	t value	Pr(>|t|)
Intercept	7.127	1.357	5.252	1.948e-07
M3K	0.9655	0.004714	204.8	0

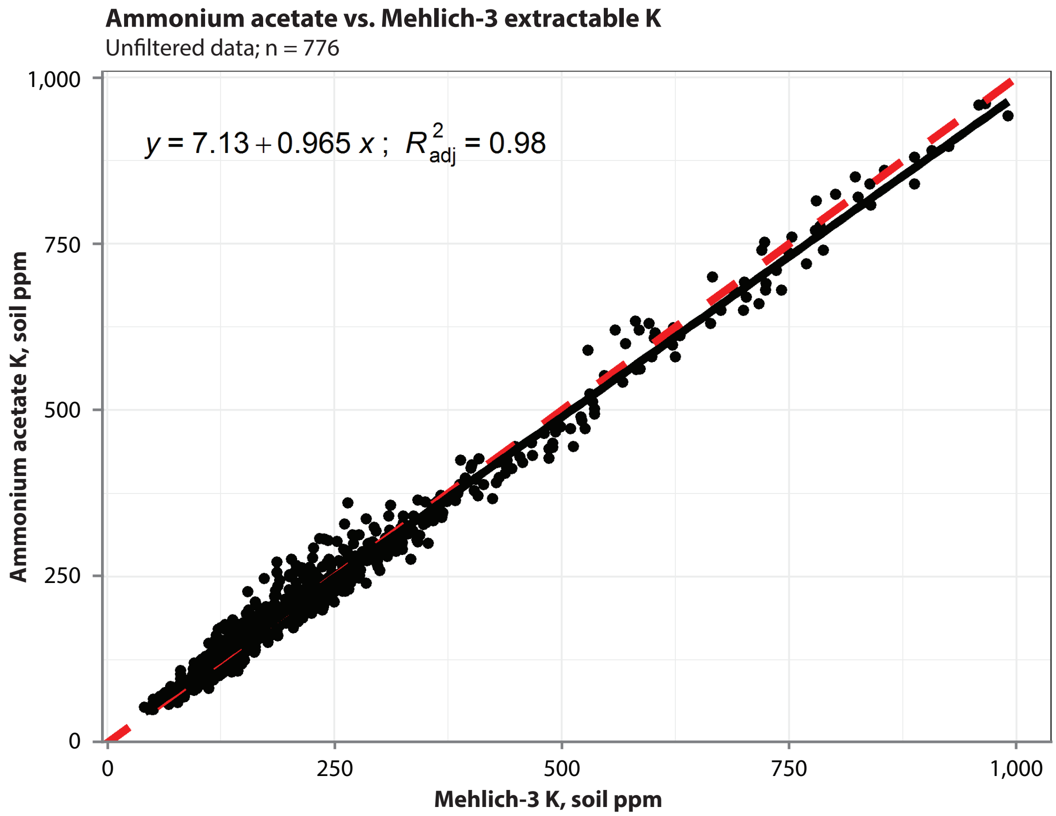

Figure 1. A strong and positive correlation was observed between Mehlich-3 and NH_4OAc extractable potassium (K) over a wide range of soil types and K concentration. The near 1:1 fit and strong fit of the model (slope = 0.97, $R^2 = 0.98$) suggest Mehlich-3 K may be a suitable replacement for NH_4OAc-K in K fertilizer recommendations.

Correlation of Sikora and Smith-McLean-Pratt Soil Buffer pH Measurements

B. Rutter, D.A. Ruiz Diaz, and J. Thomas

Summary
Historically, the K-State Research and Extension Soil Testing Laboratory has used the Smith-McLean-Pratt (SMP) buffer solution to estimate total soil acidity and estimate lime recommendations. The SMP solution contains hazardous chemicals and poses a health risk to lab workers. The Sikora buffer solution was designed as a replacement for SMP and contains no hazardous chemicals. A study was conducted to investigate the relationship between these two buffers in Kansas soils. A strong positive correlation was observed between SMP and Sikora buffer pH measurements. However, linear regression suggests that the relationship is not 1:1 (slope = 0.88). Therefore recommendation equations using the Sikora buffer would require different equations than those currently used for the SMP buffer pH measurements.

