KANSAS FERTILIZER RESEARCH 2008

Report of Progress 1012

Kansas State University

Kansas State University Agricultural Experiment Station and Cooperative Extension Service

KANSAS STATE UNIVERSITY

KANSAS FERTILIZER RESEARCH 2008

Introduction

The 2008 edition of the Kansas Fertilizer Research Report of Progress is a compilation of data collected by researchers across Kansas. Information was contributed by faculty and staff from the Department of Agronomy, Kansas agronomy experiment fields, and agricultural research and research-extension centers.

We greatly appreciate the cooperation of many K-State Research and Extension agents, farmers, fertilizer dealers, fertilizer equipment manufacturers, agricultural chemical manufacturers, and representatives of various firms who contributed time, effort, land, machinery, materials, and laboratory analyses. Without their support, much of the research in this report would not have been possible.

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Precipitation Data

Month	Manhattan	SWREC Tribune	SEARC Parsons	ECK Exp. Field Ottawa	HC Exp. Field Hesston S
	---in.---				
2007					
Aug.	2.24	3.31	1.42	7.37	2.75
Sept.	1.96	0.73	2.37	2.17	0.92
Oct.	4.36	0.14	5.05	3.09	2.60
Nov.	0.12	0.08	0.27	1.53	0.18
Dec.	3.77	1.29	2.12	2.58	2.90
Total 2007	44.80	14.52	50.75	32.28	35.37
Departure from normal	+10.00	+2.52	+8.66	-6.93	+2.30
2008					
Jan.	0.18	0.07	0.64	1.25	0.23
Feb.	1.41	0.24	2.83	1.41	1.88
Mar.	2.84	0.74	4.49	4.09	2.33
Apr.	2.24	0.89	9.84	4.37	3.60
May	4.98	0.37	7.76	6.81	5.06
June	11.42	1.23	9.20	9.75	4.32
July	4.71	2.56	12.85	8.61	3.54
Aug.	5.29	4.79	3.39	1.01	5.17
Sept.	5.42	0.83	4.79	3.71	4.92

continued

Precipitation Data

Month	NCK Exp. Field Belleville	KRV Exp. Field	SCK Exp. Field Hutchinson	ARC-Hays
	----in.----			
2007				
Aug.	2.93	1.50	1.68	3.40
Sept.	4.05	1.45	0.65	1.42
Oct.	5.08	4.14	2.91	6.02
Nov.	0.16	0.10	0.11	0.70
Dec.	1.82	0.87	4.26	0.24
Total 2007	38.40	26.06	34.21	33.70
Departure from normal	+7.51	+8.18	+3.89	+11.07
2008				
Jan.	0.50	0.20	0.49	0.45
Feb.	1.50	1.73	2.47	1.30
Mar.	0.78	1.33	1.69	0.41
Apr.	7.51	1.92	3.10	1.95
May	5.00	2.68	7.41	6.85
June	3.39	3.09	6.35	1.85
July	4.49	2.92	2.53	4.02
Aug.	3.67	1.40	2.29	3.40
Sept.	4.28	5.47	5.73	1.42

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

Plant Sensors for Determination of Side-Dress Nitrogen for Grain Sorghum on Manure-Amended Soils

M. J. Davis and N. O. Nelson

Summary

The in-season application rate of inorganic nitrogen (N) fertilizer on manure-amended fields is difficult to determine. Goals of this study are to determine N response of grain sorghum on manure-amended soil, evaluate N availability calculations recommended in Kansas State University (KSU) extension publications, and examine application of optical sensors for making in-season N recommendations in manure-amended fields. A GreenSeeker RT 200 (Ntech Industries, Inc. Ukiah, CA) was used to measure normalized difference vegetation index (NDVI) in grain sorghum on both inorganic-fertilized and manure-amended plots. Along with NDVI, chlorophyll meter readings and tissue concentrations were measured at two times. Treatments consisting of various rates of inorganic N fertilizer (0 to 80 lb/a N) were applied in season, and reference treatments of 120 lb/a N were applied at planting. Significantly greater differences in V3 chlorophyll meter readings and tissue concentrations were measured in the reference treatments compared with the control. Grain yield of manure-amended and commercially fertilized treatments responded similarly to side-dress N applications. The chlorophyll meter appears to have promise as a tool for sensing in-season N stress for grain sorghum on manure-amended soils. Additional research is needed to determine the utility of optical sensors, such as the GreenSeeker, in manured cropping systems.

Introduction

As commercial N fertilizer prices climb, alternative sources of N, such as animal manure, become increasingly important. However, manure management presents producers with a number of challenges: variability in N form and quantity in manure, in mobilization of organic N, and in current application methods. Producers often add supplemental N to manure-amended soils; however, additional research is needed to assist in determining the appropriate amount of fertilizer to add in these situations. Optical sensors that remotely sense in-season crop N need can potentially aid producers with manure and N management. It is well documented that optical sensors have produced good results in creating in-season N recommendations. However, little is known regarding the sensors' effectiveness on manure-amended fields. Goals of this study are to determine N response of grain sorghum on manure-amended soil, evaluate N availability calculations recommended in KSU extension publications, and examine application of optical sensors for making in-season N recommendations in manure-amended fields.

Procedures

2008 was the first year of this study, conducted at the Agronomy North Farm in Manhattan, KS. A randomized split-plot design with three replicates was used. The two whole-plot treatments were preplant manure and commercial fertilizer. There were six subplot treatments with in-season N application of 0, 20, 40, 60, and 80 lb/a and a reference plot that received 120 lb/a N at planting; all applications were hand broadcast with urea. Manure-amended plots received approximately 15.7 ton/a of manure. Following KSU manure-N availability calculations, 64 lb of available N per acre were applied and incorporated immediately after application. Commercially fertilized plots received 40 lb/a N and 40 lb/a P_2O_5 at planting in the form of urea ammonium nitrate (UAN) and ammonium polyphosphate (APP) in a 2 × 2 in. placement at planting. Sorghum was planted in 30-in. rows at 60,000 seeds/a on June 17. An active optical remote sensor (GreenSeeker RT 200) was used to determine the NDVI for each plot. NDVI, chlorophyll meter, and tissue samples were taken at growth stage V3. Additional chlorophyll meter and tissue samples were taken at the flag leaf growth stage. Thirty feet of the center two rows of each plot were hand harvested on November 4.

Results

The 2008 growing season had favorable conditions, as indicated by high grain sorghum yields (Table 1). Chlorophyll meter readings of the reference treatments were significantly greater than those of split-N application treatments at the V3 growth stage. The difference between chlorophyll meter readings of the reference and control increased at flag leaf. However, there was no difference in chlorophyll meter readings between the 80 lb/a N side-dress treatment and the reference treatment at flag leaf. Sorghum whole-plant tissue concentrations at the V3 growth stage were greater in the reference treatment than in the split-N application treatments in the commercially fertilized whole plots; however, no significant differences were seen in manure treatments. Sorghum flag leaf tissue concentrations were significantly lower in the 0 and 20 lb/a N side-dress treatment than in the reference treatment. However, there was no difference between the 40, 60, or 80 lb/a N side-dress treatment and the reference treatment.

Grain yields were significantly greater in the reference treatment compared with the 0 and 20 lb/a N treatments. However, there was no difference between the 40, 60, or 80 lb/a N side-dress treatments and the reference treatment. The NDVI as measured by the GreenSeeker was not significantly affected by treatment at the V3 growth stage. Furthermore, preplant N source (manure or commercial fertilizer) did not significantly affect chlorophyll meter readings, tissue N concentrations, or grain yield. The N response of grain sorghum on manure-amended soils was similar to the response on soil receiving preplant commercial fertilizer. Following the KSU recommendations for determination of available N in manure, the manure-amended soils received 64 lb/a plant available N. However, this appears to be an overestimation of plant-available N, as indicated by the similar N response between manure-amended soils and soils receiving only 40 lb/a fertilizer N.

The chlorophyll meter appears to have promise as a tool for sensing in-season N stress for grain sorghum on manure-amended soils. Additional research is needed to determine the utility of optical sensors, such as the GreenSeeker, in manured cropping systems.

Table 1. Effects of side-dress nitrogen rate on chlorophyll meter readings, tissue N concentrations, and yield of grain sorghum receiving inorganic fertilizer or manure as the preplant N source, Manhattan, KS, 2008

	V3 chlorophyll meter reading		Flag leaf chlorophyll meter reading		V3 N tissue concentration		Flag leaf N tissue concentration		Grain yield	
Side-dress N Rate	Inorganic fertilizer	Manure	Inorganic fertilizer	Manure	Inorganic fertilizer	Manure	Inorganic fertilizer	Manure	Inorganic fertilizer	Manure
lb/a					---%		---		---bu/a---	
0	41.5	39.9	39.9	37.6	2.49	2.84	2.39	2.43	80.3	97.3
20	40.5	40.1	38.1	38.1	2.46	2.65	2.50	2.43	85.9	84.3
40	42.3	40.4	43.3	41.8	2.48	2.66	2.92	2.89	112.7	98.9
60	40.5	41.0	44.2	41.5	2.50	2.93	3.01	2.95	119.5	115.0
80	41.1	40.2	45.3	43.1	2.44	2.78	2.98	2.94	123.2	120.9
reference	44.5	43.8	48.4	47.2	3.03	2.96	3.17	3.16	131.5	120.6
LSD (0.05)[1]	1.9		4.5		0.40		0.30		20.6	

[1] Least significant difference for comparison of treatment means between subplot and whole-plot treatments for each response variable at alpha equals 0.05.

Use of Nitrogen Management Products and Practices to Enhance Yield and Nitrogen Uptake in No-Till Grain Sorghum

H. S. Weber, A. N. Tucker, and D. B. Mengel

Summary
Long-term research shows that nitrogen (N) fertilizer is usually needed to optimize production of grain sorghum in Kansas. Grain sorghum is grown under dryland conditions across the state and is typically grown by using no-till production systems. These systems leave a large amount of surface residue on the soil surface, which can lead to ammonia volatilization losses from surface applications of urea-containing fertilizers and immobilization of N fertilizers placed in contact with the residue. Leaching and denitrification can also be a problem on some soils. In 2008, there was a large response to N fertilizer at the Manhattan and Ottawa locations as well as a difference in performance of different N products and practices. This research will continue next year.

Introduction
The purpose of this study is to evaluate different N fertilizers, products, and application practices used in Kansas and determine whether specific combinations can improve yield and N use efficiency of no-till grain sorghum. The long-term goal of this study is to quantify some of these relationships to assist farmers in selecting specific combinations that could enhance yield and profitability on their farm. In this study, three tools for preventing N loss were examined: fertilizer placement, or placing N in bands on the residue-covered soil surface to reduce immobilization; use of a urease inhibitor (Agrotain) that blocks the urease hydrolysis reaction that converts urea to ammonia and potentially could reduce ammonia volatilization; and use of a polyurethane plastic-coated urea (ESN) to delay release of urea fertilizer until the crop can use it more effectively. The ultimate goal of using these practices or products is to increase N uptake by the plant and enhance yield.

Procedures
The study was initiated in 2008 at the Agronomy North Farm near Manhattan, KS, the East Central Kansas Experiment Field near Ottawa, KS, and the South Central Kansas Experiment Field near Partridge, KS. Previous crops on these sites were wheat at Manhattan, soybean at Partridge, and wheat/double crop soybean at Ottawa. Sorghum hybrids DKSA 54-00, P84G62, and P85646 were planted May 19, May 21, and June 6 at Manhattan, Ottawa, and Partridge, respectively. Twenty pounds of starter fertilizer as UAN was applied at Manhattan. No starter fertilizer was applied at the other locations. Nitrogen management treatments were applied in mid-June at all locations after sorghum emerged. Common treatments at all three locations consisted of a check plot (starter N included at Manhattan, no N applied to check plots at Partridge and Ottawa), broadcast urea, broadcast urea with Agrotain, broadcast 50/50 ESN/urea blend, surface-applied UAN, and dribble-band UAN. Additional treatments of broadcast urea plus Super U, ESN-coated urea alone, surface-applied UAN with Agrotain, and coulter-banded UAN were applied at the Manhattan location.

Treatments were arranged in the field in a randomized complete block design with four replications. Plot size was four rows (10 ft) wide by 50 ft long. A preemergence herbicide was used at all locations to control weeds. Preplant soil samples were collected from each block to determine nutrient status of the site. Flag leaves were collected at half bloom as a measure of plant N content.

Plots were machine harvested. The middle two rows of each plot were harvested at Ottawa and Partridge. A 17.3-ft segment of the middle two rows was hand harvested at Manhattan. Harvest dates were: Manhattan, September 24; Partridge, November 3; and Ottawa, November 18. Grain samples were collected from each plot for grain moisture and N content. Yields were adjusted to 13% moisture.

Results

Yield and flag leaf N data are reported in Table 1. At Manhattan and Ottawa, a large increase in yield and flag leaf N content was observed in response to N fertilizer, with yields more than doubled where fertilizer was applied. At Manhattan, surface applications of urea treated with Agrotain or Super U, broadcast applications of ESN or the urea/ESN blend, and coulter-banded UAN provided highest yields. At Ottawa, no difference among N treatments was observed. At Partridge, only a limited response to N was observed.

Table 1. Effect of nitrogen product and method of application on sorghum flag leaf percentage nitrogen and yield, 2008

	Manhattan			Ottawa			Partridge		
Treatment	Total N	Yield	Flag leaf N	Total N	Yield	Flag leaf N	Total N	Yield	Flag leaf N
	lb/a	bu/a	%	lb/a	bu/a	%	lb/a	bu/a	%
Control	20	44	2.01	0	31	1.83	0	119	2.66
Urea	80	96	2.37	60	70	2.13	60	128	2.78
Broadcast urea + Agrotain	80	107	2.46	60	66	2.10	60	123	2.77
Broadcast urea + Super U	80	108	2.43	–	–	–	–	–	–
Broadcast ESN-coated urea	80	99	2.44	–	–	–	–	–	–
Broadcast 50% urea + 50% ESN urea	80	101	2.36	60	69	2.10	60	126	2.80
Broadcast UAN	80	97	2.20	60	61	2.20	60	126	2.81
Surface band UAN	80	81	2.29	60	65	2.15	60	122	2.85
Surface band UAN + Super U	80	94	2.34	–	–	–			
Coulter band UAN	80	101	2.32	–	–	–			
LSD (0.10)		10	0.13		14	0.23		8	0.12

Use of Nitrogen Management Products and Practices to Enhance Yield and Nitrogen Uptake in No-Till Corn

H. S. Weber, A. N. Tucker, and D. B. Mengel

Summary
Long-term research has shown that nitrogen (N) fertilizer is usually needed to optimize corn production in Kansas. Research has also shown differences in response to various N fertilizers, products, and practices, particularly in the eastern portion of the state, where soil and climatic conditions can lead to N loss. In 2008 at Manhattan, conditions were present that could lead to N loss. A significant response to N fertilizer as well as a significant difference in performance among some N fertilizers, products, and practices was observed. Using tools to protect N from volatilization and immobilization loss significantly increased yields at this location. This research will continue in 2009.

Introduction
The purpose of this study is to evaluate the performance of different N fertilizers, products, and application practices used in Kansas and determine whether specific combinations can improve yield and N use efficiency of no-till corn. The long-term goal of the study is to quantify some of these relationships to assist farmers in selecting specific combinations that could enhance yield and profitability on their farm. In this study, four tools for preventing N loss were examined: fertilizer placement, or putting N below surface residue to reduce ammonia volatilization and immobilization; use of a urease inhibitor (Agrotain) that blocks the urease hydrolysis reaction that converts urea to ammonia and potentially could reduce ammonia volatilization; use of a compound that contains a urease inhibitor and a nitrification inhibitor to slow the rate of ammonium conversion to nitrate (SuperU) and subsequent denitrification or leaching loss; and use of a polyurethane plastic-coated urea (ESN) to delay release of urea fertilizer until the crop can use it more effectively. The ultimate goal of using these practices or products is to increase N uptake by the plant and enhance yield.

Procedures
The study was initiated at the Agronomy North Farm near Manhattan, KS, on a predominantly Ivan and Kennebec silt loam soil. In 2007, the site had been planted to sorghum with minimal N fertilizer applied to ensure an N response. Plots were arranged in the field in a randomized complete block design with four replications Corn hybrid RX785VT3 was planted Apr. 23, 2008, at a population of 27,000 seeds/a. Starter fertilizer was applied to all treatments, including the no-N control, at a rate of 20 lb/a N as UAN with 2 × 2 in. placement. All N treatments were applied at 80 lb/a N on May 16, 2008, when the corn was at the 2-leaf growth stage. Total N applied to all treatments other than the control was 100 lb/a N.

Treatments consisted of broadcast granular urea, broadcast granular urea treated with Agrotain, broadcast granular urea treated with Super U (a combination of Agrotain and dicyandiamide, DCD, a nitrification inhibitor), broadcast-sprayed UAN, broadcast-sprayed UAN plus Super U, broadcast granular ESN urea (urea coated with polyurethane), a 50/50 ESN/urea blend, surface band treatments of UAN and UAN plus Super U, and Coulter-banded UAN and UAN plus Super U. Coulter banded treatments were placed approximately 2 in. below the soil surface in the row middles on 30-in. centers. A check plot with starter N was also included.

Ear leaves were collected at silking to determine plant N content. Firing rates (number of green leaves remaining below the ear leaf) were taken on July 24 to evaluate N stress to the plants. Whole plant samples were taken August 26 to measure plant/stover N content. Ten plants were selected at random from the plot and cut off at ground level. Ears were removed, and the remaining vegetative portions of the plants were weighed and chopped, and a subsample was collected to determine N and dry matter content. On September 22, plots were hand harvested, corn was shelled, and samples were collected for grain moisture and grain N content. Yield was adjusted to 15.5% moisture. Total N was calculated as stover N and grain N by using stover samples collected August 26, approximately 1 week prior to black layer, and grain samples collected at harvest. This method slightly underestimates total above-ground N because it does not include N content of the cob.

Results

Results are summarized in Table 1. Good yields and an excellent response to N were obtained in this study. Relatively low levels of N in the ear leaf, less than 2.7% N, suggested as critical, suggest that the 100 lb/a N application was not adequate at this site. The normal N recommendation for corn with a yield potential of 150 bu or more following sorghum is 160 lb/a N.

The potential for ammonia volatilization and immobilization loss of surface-applied N was high at this site because of moist soil, good drying conditions, and a large amount of sorghum residue on the soil surface. Surface application of both granular urea and liquid UAN were significantly less effective at supplying N to the corn than other practices. The UAN was particularly affected, likely because it would have been prone to loss of N from both volatilization and immobilization when surface applied.

Addition of a urease inhibitor as Agrotain or Super U significantly improved performance of both products at this site. Surface banding, which would have limited immobilization by reducing residue fertilizer contact, also increased performance of UAN. Addition of Super U to the surface-banded UAN further improved performance, likely through urease inihibition and reducing ammonia volatilization. Coulter banding also provided good performance.

The poly-coated ESN urea product also provided excellent performance, particularly when used in combination with some immediately available urea. The combination of some starter followed by a blend of urea and ESN broadcast after planting is a simple application system that could provide some protection from leaching, denitrification, and volatilization.

Table 1. Effect of nitrogen product and method of application on corn yield, 2008

Treatment	Total N	Yield	Ear leaf N	Green leaves below ear leaf
	lb/a	bu/a	%	
Control	20	78	1.57	1.75
Urea	100	133	1.98	2.70
Broadcast urea + Agrotain	100	158	2.09	2.80
Broadcast urea + Super U	100	164	1.90	3.45
Broadcast ESN-coated urea	100	147	1.98	3.10
Broadcast 50% urea + 50% ESN urea	100	164	1.94	2.95
Broadcast UAN	100	116	1.78	2.20
Broadcast UAN + Super U	100	133	1.82	2.35
Surface band UAN	100	135	2.13	2.60
Surface band UAN + Super U	100	158	2.11	3.45
Coulter band UAN	100	151	2.23	3.20
Coulter band UAN + Super U	100	149	2.05	3.00
LSD (0.10)		15	0.20	0.48

Timing of Nitrogen Fertilization of Wheat

A. N. Tucker and D. B. Mengel

Summary

Long-term research shows that nitrogen (N) fertilizer must be applied to optimize production of winter wheat in Kansas. Wheat is grown throughout the state with multiple planting dates, following multiple crops, and with both tillage and no-till. Because of environmental conditions, sometimes wheat does not get fertilized at optimum times. This study compares the effects of late N fertilization with normal application timings on wheat yield and grain protein content. Grain yields ranged from 46 to 58 bu/a, whereas protein ranged from 13 to 14.3%. In general, as N application was delayed, protein content increased. Use of streamer bars for application of urea-ammonium nitrate (UAN) solutions gave higher yields than traditional spray applications.

Introduction

This study was initiated in 2008 on a farmer's field near Randolph, KS, to determine response of wheat to N fertilization at Feekes 5, 7, and 9 growth stages. This study aimed to evaluate grain yield and protein response due to late applications using different common application sources and methods. Unfortunately, Replications 1 and 2 were lost because of the effects of dry weather and an adjacent tree row.

Procedures

Nitrogen fertilizer treatments consisted of an N rate of 60 lb/a N were applied at Feekes 5, Feekes 7, or Feekes 9 to established winter wheat. The N was applied by surface broadcasting urea, applying UAN with a flat fan nozzle, or applying UAN with a streamer bar. Wheat was no-till planted in late October using a blend of Dominator, Karl 92 and 2137. The center 5 ft of each plot were harvested after physiological maturity. Grain yield was adjusted to 12.5% moisture.

Results

Grain yield and protein values were increased with N fertilizer (Table 1). Highest yield and protein content was obtained from applications at Feekes 7. No visual symptoms of fertilizer injury on wheat tissue were observed with UAN applications, but banding UAN with streamers resulted in higher yields than other application methods (Table 2).

Table 1. Main effect of nitrogen fertilization timing on wheat grain yields and protein, 2008

Rate	Timing	Yield	Protein
lb/a		bu/a	%
0	NA	46	13.0
60	Feekes 5	49	13.7
60	Feekes 7	58	14.3
60	Feekes 9	48	14.2
LSD (0.10)		3	0.4

Table 2. Main effect of nitrogen fertilization method on wheat grain yields and protein, 2008

Rate	Product	Method	Yield	Protein
lb/a			bu/a	%
0	NA	NA	46	13.0
60	Urea	Broadcast	51	13.9
60	UAN	Sprayed	47	14.1
60	UAN	Streamer bars	56	14.1
LSD (0.10)			3	0.4

Use of Thiosulfates in UAN to Reduce Nitrogen Loss and Enhance Nitrogen Use Efficiency in No-Till Corn and Sorghum[1]

A. N. Tucker and D. B. Mengel

Summary
Long-term research shows that nitrogen (N) fertilizer must be applied to optimize production of corn and grain sorghum in Kansas. Most corn and sorghum in Kansas is grown using no-till production systems. These systems have many advantages; however, they leave a large amount of residue on the soil surface. Surface applications of urea-containing fertilizers are subject to ammonia volatilization losses in high-residue systems. Addition of liquid thiosulfate products to surface-applied urea-ammonium nitrate (UAN) fertilizers have been reported to reduce ammonia volatilization losses. The purpose of this study was to determine how these products perform under Kansas conditions. Adding thiosulfates to UAN did not increase N performance in 2006.

Introduction
Some claim that thiosulfates prevent ammonia-N volatilization losses by stabilizing UAN solutions when added at 5 and 10% by volume. The purpose of this study was to determine whether adding thiosulfates to UAN solutions would enhance no-till corn or grain sorghum yields.

Procedures
A field study was conducted during the 2006 crop year at the Kansas State University Agronomy North Farm in Manhattan, KS, with both corn and grain sorghum. Corn hybrid Pioneer 33R81 was planted no-till into soybean stubble May 1, 2006, at a rate of 24,000 seeds/a. UAN solution (20 lb/a N) was applied with the planter as starter. Eight nitrogen treatments were applied 50 days after planting: no additional N control, broadcast applications of granular urea, surface-band applications of UAN solution, surface-band UAN plus 5% calcium thiosulfate, surface-band UAN plus 10% calcium thiosulfate, surface-band UAN plus 5% ammonium nitrogen fertilizer treatments, surface-band UAN plus 10% ammonia thiosulfate, and coulter-band UAN. All N treatments were applied to corn at a rate of 80 lb/a N. The center two rows of each plot were harvested after physiological maturity and shelled, and grain moisture was determined. Yields were adjusted to 15.5% moisture.

Grain sorghum hybrid Pioneer 84G62 was no-till planted May 21, 2006, into sorghum stubble at a rate of 55,000 seeds/a. Twenty pounds/a N was applied with the planter as starter. The same eight nitrogen treatments used for corn were applied to sorghum 30 days after planting at a rate of 60 lb/a N. The center two rows of each plot were harvested after physiological maturity and threshed, and samples were collected for moisture analysis. Grain yield was adjusted to 12.5% moisture.

[1] We appreciate the financial support for this study provided by the Tessenderlo Kerley Company and Dr. John Clapp.

Results

Corn grain yields responded to N application in 2006 (Table 1). Because of high variability, no difference in yield among N treatments was seen.

Grain sorghum also responded to applied N (Table 2). For sorghum, placing N below the surface in the coulter-banded/injected treatment significantly increased yields compared with surface banding UAN. Adding thiosulfate did not improve performance of surface-banded UAN.