Introduction
Crop yields in acidic soils can be limited by several factors, namely reduced root growth and vigor caused by metal toxicity (e.g. aluminum (Al), iron (Fe), and manganese (Mn)), and reduced availability of essential plant nutrients. For example, the availability of phosphate (PO_4^{3-}) is highly dependent on pH, and precipitation of Al, Fe, and Mn phosphates is an important mechanism for reduced phosphorus (P) availability to plants grown in acidic soils. As such, neutralization of soil acidity is often necessary to maintain crop production and farm profitability.

Remediation of acid soils requires the neutralization of the total soil acidity, which can be conceptualized as two main pools, active acidity and reserve acidity. Active acidity is simply the hydrogen ions (H^+) in the soil solution and can be measured through soil pH measurements. Reserve acidity buffers the soil pH (active acidity) and requires some form of titration to measure, as it is caused by acidic cations (e.g. Al^{3+}, Fe^{3+}, and H^+) sorbed to the cation complex. Given the time-consuming nature of soil titrations, pH buffers are often used instead to quantify total soil acidity and to generate lime recommendations. In practice, both soil pH and buffer pH are used, where soil pH is used to determine if lime should be applied and the buffer pH is used to determine the amount of lime required to achieve the target pH.

Several different buffer solutions are used at labs across the U.S. Historically, the KSRE soil testing lab has used the Smith-McLean-Pratt (SMP) pH buffer. However, this solution contains hazardous chemicals, such as p-nitrophenol and chromium, and poses a risk to human health and the environment if not handled and disposed of carefully. Buffers without these hazardous chemicals have been developed in recent years, such as the Sikora buffer solution, and many soil testing labs are using them to reduce operating costs. The Sikora buffer solution was designed as a direct replacement for the SMP buffer. The goal of this study was to evaluate the correlation of the Sikora buffer solution with the SMP solution in Kansas soils and the potential to estimate reserve acidity and provide lime recommendations.

Experimental Procedures

Soil samples were randomly selected from across the state of Kansas. Samples were dried at 40°C overnight and ground to pass a #2 sieve (approximately 2 mm) using a flail type soil grinder. Samples were then analyzed for organic matter (OM), soil pH, SMP buffer pH, and Sikora buffer pH. Soil pH was measured from 1:1 soil-water suspensions. Organic matter was determined via the loss on ignition approach with a muffle furnace operating at 400°C. Both Sikora and SMP pH values were measured according to procedures recommended in North Central Regional Research Publication No. 221 (revised). Given the nature of random sampling, some samples were deemed inappropriate for use in the study. Soil samples with a soil pH > 6.4 or OM content > 10% were removed from the data set prior to analysis. The relationship between Sikora and SMP buffer pH values was investigated using Pearson's product-moment correlation and linear regression techniques.

Results

Soil pH ranged from 4.5–6.4 and soil OM from 0.8–9.2%, in the set of samples included in the study (279 samples). Sikora and SMP pH values ranged from 5.5–7.2 and 5.3–6.9, respectively, with a strong positive correlation (r = 0.9) (Figure 1). The strong correlation and linear nature of the relationship between Sikora and SMP suggests that Sikora could suitably replace SMP for lime recommendations in Kansas soils. However, since Sikora pH values were higher than SMP values, new equations should be used (Figure 2).

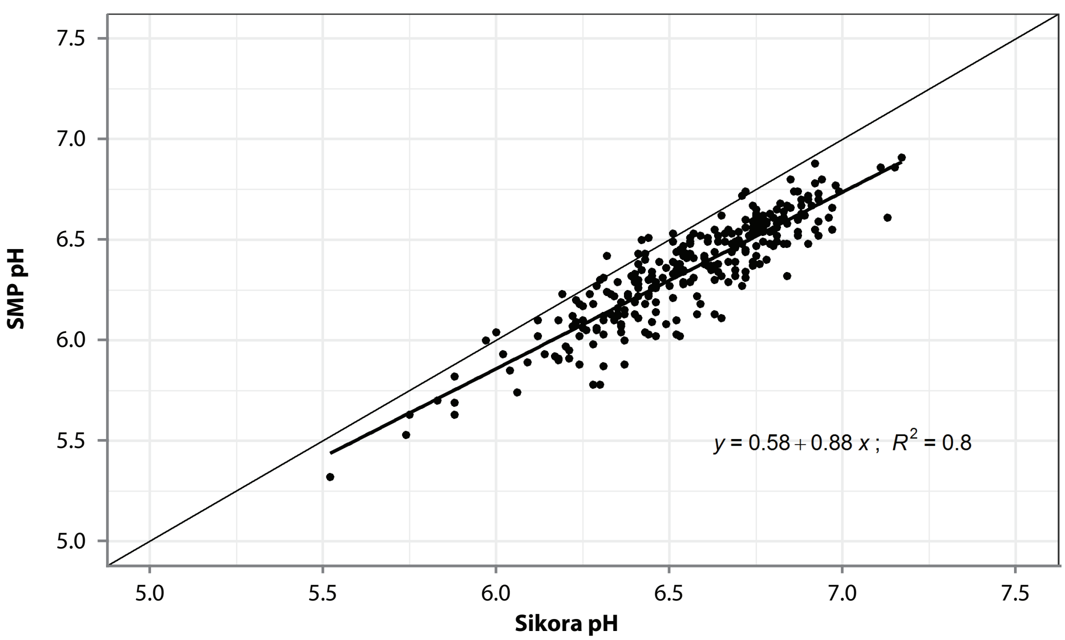

Figure 1. A strong correlation was observed between the Smith-McLean-Pratt (SMP) buffer solution and Sikora buffer pH (r = 0.9). On average, Sikora pH values tend to be higher than those measured using SMP and corrections will need to be made to lime recommendation equations.

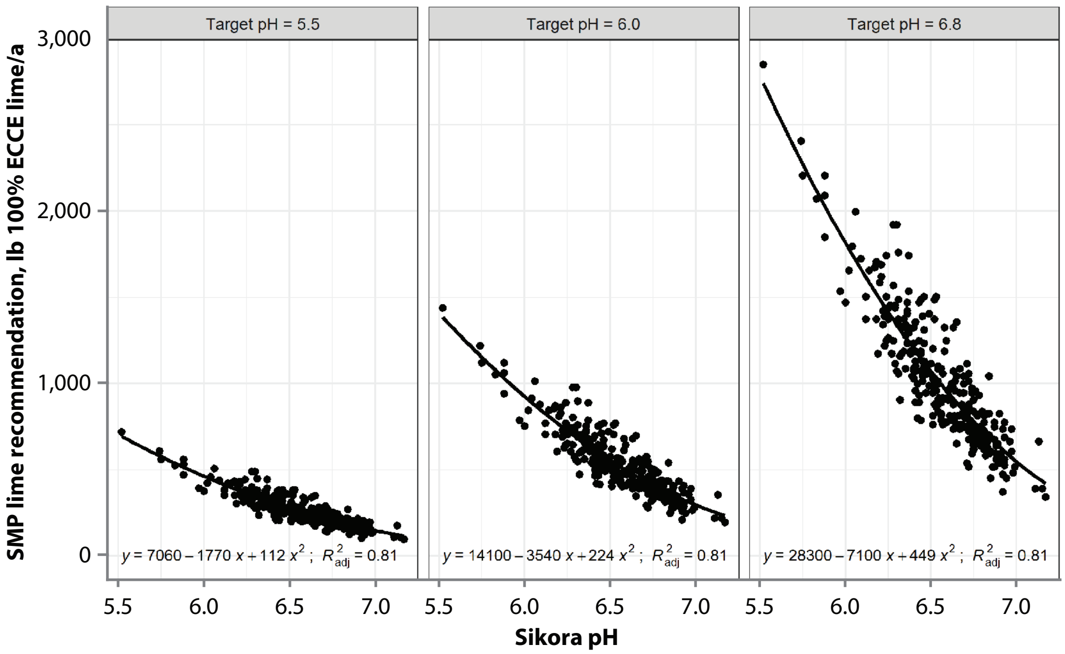

Figure 2. Lime recommendation equations for the Sikora buffer derived by regressing the Smith-McLean-Pratt (SMP) buffer solution lime recommendations against the Sikora pH values measured for each sample.