Table 1. Effect of nitrogen product and method of application on corn grain yields, 2006

Starter N	Product	Rate	Total N	Yield
lb/a		---------lb/a---------		bu/a
20	None	0	20	106
20	Urea broadcast	80	100	181
20	UAN coulter injected	80	100	190
20	UAN surface band	80	100	189
20	UAN + 5% Ca THIO	80	100	177
20	UAN +10% Ca THIO	80	100	177
20	UAN + 5% NH_4 THIO	80	100	174
20	UAN + 10% NH_4 THIO	80	100	186
LSD (0.10)				20

Table 2. Effect of nitrogen product and method of application on grain sorghum yields, 2006

Starter N	Product	Rate	Total N	Yield
lb/a		---------lb/a---------		bu/a
20	None	0	20	83
20	Urea broadcast	60	80	113
20	UAN coulter injected	60	80	120
20	UAN surface band	60	80	109
20	UAN + 5% Ca THIO	60	80	105
20	UAN +10% Ca THIO	60	80	104
20	UAN + 5% NH_4 THIO	60	80	108
20	UAN + 10% NH_4 THIO	60	80	110
LSD (0.10)				10

Nitrogen Management of Grain Sorghum[1]

A. N. Tucker and D. B. Mengel

Summary

Long-term research shows that nitrogen (N) fertilizer must be applied to optimize production of grain sorghum in Kansas. Most sorghum is grown using no-till production systems. These systems have many advantages; however, they leave a large amount of residue on the soil surface. Surface applications of urea-containing fertilizers are subject to potential ammonia volatilization losses. This study was designed to examine the differences in performance between urea and urea-ammonium nitrate solutions (UAN), N placement and the use of the product Nutrisphere-N as an additive to urea-ammonium nitrate (UAN) solutions. Conditions were not conducive to N loss, and no difference between N management treatments was observed.

Introduction

This experiment was initiated to study the effect of N management practices on yield of no-till grain sorghum. The study was conducted at the Agronomy North Farm in Manhattan, KS.

Procedures

Grain sorghum hybrid Dekalb 42-20 was no-till planted June 26, 2007, into sorghum stubble at a rate of 55,000 seeds/a. UAN (20 lb/a N) was applied with the planter as starter. Nitrogen fertilizer treatments consisted of two N rates (30 and 60 lb/a N) and application methods of surface broadcast urea, coulter-injected UAN, and surface-banded UAN with and without addition of Nutrisphere-N. Treatments were applied 30 days after planting. The center two rows of each plot were hand harvested after physiological maturity. Heads were threshed, and samples of grain were collected for moisture determination. Grain yield was adjusted to 12.5% moisture.

Results

The results from the experiment are summarized in Table 1. A significant response to the highest rate of N applied was seen. However, no significant response to fertilizer source, fertilizer placement, or addition of Nutrisphere-N was observed. This was likely due to conditions that resulted in little or no N loss during the growing season at this location.

[1] We appreciate Specialty Fertilizer Products and Dr. Larry Murphy for providing product and financial support for this project.

Table 1. Effect of nitrogen product and method of application on grain sorghum yield, 2007

Starter N	Product	Rate	Total N	Yield
lb/a		---------lb/a---------		bu/a
20	None	0	20	73
20	UAN surface band	30	50	88
20	UAN surface band + Nutrisphere-N	30	50	86
20	UAN inject	30	50	84
20	UAN inject + Nutrisphere-N	30	50	89
20	UAN surface band	60	80	103
20	UAN surface band + Nutrisphere-N	60	80	101
20	UAN inject	60	80	93
20	UAN inject + Nutrisphere-N	60	80	97
20	Urea	60	80	101
LSD (0.10)				8

Optimum Nitrogen Rates and Timing for Winter Canola Production[1]

J. D. Stamper, V. L. Martin, W. F. Heer, and D. B. Mengel

Summary
Introduction of winter canola to the southern Great Plains necessitates development of nitrogen (N) fertilizer recommendations for southern and central Kansas. Although there was a trend toward higher yields at locations where N was applied in this study, there was no statistically significant response, likely a result of high levels of variation. Research will continue in 2009.

Introduction
This study was conducted at the Redd/Bardgill portion of the Kansas State University South Central Kansas Experiment Field near Partridge, KS, as well at three on-farm locations near Offerle, Larned, and Sterling, KS, in 2007 and 2008. The objective was to determine the response of winter canola to N rates and timing.

Procedures
Nitrogen fertilization studies were established at three locations each year in the fall of 2006 and 2007. Canola varieties, weed control methods, cultural practices, and planting methods were representative of each of the areas. Preplant profile soil-test N data were collected down to 24 in. prior to planting. A randomized complete block design with four replications was used at each location.

All locations received broadcast fall preplant applications of fertilizer that included N, phosphorus, potassium, and sulfur as needed according to soil tests. At the on-farm locations, only spring N rate treatments were used. At the Redd/Bardgill site, fall, spring, and split applications of N were included, but only the spring applications are reported herein. All N fertilizer treatments were applied as urea and broadcast by hand just prior to bolting. Rates ranged from an additional 0 to 120 lb/a N above the amount applied in the fall. All plots were mechanically harvested, and grain yields were adjusted to 9% moisture.

Results
Yields from only three of the site years are presented (Table 1): on-farm results from 2007 and the Redd-Bardgill location in 2008. In 2007, a severe spring freeze followed by preharvest shattering significantly reduced yields at the Redd-Bardgill location. In 2008, The Larned site did not survive the winter, and winds near 100 mph shattered the Sterling crop prior to harvest. Although trends toward higher yields with spring fertilization were observed, no significant response to spring N was observed at any location. This is likely due to high levels of variation, primarily a result of variable winter survival across the plot area and high rates of fall N application.

[1] Thanks to the Risk Management Agency for funding this research, and to producer cooperators Clark Woodworth, John Haas, and the Wetzel Family for providing space to conduct the work.

Table 1. Effects of spring-applied nitrogen on canola

Spring N rate	Sterling 2007		Offerle 2007		Redd/Bardgill 2008	
	Fall N rate	Yield	Fall N rate	Yield	Fall N rate	Yield
	--	-----------------	lb/a	-----------------	--	
0	34	1493	50	1424	30	839
30	34	1747	50	1399	30	1164
60	34	1736	50	1646	30	1055
90	34	1577	50	1519	30	1008
120	34	1558	50	1618	30	1110
LSD (0.10)		NS		NS		NS

Effects of Nitrogen Rate, Timing, and Placement in Irrigated Corn Using Anhydrous Ammonia[1]

J. D. Stamper and D. B. Mengel

Summary

Anhydrous ammonia (AA) is an important nitrogen (N) source for corn production in Kansas and the United States. Traditionally, AA has been applied with a knife-type applicator at a depth of 6 to 8 in. to ensure good sealing and minimize potential seedling injury. This process is slow and requires significant horsepower. A new high-speed applicator has recently been introduced to the market by John Deere. This applicator uses a disk-style opener, is designed to run at substantially higher speeds, and requires significantly less horsepower than the traditional knife applicator. An experiment was conducted in 2008 to determine the effectiveness of both applicators in fall, spring, and side-dress N applications as measured by corn yield.

Excellent yield and response to N was obtained. Optimum N rate across timings and applicators was 160 lb/a N, with no difference between applicators.

Introduction

Anhydrous ammonia has been used as a primary source of N for corn in Kansas for decades. Traditionally, ammonia is applied with a knife-type applicator prior to planting, placed in bands approximately the same spacing as corn rows, and placed approximately 6 to 8 in. deep. Ammonia application requires significant horsepower and is generally done at relatively slow speeds. Thus, farmers are interested in applying AA in the fall to avoid time constraints in the spring.

A new high-speed, low disturbance applicator (HSLD) has recently been introduced to the market by John Deere. This applicator uses a disk-style opener, is designed to run at substantially higher speeds, and requires significantly less horsepower than the traditional knife applicator (TRAD). This implement places the ammonia at a shallower depth, approximately 4.5 in., than the traditional knife applicators. This raises questions regarding the effectiveness of sealing the gaseous ammonia to prevent post-application loss and safety of seedlings planted close to or directly over the ammonia band.

Procedures

This study was conducted on a Rossville silt loam in the Kansas River Valley on a field that was previously planted to soybean. This study was designed to compare effectiveness of the HSLD applicator with that of a TRAD knife applicator in fall, spring preplant, and side-dress applications to corn produced under center-pivot irrigation. Two different applicators were evaluated at each N rate and timing. The TRAD applicator operated

[1] Thanks to Dr. Larry Maddux and Charlie Clark of the Kansas River Valley Experiment Field for their help with this project, to John Deere and Company for funding this research, and to producer cooperators Bob and Shannon Hooks for providing the space needed for this large experiment.

at a lower speed (6 mph) and greater application depth (8 in.). The HSLD applicator placed AA at a shallower depth (4.5 in.) and operated at a higher speed (>8 mph).

Treatments were arranged in a split-block design with time of application (fall, spring preplant, and side-dress) serving as main plots and N rates of 0, 40, 80, 120, 160, and 200 lb/a N and applicator randomized as subplots. Fall applications were made in mid-November, preplant applications were 2 weeks prior to planting, and side-dress applications were made at the 6-leaf growth stage.

Corn (Producers brand hybrid 7624 VT3 RR) was planted at about 30,000 seeds/a on Apr. 23, 2008. Fall and preplant treatments were planted directly over the ammonia bands, whereas the side-dress application was placed in the row middles on 60-in. spacings (every other row middle). Corn was irrigated to minimize water stress. Plant samples, including ear leaf, were taken to evaluate N uptake by the crop. The center two rows of each plot were machine harvested after physiological maturity, and grain yields were adjusted to 15.5% moisture.

Results

The main effects of N rate, applicator used, and time of N application on corn yield and ear leaf N content are shown in Table 1. Fertilization with AA significantly increased grain yields and ear leaf N concentrations, with a yield increase of up to 66 bu/a. Response to N was maximized at the 160 lb/a N rate. There was no significant difference in corn yield between applicators, nor were any applicator by rate or applicator by rate by timing interactions observed. However, side-dress applications yielded significantly less grain than fall or preplant applications, likely because of early season N deficiencies, as no starter N was applied. No difference in plant stands was observed regardless of N treatment (data not shown).

Table 1. Effects of anhydrous ammonia rate, applicator, and timing on irrigated corn, 2008

	Ear leaf N	Grain yield
	%	bu/a
Rate, lb/a N		
0	1.99d	149e
40	2.16c	179d
80	2.33b	194c
120	2.38ab	208b
160	2.41ab	215a
200	2.44a	210ab
LSD (0.10)	0.09	6
Applicator		
High speed, low disturbance	2.29	193
Traditional	2.28	192
LSD (0.10)	NS	NS
Timing		
Fall	2.25b	195a
Spring preplant	2.36a	195a
Side-dress	2.24b	188b
LSD (0.10)	0.06	3

Within columns, means followed by the same letter are not significantly different according to LSD (0.10).

Nitrogen Fertilization of Grain Sorghum Using Sensor Technology[1]

A. N. Tucker and D. B. Mengel

Summary
Long-term research shows that nitrogen (N) fertilizer is usually needed to optimize production of grain sorghum in Kansas. Grain sorghum is grown in a risk-filled environment; thus, grain yields are highly variable. Also, optimum N rates are highly variable because of differences in residual N levels and grain yield. This study was initiated in 2006 and continues. Over the past 3 years, observed optimum N rates on sorghum ranged from 0 to 115 lb/a N, whereas yields ranged from 17 to 159 bu/a. Sensor technology can be used as an alternative method of estimating yield potential and N needs of grain sorghum.

Introduction
Sensor technology has been used and found effective at estimating yield potential and N status in other crops when used in conjunction with reference strips. In the reference strip method, N is applied in excess of crop need, usually at 125% of the normal N rate for the crop. This project was initiated in 2006 to determine whether sensor technology could be used to improve N recommendations for sorghum in Kansas.

Procedures
This study was conducted at the Kansas State University (KSU) North Central Kansas Experiment Field near Belleville in 2006, the KSU Agronomy North Farm near Manhattan from 2006-2008, the KSU East Central Kansas Experiment Field near Ottawa in 2008, the KSU South Central Kansas Experiment Field near Partridge from 2006-2008, and the KSU Southwest Research-Extension Center near Tribune from 2006-2007.

Nitrogen fertilizer treatments consisted of rates of 0, 30, 60, 90, and 120 lb/a N applied all preplant, all side-dress, or a combination of the two. All preplant N treatments were put on just prior to planting, whereas side-dress treatments were applied at the GS-3 growth stage, approximately 35 to 40 days after planting. Sorghum was no-till planted in late May or early June with a hybrid adapted to that area. Normalized difference vegetation index (NDVI) was collected with a GreenSeeker sensor (NTech Industries, Ukiah, CA) at the GS-3 growth stage and normalized by using INSEY (NDVI/days from planting to sensing). The center two rows of each plot were harvested after physiological maturity. Grain yield was adjusted to 12.5% moisture.

[1] Thanks to Drs. Bill Heer, Barney Gordon, Keith Janssen, and Alan Schlegel for their help with this project and to the Sorghum Commission and Center for Sorghum Improvement for financial support of this work.

Results

Grain sorghum responded to N application at most locations; however, most of the site's optimum N rates were less than 40 lb/a N. Nitrogen applied side-dress was more efficient and resulted in higher sorghum yields than preplant and combination applications (Table 1). INSEY was well correlated with grain sorghum yields (Figure 1), which suggests that sensor technology can be used as an alternative method of estimating yield potential and N needs in grain sorghum at the time of side-dress application.

Table 1. Effect of nitrogen fertilization on grain sorghum yields, 2006-2008

Treatment			Yield									
Pre	Side	Total	Bell. 2006	Man. 2006	Part. 2006	Trib. 2006	Man. 2007	Part. 2007	Trib. 2007	Man. 2008	Ott. 2008	Part. 2008
--------lb/a N--------			---------bu/a---------									
0	0	0	95	141	17	127	56	62	80	106	38	119
0	30	30	88	152	27	130	73	70	76	127	50	123
0	60	60	88	138	29	123	90	62	90	134	64	127
0	90	90	87	158	33	128	107	67	89	140	63	123
0	120	120	88	150	22	125	112	57	78	144	72	129
30	0	30	81	131	23	132	78	69	73	122	43	119
30	30	60	87	154	29	127	89	64	81	130	61	129
30	60	90	98	159	39	133	99	64	70	143	59	129
30	90	120	81	144	28	130	108	66	70	143	73	126
60	0	60	78	138	29	119	89	70	79	128	51	126
60	30	90	90	150	32	132	98	72	67	133	61	131
60	60	120	89	148	39	130	105	73	75	144	68	129
90	0	90	93	143	19	125	99	72	72	129	55	129
90	30	120	101	151	28	130	102	63	78	141	74	131
120	0	120	88	159	24	131	101	67	83	137	55	129

Bell. = Belleville, Man. = Manhattan, Ott. = Ottowa, Part. = Partridge, Trib. = Tribune.

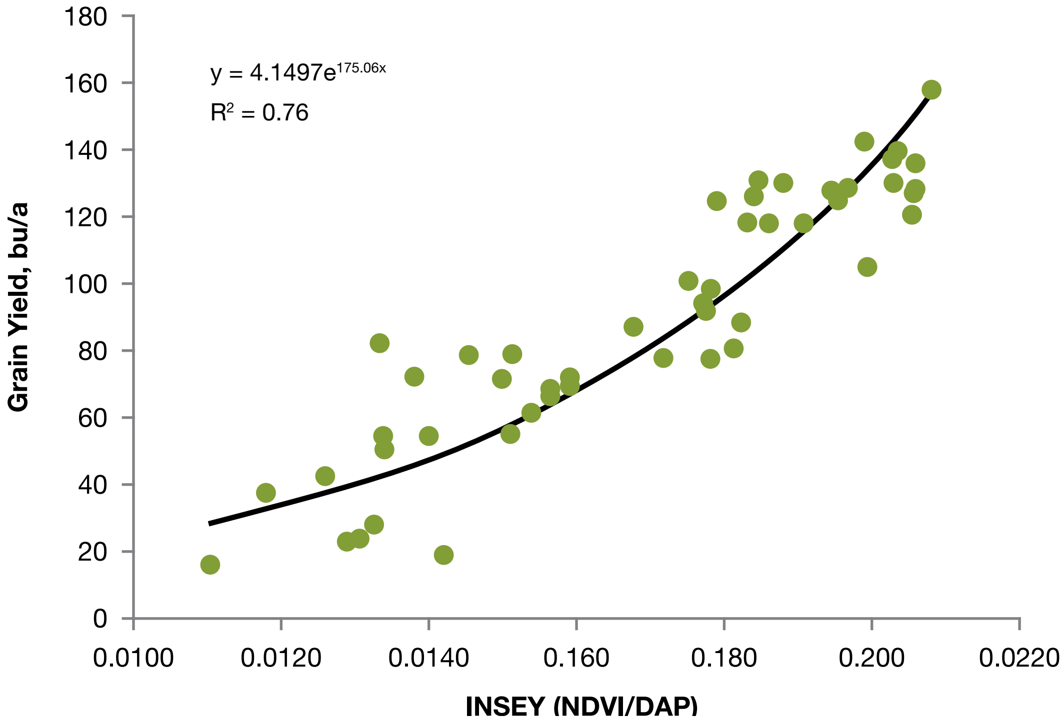

Figure 1. INSEY vs. grain sorghum yields, 2006-2008.

Nitrogen Fertilization of Corn Using Sensor Technology[1]

A. N. Tucker and D. B. Mengel

Summary
Long-term research shows that nitrogen (N) fertilizer is generally needed to optimize corn yields in Kansas. Corn is fairly susceptible to environmental stresses; thus, grain yields can be highly variable. Also, optimum N rates are variable because of differences in residual N levels, variations in N mineralization, and grain yield and need. During the 2006-2008 period of this study, optimum N rates ranged from 0 to 220 lb/a N, whereas individual treatment yields ranged from 55 to 247 bu/a. Use of sensor technology at late side-dressing time was effective at estimating yield potential and N needs of corn.

Introduction
This study was initiated in 2006 to determine the effectiveness of active sensor technologies at estimating N needs and response of corn. Sensor technology has been successfully used to make in-season N recommendations for several crops, including wheat and cotton. However, work with corn has been less successful.

Procedures
The study was conducted at the Kansas State University (KSU) Northwest Research-Extension Center near Colby in 2008, the Agronomy North Farm in Manhattan in 2006 and 2008, the KSU Kansas River Valley Experiment Field near Rossville from 2007-2008, and the KSU Southwest Research-Extension Center near Tribune from 2007-2008. Nitrogen fertilizer treatments at the Colby, Rossville, and Tribune sites consisted of rates of 0, 100, 140, and 180 lb/a N with application timings of all preplant or a split application. All preplant N treatments were put on just prior to planting, whereas side-dress treatments were put on at the V8 or V9 growth stage. All plots received 20 lb/a N as starter applied with the planter and were irrigated as needed. At Manhattan, N fertilizer treatments consisted of side-dress N rates of 0, 30, 60, 90, 120, 150, and 180 lb/a N applied at the V9 growth stage. All plots except the check received 40 lb/a N as starter applied with the planter. The site was not irrigated. At all locations, a 200 lb/a preplant treatment served as the reference strip for sensing. Corn was planted in late April or early May with a hybrid adapted to that area. Normalized difference vegetation index (NDVI) was collected with a GreenSeeker sensor (NTech Industries, Ukiah, CA) at the V9 growth stage. A response index (RI; NDVI reference/NDVI treatment) was calculated to estimate N sufficiency. The center two rows of each plot were harvested after physiological maturity. Grain yield was adjusted to 15.5% moisture.

[1] Thanks to Drs. Robert Aiken, Larry Maddux, and Alan Schlegel for their help with this project and to the Corn Commission and Kansas Fertilizer Research Fund for financial support of this work.

Results

Corn grain yields responded to N application at most locations; however, optimum N rate ranged from 0 to 220 lb/a N (Table 1). The calculated RI at V9, using the highest preplant N rate as a reference strip, was a good indicator of N response at each location. At RI near 1, no response to additional N was found, and at RI above 1.1, N response was observed. The measured NDVI at V9 was also well correlated with corn grain yields (Figure 1). This suggests that sensor technology can be used to estimate yield potential and N needs in corn at the V9 growth stage.

Table 1. Effect of nitrogen fertilization on corn grain yields, 2006-2008

Treatments				Yield						
Pre	Starter	Side	Total	Man. 2006	Ross. 2007	Trib. 2007	Colby 2008	Man. 2008	Ross 2008	Trib. 2008
---------------lb/a N---------------				--------------------------------bu/a---------------------------						
0	20	0	20	NA	132	174	188	NA	82	106
100	20	0	120	NA	219	220	191	NA	213	152
140	20	0	160	NA	208	247	194	NA	229	187
180	20	0	200	NA	221	219	188	NA	234	156
40	20	60	120	NA	223	202	189	NA	201	146
60	20	80	160	NA	224	237	207	NA	222	165
80	20	100	200	NA	219	240	210	NA	226	168
0	0	0	0	94	NA	NA	NA	55	NA	NA
160	40	0	200	162	NA	NA	NA	141	NA	NA
0	40	0	40	115	NA	NA	NA	68	NA	NA
0	40	30	70	133	NA	NA	NA	98	NA	NA
0	40	60	100	149	NA	NA	NA	108	NA	NA
0	40	90	130	164	NA	NA	NA	129	NA	NA
0	40	120	160	172	NA	NA	NA	161	NA	NA
0	40	150	190	177	NA	NA	NA	163	NA	NA
0	40	180	220	154	NA	NA	NA	186	NA	NA

Man. = Manhattan, Ross. = Rossville, Trib. = Tribune.

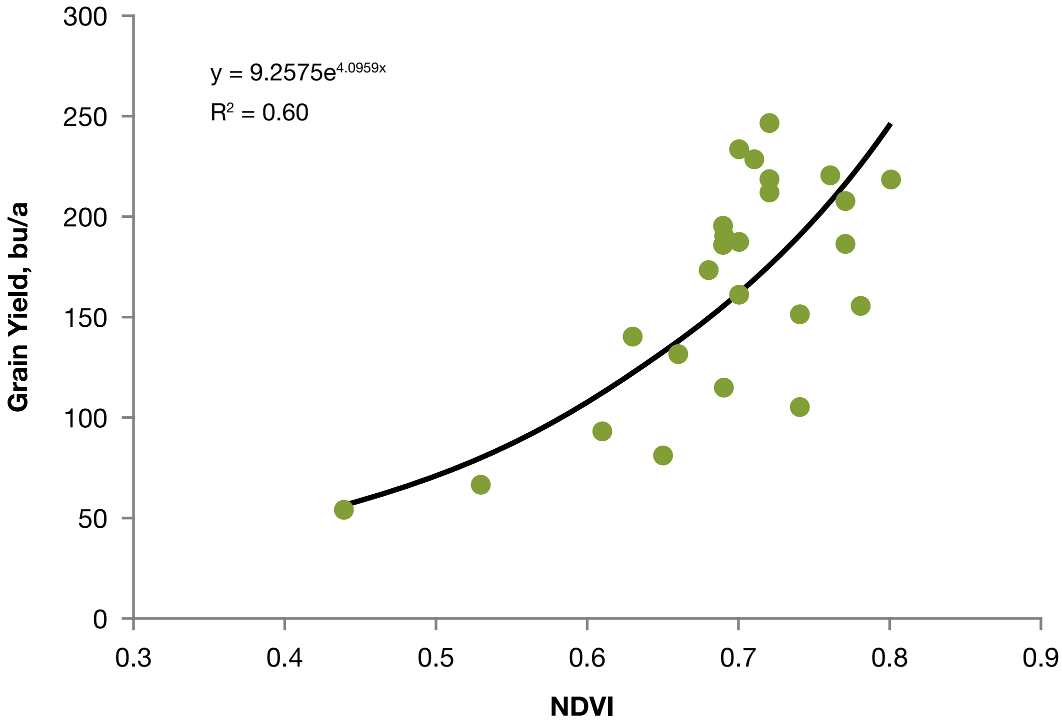

Figure 1. NDVI vs. corn grain yields, 2006-2008.

Nitrogen Fertilization of Wheat Using Sensor Technology[1]

A. N. Tucker and D. B. Mengel

Summary
Long-term research shows that nitrogen (N) fertilizer is generally needed to optimize production of winter wheat in Kansas. Wheat is grown throughout the state across a wide range of planting dates and seeding rates, following multiple crops, and with both tillage and no-till. Variable climatic conditions and production practices cause variable grain yields. Optimum N rates can also vary because of differences in residual N levels and rates of mineralization of N from organic matter and crop residue. This study was initiated in 2006 and continues. During this period, optimum N rates ranged from 0 to 90 lb/a N, whereas yields ranged from 18 to 74 bu/a. Sensor technology was found to be effective at estimating both yield potential and N needs of wheat.

Introduction
This study was initiated in 2006 to determine the response of wheat to N fertilization. Sensor technology has been used previously in wheat and has been documented to estimate yield potential and N status when used in conjunction with reference strips. In the reference strip method, N is applied in excess of crop need—usually 125% of the normal N rate for the crop—at or near planting to provide an area of adequate N.