Surface Lime Application in Long-Term No-Till Crop Production with Stratified Soil pH

F.D. Hansel and D.A. Ruiz Diaz

Summary
Lime application is a key management strategy to control the acidifying effects promoted by long-term application of nitrogen (N) fertilizers and is also a source of calcium for the crops. Two field studies located in Mitchell County was carried out during 3 years (2016-2018), exploring the effect of lime application in wheat (first year), corn (second year), and soybean (third year) crops. After the first year, there was an increase in wheat yield of up to 8% with lime application. For corn (second year), liming showed a yield response of up to 10%. Soybean (third year) yield response to lime showed a 17% yield increase in one location, however, soybean yield response was inconsistent at the second location. The magnitude of response to lime application would be dependent on the initial soil pH and the sensitivity of the crop to low soil pH. Results from this study showed that lime applied to the surface (and not incorporated), can result in yield response. However, soil pH stratification after multiple years of no-till with surface N fertilizer application, showed low soil pH only near the surface, and the soil profile maintained optimum pH levels at these locations.

Introduction
The acidification of soil is a natural process where soil pH decreases over time. This process is accelerated by agricultural production with the use of N fertilizers and can affect both the surface and subsoil depending on the N fertilizer placement. Increasing the amounts of N fertilizer rates can accelerate the soil acidification process. As a consequence of low soil pH, an increase in soluble aluminum (Al) levels can affect root growth and therefore result in poor crop growth and production. Correction of the pH/Al problem by liming can allow for more efficient use of nutrients such as N and P, as well as water (Olsen et al., 2000). In the past, lime recommendations and lime application research have focused on thorough incorporation of the lime material to the soil. However, multiple years of surface applied N in no-tillage systems often lead to a decrease in soil pH near the surface, with a stratification of soil pH (Godsey and Lamond, 2001). The objective of this study was to evaluate crop response to surface lime applications under no-till with a stratified and low soil pH near the soil surface.

Procedures
Two field sites (A and B) were established in Mitchell County, KS and evaluated during 3 years (2016, 2017, 2018); exploring the effect of lime application in wheat (first year), corn (second year), and soybean (third year). Both sites were managed with no-till for more than 25 years. The lime used in the study had 87% of effective calcium carbonate (ECC) and it was not incorporated. The studies were set the fall of 2015 using 4 lime treatments: 1) control (no lime); 2) 0.5-ton/a ECC; 3) 1-ton/a ECC; and 4) 3-ton/a ECC. The experimental design was in randomized complete blocks with 4 replications. The experimental plots were 15-ft wide × 40-ft long. Initial soil tests before lime application are presented in Figure 1.

Results

Wheat

After the first year, there was an increase in wheat yield up to 8% with lime application. At Site A, the lime application of 0.5-ton/a ECC resulted in an increase of wheat yield of about 5.9% (Figure 2A). At Site B, the 0.5 and 1.0 t/a rate showed a response of 8.1 and 7.8%, over the control respectively (Figure 2B). Combined across the two locations there was a 5.3% yield increase to lime application in wheat. The magnitude of the response was small, however there was a consistent benefit in yield (Figure 2C).

Corn

For corn (second year), liming showed yield response of up to 10% higher yields. Corn yields were increased at both sites (Figure 3A and 3B). Considering the relative response of corn yield to lime application across the two locations there was an increase of 6% in yield (Figure 3C).

Soybean

Soybean yield response to lime (third year) varied by site, with up to 17% yield increase at Site A, but variable response at Site B. (Figure 4). The relative response of soybean yield to lime application across the two sites showed an increase of 6.5% in yield (Figure 4C).

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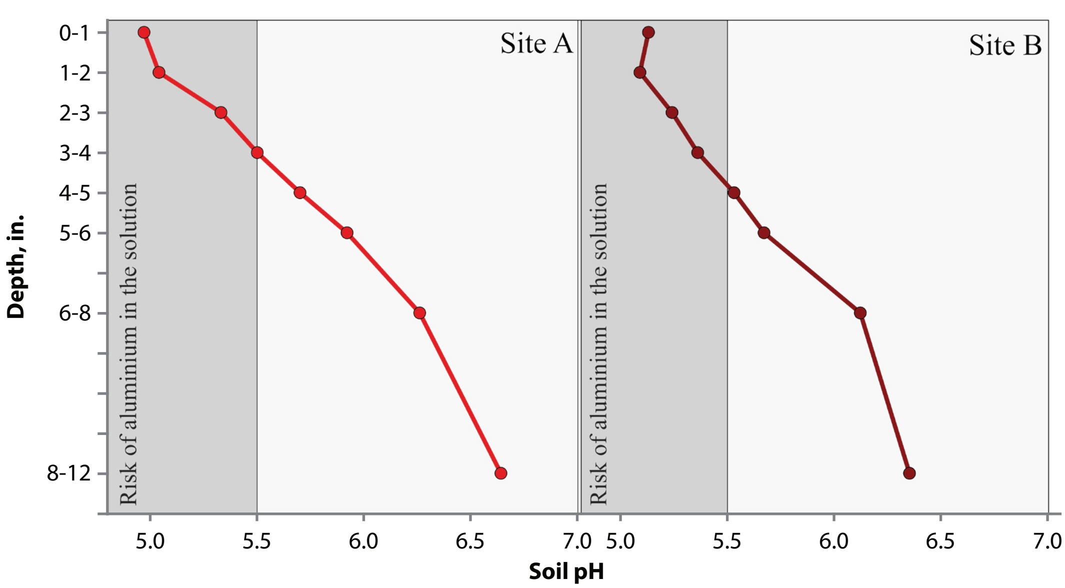

Figure 1. Initial soil pH in sites A and B in Mitchell County, KS, 2015.

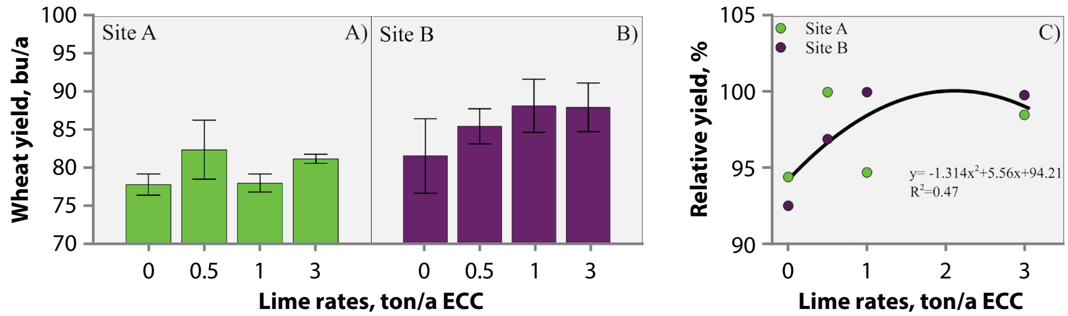

Figure 2. Wheat yield response to lime application (first year after application), 2016.