Procedures
The study was conducted at the Kansas State University (KSU) Agronomy North Farm in Manhattan from 2006-2008, the Jack Tucker Farm near Johnson in 2008, the KSU South Central Kansas Experiment Field near Partridge from 2007-2008, and the KSU Southwest Research-Extension Center near Tribune in 2007. In 2007, the Partridge and Agronomy Farm sites were lost or damaged because of a hard April freeze. Nitrogen fertilizer treatments consisted of rates of 0, 30, 60, 90, and 120 lb/a N and timings of all preplant, all Feekes 5 (jointing), all Feekes 8 (early boot), or split applications of preplant and Feekes 5 or preplant and Feekes 8. The Feekes 8 timings were used only in 2008. Wheat was no-till planted in late October or early November with a variety adapted to that area. Plots (10 × 50 ft) were arranged in the field in a randomized complete block design with four replications. Urea was applied prior to planting and incorporated with the drill. Normalized difference vegetation index (NDVI) was collected with a GreenSeeker sensor (NTech Industries, Ukiah, CA) at several growth stages. A response index was calculated (NDVI Reference/NDVI treatment). Delayed applications of N were broadcast by hand as urea. Plots were end trimmed at harvest, and the center 5 ft of each plot were harvested after physiological maturity. Grain yield was adjusted to 12.5% moisture.

[1] Thanks to Dr. Bill Heer, Dr. Alan Schlegel, and Jack Tucker for their help with this project.

Results

Wheat responded to N application at most locations; however, optimum N rates at most sites were less than 60 lb/a N (Table 1). Split applications of preplant and Feekes 5 provided best yields in most instances. Application of N at Feekes 8 showed some yield increases, but if those plots were under significant N stress at the time of application, they could not recover fully with N application. The NDVI at Feekes 5 correlated well with wheat yields, which suggests sensor technology can be used as an alternative method of estimating yield potential and N needs in wheat at Feekes 5 (Figure 1).

Table 1. Effect of nitrogen fertilization on wheat grain yields, 2006-2008

Treatments				Yield					
Pre	Feekes 5	Feekes 8	Total	Man. 2006	Man. 2007	Trib. 2007	John. 2008	Man. 2008	Part. 2008
-----------lb/a-----------				-----------bu/a-----------					
0	0	0	0	NA	45	64	18	23	47
0	0	30	30	NA	NA	NA	22	26	50
0	0	60	60	NA	NA	NA	26	25	58
0	30	0	30	NA	47	61	26	28	63
0	60	0	60	55	46	58	27	30	63
0	90	0	90	57	48	57	26	28	68
0	120	0	120	62	40	51	27	30	67
30	0	0	30	NA	47	63	25	28	55
30	0	30	60	NA	NA	NA	25	30	64
30	0	60	90	NA	NA	NA	25	31	59
30	0	90	120	NA	NA	NA	23	32	61
30	30	0	60	51	43	60	33	26	61
30	60	0	90	61	44	57	28	33	72
30	90	0	120	60	42	50	29	33	74
60	0	0	60	45	45	58	30	31	61
60	0	30	90	NA	NA	NA	30	35	66
60	0	60	120	NA	NA	NA	34	32	66
90	0	0	90	59	47	57	31	32	73
90	0	30	120	NA	NA	NA	31	33	71
120	0	0	120	61	45	52	33	36	69

Man. = Manhattan, Trib. = Tribune, John. = Johnson, Part. = Partridge.

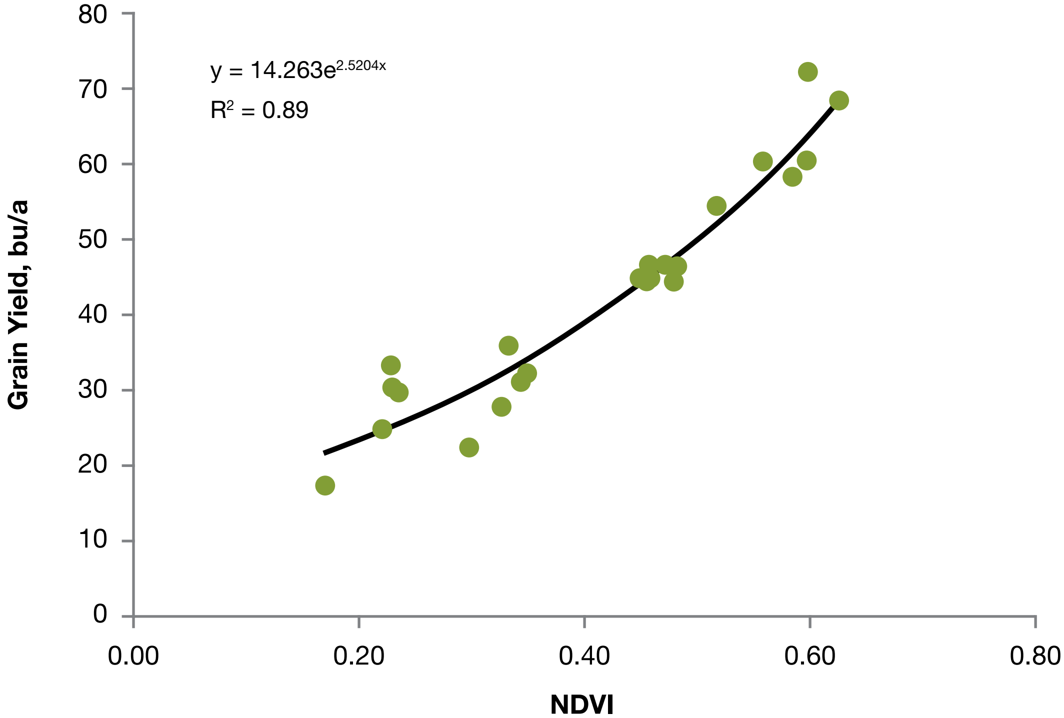

Figure 1. NDVI vs. wheat grain yields, 2006-2008.

Potassium Fertilizer Placement for No-Till and Strip-Till Soybean and Residual Effects on No-Till Corn in East Central Kansas[1]

S. M. Blocker and D. B. Mengel

Summary
Use of alternative fertilizer placement techniques to enhance availability of potassium (K) to crops has been suggested, and sometimes used, for many years. However, fertilizer placement or even direct fertilization of soybean is not commonly practiced in Kansas, which might be affecting K uptake and crop yield.

During this 2-year study, K fertilizer uptake, as observed through soybean tissue analysis, has benefitted from deep placement of K or broadcasting high rates of K. However, extreme environmental conditions encountered during this study contributed to significant variation in yield data, and as a result, no conclusions can be made regarding K fertilization rate or placement on soybean yield or residual effects on corn yield. Continued work is necessary to evaluate K deficiency effects on soybean and residual fertilization effects on corn.

Introduction
Potassium deficiency has been increasing in Kansas over the past decade. Although many Kansas soils were naturally high in K, continued removal of K from soils by crops, especially high K extracting crops such as soybean, has reduced soil test K levels over time. Deficiency symptoms are becoming more common, especially on the older, more highly weathered soils of east central Kansas. In addition, use of reduced-tillage systems, such as no-till and strip tillage, has raised a second concern: K stratification and positional unavailability.

This study was initiated in 2007 to determine whether observed K deficiencies seen in soybean under no-till and strip tillage in east central Kansas are affecting soybean yields and if so, what fertilizer application practices including rates of broadcast, deep band, or starter may be used to correct the problem. Residual effects of K fertilization and placement were also evaluated on the 2008 rotational corn crop.

Procedure
This on-farm research was conducted in cooperation with local producers. Soybean sites were located near Ottawa, Harris, and Westphalia, KS, in 2007; to evaluate residual effects of 2007 treatments in 2008, corn was grown near Ottawa and Westphalia. Additional soybean sites were established in 2008 near Ottawa and Welda, KS. Selected sites were generally near or below the currently used soil test K critical level of 130 ppm extractable K.

[1] Thanks to Dr. Keith Jansen and Jim Kimble of the East Central Kansas Experiment Field for their help with this project, to the Kansas Soybean Commission for funding, and to producer cooperators Grant Corley, Clyde Parks, Rex Lizer, and John Wray.

Eight different treatments were applied to soybean: rates and fertilizer placement methods of 0, 60, and 120 lb K_2O broadcast, 60 and 120 lb K_2O deep banded, starter fertilizer applied 2 × 2 containing 10.5 lb K_2O, starter plus 60 lb K_2O broadcast, and starter plus 60 lb K_2O deep banded.

Soybean fields were scouted for signs of K deficiency, but none were seen in either year. Leaf tissue samples were collected from each plot twice during each growing season from nonharvest rows, once at pod set (early) and once at pod fill (late), and analyzed for percentages of nitrogen (N), phosphorus (P), and K. In 2007, whole plant samples were taken at pod fill for measurement of dry weight, dry biomass yield, and harvest index. Grain yield; moisture; test weight; percentage N, P, and K; protein; and oil data were also collected.

Corn fields were also scouted for observable signs of K deficiency, but none were seen. Leaf tissue samples were collected at green silk and analyzed for percentages of N, P, and K. Grain yield; moisture; and percentage N, P, and K data were also collected.

Results

Percentage of K in soybean leaf tissue was significantly higher when K fertilizer was deep banded or broadcast at a high rate (Table 1). Residual effects of K_2O fertilization on percentage of K in corn leaf tissue the following year differed by site (Table 2). However, no significant differences in soybean yield due to K fertilization (Table 3) or corn yield due to residual K_2O fertilization (Table 2) were seen.

A significant yield response to P in starter was observed in soybean at the Ottawa site in 2008. Soil test P levels at this site were below 10 ppm.

Table 1. Average percentage potassium in soybean leaf tissue at pod set (early) and pod fill (late) by treatment and site

	Percentage K in leaf tissue									
	2007						2008			
	Ottawa		Harris		Westphalia		Ottawa		Welda	
Treatment[1]	Early	Late	Early	Late	Early	Late	Early	Late	Early	Late
	%									
Control	1.30	0.72	1.95	0.93	1.33	0.72	1.74	2.01	1.70	1.79
B60	1.38	0.78	2.10	1.03	1.41	0.77	1.80	1.99	1.60	1.89
B120	1.53	0.81	2.16	1.06	1.42	0.80	1.89	2.08	1.74	2.02
D60	1.68	0.90	2.09	1.10	1.71	0.84	1.83	2.07	1.75	1.93
D120	1.79	1.08	2.12	1.23	1.61	0.88	1.80	1.98	1.87	1.94
S10.5	1.33	0.68	1.88	0.92	1.47	0.76	1.76	2.06	1.70	1.87
S10.5+B60	1.49	0.75	2.00	1.08	1.40	0.70	1.79	2.08	1.70	1.94
S10.5+D60	1.73	0.89	1.97	1.07	1.73	0.84	1.84	2.06	1.71	1.94
LSD (0.05)	0.12	0.08	0.25	0.11	0.19	0.08	NS	NS	0.17	0.11

[1] Treatments: 0, 60, and 120 lb K_2O broadcast, 60 and 120 lb deep banded, starter fertilizer applied 2 × 2 containing 10.5 lb K_2O, starter plus 60 lb K_2O broadcast, and starter plus 60 lb K_2O deep banded.

Table 2. Average percentage potassium in corn leaf tissue at black layer and corn yield by treatment and site, 2008

	Percentage K in leaf tissue		Yield	
Treatment[1]	Westphalia	Ottawa	Westphalia	Ottawa
	%		bu/a	
Control	1.33	1.38	83	115
B60	1.38	1.54	89	116
B120	1.41	1.55	65	105
D60	1.46	1.49	99	122
D120	1.56	1.52	102	114
S10.5	1.50	1.41	77	117
S10.5+B60	1.43	1.48	87	125
S10.5+D60	1.40	1.69	90	114
LSD (0.05)	0.16	0.19	NS	NS

[1] Treatments applied to previous soybean crop: 0, 60, and 120 lb K_2O broadcast, 60 and 120 lb deep banded, starter fertilizer applied 2 × 2 containing 10.5 lb K_2O, starter plus 60 lb K_2O broadcast, and starter plus 60 lb K_2O deep banded.

Table 3. Soybean yield by treatment and site

	2007			2008	
Treatment[1]	Ottawa	Harris	Westphalia	Ottawa	Welda
	---bu/a---				
Control	26	33	7	31	57
B60	30	35	7	31	56
B120	25	34	7	30	56
D60	28	34	7	31	57
D120	29	35	7	30	56
S10.5	26	33	9	38	58
S10.5+B60	27	33	9	37	58
S10.5+D60	31	33	7	37	57
LSD (0.05)	NS	NS	NS	4	NS

[1] Treatments: 0, 60, and 120 lb K_2O broadcast, 60 and 120 lb deep banded, starter fertilizer applied 2 × 2 containing 10.5 lb K_2O, starter plus 60 lb K_2O broadcast, and starter plus 60 lb K_2O deep banded.

Effects of Phosphorus Fertilizer Enhancement Products on Corn[1]

N. C. Ward and D. B. Mengel

Summary
In the spring of 2008, field studies were established to evaluate the performance of two widely marketed products that claim to enhance availability of soil or fertilizer phosphorus (P): AVAIL (Specialty Fertilizer Products, Leawood, KS), a P fertilizer enhancer added to commercial fertilizer, and JumpStart (Novozymes Biologicals, Saskatoon, Canada), a seed inoculant that infects crop roots and enhances availability of native soil P. This study was conducted at three locations across north central and northeastern Kansas. All three sites tested low to medium in available P with Mehlich-3 soil tests ranging from 11 to 15 ppm. A P response would have been expected.

Excellent corn yields, greater than 200 bu/a, were obtained at all three sites. Significant responses to applied P were obtained at Scandia and Rossville. JumpStart significantly increased yield at Rossville when no fertilizer P was applied but gave no additional response when P was applied. A similar trend was observed at Scandia. No response to use of AVAIL was seen.

Introduction
In recent years, the increasing price of P fertilizers has created interest among producers in enhancing efficiency of fertilizers being applied. This project was developed to test two such products widely advertised in Kansas: AVAIL, a long-chain organic polymer created to reduce fixation of fertilizer P by aluminum and calcium, and JumpStart, a *Penicillium bilaii* seed inoculant that increases availability of native soil P to plant roots.

Procedures
This study was established at three locations in northeastern and north central Kansas: Manhattan (Kahola silt loam), Scandia (Crete silt loam), and Rossville (Eudora sandy loam). Both the Rossville and Scandia locations receive supplemental irrigation during the growing season.

All locations were planted to the same hybrid (Pioneer 33M16). Planting dates were April 23, April 29, and May 1 for Manhattan, Rossville, and Scandia, respectively. Populations appropriate to the soils and cropping system were used.

Plots were arranged in the field using a randomized complete block design with three or four replications. Fourteen treatments consisting of rates of P fertilizer—0, 20, and 40 lb/a P_2O_5 as monoammonium polyphosphate (MAP) broadcast and 20 lb/a P_2O_5 as ammonium polyphosphate (APP) liquid starter—with and without addition of AVAIL P enhancer were applied. Each of the fertilizer/AVAIL treatments was planted with and without the Jumpstart seed treatment. Broadcast treatments were applied by hand prior to planting using MAP or commercial AVAIL-treated MAP obtained locally. Liquid APP

[1] Thanks to Novozyme Biologicals for their support for this project.

starter treatments were placed in a 2 × 2 band with the planter. AVAIL was mixed with the fertilizer prior to being placed in the fertilizer tank All P treatments were balanced for nitrogen with urea, which was broadcast prior to planting.

Whole plant samples were taken at the V4 growth stage, ear leaf samples were taken at green silk, and whole plant samples were taken again at physiological maturity. Dry matter accumulation and P uptake were calculated at the times of whole plant sampling. Ear leaf samples were analyzed for P concentration only. Results of the plant analyses are not included in this report. Yield, moisture, and P content of the grain were measured at harvest. All yields were corrected to 15.5% grain moisture.

At all three locations, significant damage to a small number of plots was observed. At Manhattan, seven plots were damaged because of flooding and wildlife activity; at Scandia, eight plots were damaged because of a tornado that knocked the lateral move irrigation system down in the experiment; and at Rossville, seven plots were damaged because of apparent herbicide carryover issues. At each location, detailed notes were made documenting the damage, and where appropriate, data from damaged plots was replaced by using a missing plot calculation.

Results

Individual treatment means at each location are reported in Table 1. Initial preplant soil tests indicated low available P at all locations. Good responses to applied P were observed at Scandia and Rossville. No response to applied P or P-enhancing products was observed at Manhattan, however. One possible explanation is that a significant flooding event in late May left a deposit of high-P sediment across the entire plot area from adjacent heavily fertilized areas. Soil samples taken from each plot after harvest showed all plots to be near or above the established P critical value of 20 ppm.

Main effects of fertilizer additives across fertilizer treatments are summarized in Table 2. When P was applied, no effect of the AVAIL fertilizer P enhancer or the JumpStart seed treatment was observed at any location in this study. However, when no P was applied, JumpStart did increase yield compared with the unfertilized check at Rossville, and a similar trend was observed at Scandia. At Scandia, this increase was less than that obtained with fertilizer alone, whereas at Rossville, the response to JumpStart was equivalent to that obtained with fertilizer. This supports earlier work in Canada that showed JumpStart could increase P availability equivalent to modest amounts, approximately 15 lb/a P_2O_5, of P fertilizer. This study will be repeated in 2009.

Table 1. Response to phosphorus fertilizer by corn with and without use of phosphorus-enhancing additives

Rate	Placement	Additives	Manhattan yield	Scandia yield	Rossville yield
lb/a P_2O_5			----------------	bu/a	----------------
0		None	195	197	218
0		JumpStart	201	207	233
20	Starter band	None	205	214	223
20	Starter band	JumpStart	203	210	227
20	Starter band	AVAIL	202	214	219
20	Starter band	JumpStart + AVAIL	198	217	221
20	Broadcast	None	198	217	225
20	Broadcast	Jumpstart	200	215	231
20	Broadcast	AVAIL	199	223	220
20	Broadcast	JumpStart + AVAIL	204	209	227
40	Broadcast	None	197	222	228
40	Broadcast	Jumpstart	198	220	219
40	Broadcast	AVAIL	212	213	235
40	Broadcast	JumpStart + AVAIL	198	221	229
LSD (0.10)			13	12	11

Table 2. Main effects of phosphorus-enhancing products across fertilizer rate

Product	Manhattan yield	Scandia yield	Rossville yield
	-------------------------	bu/a	-------------------------
None	200	218	225
JumpStart	200	215	225
AVAIL	204	217	225
JumpStart + AVAIL	200	216	226
LSD (0.10)	NS	NS	NS

Excludes no-phosphorus treatments.

Phosphorus Placement in Reduced-Tillage and No-Till Cropping Systems in Kansas[1]

K. L. Martin, A. J. Schlegel, K. A. Janssen, W. B. Gordon, and D. B. Mengel

Summary
Phosphorus (P) stratification is an increasing concern among producers in Kansas. This study was initiated in 2005 to determine the effects of P application and placement on mid-season P status and crop yield. Two sites that were low in soil test P had a yield response to P fertilization, but only one of the sites had a mid-season P concentration response. There was an effect due to placement in the mid-season P concentration at only one site, but there was not a placement response in grain yield. The other two sites had high soil test P and did not respond to P application in rate or placement. Data also show the observed P removal and expected increase or decrease in soil test P. In the future, this project will show long-term effects of P placement and describe shifts in soil test P over time.

Introduction
Phosphorus stratification is commonly found in no-till or reduced-tillage production systems and is a result of years of broadcast P application, decomposition of plant material and P release on the soil surface, and decreased soil mixing via tillage. Many producers question whether stratification of P decreases P availability to crops and whether a more even distribution of P will cause a crop response to P.

Crop response to P is common on low-P soil but is rarely observed on high-P soils. Stratified soils cause confusion as to what depth should be used to evaluate the P status of soil. Also, because soil moisture is important for root growth and P uptake, differing soil moisture could affect the response to varying P concentration with depth. Some research has been conducted to determine whether deep-placed P will have a crop yield effect in a P-stratified soil. This study combines knowledge of soil moisture and P placement to determine whether there is a crop response to P rate and placement in P-stratified soil in moisture-limited environments.

Procedures
Four sites were established in the spring of 2005 at Scandia, Ottawa, Manhattan, and Tribune, KS (Crete, Woodson, Smolan, and Ulysses silt loam, respectively). Typical crop rotations for each region were used at each location with a corn/soybean rotation at Ottawa and Scandia, sorghum/soybean/wheat rotation at Manhattan, and wheat/sorghum/fallow rotation at Tribune. Corn, sorghum, and wheat were fertilized with 20 lb/a P_2O_5 as a starter (2 × 2 or with the seed), 40 and 80 lb/a P_2O_5 as a broadcast, deep band,

[1] We appreciate the financial support provided for this project by J.R. Simplot and Company, Potash Corp, Mosaic, and Agrium as well as the continued support of Dr. Mike Stewart, International Plant Nutrition Institute, who helped organize and continues to provide guidance for the project.

or each split with starter. Soybean relied on residual fertilization from the previous crops as well as direct fertilization of 40 lb/a P_2O_5 broadcast fertilization on two treatments in addition to 80 lb/a P_2O_5 on the previous corn crop. The purpose of these treatments was to determine whether there was a benefit to direct fertilization of soybean.

Starter fertilizer was applied 2 × 2 with a planter or with the seed in wheat. Broadcast treatments were applied with a drop-type spreader or were hand applied. Deep band treatments were applied 5 to 6 in. deep with a strip-till unit in all crops except wheat at Manhattan and both wheat and sorghum at Tribune. Wheat and Tribune crops were fertilized deep with a coulter applicator as deep as possible (4 to 5 in.).

Plant samples were taken (ear leaves, flag leaves, or trifoliates) to evaluate mid-season P concentration. Grain was collected at maturity, yield was calculated, and grain was analyzed for P concentration and used to calculate P removal.

Results

Initial soil test P data (Table 1) shows that all sites had P stratification at the beginning of this study. Scandia and Ottawa had a low soil test P level, so a P response was expected. Manhattan and Tribune P was considered very high; thus, a P response was not expected.

Scandia was the highest yield potential site with low soil test P and supplemental irrigation. Figure 1 shows the corn ear leaf P concentration response to rotational P rate. There was not a clear difference in P rate, but it is noteworthy that without P application, the ear leaf P concentration was less than the 0.25% critical level. Although there was not a well-defined response to P in the ear leaves, there was a nice quadratic plateau model that fit the corn yield response to P application (Figure 2). These data show that corn yield was maximized at about 32 lb/a P_2O_5. Further data analysis showed there was a small starter and placement response in corn ear leaves (0.01% with starter and broadcast-applied P). However, there was only a starter response in grain yield. Placement did not affect grain yield.

Scandia soybean trifoliate P concentration did not produce a significant rate response model to explain the data but did show that starter fertilizer increased trifoliate P concentration (0.01%). Yield data showed a response to P application, but only to the lowest rate (20 lb/a P_2O_5; data not shown). Scandia soybean data revealed one important finding: Direct application to soybean is important. Table 2 shows the effect of direct application on residual broadcast and deep band treatments on both trifoliate P concentration and grain yield. During the growing season, direct application after broadcast application on the corn crop increased P concentration in the trifoliates. However, yield was greatest when direct application occurred on residual deep band application. Although different portions of the growing season showed different responses, the most important outcome is that direct application of P on soybean is important.

The Ottawa corn ear leaf P response is shown in Figure 3. Ear leaf P concentration increased when P was applied, but because of data variability, the rate at which the response was observed is unclear. Ottawa corn ear leaf P concentration also increased when P was applied as a deep band (0.02%). Similar to Scandia, Ottawa ear leaf P concentration was above the critical 0.25% in all treatments that received P application.

Corn grain yield at Ottawa responded up to about 25 lb/a P_2O_5 (Figure 4). However, there was not a placement effect on corn grain yield at Ottawa.

Ottawa soybean trifoliate P concentration or grain yield did not respond to P application. Data from Ottawa suggest P application was important for corn grain production, but placement options produced similar yields.

Crops at Manhattan and Tribune did not respond to P application, likely because of high soil test P levels and relatively lower yield potential.

A P balance sheet was constructed from data in this study and is summarized in Table 3. The P removed in the grain at harvest was calculated and subtracted from the P fertilizer application rate (total application rates are different depending on crop rotation). This resulted in a positive or negative balance depending on whether the crop removed more P than was applied. Table 3 shows that Scandia will continue to remove more P than was applied at all rates. The other sites eventually reach a positive balance at the higher rates. Without P application, the soil test P would annually decrease by 2.6, 1.5, 2.0, and 1.0 ppm at Scandia, Ottawa, Manhattan, and Tribune, respectively. At the highest P rate, Scandia would continue to decrease by 0.4 ppm, whereas Ottawa, Manhattan, and Tribune would annually increase soil test P by 1.1, 3.0, and 2.5 ppm, respectively. This balance data shows that P application is important at some sites to maintain or build soil test P. At the highest application rate, Scandia soil test P will continue to decrease, whereas at Ottawa, it would take about 11 years to build soil test P to the critical level. Alternatively, Manhattan and Tribune could produce crops for 9 and 33 years, respectively, before the soil test P level decreases to the sufficient P concentration.

In conclusion, this study showed that at low soil test P levels, crops respond to P application, especially in high yield potential environments. However, P placement generally did not have a significant effect. The importance of this is that P placement options are available without a yield reduction if a producer needs to place P in any specific manner depending on their management system or environmental considerations. Producers commonly allow soybean P fertility to rely on residual fertilization from corn, but the P responses in high soybean yielding sites serve as an excellent reminder that it is necessary to fertilize soybean to achieve maximum yield.