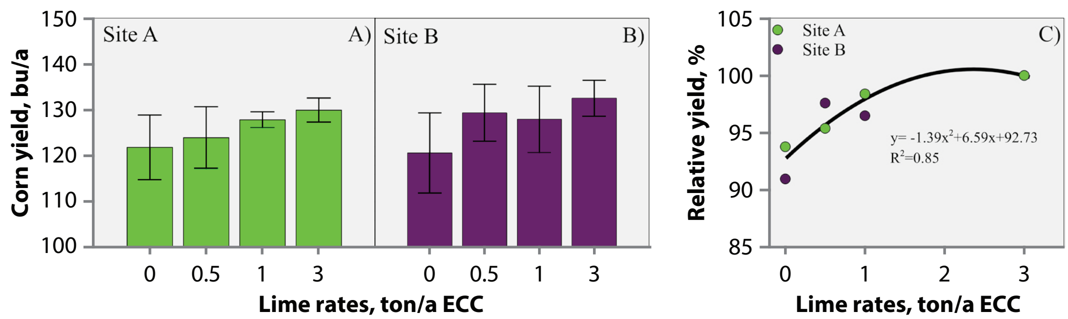

Figure 3. Corn yield response to lime application (second year after application), 2017.

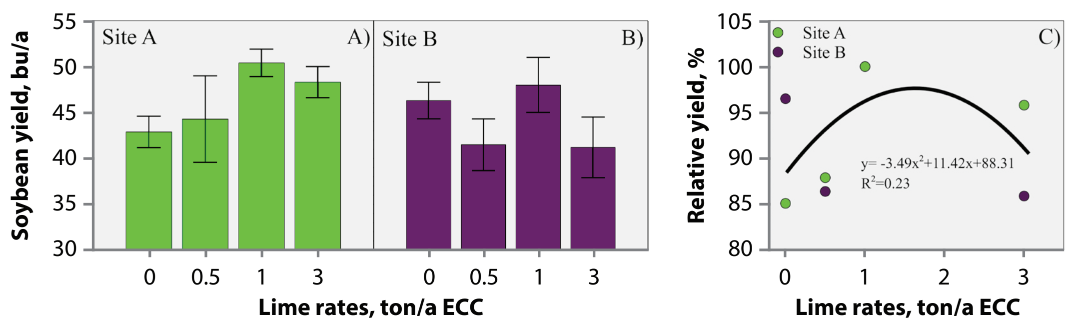

Figure 4. Soybean yield response to lime application (third year after application), 2018.

Corn Yield Response to the Use of a Nitrification Inhibitor with Anhydrous Ammonia

F.D. Hansel and D.A. Ruiz Diaz

Summary
Nitrification inhibitors are used to delay the nitrification process, reducing nitrogen (N) loss. The increase of nitrogen fertilization efficiency could promote greater corn grain yields and reduce environmental losses. The objective of this study was to evaluate corn response to the use of a nitrification inhibitor in corn grain. The study was carried out at four locations (Manhattan, Scandia, Rossville, and Ashland, KS) during 2017 and 2018 crop seasons. There was corn response to N fertilization, but no differences in corn yield were observed when anhydrous ammonia was treated with nitrification inhibitor at these site-years.

Introduction
Nitrogen is an essential element for plant growth and reproduction. After it is applied as fertilizer on soil, N changes its chemical form, continually being subjected to critical processes of loss. Nitrification is an important step in the N cycle in soil promoted by the biological oxidation of ammonium to nitrite and nitrate. Conversion of this ammonium (NH_4^+-N) to nitrate (NO_3^--N) increases nitrogen leaching due to the mobility of NO_3^--N, and can be lost from the plant rooting zone (Wiederholt and Johnson, 2005). Nitrification proceeds rapidly in warm, moist, well-aerated soils.

Nitrification inhibitors are chemicals that slow down or delay the nitrification process, thereby decreasing the probability that large losses of nitrate will occur before the fertilizer nitrogen is taken up by plants (Nelson and Huber, 2001). The objective of this study was to evaluate the response from the use of a nitrification inhibitor on corn grain yield.

Procedures
The study was carried out at four locations (Manhattan, Scandia, Rossville, and Ashland, KS) during 2017 and 2018 crop seasons. Treatments were: 1) N fertilizer without nitrification inhibitor (control), and 2) N fertilizer treated with nitrification inhibitor. Anhydrous ammonia was applied in four rates 0, 100, 150, and 200 lb/a. The experimental design was in randomized complete blocks with 4 repetitions. Experimental plots were 10-ft wide × 60-ft long. Chlorophyll meter measurements (SPAD) were taken at the V2, V4, V8, V12, and R1 corn growth stages. Soil samples were taken at the same growth stages at the soil depth of 0–24 inches and submitted on the same day to the K-State Research and Extension Soil Testing Laboratory for NO_3^--N and NH_4^+-N analysis. The two central rows of each plot were machine harvested. Grain weight was recorded and adjusted for 15.5 % moisture.

Results

SPAD Measurements and the Relationship with NO_3-N and NH_4-N in the Soil

The SPAD measurements have high correlation with N content in the tissue (Ma et al., 1994). During the corn season there was a gradual increase in the SPAD values with a posterior decrease at the R1 growth stage. Similarly, soil NO_3-N showed an increase during corn growing season in most sites, suggesting important contribution of this N form for corn N nutrition (Figure 1). Therefore, SPAD measurements showed higher correlation with soil NO_3-N than soil NH_4-N.

Corn Yield Response to N Fertilization and Nitrification Inhibitors

Nitrogen fertilizer application increased corn yield (N fertilizer vs. the check); however, corn response among N rates was not statically significant in this study (Figure 2). The optimum N rate across all locations was at 117 lb N/a (Figure 2). Furthermore, no differences in corn yield were observed when anhydrous ammonia was treated with a nitrification inhibitor at the locations for this study (Figure 3). It is likely that N loss potential was low for these locations/years, resulting in no yield difference with the use of nitrification inhibitors.

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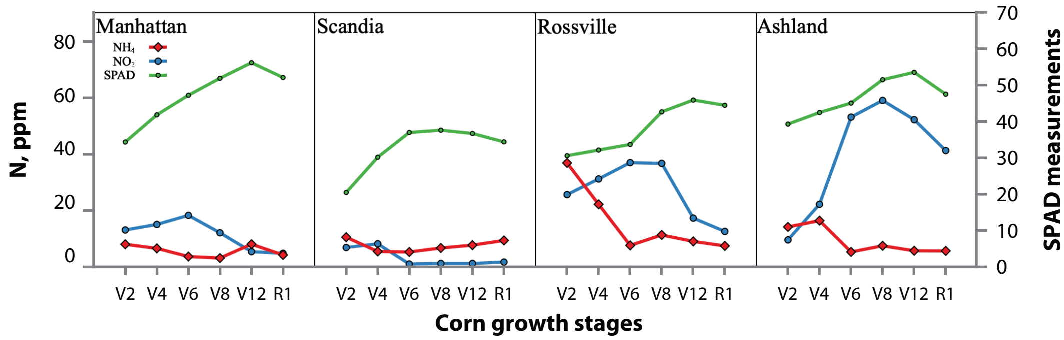

Figure 1. Chlorophyll meter measurements (SPAD), soil nitrate (NO_3-N), and ammonium (NH_4-N) during corn growing season in Manhattan, Ashland, Rossville, and Scandia, KS.