Table 1. Initial mean soil test phosphorus content for each site by depth

	Phosphorus content			
Depth	Scandia	Ottawa	Manhattan	Tribune
in.	------------	ppm	------------	
3	9.5	9.4	55.4	74.1
6	5.7	5.8	19.9	31.3
9	5.1	4.8	7.0	10.3
12	5.4	4.7	4.2	13.4
24	4.6	4.6	3.4	23.5

Table 2. Effect of direct and residual phosphorus application on soybean plant and grain phosphorus concentration and yield at Scandia in 2007 and 2008

Treatment	Trifoliate phosphorus concentration	Grain yield
	%	bu/a
None	0.27c	60c
Residual broadcast	0.28bc	67b
Residual broadcast + direct application	0.31a	68b
Residual band	0.30b	66b
Residual band + direct application	0.30b	72a
P-value	<0.01	<0.01

Within columns, means followed by a common letter are not significantly different at (P<0.05).

Table 3. Phosphorus balance calculation using phosphorus application totals for the rotation and grain phosphorus removed for each rotation

	Phosphorus application (lb/a P_2O_5)				
Location	0	20	40	80	120
Scandia	-105.975	-106.894	-88.5038	-54.2517	-17.0111
Ottawa	-59.309	-47.5852	-34.2521	1.83904	42.06804
	Phosphorus application (lb/a P_2O_5)				
	0	17.4	34.8	69.6	109.6
Manhattan	-122.756	-89.6532	-48.0449	31.26368	121.1468
Tribune	-58.1596	-20.4593	24.82704	101.8368	

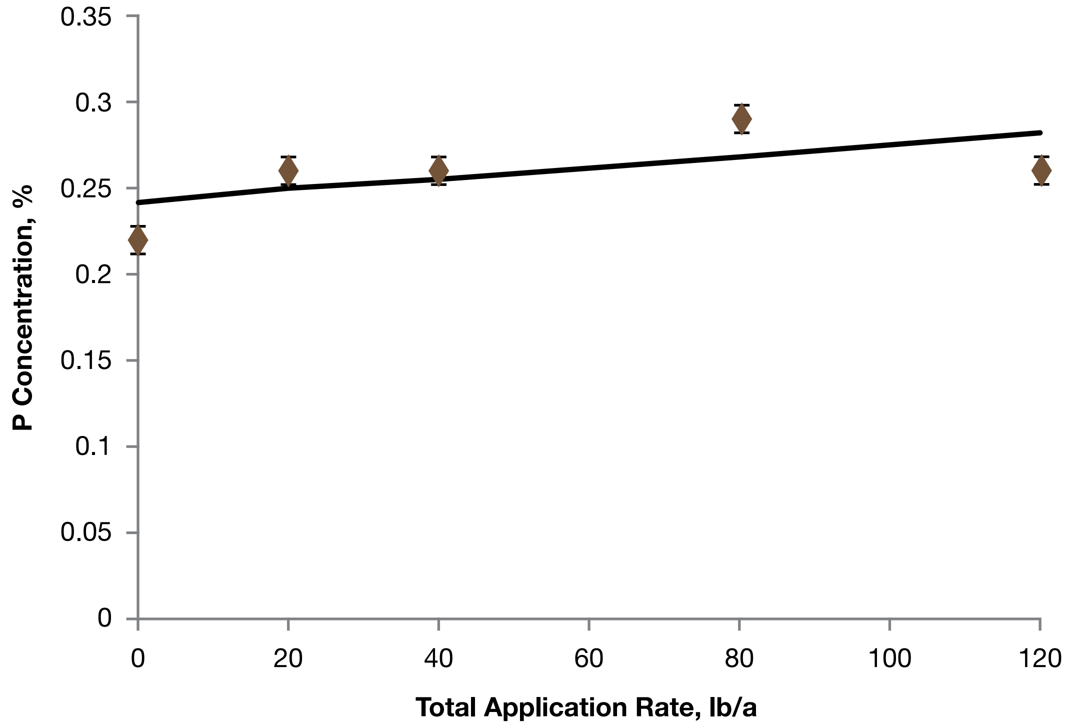

Figure 1. Phosphorus fertilizer application and corn ear leaf P concentration response at Scandia in 2007 and 2008.

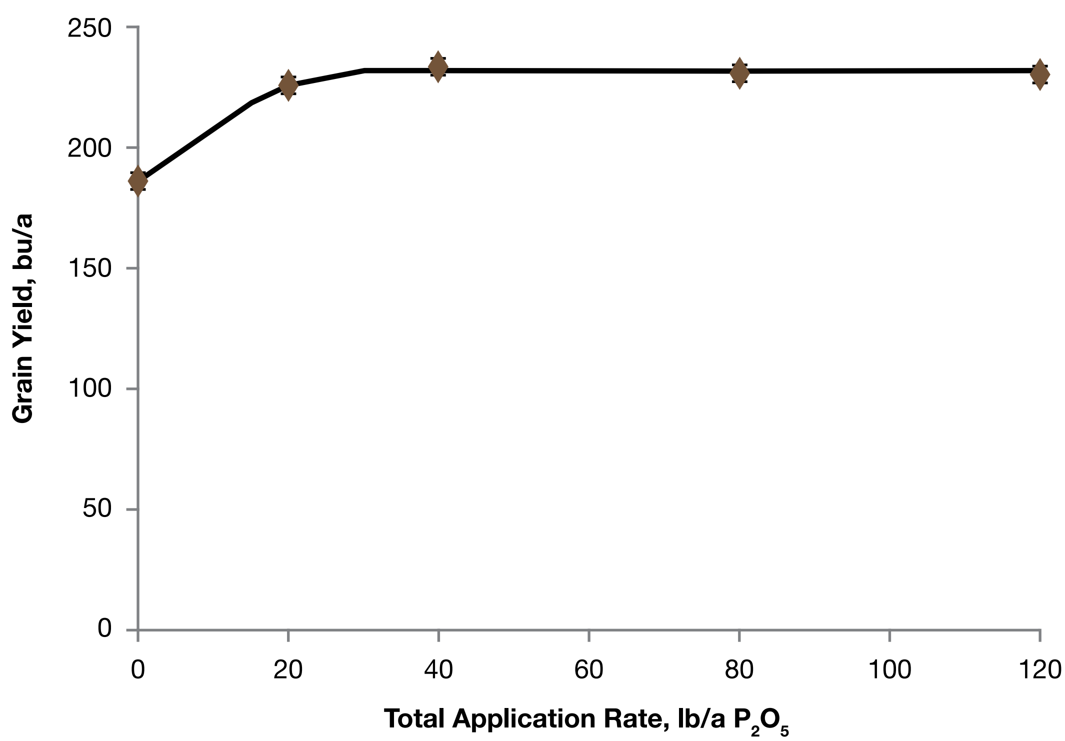

Figure 2. Phosphorus fertilizer application and corn grain yield response at Scandia in 2007 and 2008.

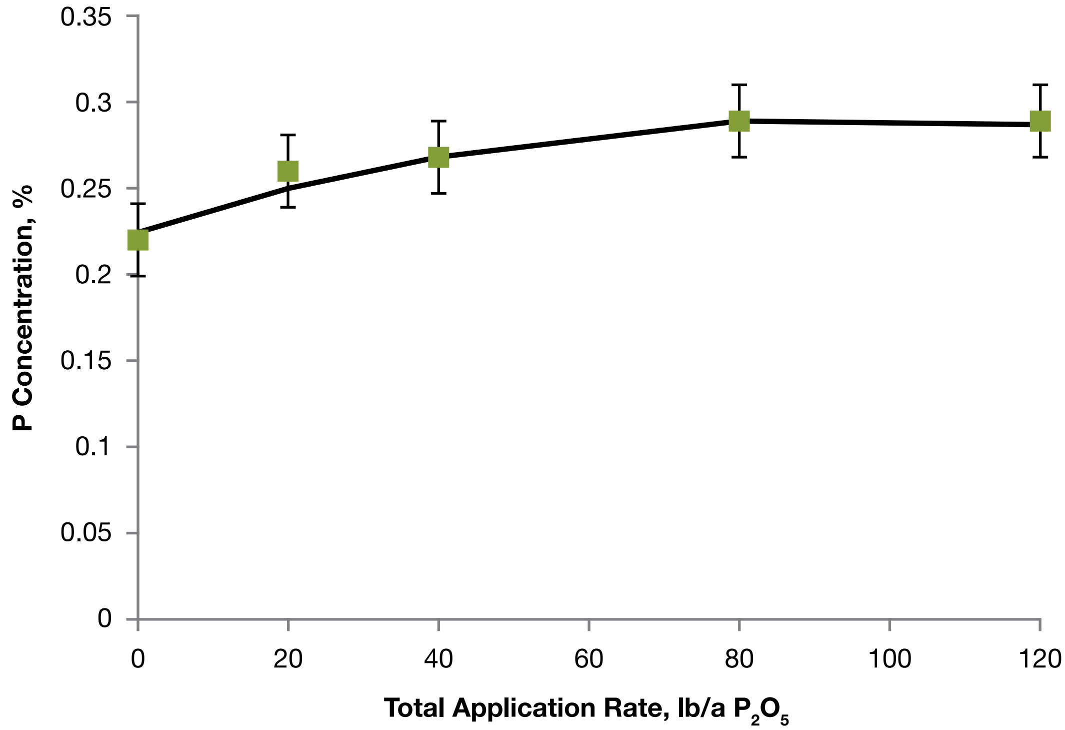

Figure 3. Response of phosphorus fertilizer application on corn ear leaf P concentration response at Ottawa in 2007 and 2008.

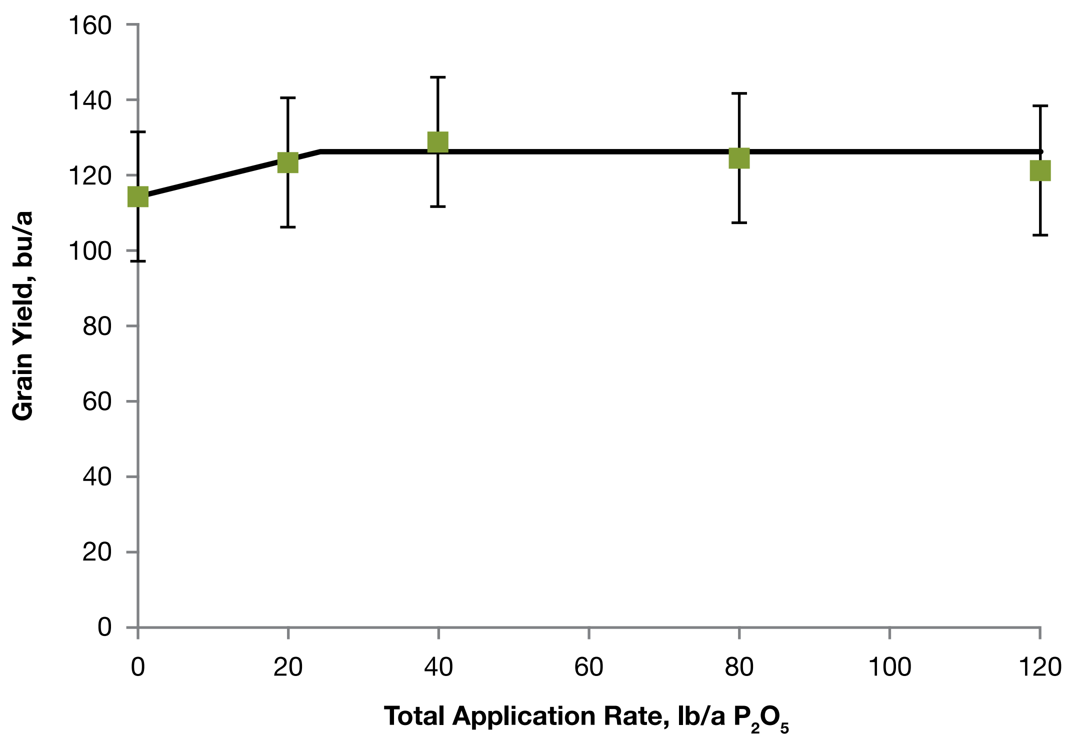

Figure 4. Response of phosphorus fertilizer application on corn grain yield response at Ottawa in 2007 and 2008.

Evaluation of Nitrogen Rates and Starter Fertilizer for Strip-Till Corn in Eastern Kansas

K. A. Janssen

Summary
Effects of nitrogen (N) rates and starter fertilizer application on nonirrigated strip-till corn were evaluated at the East Central Kansas Experiment Field at Ottawa in 2006, 2007, and 2008. With below-average seasonal rainfall in 2006 and 2007 and above-average rainfall in 2008, 80 to 140 lb/a N were required to maximize corn grain yields. Not knowing the amount of rainfall prior to fertilization makes precise application of N difficult. Some in-between N rate will likely be most environmentally and economically appropriate. In 2006 and 2008, starter fertilizer placed beside and below the seed row at planting increased early-season growth of strip-till corn more than applying all starter in the strip-till zone. In 2007, there were no early season growth differences. None of the increases in early season growth increased grain yields in any year. Highest grain yields were generally produced when starter fertilizers (N-phosphorus-potassium; NPK) were applied in the strip-till zone. These results suggest it may not be necessary to apply starter fertilizer at planting for strip-till fertilized corn in eastern Kansas. More years of testing are needed before reliable N recommendations can be made.

Introduction
Corn growers in eastern Kansas might benefit from reducing traditional N rates when growing corn with an under-the-row, strip-till banded fertilization program. The high cost of N fertilizer demands prudent use. Research is needed to determine whether there is any yield benefit from applying starter fertilizer at planting with strip-till, under-the-row-fertilized corn. Research results can help determine whether strip-till corn producers may be able to lower N rates, refrain from purchasing costly planter fertilizer banding equipment, and not have to apply starter fertilizer at planting.

Procedures
This was the third year for this study. Six N rates and three starter fertilizer scenarios were evaluated for strip-till corn on an upland Woodson silt loam soil at the East Central Kansas Experiment Field. Rates of N compared were 60, 80, 100, 120, 140 and 160 lb/a and a no-N check. Starter fertilizer options evaluated included placement of all of the starter fertilizer 5 to 6 in. below the row during the strip-till operation, placement of the starter 2.5 in. to the side and 2.5 in. below the seed row at planting, and as a combination of half of the starter fertilizer applied in the strip-till zone and half at planting. In all cases, 30 lb/a N was included with the P and K starter fertilizers. Research by Barney Gordon at the North Central Kansas Experiment Field at Scandia showed that at least a 1:1 ratio of N-P fertilizer mix should be used for best starter P benefits.

The experiment design was a randomized complete block with four replications. Soybean was grown prior to the corn studies each year. For preplant weed control, 1 qt/a atrazine 4L plus 0.66 pint/a 2,4-D LVE plus 1 qt/a crop oil concentrate were applied. Pioneer 35P17 corn was planted Apr. 6, 2006, May 19, 2007, and May 13, 2008.

Plantings in 2007 and 2008 were delayed because of wet weather. Corn was planted at 24,500 seeds/a in 2006 and at 26,500 seeds/a in 2007 and 2008. Preemergence herbicides containing 0.5 qt/a atrazine 4L plus 1.33 pint/a Dual II Magnum were applied the day after planting each year for weed control. Effects of the N rates and the starter fertilizer applications on plant establishment were evaluated by counting all plants in the center two rows of each plot. Six whole plants were collected from each plot at the 6-leaf corn growth stage for the purpose of measuring treatment effects on early season growth. Grain yields were measured by machine harvesting and weighing grain from the center two rows of each 10-ft-wide × 40-ft-long plot. Harvest dates were Sept. 1, 2006, Sept. 20, 2007, and Sept. 22, 2008.

Results

Seasonal moisture for corn growth was below average in 2006 and 2007 and above average in 2008. Under these conditions and with corn following soybean, 80 to 100 lb/a N optimized corn grain yields in 2006 and 2007, and 120 to 140 lb/a N optimized corn yield in 2008 (Table 1). Increased demand for N in 2008 was due to higher yield and possibly greater N losses from leaching and denitrification. Not knowing the amount of seasonal rainfall that will occur and the potential for N loss prior to fertilization makes accurate application of N difficult. Some intermediate rate in between these amounts will likely be most appropriate from an environmental and economic standpoint. Application of starter fertilizer placed 2.5 in. to the side and 2.5 in. below the seed row at planting increased early growth of corn in 2006 and 2008 but not in 2007 (Table 1). The combination application of half the starter fertilizer applied at planting and half applied in the strip-till zone produced intermediate early season plant growth response (Figure 1). However, neither of these starter fertilizer applications increased grain yields (Figure 2). Highest grain yields were generally produced when all starter fertilizer nutrients (i.e., NPK) were included in the strip-till zone. These data suggest that starter fertilizer application at planting may not be necessary for strip-till fertilized corn in eastern Kansas. More years of testing under different growing conditions are needed before reliable N recommendations can be made. This study will be repeated in 2009.

Table 1. Effects of nitrogen rates and application of starter fertilizer on plant stands, V6 plant dry weights, and grain yields of strip-till corn, East Central Kansas Experiment Field, Ottawa, 2006-2008

Fertilizer treatments		Plant populations			V6 dry weights			Grain yields		
Strip-till	Starter 2.5 × 2.5 in.	2006	2007	2008	2006	2007	2008	2006	2007	2008
------N-P_2O_5-K_2O, lb/a-------		-------× 1000------			--------g/plant--------			--------bu/a--------		
Check 0-0-0		24.3	25.8	24.6	2.1	5.3	7.1	47	37	63
60-40-20		24.3	26.0	24.0	5.5	9.5	10.9	101	89	121
80-40-20		24.8	25.9	24.4	4.2	9.8	11.4	109	95	134
100-40-20		24.3	25.6	24.4	4.4	8.3	11.4	103	93	138
120-40-20		24.9	25.6	24.2	4.3	9.4	9.7	108	99	138
140-40-20		24.1	25.4	24.4	3.9	9.0	10.5	109	98	147
160-40-20		24.1	26.1	24.1	4.0	8.9	10.1	108	101	145
Evaluation of starter										
80-40-20		24.8	25.9	24.4	4.2	9.8	11.4	109	95	134
50-20-10	30-20-10	24.6	25.4	24.7	6.4	9.5	12.8	101	88	124
50	30-40-20	24.8	25.9	24.6	6.6	9.7	12.9	103	90	121
120-40-20		24.9	25.6	24.2	4.3	9.4	9.7	108	99	138
90-20-10	30-20-10	24.2	25.6	24.1	6.2	9.5	11.8	105	102	140
90	30-40-20	24.8	25.7	24.2	7.6	9.2	12.2	102	95	136
160-40-20		24.1	26.1	24.1	4.0	8.9	10.1	108	101	145
130-20-10	30-20-10	24.0	25.8	24.6	5.3	9.2	12.4	106	99	150
130	30-40-20	24.3	25.5	24.7	6.8	8.7	14.5	100	98	143
LSD (0.05)		NS	NS	NS	1.0	1.4	0.9	6	9	7

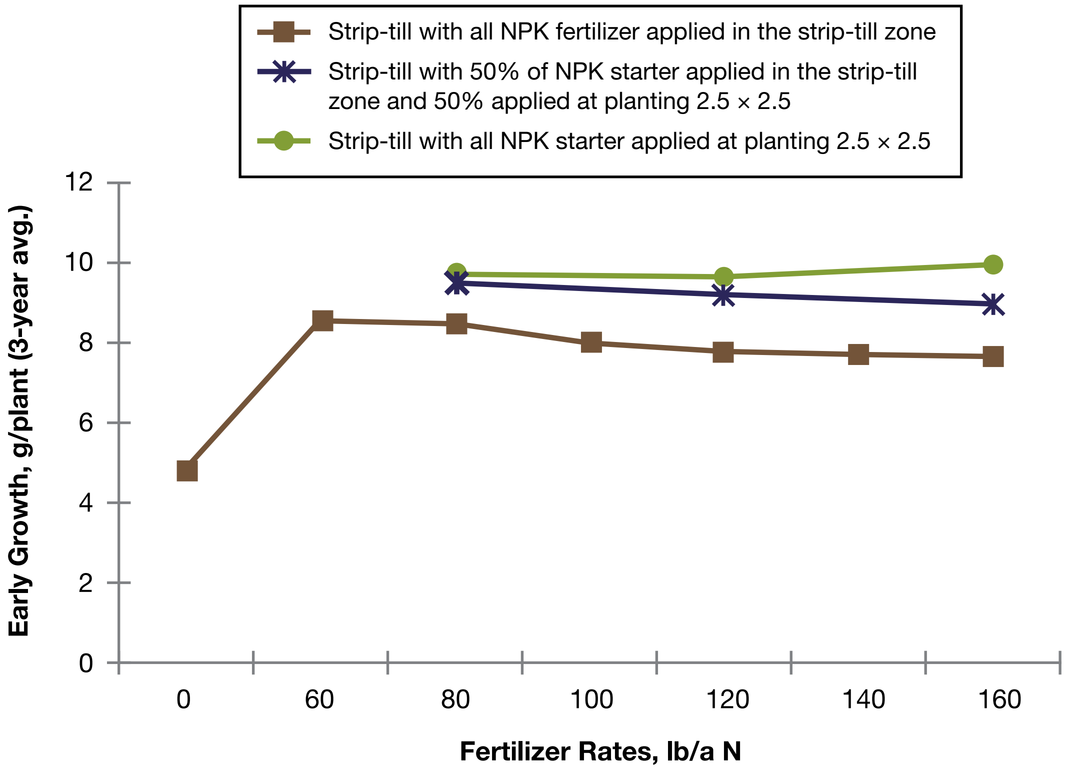

Figure 1. Nitrogen rates and starter NPK fertilizer placement effects on 6-leaf stage growth of strip-till corn.

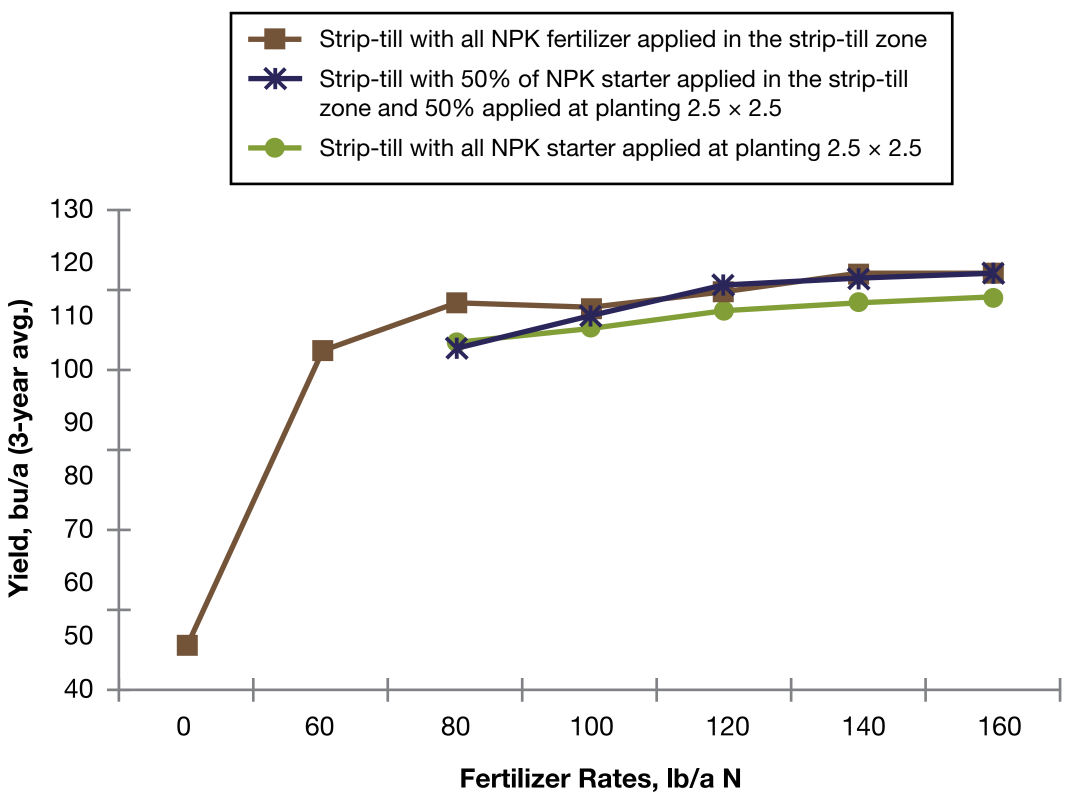

Figure 2. Nitrogen rates and starter NPK fertilizer placement effects on yield of strip-till corn.

Evaluation of Strip-Till and No-Till Tillage Fertilization Systems for Grain Sorghum Planted Early and at the Traditional Planting Time in Eastern Kansas[1]

K. A. Janssen

Summary
Field studies were conducted at the East Central Kansas Experiment Field at Ottawa in 2006, 2007, and 2008 to evaluate how strip tillage performed compared with no-till for growing grain sorghum planted early and at the traditional planting time. Nitrogen (N) rates and effects of starter fertilizer were also studied. No obvious differences were observed between strip-till and no-till systems regarding plant stands. Strip tillage slightly increased early season growth of grain sorghum in some instances compared with no-till but had a variable effect on yield. In 2007, strip tillage increased grain yields 3 to 6 bu/a, on average, compared with no-till. In 2008, yield of sorghum planted June 19 was 12 bu/a less for strip tillage than for no-till. The lower yield for the June 19 strip-till sorghum is thought to be due to increased N loss resulting from earlier N application in the strip-till treatment. Starter fertilizer application at planting produced little benefit for strip-till fertilized sorghum, except when it offset strip-till N that had been previously lost. On average, 60 to 90 lb/a N optimized grain sorghum yields following soybean in both tillage systems when moisture was limiting. Up to 150 lb/a N was required to maximize yields when rainfall was greater, yield potential was higher, and N losses occurred.