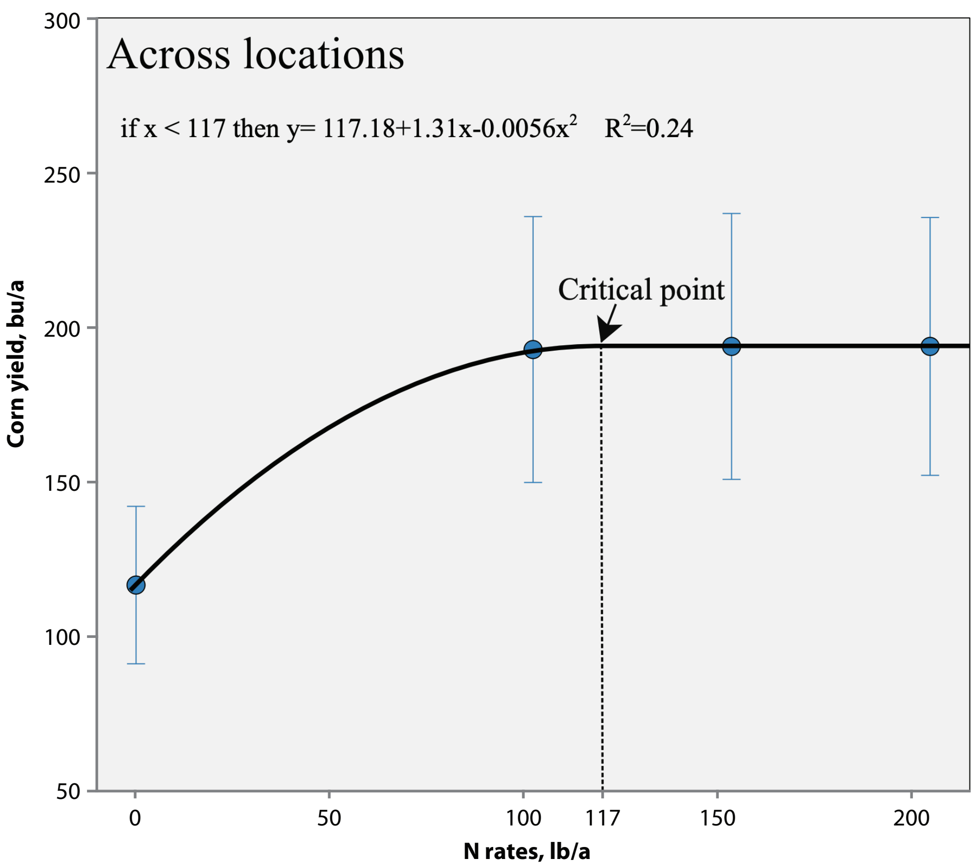

Figure 2. Corn grain yield across locations affected by nitrogen (N) rates (lb/a). The maximum value for corn yield was 194 bu/a at the rate of 117 lb N/a.

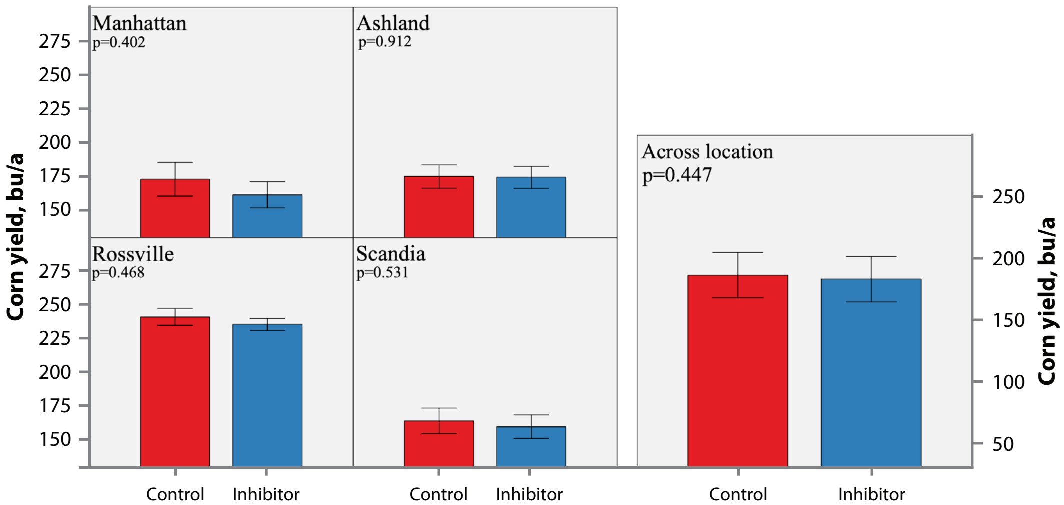

Figure 3. Corn grain yield in Manhattan, Ashland, Rossville, Scandia, KS, and across locations as affected by the use of nitrification inhibitor at the nitrogen (N) application rate of 150 lb N/a .

Kansas Fertilizer Research 2019

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