Introduction
In Kansas, midsummer heat and drought are significant factors limiting grain sorghum production. Scheduling grain sorghum planting to avoid pollination and grain fill during this period is important. One strategy is to plant grain sorghum early to make better use of spring precipitation, cooler air temperatures, and lower evaporation. Another strategy is to wait, store as much water in the soil profile as possible, plant grain sorghum in mid to late June, and then rely on stored soil water and fall rains to produce the grain sorghum crop.

Leaving crop residues on the soil surface and not tilling the soil can help retain valuable moisture. However, these practices, combined with planting grain sorghum early, can be challenging. The extra residue can shade the soil and keep no-till field soils cool and wet longer in the spring. This can interfere with timely planting some years, result in poor plant stands, and slow early season grain sorghum growth. Consequently, use of no-till and early planting of grain sorghum has not been widely adopted. Strip-till, on the other hand, is a compromise conservation tillage system. This system includes some tillage, but only where seed rows are to be planted. Row middles are left untilled and covered with crop residue for soil erosion protection and water conservation. This method of seedbed preparation also enables fertilizers to be precision applied under the row, minimizing the need to apply starter fertilizers at planting.

[1] Financial support for this research was provided by the Kansas Grain Sorghum Commission.

Objectives of this study were to (1) evaluate strip-till and no-till fertilization systems for growing grain sorghum planted early and at the traditional time, (2) determine N needs for sorghum grown using these systems, and (3) determine whether there is any yield benefit from applying starter fertilizer at planting for strip-till fertilized grain sorghum.

Procedures

Field experiments were conducted in 2006, 2007, and 2008 at the East Central Kansas Experiment Field on an upland Woodson silt loam soil. Strip-till and no-till systems were compared, and N rates ranging from 0 to150 lb/a were tested. Also, effects of starter fertilizer placed 2.5 in. to the side and 2.5 in. below the seed row at planting were evaluated for strip-till fertilized sorghum. The sorghum experiments followed no-till soybean each year. For preplant weed control, 1 qt/a atrazine 4L plus 0.66 pint/a 2,4-D LVE plus 1 qt/a crop oil concentrate were applied. Pioneer 84G62 grain sorghum was planted Apr. 14, 2006 (early) and May 24, 2006 (traditional). In 2007, early planting was not possible because of a prolonged wet spring. Instead, two hybrids (Pioneer 84G62 and 86G08) were planted in early June. In 2008, early planting was delayed again by wet weather. Pioneer 87G57 grain sorghum was planted May 15, 2008 (early), and Pioneer 84G62 was planted June 19, 2008 (traditional). Seed drop each year was 69,000 seeds/a. Preemergence herbicides containing 0.5 qt/a atrazine 4L plus 1.33 pint/a Dual II Magnum were applied each year at planting for additional weed control.

Plant stands, early season grain sorghum growth, and grain yields were measured each year. Plant stands were evaluated by counting all plants in the center two rows of each plot. Early season grain sorghum growth was measured by collecting and weighting six plants from each plot at the 5- to 7-leaf growth stage, and grain yields were measured by machine harvesting the center two rows of each 10-ft-wide × 40-ft-long plot. Harvest dates were Sept. 19, 2006, Oct. 10, 2007, and Sept. 17, 2008 for the May-planted sorghum and Oct. 31, 2008, for the June-planted sorghum.

Results

Moisture for pollination and grain fill for 2006, 2007, and the May planting date of 2008 was below average. Seasonal moisture was above average for the June planting date in 2008. Overall, few differences in plant stands were observed between strip tillage and no-till in these experiments (data not shown). In 2006, early season grain sorghum growth, days to half bloom, and grain yields were similar for strip-till and no-till planted sorghum (Table 1). In 2007, when two hybrids were planted in June, strip tillage increased early growth slightly and increased grain yields 3 to 6 bu/a, on average, compared with no-till (Table 2). The largest yield differences occurred with Pioneer 84G62, a long-season hybrid. In 2008, early season sorghum growth was again similar for both the May- and June-planted strip-till and no-till systems, but yield for June-planted sorghum was significantly affected (Table 3). Strip-till yield, averaged over all N rates, was 12 bu/a less than no-till yield. Fertilizer N for the 2008 strip-till sorghum was applied April 30 during the strip-till operation, and fertilizer N for the no-till sorghum was applied at planting on June 19. Twelve inches of rain fell between these two dates of application. Thus, we believe that some strip-till fertilizer N was lost and that is what caused most of the yield difference. Overall, application of starter fertilizer at planting for strip-till fertilized sorghum had little effect on early season sorghum growth and yields, except for the June-planted sorghum in 2008. Starter (30-20-10) applied at planting for the June 2008 sorghum increased strip-till sorghum yield by 10 bu/a compared with all starter applied in the strip-till zone. This single response to starter further confirms that N had been lost from the earlier strip-till fertilizer. For both tillage systems, 60 to 90 lb/a N optimized grain sorghum yields following soybean when moisture was limited. Up to 150 lb/a N was required to maximize yields for sorghum planted in June 2008, when rainfall was greater, yield potential was higher, and N losses were evident. Additional years of testing with more normal rainfall amounts are needed before meaningful N rate recommendations for strip-till and no-till sorghum can be made. Also, more years of research comparing strip-till and no-till systems at early planting dates are needed before recommendations can be made regarding best tillage systems for planting grain sorghum early and at the traditional planting time. These studies will continue in 2009.

Table 1. Effects of tillage, planting date, nitrogen rate, and starter fertilizer placement on early season grain sorghum growth, days to half bloom, and yields of early and traditional-planted grain sorghum, East Central Kansas Experiment Field, Ottawa, 2006

		Early planting April 14			Traditional planting May 24		
Tillage	Fertilizer rate and placement	6-leaf dry weight	Half bloom date	Yield	6-leaf dry weight	Half bloom date	Yield
		g	July	bu/a	g	July	bu/a
Strip-till	0-0-0	4.3	17	73	7.3	26	85
Strip-till	60-30-10, 5 in. below the row	6.0	10	93	9.4	22	107
Strip-till	90-30-10, 5 in. below the row	7.0	12	101	8.7	23	115
Strip-till	120-30-10, 5 in. below the row	6.4	11	95	8.9	22	101
Strip-till	150-30-10, 5 in. below the row	6.7	12	84	8.2	23	108
Mean		6.1	12	89	8.5	23	103
No-till	0-0-0	5.4	14	74	6.4	28	48
No-till	60-30-10, 2.5 × 2.5 in. at planting	6.8	11	106	8.8	24	95
No-till	90-30-10, 2.5 × 2.5 in. at planting	6.6	11	92	8.6	24	101
No-till	120-30-10, 2.5 × 2.5 in. at planting	5.5	14	94	8.4	24	84
No-till	150-30-10, 2.5 × 2.5 in. at planting	6.5	13	96	8.0	25	93
Mean		6.2	13	92	8.0	25	84
Evaluation of starter							
Strip-till	90-30-10, 5 in. below the row	7.0	12	101	8.7	23	115
Strip-till	60-15-5 strip-till and 30-15-5 at planting	6.6	12	83	9.2	22	107
Strip-till	120-30-10, 5 in. below the row	6.4	11	95	8.9	22	101
Strip-till	90-15-5 strip-till and 30-15-5 at planting	6.8	11	94	9.0	22	100
LSD (0.05)		1.1	NS	15	1.4	2	22

Table 2. Effects of tillage, hybrid, nitrogen rate, and starter fertilizer placement on early season grain sorghum growth, days to half bloom, and yields of Pioneer 84G62 and 86G08 grain sorghum planted at the traditional planting time, East Central Kansas Experiment Field, Ottawa, 2007

		Pioneer 84G62 Planted June 7			Pioneer 86G08 Planted June 11		
Tillage	Fertilizer rate and placement	5-leaf dry weight	Half bloom date	Yield	7-leaf dry weight	Half bloom date	Yield
		g	July	bu/a	g	July	bu/a
Strip-till	0-0-0	4.3	17	73	7.3	26	85
Strip-till	60-30-10, 5 in. below the row	6.0	10	93	9.4	22	107
Strip-till	90-30-10, 5 in. below the row	3.7	9	98	23.0	10	75
Strip-till	120-30-10, 5 in. below the row	3.5	9	92	19.8	10	73
Strip-till	150-30-10, 5 in. below the row	3.0	9	95	21.8	9	76
Mean		3.4	10	88	21.4	10	69
No-till	0-0-0	2.2	14	50	15.7	13	45
No-till	60-30-10, 2.5 × 2.5 in. at planting	3.7	11	83	21.1	10	71
No-till	90-30-10, 2.5 × 2.5 in. at planting	3.2	10	91	20.0	10	70
No-till	120-30-10, 2.5 × 2.5 in. at planting	2.7	11	92	20.7	10	74
No-till	150-30-10, 2.5 × 2.5 in. at planting	2.6	11	94	17.9	11	71
Mean		2.9	11	82	19.1	11	66
Evaluation of starter							
Strip-till	90-30-10, 5 in. below the row	3.7	9	98	23.0	9	75
Strip-till	60-15-5 strip-till and 30-15-5 at planting	4.2	8	96	22.2	10	75
Strip-till	120-30-10, 5 in. below the row	3.5	9	92	19.8	10	75
Strip-till	90-15-5 strip-till and 30-15-5 at planting	3.4	9	93	23.9	9	76
LSD (0.05)		0.6	1	5	2.7	1	7

Table 3. Effects of tillage, planting date, nitrogen rate, and starter fertilizer placement on early season grain sorghum growth, days to half bloom, and yields of early and traditional-planted grain sorghum, East Central Kansas Experiment Field, Ottawa, 2008

		Early planting May 15 (delayed)			Traditional planting June 19		
Tillage	Fertilizer rate and placement	6-leaf dry weight	Half bloom date	Yield	6-leaf dry weight	Half bloom date	Yield
		g	July	bu/a	g	July	bu/a
Strip-till	0-0-0	6.8	28	24	7.1	25	50
Strip-till	60-30-10, 5 in. below the row	13.8	19	71	10.6	19	85
Strip-till	90-30-10, 5 in. below the row	14.8	18	88	11.6	18	91
Strip-till	120-30-10, 5 in. below the row	14.6	19	83	11.2	18	107
Strip-till	150-30-10, 5 in. below the row	15.1	18	88	12.2	18	115
Mean		13.0	20	71	10.5	20	90
No-till	0-0-0	5.2	28	27	7.5	24	48
No-till	60-30-10, 2.5 × 2.5 in. at planting	13.3	18	76	11.0	18	105
No-till	90-30-10, 2.5 × 2.5 in. at planting	13.6	19	81	10.3	18	113
No-till	120-30-10, 2.5 × 2.5 in. at planting	14.7	19	85	10.2	19	119
No-till	150-30-10, 2.5 × 2.5 in. at planting	13.0	19	73	9.9	19	127
Mean		12.0	21	68	9.8	20	102
Evaluation of starter							
Strip-till	90-30-10, 5 in. below the row	14.8	18	88	11.6	18	105
Strip-till	60-15-5 strip-till and 30-15-5 at planting	15.6	18	87	11.9	18	111
Strip-till	120-30-10, 5 in. below the row	14.6	19	83	11.2	18	107
Strip-till	90-15-5 strip-till and 30-15-5 at planting	13.6	18	88	11.8	18	122
LSD (0.05)		2.4	1	13	1.5	1	10

Effect of Various Foliar Fertilizer Materials on Irrigated Soybean

L. D. Maddux

Summary
Various fertilizer materials were foliar applied to soybean at V5 to R2 growth stages depending on the fertilizer material being applied. No effect of any of the fertilizer materials on grain yield was observed.

Introduction
This study was conducted with a grant provided by Tessenderlo Kerley, Inc. (TKI), a producer of specialty products used in the agriculture, mining, and process chemical industries. The TKI products tested included calcium thiosulfate (CaTs, 0-0-0-10S-6Ca), Trisert K+ (5-0-20-13S), Trisert CB (26-0-0-0.5B), and magnesium thiosulfate (MagThio, 0-0-0-10S-4Mg). Gold'n Gro (10-0-1-3S-0.4Fe-3Mn-0.5Zn), manufactured by Itronics Metallurgical, Inc., was also included in this test. This study was conducted to evaluate the effect of foliar applications of these materials on soybean yield.

Procedures
This study was conducted in 2008 on a Eudora silt loam soil at Rossville, KS. Foliar treatments included a check; Trisert K+ at 2.5 and 5 gal/a applied at V5; MagThio at 1.0, 1.5, and 2.0 gal/a applied at V5; Trisert CB at 1.0 and 1.5 gal/a applied at R2; CaTs at 3.0 and 5.0 gal/a applied at R1; and Gold'n Gro at 1.6 gal/a applied 8 days after a glyphosate treatment was applied. Soybean variety NK S37-F7 was planted at 139,000 seeds/a May 16. The V5 foliar treatments were applied June 30, the R1 foliar treatments were applied July 2, and the Gold'n Gro and R2 foliar treatments were applied July 14. Glyphosate (0.75 lb ae/a) plus Intrro (2.0 qt/a) was applied June 17, and a second glyphosate application was made June 30. Plots were harvested with a John Deere 3300 plot combine.

Results
Soybean yields are shown in Table 1. Yields ranged from 57.5 to 63.2 bu/a, but no significant differences among treatments were observed. Gold'n Gro, which contains Mn as well as other micronutrients, was to be applied 8 days after glyphosate application. Research conducted at the North Central Kansas Experiment Field near Scandia has shown some yield increase with Mn applications. However, no effect on soybean yield was observed with this treatment in this study. Previous research on Mn applications on soybean conducted at Rossville also showed no yield increase.

Table 1. Effect of various foliar fertilizer applications on soybean yield, Kansas River Valley Experiment Field, Rossville, 2008

Fertilizer	Rate	Growth stage	Soybean yield
	gal/a		bu/a
Check			59.9
Trisert K+	2.5	V5	60.6
Trisert K+	5.0	V5	59.3
MagThio	1.0	V5	60.7
MagThio	1.5	V5	61.0
MagThio	2.0	V5	63.9
Trisert CB	1.0	R2	60.9
Trisert CB	1.5	R2	57.5
CaTs	3.0	R1	61.1
CaTs	5.0	R1	63.2
Gold'n Gro	1.6	R2 - 8 days after glyphosate	57.6
LSD (0.05)			NS

Effect of Various Fertilizer Materials on Irrigated Corn and Dryland Grain Sorghum

L. D. Maddux

Summary
A lower-than-optimal nitrogen (N) rate applied to irrigated corn from 2006 to 2008 and to dryland grain sorghum in 2008 resulted in yields equal to those obtained with the same N rate plus CaTs, N-Sure or Trisert NB, and MagThio. In only one year (2006 on irrigated corn), however, was a yield response to the higher, optimal N rate observed. Yields for all treatments were higher than for the no-N check. There were no differences in N content of grain observed among treatments; all treatments had a higher level of grain N than the no-N check.

Introduction
These studies were conducted with grants provided by Tessenderlo Kerley, Inc. (TKI), a producer of specialty products used in the agriculture, mining, and process chemical industries. The TKI products tested were calcium thiosulfate (CaTs; 0-0-0-10S-6Ca), N-Sure (28-0-0 with 72% slow release N), Trisert NB (26-0-0 with 33% slow release N), and magnesium thiosulfate (MagThio; 0-0-0-10S-4Mg). A lower-than-optimal N rate—100 lb/a N on irrigated corn and 60 lb/a N on dryland grain sorghum—was used to evaluate the effectiveness of N-Sure and Trisert NB at supplying foliar N to the corn and sorghum plants to increase grain yield. Applications of CaTs and MagThio with urea ammonium nitrate (UAN) were also evaluated for their effects on grain yield at the lower N rate.

Procedures
A study was started in 2006 to evaluate the effect of CaTs and a foliar N treatment on conventionally tilled irrigated corn following soybeans on a Eudora silt loam soil at the Rossville Unit of the Kansas River Valley Experiment Field. Treatments included a no-N check, 150 and 100 lb/a N; 100 lb/a N + 5 or 10 gal/a CaTs, 100 lb/a N + 5 gal/a CaTs + 4 gal/a foliar N, and 100 lb/a N + 4 gal/a foliar N. Urea-ammonium nitrate solution was used as the N source and knifed 6 to 8 in. deep on 30-in. centers. Foliar N treatments were applied as N-Sure in 2006 and 2007 and as Trisert NB in 2008. In 2008, three additional treatments were added: 100 lb/a N + 1.0, 1.5, and 2.0 gal/a MagThio. In 2008, the same treatments were also evaluated on no-till dryland grain sorghum following soybean on a Woodson silt loam soil at the East Central Kansas Experiment Field near Ottawa. Nitrogen rates used in this study were 60 lb/a N with the UAN + CaTs, MagThio, and Trisert NB treatments and 60 and 90 lb/a N of UAN alone. The UAN treatments were applied to the irrigated corn plots on Apr. 20, 2006, and Apr. 29, 2007 and 2008, and to the grain sorghum on May 20, 2008. Foliar N treatments were applied to 8-leaf corn on June 13, 2006, and to 10- to 11-leaf corn on June 26, 2007 and 2008. Corn hybrids were planted at 29,600 seeds/a: Taylor 855BT on Apr. 20, 2006, and DeKalb DKC63-74 YG Plus, RR2 on Apr. 30, 2007, and Apr. 29, 2008. The UAN treatments were applied to the dryland grain sorghum on May 20, 2008. Foliar N treatments were applied to 10-leaf sorghum on July 11, 2008. Grain sorghum hybrid Pioneer

84G62 was planted no-till into soybean stubble at 65,000 seeds/a on May 20, 2008. Herbicides were applied as needed for weed control. Plots were harvested with a John Deere 3300 plot combine, and grain samples were saved for N analyses.

Results

The N content of the corn and sorghum grain was not significantly changed by any treatments (data not shown), although all treatments increased N content of the grain over that of the check. Grain yields of irrigated corn and dryland grain sorghum are shown in Table 1. All treatments increased yield of irrigated corn and dryland sorghum over that of the no-N check. Only in the 2006 irrigated corn test, however, did the optimal N rate (150 lb/a N) increase grain yield over the lower N rate used in combination with CaTs, Trisert NB, and MagThio. This lack of response to N could be due to the lack of response of the UAN + CaTs, N-Sure/Trisert NB, and MagThio. However, no response to these materials was observed in 2006, when an N response to 150 lb/a N was observed.

Table 1. Effect of urea ammonium nitrate (UAN) and other fertilizer materials on irrigated corn yield (Rossville, 2006–2008) and dryland grain sorghum yield (Ottawa, 2008)

Fertilizer treatment		Corn yield			Sorghum yield
UAN	Other[1]	2006	2007	2008	2008
lb/a N[2]	gal/a	----------------------	---bu/a---		----------------------
0	0	124	124	159	60
150/90	0	164	187	209	85
100/60	0	140	184	203	86
100/60	CaTs, 5	145	174	200	83
100/60	CaTs, 10	145	186	217	84
100/60	CaTs, 5 + N-Sure, 4	143	169	196	89
100/60	N-Sure/Trisert NB, 4	134	192	201	85
100/60	MagThio, 1.0			201	89
100/60	MagThio, 1.5			187	87
100/60	MagThio, 2.0			213	84
LSD (0.05)		20	21	24	12

[1] CaTs and MgThio were soil applied with UAN, N-Sure (2006 and 2007) or Trisert NB (2008) were foliar applied at the 8- to 10-leaf stage of growth.

[2] First number is N rate for irrigated corn, second number is N rate for dryland grain sorghum.

Macronutrient Fertility on Irrigated Corn and Soybean in a Corn/Soybean Rotation

L. D. Maddux

Summary
Effects of nitrogen (N), phosphorus (P), and potassium (K) fertilization on a corn/soybean cropping sequence were evaluated from 1983 to 2008 (corn planted in odd years). Corn yield increased with increasing N rates up to 160 lb/a N. Fertilization at 240 lb/a N did not increase yield over that obtained with 160 lb/a N. Phosphorus fertilization resulted in corn yield increases 3 of the 13 years of this test. Potassium fertilization increased corn yield an average of 6 bu/a from 1983 to 1995 with no significant differences observed since then. Soybean following corn fertilized with 160 lb/a N yielded 3.2 bu/a higher than when N was not applied to corn. Phosphorus fertilization of the previous corn crop at 60 lb/a P_2O_5 resulted in a 13-year average increase in soybean yield of 5.0 bu/a over that when no P was applied. Potassium fertilization of the previous corn crop has not resulted in much of a significant soybean yield increase; the 13-year average is only 1.5 bu/a higher than when K is not applied.

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

Procedures
The initial soil test in March 1972 on this silt loam soil was 47 lb/a available P and 312 lb/a exchangeable K in the top 6 in. of the soil profile. Rates of P were 50 and 100 lb/a P_2O_5 (1972-1975) and 30 and 60 lb/a P_2O_5 (1976-2007), except in 1997 and 1998, when a starter of 120 lb/a of 10-34-0 (12 lb/a N + 41 lb/a P_2O_5) was applied to all plots of corn and soybean. Rates of K were 100 lb/a K_2O (1972-1975), 60 lb/a K_2O (1976-1995), and 150 lb/a K_2O (1997-2007). Nitrogen rates included a factorial arrangement of 0, 40, and 160 lb/a of preplant N (with single treatments of 80 and 240 lb/a N). The 40 lb/a N rate was changed to 120 lb/a N in 1997. Treatments of N, P, and K were applied every year to continuous soybean (1972-1982) and every other year (odd years) to corn (1983-1995, 1999-2007).

Corn hybrids planted were: BoJac 603 (1983), Pioneer 3377 (1985, 1987, 1989), Jacques 7820 (1991, 1993), Mycogen 7250 (1995), DeKalb DKC626 (1997, 1999), Golden Harvest H2547 (2001), Pioneer 33R77 (2003), DeKalb DKC63-81 (2005), and Asgrow RX785 (2007). Soybean varieties planted in even years were: Douglas (1984), Sherman (1986, 1988, 1990, 1992, 1996, 1998), Edison (1994), IA 3010 (2000), Garst 399RR (2002), Stine 3982-4 (2004), Stine 4302-4 (2006), and Midland 9A385 (2008). Corn was planted in mid-April, and soybean was planted in early to mid-May. Herbicides were applied preplant and incorporated each year, and postemergence herbicides were applied as needed. Plots were cultivated, furrowed, and furrow irrigated through 2001 and sprinkler irrigated with a linear move irrigation system from 2002 to 2008. A plot combine was used for harvesting grain yields.

Results

Average corn yields for the 7-year period from 1983 to 1995 and yields for 1997 to 2007 are shown in Table 1. Yields were maximized with 160 lb/a N most years. Fertilization at 240 lb/a N did not significantly increase corn yield. From 1997 to 2007, corn yield with 120 lb/a N was not significantly different from that with 160 lb/a N and ranged from 0 to 8 bu/a less (LSD 0.05 was 13 to 19 bu/a). A yield response to P fertilization was obtained in 1985 and 1993 (yearly data not shown), whereas the 7-year average showed no significant difference in yield. No P response was observed in 1997, when starter fertilizer was applied to all plots. A significant yield response to P was obtained in 2003. The 13-year average showed a nonsignificant yield increase for the 30 lb/a P_2O_5 treatment of 3 bu/a over that when no P was applied. Fertilization with K resulted in a significant yield increase in 1985, 1989, and 1993 (yearly data not shown), and the 7-year average showed a 6 bu/a yield increase. No significant corn yield response to K fertilization was observed from 1997 to 2007.

Soybean yields are shown in Table 2. Soybean yield over 7 years (1984-1996) averaged 3.1 bu/a higher when 160 lb/a N was applied to the previous corn crop than when no N was applied. During the next 6 years of soybean production (1998-2008), 4 years showed a significant yield increase with a similar average of 3.3 bu/a for the 160 lb/a N corn fertilization rate. Phosphorus fertilization of 60 lb/a P_2O_5 increased the 7-year average soybean yield by 4.5 bu/a over that when no P was applied. No significant P response was observed in 1998, when starter fertilizer was applied to all plots. Only two significant yield responses to P were observed during from 2000 to 2008, but the average yield increase for the 60 lb/a P_2O_5 treatment for those years was 5.4 bu/a over that of the check. Potassium fertilization has not resulted in a significant soybean yield increase very often. Average yield of the K-fertilized plots for the 13 years in the rotation is only 1.5 bu/a.

Table 1. Effects of nitrogen, phosphorus, and potassium applications on corn yields in a corn/soybean cropping sequence, Kansas River Valley Experiment Field, Topeka Unit

Fertilizer[1]			Corn yield						
N	P_2O_5[2]	K_2O	1983-1995	1997	1999	2001	2003	2005	2007
----lb/a----			----bu/a----						
0	0	0	87	93	88	119	88	92	126
0	0	60/150	86	95	106	123	84	83	101
0	30	0	93	101	115	124	107	114	120
0	30	60/150	86	87	90	115	102	80	108
0	60	0	84	86	76	110	101	102	100
0	60	60/150	92	89	79	115	106	105	104
40/120	0	0	129	200	202	183	174	171	191
40/120	0	60/150	126	181	195	173	167	189	201
40/120	30	0	123	189	188	168	188	179	187
40/120	30	60/150	138	208	181	192	198	200	189
40/120	60	0	117	195	159	183	202	194	194
40/120	60	60/150	132	190	213	182	195	201	194
160	0	0	171	203	171	171	188	196	197
160	0	60/150	177	177	206	168	175	194	206
160	30	0	168	184	189	174	184	174	168
160	30	60/150	181	205	209	190	211	200	184
160	60	0	167	191	199	205	205	203	196
160	60	60/150	178	204	203	198	193	213	201
80	30	60/150	151	187	177	167	167	167	202
240	30	60/150	182	206	219	192	192	192	197
LSD (0.05)			15	27	46	26	34	28	26

continued

Table 1. Effects of nitrogen, phosphorus, and potassium applications on corn yields in a corn/soybean cropping sequence, Kansas River Valley Experiment Field, Topeka Unit

Fertilizer[1]			Corn yield						
N	P_2O_5[2]	K_2O	1983-1995	1997	1999	2001	2003	2005	2007
----lb/a----			----bu/a----						
Nitrogen means									
0			88	92	92	118	98	96	110
40/120			127	194	190	180	187	189	193
160			174	194	196	184	193	197	192
LSD (0.05)			8	19	19	13	17	13	13
Phosphorus means									
	0		129	158	161	156	146	154	170
	30		131	162	162	160	165	158	159
	60		128	159	155	166	167	170	165
LSD (0.05)			NS	NS	NS	NS	17	NS	NS
Potassium means									
		0	127	160	154	160	160	158	164
		60/150	133	159	165	162	159	163	165
LSD (0.05)			6	NS	NS	NS	NS	NS	NS

[1] Fertilizer applied to corn in odd years from 1983 to 2007 and to soybean for 11 years prior to 1983 (the first number of two is the rate applied to corn from 1983 to 1995).

[2] P treatments not applied in 1997. Starter fertilizer of 10 gal/a of 10-34-0 was applied to all treatments in 1997 and 1998 (corn and soybean). N and K treatments were applied to corn in 1997.

Table 2. Effects of nitrogen, phosphorus, and potassium applications on soybean yields in a corn/soybean cropping sequence, Kansas River Valley Experiment Field, Topeka Unit

Fertilizer[1]			Soybean yield						
N	P_2O_5[2]	K_2O	1984-1996	1998	2000	2002	2004	2006	2008
----lb/a----			----bu/a----						
0	0	0	63.9	65.1	48.1	41.8	46.3	39.7	47.3
0	0	60/150	65.6	64.8	54.4	39.1	47.3	39.9	43.2
0	30	0	69.0	65.5	53.6	48.1	52.5	43.7	59.8
0	30	60/150	69.8	65.6	58.1	47.7	48.3	42.4	52.8
0	60	0	69.6	62.6	53.4	48.1	53.4	43.6	61.1
0	60	60/150	72.3	64.7	57.8	55.3	51.0	41.9	55.5
40/120	0	0	66.3	67.0	51.6	47.0	52.0	40.5	50.6
40/120	0	60/150	67.7	64.7	57.6	48.1	55.5	42.5	54.7
40/120	30	0	66.7	62.0	53.3	47.7	55.7	45.2	58.0
40/120	30	60/150	72.7	71.0	61.6	51.5	52.5	41.6	53.8
40/120	60	0	70.8	65.6	50.8	53.9	54.0	46.1	59.8
40/120	60	60/150	71.4	64.9	60.2	53.5	50.3	40.8	54.6
160	0	0	68.8	65.8	55.1	49.3	52.9	43.4	51.9
160	0	60/150	70.0	65.8	57.0	53.9	47.0	37.1	48.6
160	30	0	70.5	62.1	53.4	53.3	52.5	48.7	53.4
160	30	60/150	73.8	65.0	59.5	57.8	53.1	49.3	53.8
160	60	0	71.3	65.0	59.6	55.4	56.6	48.6	59.9
160	60	60/150	74.2	68.5	64.9	56.1	50.5	42.4	59.5
80	30	60/150	71.5	68.3	63.9	54.6	53.1	47.6	54.4
240	30	60/150	71.7	67.7	60.7	55.6	53.3	48.9	52.5
LSD (0.05)			5.1	NS	2.1	8.2	NS	NS	6.0

continued

Table 2. Effects of nitrogen, phosphorus, and potassium applications on soybean yields in a corn/soybean cropping sequence, Kansas River Valley Experiment Field, Topeka Unit

Fertilizer[1]			Soybean yield						
N	P_2O_5[2]	K_2O	1984-1996	1998	2000	2002	2004	2006	2008
---lb/a---			---bu/a---						
Nitrogen means									
0			68.4	64.7	54.2	46.7	49.8	41.8	52.6
40/120			69.3	65.9	55.9	50.3	53.3	42.8	55.8
160			71.5	65.4	58.2	54.3	52.1	44.9	54.5
LSD (0.05)			2.5	NS	3.1	2.2	2.7	2.9	NS
Phosphorus means									
	0		67.1	65.5	54.0	46.5	50.2	40.5	48.7
	30		70.4	65.2	56.6	51.0	52.4	45.1	55.3
	60		71.6	65.2	57.8	53.7	52.6	43.9	59.0
LSD (0.05)			4.5	NS	NS	4.8	NS	NS	3.8
Potassium means									
		0	68.6	64.5	53.2	49.4	52.9	44.4	55.3
		60/150	70.9	66.1	59.0	51.5	50.6	42.0	53.3
LSD (0.05)			NS	NS	3.2	NS	NS	NS	NS

[1] Fertilizer applied to corn in odd years from 1983 to 2007 and to soybean for 11 years prior to 1983 (the first number of two is the rate applied to corn from 1983 to 1995).

[2] P treatments not applied in 1997. Starter fertilizer of 10 gal/a of 10-34-0 was applied to all treatments in 1997 and 1998 (corn and soybean). N and K treatments were applied to corn in 1997.

Effects of Late-Maturing Soybean and Sunn Hemp Summer Cover Crops and Nitrogen Rate in a No-Till Wheat/Grain Sorghum Rotation

M. M. Claassen

Summary
Wheat and grain sorghum were grown in three no-till crop rotations, two of which included either a late-maturing Roundup Ready soybean or a sunn hemp cover crop established following wheat harvest. Nitrogen (N) fertilizer was applied to both grain crops at rates of 0, 30, 60, and 90 lb/a. Experiments were conducted on adjacent sites where different phases of the same rotations were established.

On the first site, wheat followed grain sorghum after these cover crops had been grown in the third cycle of the rotations in 2006. In that season, these crops produced 66 and 113 lb/a, respectively, of potentially available N. The grain sorghum crop that followed produced an average of 99 bu/a. Residual effects of soybean on wheat after grain sorghum were similar to those of sunn hemp. Wheat yields ranged from 8.7 to 41.7 bu/a. Averaged over N rate, wheat yields were 3.4 bu/a greater with cover crops than with no cover crop in the rotation. Nitrogen increased wheat yield by 9 to 10 bu/a for each 30-lb/a increment. Notably, wheat yields were significantly greater at N rates of 60 and 90 lb/a in the rotation that included soybean than in the rotation without a cover crop. Also, wheat yields were significantly greater at N rates of 30 and 60 lb/a where sunn hemp was grown in the rotation vs. no cover crop. Cover crops increased plant N content and plant height but had no effect on wheat test weight.

On the second site, grain sorghum followed cover crops that had been grown in 2007 for the second time in the rotations. In that season, soybean and sunn hemp produced an average of 1.06 and 3.50 ton/a with corresponding N yields of 65 and 165 lb/a, respectively. Grain sorghum yields ranged from 69.4 to 130.6 bu/a. Averaged over N rate, grain sorghum produced 7.0 and 19.7 bu/a more in the rotations with soybean and sunn hemp, respectively, than in the rotation with no cover crop. Nitrogen rate main effect was significant, with increases in grain sorghum yield at 30 and 60 lb/a but not at the highest N level. In grain sorghum after soybean vs. no cover crop, yields tended to be higher at most N rates but were significantly higher only at the 30 lb/a rate. On the other hand, grain sorghum following sunn hemp vs. no cover crop had significantly higher yields at all but the 90 lb/a rate. Both legumes tended to increase grain sorghum leaf N concentration at low N rates. At 90 lb/a N, sorghum leaf N levels were similar in all rotations.

Introduction
Research at the Harvey County Experiment Field over an 8-year period explored the use of hairy vetch as a winter cover crop following wheat in a winter wheat/sorghum rotation. Results of long-term experiments showed that between September and May, hairy vetch can produce a large amount of dry matter with an N content of approximately 100 lb/a. However, using hairy vetch as a cover crop also has significant disadvantages including cost and availability of seed, interference with control of volunteer wheat and winter an-

nual weeds, and the possibility of hairy vetch becoming a weed in wheat after sorghum. New interest in cover crops has been generated by research in other areas that shows the positive effect these crops can have on overall productivity of no-till systems.

In the current experiment, late-maturing soybean and sunn hemp, a tropical legume, were evaluated as summer cover crops for their effect on no-till sorghum grown in the spring after wheat harvest as well as on double-crop, no-till wheat after grain sorghum. In 5 site-years during the period 2002 through 2007, soybean and sunn hemp produced average N yields of 94 and 132 lb/a, respectively. Averaged over N rates, soybean and sunn hemp resulted in 5-year average grain sorghum yield increases of 7.2 and 14.8 bu/a, respectively. Residual effects of soybean and sunn hemp on wheat after sorghum averaged over N rates were minor, with 4-year yields averaging 2.3 and 2.6 bu/a, respectively, more than wheat in the rotation without cover crops.

Procedures

Experiments were established on adjacent Geary silt loam sites that had been used for hairy vetch cover crop research in a wheat/sorghum rotation from 1995 to 2001. In accordance with the previous experimental design, soybean and sunn hemp were assigned to plots where vetch had been grown, and remaining plots retained the no-cover-crop treatment. The existing factorial arrangement of N rates on each cropping system also was retained. In 2008, wheat was grown on Site 1 in the third cycle of the rotations. Grain sorghum was produced on Site 2 in the second cycle of the rotations.

Wheat

Grain sorghum on Site 1 was combine harvested on Oct. 3, 2007. After a wet weather delay, winter wheat variety Jagger was no-till planted in 7.5-in. rows with a JD1590 drill on November 3 at 90 lb/a with 32 lb/a P_2O_5 fertilizer banded as 0-46-0 in the furrow. Nitrogen rates were reapplied as broadcast 46-0-0 just before planting. Wheat was harvested on July 1, 2008.

Grain Sorghum

Wheat on Site 2 was harvested on July 9, 2007. Weeds in wheat stubble were controlled with glyphosate application 5 days later. Asgrow AG7601 Roundup Ready soybean and sunn hemp seed were treated with respective rhizobium inoculants and no-till planted in 7.5-in. rows with a JD 1590 drill on July 16, 2007, at 60 and 10 lb/a, respectively. Soybean and fallow plots were sprayed with glyphosate in late August. Also, sunn hemp was sprayed at that time with Fusilade DX for volunteer wheat and grass weed control. The first fall freeze occurred on October 23. Before loss of leaves, forage yield of each cover crop was determined by harvesting a 3.28-ft^2 area in each plot. Samples were subsequently analyzed for N content. Cover crops were rolled down on October 30 with a crop roller. Glyphosate was applied in early April and reapplied with very low rates of Clarity and 2,4-D_{LVE} in early June. Pioneer 85G01 grain sorghum treated with Concep III safener and Cruiser insecticide was planted in 30-in. rows at approximately 42,000 seeds/a on June 3, 2008. Atrazine and Dual II Magnum were applied preemergence for residual weed control. All plots received 37 lb/a P_2O_5 banded as 0-46-0 at planting. Nitrogen fertilizer treatments were applied as 28-0-0 injected 10 in. from the row on June 12. Grain sorghum was combine harvested on Oct. 1, 2008.

Results

Wheat

The third cycle of the crop rotations on Site 1 began in 2006, when soybean and sunn hemp produced an average of 1.34 and 2.08 ton/a with corresponding N yields of 66 and 113 lb/a, respectively (Table 1). In 2007, averaged across N rate, grain sorghum yielded 97.6 bu/a after soybean and 106.1 bu/a following sunn hemp.

Wheat yield potential was limited to some extent by late planting. Fall wheat development was further hindered by dry weather that persisted until December. Both cover crops significantly increased wheat plant height by 2 in. when averaged over N rates. Most of this increase occurred at the lowest levels of N. Each N increment significantly increased plant height as well. Cover crop influence on wheat plant N content was similar with both species. The overall average increase was 0.09% N. Notably, this cover crop effect was observed at the two highest N rates.

Relatively cool spring temperatures enabled wheat to produce top yields on the order of 40 bu/a. Highest yields occurred with cover crops and 90 lb/a N. Positive yield response to cover crops in the rotations was similar for soybean and sunn hemp. Averaged over N rate, the cover crop benefit was 3.4 bu/a. Each 30-lb/a N increment increased wheat yield by 9 to 10 bu/a on average. The residual contribution of cover crops to wheat yield continued to be seen at the higher N rates. Grain test weights were not affected by cover crop but tended to decrease as N rate and yield increased.

Grain Sorghum

During the week preceding cover crop planting in 2007, several small showers brought 0.4 in. of rainfall. But dry weather prevailed during the first two weeks after planting, resulting in limited cover crop emergence until after heavy rainfall in late July. Total rainfall for August, September, and October was 3.55 in. below normal. Final soybean plant populations were incomplete, with a mature plant height of 15 in. and canopy cover of about 35%. Some pod and seed development occurred by late October. Late-maturing soybean produced 1.06 ton/a of above-ground dry matter with an N content of 3.11%, or 65 lb/a N. Sunn hemp stands were reasonably good, with a canopy cover of approximately 86%. Sunn hemp reached full flowering stage in late October with a height of 69 in. and produced 3.50 ton of above-ground dry matter with an N content of 2.37%, or 165 lb/a N. With one seasonal herbicide application, late-maturing soybean and sunn hemp at maturity provided 96 and 81% volunteer wheat control, respectively.

The 2008 grain sorghum crop emerged 6 days after planting. Final stands averaged 36,800 plants/a without a crop rotation effect (Table 2). During the first 10 days after planting, rainfall from several events totaled 0.61 in. The season was relatively mild and generally favorable for sorghum. Both cover crop and N rate effects on grain sorghum were significant. Soybean and sunn hemp significantly increased sorghum nutrient concentration by 0.12 and 0.19% N, respectively, when averaged over N rate. Most of this effect occurred at rates of 60 lb/a N or less. At 90 lb/a N, sorghum leaf N concentration was comparable in all rotations. Averaged over N rate, grain sorghum heads/plant increased by 8 and 14% in rotations with soybean and sunn hemp, respectively. This positive effect of cover crops was seen throughout the range of fertilizer N. Cover crops generally did not influence the length of time for grain sorghum to reach the half-bloom stage. However, at 0 lb/a N, half bloom was delayed by several days in the rotations with no cover crop or with soybean.

The main effect of cover crop on grain sorghum yield was significant, with increases of 7.0 and 19.7 bu/a for soybean and sunn hemp, respectively. Grain yields tended to increase with cover crops at N rates up to 90 lb/a N, at which point differences among the rotations became insignificant. Sorghum yields responded well to fertilizer N, with significant increases up to but not including the 90 lb/a rate.

Table 1. Residual effects of soybean and sunn hemp summer cover crops and nitrogen rate on no-till wheat after grain sorghum, Harvey County Experiment Field, Hesston, 2008

		Cover crop yield[3]		Sorghum	Wheat			
Cover crop[1]	N rate[2]	Forage	N	yield 2007[4]	Yield	Bushel weight	Plant height	Plant N[5]
	lb/a	ton/a	lb/a	bu/a	bu/a	lb	in.	%
None	0	–	–	72.0	8.7	59.1	18	1.50
	30	–	–	89.3	17.5	59.1	23	1.23
	60	–	–	100.9	25.9	58.6	27	1.24
	90	–	–	111.6	37.0	58.2	29	1.32
Soybean	0	1.14	58	80.9	10.9	59.3	21	1.50
	30	1.38	70	93.5	18.5	59.1	23	1.28
	60	1.43	71	111.4	30.6	58.4	28	1.36
	90	1.41	68	104.7	41.7	57.7	31	1.55
Sunn hemp	0	1.87	112	95.0	11.4	59.3	20	1.46
	30	2.08	109	102.3	22.2	59.2	26	1.30
	60	2.41	127	109.6	30.9	58.5	28	1.37
	90	1.96	103	117.4	39.0	57.2	30	1.50
LSD (0.05)		0.61	39	11.3	3.5	0.6	2	0.10
Means								
Cover crop								
None		–	–	93.5	22.3	58.7	24	1.32
Soybean		1.34	66	97.6	25.4	58.6	26	1.42
Sunn hemp		2.08	113	106.1	25.9	58.6	26	1.41
LSD (0.05)		0.30	20	5.6	1.7	NS	1	0.05
N rate								
0		1.50	85	82.7	10.3	59.2	20	1.49
30		1.73	89	95.0	19.4	59.1	24	1.27
60		1.92	99	107.3	29.1	58.5	28	1.32
90		1.68	85	111.2	39.2	57.7	30	1.46
LSD (0.05)		NS	NS	6.5	2.0	0.4	1	0.06

[1] Cover crops planted on Aug. 8, 2006, and terminated by mid-October.
[2] N applied as 28-0-0 injected June 11, 2007, for sorghum and 46-0-0 broadcast on Nov. 2, 2007, for wheat.
[3] Oven-dry weight and N content for sunn hemp and soybean at termination. Note: Soybean dry matter and N yields represent corrected values (small decrease) from those previously reported for plots with an historic 90 lb/a N rate and for soybean overall means.
[4] Previously reported grain sorghum production data for 2007 excluded the yield of eight heads sampled from each plot for seed size and nutrient analyses. Inclusion of the subsample yield did not affect the interpretation of treatment differences.
[5] Whole-plant N concentration at early heading.

Table 2. Effects of soybean and sunn hemp summer cover crops and nitrogen rate on no-till grain sorghum after wheat, Harvey County Experiment Field, Hesston, 2008

		Cover crop yield[3]		Grain sorghum					
Cover crop[1]	N rate[2]	Forage	N	Grain yield	Bushel weight	Stand	Half[4] bloom	Heads/ plant	Leaf N[5]
	lb/a	ton/a	lb/a	bu/a	lb	1000/a	days	no.	%
None	0	–	–	69.4	54.1	37.2	65	1.08	2.07
	30	–	–	91.8	55.4	37.5	62	1.11	2.16
	60	–	–	115.6	55.5	37.6	61	1.22	2.42
	90	–	–	125.3	56.7	36.5	60	1.26	2.56
Soybean	0	0.49	32	72.2	51.9	37.0	66	1.06	2.03
	30	1.05	63	106.5	54.9	36.8	62	1.24	2.40
	60	1.25	76	125.2	56.0	36.7	62	1.37	2.61
	90	1.46	88	125.9	56.5	36.4	62	1.35	2.64
Sunn hemp	0	3.26	160	102.8	54.2	36.7	63	1.19	2.33
	30	3.29	150	117.8	56.1	36.2	62	1.32	2.48
	60	3.96	202	130.6	56.5	36.3	62	1.41	2.54
	90	3.51	149	129.7	56.4	37.0	62	1.36	2.63
LSD (0.05)		0.96	57	12.0	2.0	NS	2.1	0.09	0.15
Means									
Cover crop									
None		–	–	100.5	55.4	37.2	62	1.16	2.30
Soybean		1.06	65	107.5	54.8	36.7	63	1.25	2.42
Sunn hemp		3.50	165	120.2	55.8	36.5	62	1.32	2.49
LSD (0.05)		0.48	28	6.0	NS	NS	NS	0.05	0.08
N rate									
0		1.87	96	81.5	53.4	37.0	65	1.11	2.14
30		2.17	106	105.4	55.5	36.8	62	1.22	2.35
60		2.60	139	123.8	56.0	36.9	62	1.33	2.52
90		2.48	118	127.0	56.5	36.6	61	1.32	2.61
LSD (0.05)		NS	NS	7.0	1.14	NS	1.2	0.05	0.09

[1] Cover crops planted July 16, 2007, and terminated at the end of October.
[2] N applied as 28-0-0 injected June 12, 2008.
[3] Oven-dry weight and N content for sunn hemp and soybean at termination.
[4] Days from planting to half bloom.
[5] Flag leaf at late boot to early heading.

Potassium Fertilization of Irrigated Corn

W. B. Gordon

Summary
Use of conservation tillage has increased in recent years because of its effectiveness at conserving soil and water. Potassium (K) deficiency can be a problem on soils that have been managed with reduced-tillage practices. The large amount of residue left on the soil surface can depress soil temperature early in the growing season. Low soil temperature can interfere with plant root growth, nutrient availability in soil, and crop nutrient uptake.

Introduction
Soil temperature influences both K uptake by roots and K diffusion through the soil. Ching and Barbers (1979) investigated effects of temperature on K uptake by corn by using a simulation model. At the low soil K level, increasing soil temperature increased uptake. At the high K level, there was no effect of temperature on uptake.

Low soil water content or zones of soil compaction also can reduce K availability. Potassium uptake in corn is greatest early in the growing season and accumulates in plant parts at a relatively faster rate than dry matter, nitrogen (N), or phosphorus (P). Cool spring temperatures can limit early season root growth and K uptake by corn.

In plant physiology, K is the most important cation not only with regard to concentration in tissues but also with respect to physiological functions. Potassium is considered to be immobile in soil but mobile in plants. In general, K in plants moves from older to younger leaves. Potassium deficiency in corn may not be visible initially but results in an overall reduction in plant growth rate. Visual K deficiency appears first as yellowing in the tips of lower leaves. Deficiency symptoms appear as yellow, tan, and then brown discoloration and progress from the tip along the outside margins of the leaf blades. The inner part of the leaf near the midrib may stay green for a time while margins of the leaves fire and turn brown.

A K deficiency affects important physiological processes such as respiration, photosynthesis, chlorophyll development, and regulation of stomatal activity. Plants suffering from a K deficiency show a decrease in turgor, resulting in poor drought resistance. The main function of K in biochemistry is activating many different enzyme systems involved in plant growth and development. Potassium also influences crop maturity and plays a role in reducing disease and stalk lodging in corn. Potassium deficiency may result in stalk diseases that can weaken stalks and cause lodging problems.

Main K fertilizer sources are given in Table 1. The most common source of K used on corn is potassium chloride (KCl). It is also generally least cost source per unit of K. Potassium thiosulfate ($K_2S_2O_3$) is a true liquid source. This fertilizer is compatible with most fluid fertilizers and also provides a source of sulfur for use in starter fertilizer blends.

Appearance of K deficiency in fields managed with conservation-tillage systems has been reported with greater frequency in resent years and has become a concern for producers. In the central Great Plains, starter fertilizer applications have proven effective at enhancing nutrient uptake and yield of corn even on soils that are not low in available K.

Procedures

Two separate studies were conducted at the North Central Kansas Experiment Field. Both experiments were conducted on a Crete silt loam soil in areas that had been ridge tilled since 1984. Both sites also were furrow irrigated. Potassium deficiencies had been observed in these two areas prior to initiation of the studies. Ear leaf K concentrations had proven to be below published sufficiency ranges.

In the first study, a field experiment was conducted for three crop years. Soil test results showed that initial pH was 6.2, organic matter was 2.4%, and Bray-1 P and exchangeable K in the top 6 in. of soil were 40 and 420 ppm, respectively. Treatments consisted of liquid starter fertilizer N-P_2O_5-K_2O combinations of 30-15-5, 15-30-5, 30-30-0, and 30-30-5. A no-starter check also was included. Starters were made with 28% urea ammonium nitrate (UAN), ammonium polyphosphate (10-43-0), and potassium thiosulfate (KTS; 0-0-25-17). Nitrogen was balanced so that all plots received 220 lb/a N regardless of starter treatment. On plots receiving no K as KTS, ammonium sulfate was included to eliminate sulfur as a variable. Starter fertilizer was applied 2 in. to the side and 2 in. below the seed at planting.

Another study was conducted for three growing seasons on a site that was lower in soil test K than soil in the previous experiment. Analysis showed that initial soil pH was 6.9, organic matter was 2.5%, Bray-1 P was 35 ppm, and exchangeable K was 150 ppm. Treatments consisted of liquid starter fertilizer rates of 0, 5, 15 or 25 lb/a K_2O applied in combination with 30 lb N, 15 lb P_2O_5, and 5 lb/a sulfur (S). A 30-15-15-0 treatment was included to separate the effects of K and S. The K source used in this treatment was KCl. The source of K used in all other treatments was KTS. Starter fertilizer was again applied 2 in. to the side and 2 in. below the seed at planting. Nitrogen was balanced on all plots to give a total of 220 lb/a.

Results

In the first study, the 30-30-5 starter treatment increased corn 6-leaf stage dry matter and tissue K content, decreased number of days from emergence to mid-silk, and increased grain yield compared with the 30-30-0 treatment (Table 2). A small amount of K applied as a starter on this high soil test K soil resulted in better growth and nutrient uptake and 12 bu/a greater yield than starter that did not include K. In all cases, the 30-30-5 starter also was superior to the 15-30-5 treatment, indicating that N is an important element of starter fertilizer composition. All starter treatments improved growth and yield over the no-starter check.

Grain yield was maximized with application of 15 lb K_2O in the starter (Table 3). Addition of 15 lb/a K_2O to the starter increased grain yield by 13 bu/a over the starter containing only N and P. No response to sulfur was seen at this site. All combinations improved yields over the no-starter check.

Even though soil test K was in the high range, addition of K in the starter fertilizer increased early season growth and yield of corn. At this site, 15 lb/a K_2O was required to reach maximum yield. In the previous experiment, on a soil much higher in available K, only 5 lb/a K was needed to maximize yields.

Nutrient management in conservation-tillage systems can be challenging. The increased amounts of crop residue present in these systems can cause early season nutrient deficiency problems that the plant may not be able to overcome later in the growing season. Early season P and K nutrition is essential for maximizing corn yield. In these experiments, addition of K to starters containing N and P improved early season growth, nutrient uptake, earliness, and yield of corn grown in a long-term ridge-tillage production system.

In reduced-tillage or no-till systems, immobile elements such as K can become stratified. After 24 consecutive years in a ridge-tillage production system on a Crete silt loam soil at the North Central Kansas Experiments Field, soil test K levels were still in the “high” category in the inter-row area but in the “low” category in areas directly under the row (Figure 1). In work done in Ontario, Vyn et al. (1999) found that K needs are higher on soils managed with less tillage and that K placement also can be critical. The researchers found that corn managed with a strip-tillage system responded to a deep band (6 in. below the soil surface) placement, whereas corn in a no-till field responded well to surface-applied K. In a multisite experiment conducted in Iowa, Mallarino et al. (1999) also reported that K increased yields in several soils that tested optimum in soil test K and yields were higher when K was deep banded.

In another experiment conducted on a Carr sandy loam soil in the Republican River Valley in North Central Kansas for maximum yield under irrigated conditions, addition of K fertilizer increased yield of corn by more than 40 bu/a compared with N and P alone (Table 4).

Nutrient management in conservation-tillage systems can be challenging. The increased amounts of crop residue present in these systems can cause nutrient deficiencies on soil that may not be low in available nutrients. Stratification of immobile elements, such as K, also can occur. On many soils, addition of relatively small amounts of K may overcome these problems and increase yields of corn in systems managed for maximum yield.

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Table 1. Sources of potassium fertilizers

Source material	Formula	Grade $N\text{-}P_2O_5\text{-}K_2O\text{-}S$
Potassium chloride	KCl	0-0-60-0
Potassium hydroxide	KOH	0-75-0-0
Potassium nitrate	KNO_3	13-0-44-0
Potassium sulfate	K_2SO_4	0-0-50-18
Potassium thiosulfate	$K_2S_2O_3$	0-0-25-17

Table 2. Starter fertilizer combinations effects on V6 dry weight, potassium uptake, days from emergence to mid-silk, and yield of corn, Experiment 1

Treatment $N\text{-}P_2O_5\text{-}K_2O$	V6 dry weight	V6 K uptake	Days to mid-silk	Grain yield
	---lb/a---			bu/a
0-0-0 check	210	6.2	79	162
30-15-0	382	10.9	71	175
15-30-5	355	15.2	71	173
30-30-0	395	11.2	71	184
30-30-5	460	15.2	68	195
LSD (0.05)	28	1.5	2	10

Table 3. Starter fertilizer combinations effects on V6 dry weight, potassium uptake, days from emergence to mid-silk, and yield of corn, Experiment 2

Treatment $N\text{-}P_2O_5\text{-}K_2O\text{-}S$	V6 dry weight	V6 K uptake	Days to mid-silk	Grain yield
	---lb/a---			bu/a
0-0-0-0 check	208	6.9	82	161
30-15- 5-5	312	12.8	76	189
30-15-15-5	395	16.2	72	198
30-15-25-5	398	16.9	72	197
30-15-0	290	8.8	76	185
30-15-15-0	398	16.1	72	198
LSD (0.05)	31	1.9	2	11

Table 4. Response of irrigated corn yields to application of nitrogen, phosphorus, potassium, and sulfur on a Carr sandy loam soil

Treatment	Grain yield
	bu/a
Unfertilized check	80
N	151
N + P	179
N + P + K	221
N + P + K + S	239
LSD (0.05)	10

Fertilization rates were 300 lb/a N, 100 lb/a P_2O_5, 80 lb/a K_2O, and 40 lb/a S.

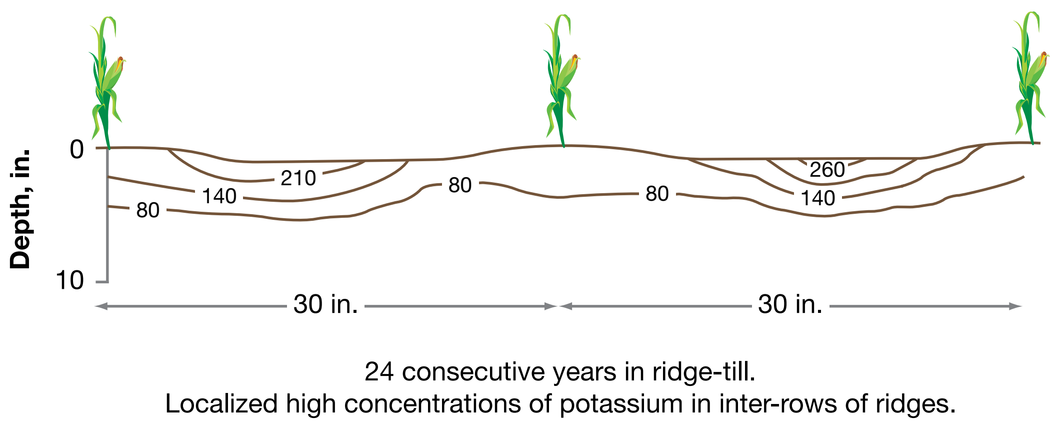

Figure 1. Potassium stratification on a Crete silt loam soil in north central Kansas.

Use of Starter Fertilizer for Irrigated Corn Production in the Great Plains

W. B. Gordon

Summary
An increasing number of producers in the central Great Plains have adopted conservation-tillage production methods because these systems help conserve soil and water. The large amount of surface residue present in these reduced-tillage systems can reduce seed zone temperatures, which can inhibit root growth and reduce nutrient uptake, especially early in the growing season. Several field studies have been conducted over the years at the North Central Kansas Experiment Field involving use starter fertilizer in no-till or reduced-tillage crop production systems Starter fertilizer applications have proven effective at enhancing nutrient uptake, even on soils not low in available nutrients.

Introduction
Nutrients are taken up by plant roots in three ways: (1) root interception, (2) mass flow, and (3) diffusion. As roots grow through soil, they physically contact pockets of nutrients that are available for uptake; this is root interception. In general, only a small percentage of the total nutrient supply needed for plant growth is acquired through root interception. Most plant nutrients are taken up by mass flow or diffusion. Nitrogen (N) and sulfur (S) move mainly by mass flow. Mass flow occurs when nutrients are transported with the flow of water from the soil to the roots. The amount of nutrients that reach the root is dependant on the rate of water flow and the average nutrient concentration in the water. Phosphorus (P) and potassium (K) move mainly by diffusion. Diffusion occurs when ions move from areas of high concentration to areas of lower concentration. Diffusion comes into operation when the concentration at the surface of the root is either higher or lower than that of the surrounding soil solution. It is directed toward the root when the concentration at the root surface is low and away from the plant roots when the concentration at the root surface is increased. Plant roots absorbing nutrients from the soil can create a sink to which nutrients diffuse (Drew et al., 1969). The nutrient depletion depends on the balance between supply from the soil and the demand by the plant.

The rate of diffusion in soils depends on several factors. Increasing soil moisture levels increase the rate of diffusion. Changing the bulk density of the soil affects the ability of nutrients to diffuse to the root surface. Compaction in soils makes it more difficult for nutrients to reach the root surface and can also limit root growth, which reduces nutrient uptake. Initial concentrations of nutrients in the soil also affect diffusion rates. Increasing soil temperatures increase nutrient concentration in the soil.

Conservation-tillage systems are being used by an increasing number of producers in the central Great Plains. No-till systems have proven effective at maintaining soil quality and reducing soil erosion because of several inherent advantages: reduction of soil erosion losses, increased soil water use efficiency, and improved soil quality. The large amount of surface residue present in reduced-tillage systems can reduce seed zone temperatures, which may inhibit root growth and reduce nutrient uptake. Lower-than-optimum soil temperature can reduce the rate of root growth (Ching and Barbers, 1979) and P uptake by the root (Carter and Lathwell, 1967). Mackay and Barber (1984) found that when soil temperature was reduced from 70 to 58°F, corn root growth decreased fivefold, and P uptake by corn roots decreased fourfold. Because of these environmental and physical conditions, nutrient deficiencies can take place even on soils that are not low in available nutrients.

Plant nutrient uptake per unit length of row is very high early in the growing season and decreases as the plant grows and the roots explore an increasing amount of the soil volume. This is illustrated for P uptake in Figure 1.

The seed itself is the source of P during germination. At the 2-leaf stage, soil becomes the dominant P source. Root systems are very small at this time, and growth may be inhibited by unfavorable environmental conditions. The practice of placing small amounts of nutrients close to or with the seed at planting has proven effective at enhancing early season plant nutrient uptake and yield of corn.

Various placement methods have been adapted to provide options for starter fertilizer application. Some of the common starter placements include in-furrow in contact with the seed; banded near the seed either on the surface or, more traditionally, 2 in. to the side and 2 in. below the seed (2 × 2); or applied in a band over the seed row. In-furrow placement of fertilizer, commonly referred to as pop-up fertilizer, is intended to promote vigorous seedling growth because of supplying available nutrients to young plant root systems. Placing fertilizer in contact with seed increases the salt concentration surrounding the seed. With an increase in salt concentration, the plant's capacity to absorb water is greatly reduced; this may cause germination and growth problems. In-furrow placement of urea-containing starters can result in ammonia toxicity. Rapid hydrolysis of urea can result in production of very high concentrations of ammonia, which can result in plant stand loss. Subsurface band applications (2 × 2) have generally been proven to be a safe, effective way of applying nutrients as a starter. The fertilizer is separated from the seed, so larger amounts of nutrients can be applied without risking seedling injury. Many producers favor in-furrow application because of the low initial cost of planter-mounted equipment and problems associated with knife and coulter systems in high-residue environments. Surface dribble or band application of starter fertilizer has not been extensively investigated and compared with subsurface applications.

There also is debate on what elements should be included in starter fertilizers and in what ratios. Some studies that have evaluated crop response to N and P starter fertilizers have demonstrated improved early growth and yield increase and attributed those responses to the P component of the combination (Farber and Fixen, 1986). Other studies have indicated that N is the most critical nutrient (Touchton, 1988.). Other elements such as S (Niehues et al., 2004) and zinc (Zn) (Gordon and Pierzynski, 2006) can be important contributors to corn response to starter fertilizers.

Procedures

Irrigated, reduced-tillage experiments were conducted at the North Central Kansas Experiment Field to compare methods of application and composition of starter fertilizer.

Soil test P values were in the upper part of the medium range, and soil test K was in the high range. Soil organic matter was 2.5%, and pH was 7.0.

The study consisted of four methods of starter fertilizer application: in-furrow with the seed, 2 × 2 at planting, dribbled in a narrow band on the soil surface 1 in. to the side of the row at planting, and placed on the soil surface in an 8-in. band centered on the row. Starter fertilizer consisted of combinations that included either 5, 15, 30, 45, or 60 lb/a N with 15 lb/a P_2O_5 and 5/a lb K_2O. Nitrogen as 28% urea ammonium nitrate (UAN) was balanced so that all plots received 220 lb/a N regardless of starter treatment. Starter fertilizer combinations were made using liquid 10-34-0, 28% UAN, and potassium chloride (KCl).

Results

When starter fertilizer containing 5 lb/a N and 5 lb/a K_2O was applied in-furrow with the seed, plant population was reduced by more than 6,000 plants/a (Figure 2). As N rate increased, plant population continued to decrease. Averaged over starter fertilizer rate, corn yield was 36 bu/a lower when starter fertilizer was applied in-furrow with the seed than when applied 2 × 2 (Table 1). Dribble application of starter fertilizer in a narrow surface band to the side of the row was statistically equal to starter that was placed below the soil surface in the traditional 2 × 2 band. A surface band is much easier and much less costly to producers than the 2 × 2 band. The 8-in. band over-the-row treatment resulted in yields that were greater than those in the in-furrow treatment but less than those in the 2 × 2 or surface dribble treatments. The fertilizer band was just too diffuse to receive the full benefit of a starter fertilizer application. Regardless of whether the starter fertilizer was placed 2 × 2 or dribbled on the soil surface, yields increased with increasing starter N rate up to the 30 lb/a rate. Plant P content also increased with increasing N up to the 30 lb/a N rate (Figure 3).

In work done at Manhattan, KS, addition of sulfur to the starter fertilizer mix increased early season growth and yield of dryland corn. The starter fertilizer was applied 2 × 2, and N was balanced on all plots to bring the total amount applied to 160 lb/a.

There have been increasing numbers of reports of K deficiency on soils managed with reduced-tillage practices, even though soil test levels were not low. Results of a 2-year experiment at Scandia, KS, on a soil that tested high in available K indicate that addition of a small amount of K to the starter fertilizer mix can greatly improve K uptake, early season growth, and yield of irrigated corn (Table 2).

This experiment also points out another advantage of using starter fertilizer. The number of days from emergence to mid-silk was reduced from 79 with the no-starter check to 68 with the N-P-K starter. Heat stress can be a problem with corn production in the Great Plains, even when corn is grown under irrigation. Shortening the period of time from emergence to the critical reproductive stage of growth can ensure pollination occurs earlier in the growing season when temperatures are likely to be cooler, thus avoiding the hot temperatures of midsummer.

Zinc deficiencies can occur in areas where topsoil was removed by erosion, land leveling, or terracing (Gerwing et al., 1982). Zinc deficiencies are frequently reported during cool, wet springs and can be attributed to slow, microbial, temperature-dependant release of Zn from soil organic matter and to restricted root growth (Vitosh et al., 1981). High available soil P concentrations and high soil pH also can induce Zn deficiency (Murphy et al., 1981). Including Zn in a starter fertilizer mixture can be a convenient way to correct deficiency problems in corn. In an experiment conducted at Scandia, KS, on soil that had been leveled for furrow irrigation, two corn hybrids were compared for response to starter fertilizer with or without 1 lb/a Zn (Table 3). Although both hybrids responded well to addition of Zn in the starter, the magnitude of response in one of the hybrids tested was much greater than in the other.

Researchers have found that some corn hybrids grown under reduced-tillage conditions respond to starter fertilizer, whereas others do not (Table 4).

In this study conducted at Belleville, KS, under no-till conditions, three of the corn hybrids responded to addition of starter fertilizer containing 30 lb/a N and 30 lb/a P_2O_5, whereas the other two hybrids showed no response. Soil test P values were in the high category. In the three responding hybrids, starter fertilizer increased grain yield by 13 bu/a. Through further research, we found that addition of starter fertilizer increased the number and depth of roots for some corn hybrids but had no effect on other hybrids and that rooting characteristics were related to yield response to starter fertilizer (Gordon and Pierzynski, 2006). However, other research has not found any differential corn hybrid response to starter fertilizer (Buah et al., 1999).

Nutrient management in conservation-tillage systems can be challenging. The increased amounts of crop residue present in these systems can cause early season nutrient deficiency problems that the plant may not be able to overcome later in growing season. Early season nutrition is essential for maximum corn yield. Use of starter fertilizer has proven to be beneficial at overcoming some problems related to high-residue-production systems, even on soils that are not low in available nutrients. Because responses to starter fertilizer can be independent of soil test values, in any single growing season it may be difficult to predict which elements in a starter fertilizer mix may give the best results. Starters with a broad spectrum of nutrients may maximize early season growth and yield response of corn.

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Table 1. Starter fertilizer effects on corn yield, 3-year average

	Corn yield			
Starter N-P-K	In-furrow	2 × 2	Dribble	Row band
lb/a	---bu/a---			
5-15-5	172	194	190	179
15-15-5	177	197	198	180
30-15-5	174	216	212	192
45-15-5	171	25	213	195
60-15-5	163	214	213	201
Avg.	171	207	205	189

Table 2. Starter fertilizer effects on irrigated corn, 2-year average

Treatment $N-P_2O_5-K_2O$	V6 dry weight	V6 potassium uptake	Days to mid-silk	Grain yield
---lb/a---				bu/a
0-0-0-0	210	6.2	79	162
30-30-0	395	11.2	71	184
30-30-5	460	15.2	68	195

Table 3. Effects of starter with and without zinc on yield of two corn hybrids

	Corn yield	
Starter	Hybrid 1	Hybrid 2
	---bu/a---	
0-0-0-0-0	165	163
N-P-K-S	172	171
N-P-K-S-Zn	188	178

Table 4. Corn hybrid and starter fertilizer effects on corn grain yield, 3-year average

Hybrid	Starter	Grain yield
		bu/a
Hybrid 1	With	150
	Without	148
Hybrid 2	With	174
	Without	171
Hybrid 3	With	188
	Without	174
Hybrid 4	With	175
	Without	161
Hybrid 5	With	176
	Without	165
LSD (0.05)		9

Table adapted from Gordon et al. (1997).

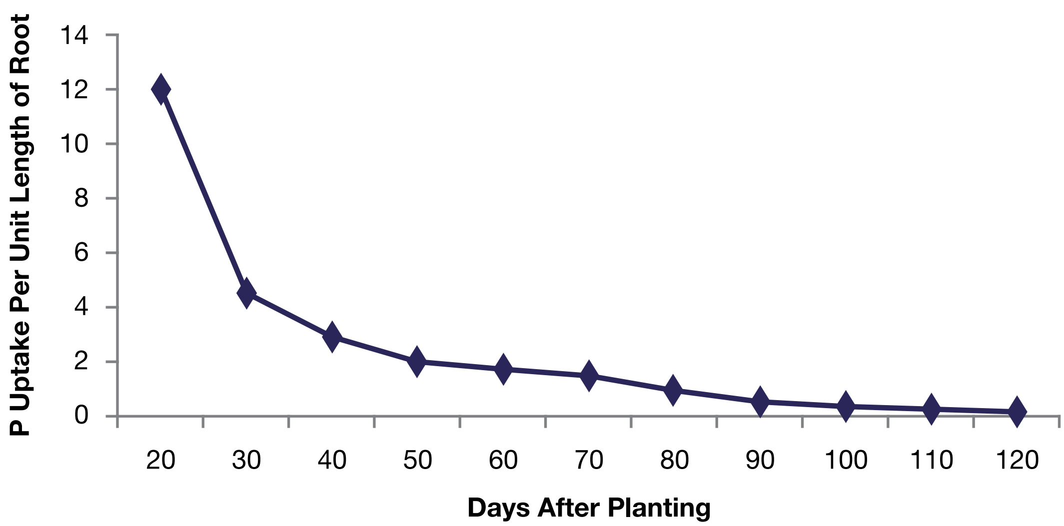

Figure 1. Phosphorus uptake per unit of root length over time.
Figure adapted from Mengel and Barber (1974).

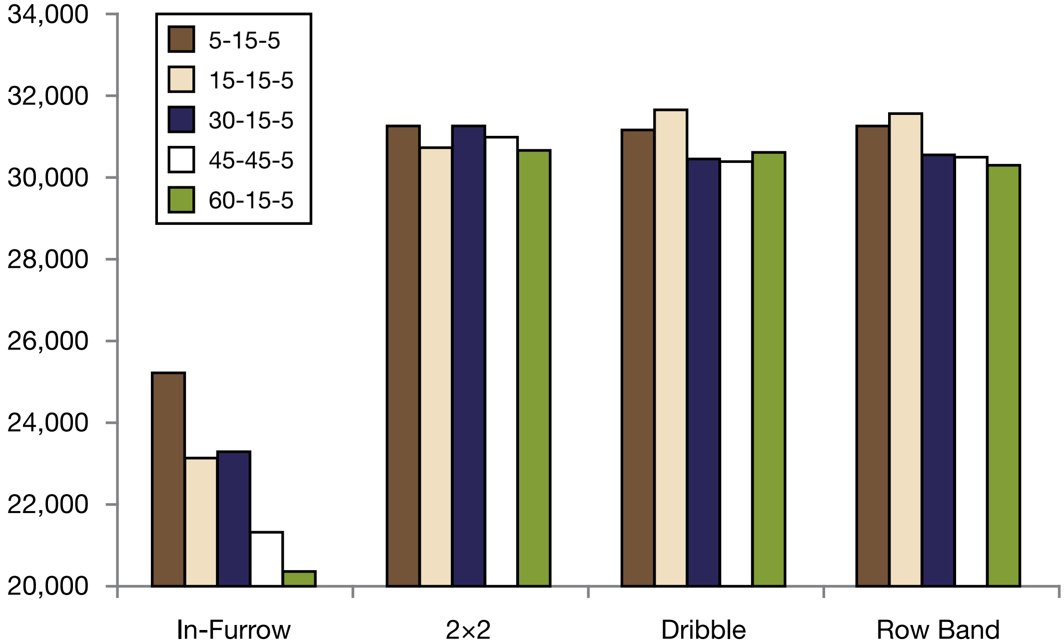

Figure 2. Plant population, 3-year average.

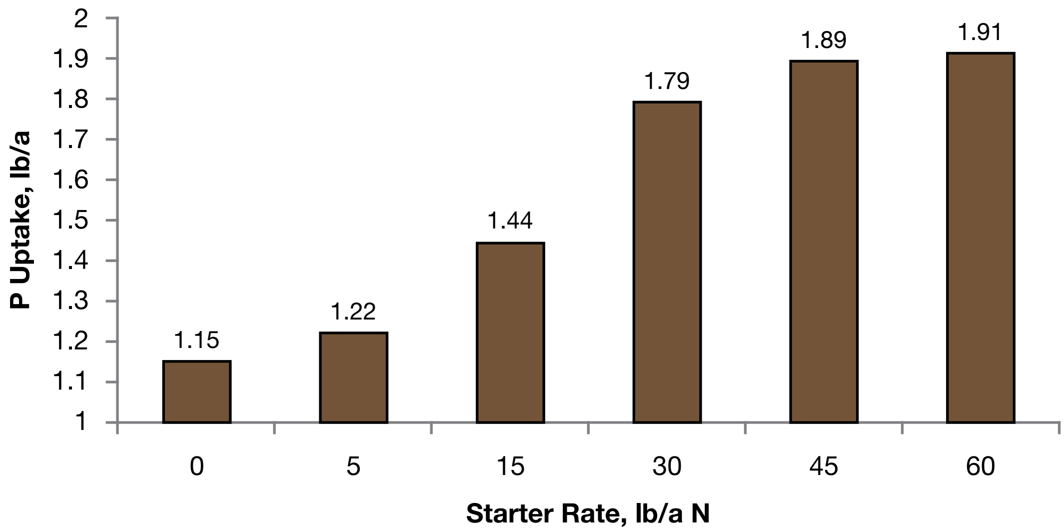

Figure 3. Starter nitrogen rate effects on V6 stage whole plant phosphorus uptake, 3-year average.

Chloride Fertilization for Wheat and Grain Sorghum

W. B. Gordon

Summary
Research to date on chloride (Cl) application on wheat shows a significant yield response in Kansas in a majority of experiments. Chloride affects the progression of some diseases by suppressing or slowing infection; it does not, however, completely eliminate diseases. Chloride responses have been noted even in absence of disease, suggesting some soils in Kansas may not be able to supply needed amounts of Cl. Soil test calibration experiments have shown that when soil Cl levels (0 to 24 in.) are below 20 to 30 lb/a, responses to applied Cl are likely. In these experiments with wheat and grain sorghum, Cl consistently increased grain yield.

Introduction
For wheat and other grains, Cl has been reported to have an effect on plant diseases by either suppressing the disease organism or improving overall plant health and allowing the plant to withstand infection. Researchers from all parts of the Great Plains have shown yield increases from Cl application. The objective of these experiments was to evaluate Cl fertilization on wheat and grain sorghum in north central Kansas.

Procedures
From 2004 to 2007, Cl rates of 10, 20, and 30 lb/a were applied to wheat variety 2145 at the North Central Kansas Experiment Field on a Crete silt loam soil. An unfertilized check plot also was included. The Cl source used was ammonium chloride (6% nitrogen (N) and 16.5% Cl). Nitrogen was balanced on all plots, with each plot receiving 90 lb/a N. Soil test Cl level at the test site was 15 lb/a in the top 24 in. of soil. Chloride was applied broadcast in the spring before jointing stage. In 2007 and 2008, the same Cl rates were applied to wheat variety Overley. Chloride was applied with or without the fungicide Quilt at the rate of 14 oz/a. The fungicide was applied at flag leaf emergence. During 2004 to 2007, Cl rates (0, 20 and 40 lb/a Cl) and method of application were evaluated on grain sorghum. Chloride was applied by using one of two methods: broadcast on the soil surface immediately after planting or applied as a starter placed 2 in. to the side and 2 in. below the seed at planting (2 × 2). The Cl source used was liquid ammonium chloride (NH_4Cl). The NH_4Cl was added to a starter fertilizer containing 30 lb/a N and 30 lb/a P_2O_5. Plots receiving broadcast NH_4Cl also received the same amount of starter fertilizer but without the NH_4Cl. Nitrogen was balanced on all plots so that plots received 150 lb/a N regardless of NH_4Cl treatment. The experiment was conducted in areas in which soil test Cl was 14 to18 lb/a Cl.

Results
Averaged over the 3-year period, addition of 10 lb/a Cl increased grain yield of 2145 wheat by 5 bu/a over the unfertilized check (Table 1). Addition of higher rates of Cl did not result in any increases in yield. In 2007 and 2008, addition of Cl to Overley wheat increased grain yield by 11 bu/a over the unfertilized check (Table 2). When no Cl was

applied, fungicide application improved grain yield by 5 bu/a compared with the no-fungicide check. When 10 lb/a Cl was applied with fungicide, yields were 5 bu/a greater than with Cl alone. At the two higher Cl rates, fungicide application did not result in statistically significantly yield increases.

Application of Cl increased grain sorghum yield in all 3 years of the experiment (Table 3). Averaged over years and methods of application, addition of 20 lb/a Cl increased yield by 11 bu/a over the untreated check. Applying Cl at a higher rate than 20 lb/a Cl did not significantly increase grain yield. Applying Cl as a 2 × 2 starter significantly increased grain yield in only 1 of the 3 years of the study. Averaged over years, there was no difference in application method. Results of this experiment suggest that when soil test Cl levels are below the 20 lb/a level, consistent increases in yield can be obtained with application of fertilizer containing Cl.

Table 1. 2145 wheat yield response to chloride application, 2004-2007

Chloride rate	2145 wheat yield
lb/a	bu/a
0	66
10	71
20	71
30	73
LSD (0.05) = 3	

Table 2. Overley wheat yield response to chloride and foliar fungicide application, 2007-2008.

	Overley wheat yield	
Chloride rate	No fungicide	Fungicide
lb/a	---------------------bu/a---------------------	
0	48	54
10	57	62
20	60	64
30	60	64
LSD (0.05) = 3		

Table 3. Grain sorghum yield response to chloride, 2004-2006

		Grain sorghum yield			
Method	Chloride rate	2004	2005	2006	Avg.
	lb/a	----------------------------bu/a----------------------------			
Check	0	120.3	115.2	125.8	120.4
Broadcast	20	127.0	124.2	133.2	128.1
	40	132.8	128.1	136.2	132.4
2 × 2	20	130.0	131.5	140.5	134.0
	40	131.0	131.3	139.0	133.8
Mean values					
Rate	0	120.3	115.2	125.8	120.4
	20	128.5	127.9	136.9	131.0
	40	131.9	129.7	137.6	133.1
LSD (0.05)		5.2	3.9	4.9	4.8
Method					
Broadcast		129.9	126.2	134.7	130.3
2 × 2		130.5	131.4	139.7	133.9

Effects of Nitrogen Rate and Previous Crop on Grain Yield in Continuous Wheat and Alternative Cropping Systems in South Central Kansas

W. F. Heer

Summary

Predominant cropping systems in south central Kansas have been continuous wheat and wheat/grain sorghum/fallow. With continuous wheat, tillage is preformed to control diseases and weeds. In the wheat/sorghum/fallow system, only two crops are produced every 3 years. Other crops (corn, soybean, sunflower, winter cover crops, and canola) can be placed in these cropping systems. To determine how winter wheat (and alternative crop) yields are affected by alternative cropping systems, winter wheat was planted in rotations following the alternative crops. Yields were compared with yield of continuous winter wheat under conventional tillage (CT) and no-till (NT) practices. Initially, CT continuous wheat yields were greater than those from the other systems. However, over time, wheat yields following soybean have increased, reflecting the effects of reduced weed and disease pressure and increased soil nitrogen (N). However, CT continuous winter wheat seems to out yield NT winter wheat regardless of the previous crop.

Introduction

In south central Kansas, continuous hard red winter wheat and winter wheat/grain sorghum/fallow are the predominate dryland cropping systems. The summer fallow period following sorghum is required because the sorghum crop is harvested in late fall, after the optimum planting date for wheat in this region. Average annual rainfall is only 30 in./year, with 60 to 70% occurring between March and July. Therefore, soil moisture is often not sufficient for optimum wheat growth in the fall. No-till systems often increase soil moisture by increasing infiltration and decreasing evaporation. However, higher grain yields associated with increased soil water in NT have not always been observed. Cropping systems with winter wheat following several alternative crops would provide improved weed control through additional herbicide options, reduce disease incidence by interrupting disease cycles, and allow producers several options under the 1995 Farm Bill. However, the fertilizer N requirement for many crops is often greater under NT than CT. Increased immobilization and denitrification of inorganic soil N and decreased mineralization of organic soil N have been related to the increased N requirements under NT. Therefore, effect of N rates on hard red winter wheat in continuous wheat and in cropping systems involving alternative crops for the area have been evaluated at the South Central Kansas Experiment Field. The continuous winter wheat study was established in 1979 and was restructured to include a tillage factor in 1987. The first of the alternative cropping systems in which wheat follows short-season corn was established in 1986 and modified in 1996 to a wheat/cover crop/grain sorghum rotation. The second alternative cropping system, established in 1990, has winter wheat following soybean. Both cropping systems use NT, seeding into the previous crop's residue. All three systems have the same N rate treatments.

Procedures

The research is conducted at the South Central Kansas Experiment Field–Hutchinson. Soil is an Ost loam. The sites were in wheat prior to the start of the cropping systems. The research is replicated four or five times in a randomized block design with a split-plot arrangement. The main plot is crop, and the subplot is six N levels (0, 25, 50, 75, 100, and 125 lb/a). Nitrogen treatments were broadcast applied prior to planting as NH_4NO_3 and as urea after ammonium nitrate became unavailable. Phosphate was applied in the row at planting. All crops were produced each year of the study and planted at the normal time for the area. Plots are harvested at maturity to determine grain yield, moisture, and test weight.

Continuous Wheat

These plots were established in 1979 and modified (split into subplots) in 1987 to include both CT and NT. The CT treatments are plowed immediately after harvest then worked with a disk as necessary to control weed growth. Fertilizer rates are applied with a Barber metered screw spreader prior to the last tillage (field cultivation) on the CT and seeding of the NT plots. Plots are cross seeded in mid-October to winter wheat. Because of a cheat infestation in the 1993 crop, plots were planted to oat in the spring of 1994. Fertility rates were maintained, and the oat was harvested in July. Winter wheat has been planted in mid-October each year in the plots since the fall of 1994. New herbicides have helped control cheat in the NT treatments. These plots were seeded to canola in the fall of 2005 and then back to wheat in October 2006. We hoped this would provide field data on the effects of canola on wheat yields in a continuous wheat cropping system. However, an extended freeze the first week of April had a major effect on wheat yields as discussed in the results section.

Wheat After Corn/Grain Sorghum/Fallow

Winter wheat is planted after short-season corn is harvested in late August to early September. This early harvest of short-season corn allows the soil profile water to be recharged (by normal late summer and early fall rains) before winter wheat is planted in mid-October. Fertilizer rates are applied with the Barber metered screw spreader in the same manner as for continuous wheat. In 1996, the corn crop in this rotation was dropped and three legumes (winter pea, hairy vetch, and yellow sweet clover) were added as winter cover crops. Thus, the rotation became a wheat/cover crop/grain sorghum/fallow rotation. The cover crops replaced the 25, 75, and 125 lb/a N treatments in the grain sorghum portion of the rotation. Yield data can be found in Field Research 2000, KAES Report of Progress 854.

Wheat After Soybean

Winter wheat is planted after soybean is harvested in early to mid-September. As with the continuous wheat plots, these plots are planted to winter wheat in mid-October. Fertilizer rates are applied with the Barber metered screw spreader in the same manner as for continuous wheat. Since 1999, a group III soybean has been used. This delayed harvest from late August to early October. In some years, this effectively eliminates the soil profile water recharge time prior to wheat planting.

Wheat After Grain Sorghum in a Cover Crop/Fallow/Grain Sorghum/Wheat Rotation

Winter wheat is planted into stubble from grain sorghum harvested the previous fall. Thus, soil profile water has had 11 months to recharge before winter wheat is planted in mid-October. Nitrogen fertilizer is applied at a uniform rate of 75 lb/a with the Barber metered screw spreader in the same manner as for the continuous wheat. This rotation was terminated after the harvest of each crop in 2006. In the fall of 2006, canola was introduced into this rotation in place of the cover crops. The winter canola did not establish uniformly, so spring canola was seeded into these plots to establish canola stubble for the succeeding crop.

Winter wheat is also planted after canola and sunflower to evaluate the effects of these two crops on winter wheat yield. Uniform N fertility is used; therefore, this data is not presented. Yield of wheat after these two crops is comparable to yield of wheat after soybean.

Results

The major influence on all wheat yields in 2008 regardless of rotation or N rate was the wall of hail on May 5. Therefore, it will be hard to use this data to determine any treatment effects in 2008. Several wheat plots were not harvested because the hail damage was so severe.

Continuous Wheat–Canola 2006

Continuous winter wheat grain yield data from the plots are summarized by tillage and N rate in Table 1. Data for years prior to 1996 can be found in Field Research 2000, KAES Report of Progress 854. Conditions in 1996 and 1997 were excellent for winter wheat production in spite of the dry fall of 1995 and the late spring freezes in both years. Excellent moisture and temperatures during the grain filling period resulted in decreased grain yield differences between the CT and NT treatments within N rates. Conditions in the springs of 1998 and 1999 were excellent for grain filling in wheat. However, differences in yield between CT and NT wheat were still expressed. In 2000, differences were wider up to the 100 lb/a N rate. At that point, differences were similar to those of previous years (data for the years 1996 through 2000 can be found in Agronomy Field Research 2006, KAES Report of Progress 975). The wet winter and late spring of the 2003-2004 harvest year allowed for excellent tillering, grain fill, and yields (Table 1). In 2005, the dry period in April and May seemed to affect yields in the 0 and 25 lb/a N rate plots. These plots were seeded to canola in the fall of 2005. Canola in the NT plots did not survive. Yield data for the CT plots is presented in Table 1. There was a yield increase for each increase in N rate. However, the increase was not significant above the 50 lb/a rate. All N fertilizer was applied in the fall, and effects of the winterkill were more noticeable at the lower N rates. An N-rate study with canola was established at the Redd Foundation land to more fully evaluate effects of fertility on canola. Wheat planted after canola looked promising until the April freeze. Because of the growth stage at the time of the freeze, the lower N rate and NT treatment had higher yields than the CT and higher N rate treatments (Table 1). The higher yielding treatments were slightly behind the other plots when the freeze hit; thus, they were not affected as severely by the freeze. These plots were not harvested for yield data in 2008 because of the severe hail damage from the May 5 storm.

Wheat After Soybean

Wheat yields after soybean also reflect differences in N rate. However, when comparing wheat yields from this cropping system with yields from systems in which wheat followed corn, effects of residual N from soybean production in the previous year are evident, particularly for the 0 to 75 lb/a N rates in 1993 and the 0 to 125 lb/a rates in 1994. Yields for 1995 reflect the added N from the previous soybean crop with yield by N rate increases similar to those of 1994. The 1996 yields with spring wheat reflect the lack of response to N fertilizer in spring wheat. Yields for 1997 and 1998 leveled off after the first four increments of N. As with wheat in the other rotations in 1999, ideal moisture and temperature conditions allowed wheat yields after soybean to express differences in N rate up to the 100 lb/a N rate. In the past, those differences stopped at the 75 lb/a N rate. Compared with continuous wheat yields, rotational wheat is starting to reflect the presence of the third crop (grain sorghum) in the rotation. Wheat yields were lower in 2000 than in 1999. This is due to the lack of timely moisture in April and May and the hot days at the end of May. Data for the years 1991 through 2000 can be found in Agronomy Field Research 2006, KAES Report of Progress 975. This heat caused plants to mature early and also caused low test weights. There was not as much cheat in 2004 as in 2003; thus, yields were much improved (Table 2). Yields in 2004 through 2006 indicate that wheat is showing a 50 to 75 lb/a N credit from the soybean and rotational effects. The early April freeze had a major effect on wheat yields in 2007. The effect of the May 2008 hail is reflected in the yields as well as the CV for the data (Table 2). However, the trend for N credits to soybean seems to have continued. As with the continuous wheat cropping system, yields for the 0 and 25 lb/a N rates were less than those for the 50 to 125 lb/a rates, but the differences are not significant. As the rotation continues to cycle, differences at each N rate will probably stabilize after four to five cycles, potentially reducing fertilizer N applications by 25 to 50 lb/a in treatments in which wheat follows soybean.

Wheat After Grain Sorghum/Cover Crop

These plots were severely damaged by the hail on May 5, 2008, and, therefore, were not harvested for yield data. This is only the second time that the wheat plots were not harvested since the rotations were started in this location in 1986. The first year that wheat was harvested after a cover crop/grain sorghum planting was 1997. Data for the years 1997 through 2000 can be found in Agronomy Field Research 2006, KAES Report of Progress 975. From 1997 to 2000, there did not appear to be a definite effect of the cover crop on yield. This is most likely due to the variance in cover crop growth within a given year. In years like 1998 and 1999 when sufficient moisture and warm winter temperatures produced good cover crop growth, additional N from the cover crop appears to carry through to wheat yields. With the fallow period after sorghum in this rotation, the wheat crop has a moisture advantage over wheat after soybean. Cheat was the limiting factor in this rotation in 2003. More aggressive herbicide control of cheat in the cover crops was started, and 2004 yields reflect the control of cheat. Management of grasses in the cover crop portion of this rotation seems to be the key factor in controlling cheat and increasing yields. This is evident when yields for 2005 and 2006 (Table 3) are compared with either continuous wheat yields or yields from wheat in rotation with soybean. Because of the stage of development at the time of the April freeze, wheat yields in these plots were more adversely affected than yields of plants in other rotations. We think that lack of a third crop taken to maturity has positively influenced yields.

Other Observations

Nitrogen application significantly increased grain N contents in all crops. Grain phosphate levels did not seem to be affected by increased N rate.

Loss of the wheat crop after corn can occur in years when fall and winter moisture are limited. This loss has not occurred in continuous winter wheat regardless of tillage or in wheat after soybean. Corn has potential to produce grain in favorable (cool and moist) years and silage in non-favorable (hot and dry) years. In extremely dry summers, extremely low grain sorghum and soybean yields can occur. The major weed control problem in the wheat-after-corn system is grasses. This was expected, and work is being done to determine the best herbicides and time of application to control grasses.

Soybean and Grain Sorghum in the Rotations

Soybean was added to intensify the cropping system in south central Kansas. Soybean, a legume, can add N to the soil system. Thus, N rates are not applied when soybean is planted in the plots for the rotation. This provides opportunities for following crops to use the added N and to check yields against yields for the crop in other production systems. Yield data for soybean following grain sorghum in the rotation are given in Table 4. Soybean yields are affected more by the weather for the given year than by the previous crop. This is seen in yields for 2001, 2003, 2005, 2006, 2007, and 2008, when summer growing season moisture was limiting. As in 2007, a combination of a wet spring that delayed planting and a hot, dry period from July through early September 2008 affected yields. There has been a significant effect of N on soybean yield in only 3 out of the 13 years that the research has been conducted. In the 2 of the 3 years that N application rate affected yield, it did so only at the lower N rates.

Yield data for grain sorghum after wheat in the soybean/wheat/grain sorghum rotation is shown in Table 5. As with soybean, weather is the main factor affecting yield. Addition of a third cash crop (soybean), which intensifies the rotation (cropping system), will reduce the yield of grain sorghum in the soybean/wheat/grain sorghum vs. the wheat/cover crop/grain sorghum rotation (Tables 5 and 6). More uniform yields were obtained in the soybean/wheat/grain sorghum rotation (Table 5) than in the wheat/cover crop/grain sorghum rotation (Table 6). The lack of precipitation in 2005 and 2006 can be seen in grain sorghum yields for 2006. As with soybean, the combination of a wet spring that delayed planting and the hot, dry period from July through early September affected yields. The cool, wet weather in September and October 2008 delayed maturation, and the grain did not dry down until after the first killing frost. Grain sorghum yields were reduced in the intensified cropping system (soybean, wheat, and grain sorghum) compared with the less intense rotation (wheat, winter cover crop, grain sorghum).

Other systems studies at the field are a wheat/cover crop (winter pea)/grain sorghum rotation with N rates (detailed below) and a date of planting, date of termination cover crop rotation with small grains (oat)/grain sorghum.

Table 1. Wheat (2001-2005), canola (2006), and wheat (2007) yields by tillage and nitrogen rate in a continuous wheat cropping system, South Central Kansas Experiment Field, Hutchinson

	Yield[1]													
	2001		2002		2003		2004		2005		2006		2007	
N Rate	CT[2]	NT	CT	NT	CT	NT	CT	NT	CT	NT	CT	NT[3]	CT	NT
lb/a	bu/a													
0	50	11	26	8	54	9	66	27	47	26	10	0	15	14
25	53	26	34	9	56	9	68	41	63	36	19	0	13	16
50	54	35	32	8	57	22	65	40	68	38	26	0	12	14
75	58	36	34	7	57	42	63	37	73	43	28	0	12	14
100	54	34	35	5	56	35	64	43	73	40	31	0	9	13
125	56	36	32	5	57	38	63	31	69	35	31	0	9	16
LSD[4] (0.01)	10	10	6	NS	NS	18	NS	9	14	14	6	0	6	NS

Plots were not harvested for yield data in 2008 because of severe hail damage.

[1] Data for years prior to 1996 can be found in Field Research 2000, KAES Report of Progress 854. Data for the years 1996 through 2000 can be found in Agronomy Field Research 2006, KAES Report of Progress 975, p. SC-8.

[2] CT = conventional tillage; NT = no-till.

[3] NT canola did not get established.

[4] Unless two yields in the same column differ by at least the least significant difference (LSD), little confidence can be placed in one being greater than the other.

Table 2. Wheat yields after soybean in a soybean/wheat/grain sorghum rotation with nitrogen rates, South Central Kansas Experiment Field, Hutchinson

	Yield[1]							
N Rate	2001	2002[2]	2003	2004	2005	2006	2007	2008
lb/a	---bu/a---							
0	12	9	31	40	30	29	15	9
25	16	10	48	46	43	38	21	15
50	17	9	59	48	49	46	23	19
75	17	7	65	46	52	46	24	23
100	20	8	67	43	50	52	23	23
125	21	8	66	40	48	50	20	23
LSD[3] (0.01)	7	4	3	5	5	3	3	3
CV (%)	23	24	4	6	6	5	9	11

[1] Data for the years 1991 through 2000 can be found in Agronomy Field Research 2006, KAES Report of Progress 975, p. SC-9.
[2] Yields severely reduced by hail.
[3] Unless two yields in the same column differ by at least the least significant difference (LSD), little confidence can be placed in one being greater than the other.

Table 3. Wheat yields after grain sorghum in a wheat/cover crop/grain sorghum rotation with nitrogen rates, South Central Kansas Experiment Field, Hutchinson

	Yield[1]						
N Rate	2001	2002[2]	2003	2004	2005	2006	2007
lb/a	---bu/a---						
0	45	10	9	47	59	38	10
HV[3]	45	10	5	36	63	58	13
50	41	8	4	35	56	61	15
WP[3]	41	9	8	37	60	64	13
100	39	5	5	32	55	58	14
SC[3]	42	6	6	36	55	55	11
LSD[4] (0.01)	5	3	NS	8	6	5	2
CV (%)	6	20	70	12	6	7	10

[1] Data for the years 1997 through 2000 can be found in Agronomy Field Research 2006, KAES Report of Progress 975, p. SC-10.
[2] Yields severely reduced by hail.
[3] HV = hairy vetch; WP = winter pea; SC = sweet clover.
[4] Unless two yields in the same column differ by at least the least significant difference (LSD), little confidence can be placed in one being greater than the other.

Table 4. Soybean yields after grain sorghum in a soybean/wheat/grain sorghum rotation with nitrogen rates, South Central Kansas Experiment Field, Hutchinson

	Yield												
N Rate[1]	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
lb/a	bu/a												
0	16	26	22	33	25	7	22	5	53	20	18	15	36
25	17	29	23	35	21	8	22	6	50	19	18	16	39
50	18	30	23	36	23	9	22	6	50	18	18	14	37
75	20	29	24	36	24	8	21	7	51	18	18	15	37
100	22	31	25	37	21	9	21	7	51	19	18	16	39
125	20	25	24	34	22	8	22	7	49	19	19	14	39
LSD[2] (0.01)	3	NS	NS	NS	NS	NS	NS	1.4	NS	NS	1	NS	NS
CV (%)	10	12	6	12	15	13	7	17	6	11	5	11	8

[1] N rates are not applied to the soybean plots in the rotation.
[2] Unless two yields in the same column differ by at least the least significant difference (LSD), little confidence can be placed in one being greater than the other.

Table 5. Grain sorghum yields after wheat in a soybean/wheat/grain sorghum rotation with nitrogen rates, South Central Kansas Experiment Field, Hutchinson

	Yield												
N Rate	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007[1]	2008
lb/a	bu/a												
0	32	13	57	52	55	15	34	10	86	86	19	–	39
25	76	29	63	67	56	15	41	10	112	90	18	–	43
50	93	40	61	82	54	13	43	9	129	97	16	–	54
75	107	41	60	84	49	9	43	8	136	95	14	–	56
100	106	65	55	77	50	7	46	8	141	101	12	–	61
125	101	54	55	82	49	7	47	9	142	95	12	–	74
LSD[2] (0.01)	8	13	NS	13	NS	NS	8	NS	9	12	4	–	16
CV (%)	5	18	10	9	10	58	11	24	4	7	18	–	17

[1] Because of the dry, hot conditions in July and August and the excessive amount of bird damage (100% in some plots), these plots were not harvested for yield in 2007.
[2] Unless two yields in the same column differ by at least the least significant difference (LSD), little confidence can be placed in one being greater than the other.

Table 6. Grain sorghum yields after canola in a canola/grain sorghum/wheat rotation with nitrogen rates, South Central Kansas Experiment Field, Hutchinson

	Yield[1]												
N Rate	1996	1997	1998	1999	2000	2001	2002[2]	2003	2004	2005	2006	2007	2008
lb/a	-------------------------bu/a-------------------------												
0	73	26	69	81	68	17	22	21	92	84	20	37	70
25	99	36	70	106	54	17	21	16	138	93	21	50	85
50	111	52	73	109	66	13	25	15	135	90	28	48	98
75	93	35	72	95	51	19	23	17	138	101	23	52	96
100	109	54	67	103	45	12	25	14	136	89	27	52	100
125	94	21	72	92	51	19	19	19	94	80	28	53	101
LSD[3] (0.01)	13	14	NS	21	16	6	NS	5	19	16	6	16	18
CV (%)	8	22	13	12	16	21	20	22	9	10	19	18	11

[1] In years 1996-2007, the 25, 75, and 125 lb/a N rates were replaced with hairy vetch (HV), winter pea (WP), and sweet clover (SC), respectively.
[2] Yields affected by hot, dry conditions in July and bird damage.
[3] Unless two yields in the same column differ by at least the least significant difference (LSD), little confidence can be placed in one being greater than the other.

Effects of Termination Date of Austrian Winter Pea Winter Cover Crop and Nitrogen Rates on Grain Sorghum and Wheat Yields

W. F. Heer

Summary
Effects of the cover crop most likely were not expressed in the first year (1996) grain sorghum harvest (Table 8 in Agronomy Field Research 2005, KAES Report of Progress 956). Limited growth of the cover crop (winter pea) due to weather conditions produced limited amounts of organic nitrogen (N). Therefore, effects of the cover crop compared with fertilizer N were limited and varied. The 1998 wheat crop was harvested in June. Winter pea plots were then planted and terminated the following spring prior to planting of the 1999 grain sorghum plots. The N rate treatments were applied and grain sorghum was planted on June 11, 1999. Winter wheat was again planted on the plots in October 2000 and harvested in June 2001. Winter pea was planted in September 2001 and terminated in April and May 2002. Grain sorghum was planted in June and harvested in October. During 2003, this area was in sorghum fallow, and plots were fertilized and planted to wheat in October 2003 for harvest in 2004. The winter pea cover crop was planted into wheat stubble in the fall of 2004. These plots were terminated as indicated in Table 1 and planted to grain sorghum in June 2005. Plots were again in sorghum fallow until planted to wheat in the fall of 2006. These plots were harvested in June 2007. As with other wheat plots on the field, the April freeze was the major yield-determining factor. Wheat yield data is shown in Table 1.

Introduction
There is a renewed interest in using winter cover crops to conserve soil and water, substitute for commercial fertilizer, and maintain soil quality. One winter cover crop that may be a good candidate for these purposes is winter pea. Winter pea is established in the fall, overwinters, produces sufficient spring foliage, and is returned to the soil prior to planting of a summer annual. Because winter pea is a legume, it can add N to the soil system. Research projects were established at the South Central Kansas Experiment Field to evaluate the effect of winter pea and its ability to supply N to the succeeding grain sorghum crop compared with commercial fertilizer N in a winter wheat/winter pea/grain sorghum rotation with two termination dates for the winter pea and four N rates with and without winter pea.

Procedures
The research is being conducted at the South Central Kansas Experiment Field–Hutchinson. Soil in the experimental area is an Ost loam. The site was in wheat prior to the cover crop cropping system. The research uses a randomized block design and is replicated four times. Cover crop treatments consist of fall-planted winter pea with projected termination dates in April and May and no cover crop (fallow). Winter pea is planted into wheat stubble in early September at a rate of 35 lb/a in 10-in. rows with a double disk opener grain drill. Prior to termination of the cover crop, above ground biomass

samples are taken from a 1-m^2 area and used to determine forage yield (winter pea and other), forage N content, and phosphate content for the winter pea portion. Four fertilizer treatments (0, 30, 60, and 90 lb/a N) are broadcast applied as NH_4NO_3 (34-0-0) prior to planting of grain sorghum. Phosphate is applied at a rate of 40 lb/a P_2O_5 in the row at planting. Grain sorghum plots are harvested to determine grain yield, moisture, test weight, N content, and phosphate content. Sorghum plots are fallowed until the plot area is planted to wheat in the fall of the following year. Fertilizer treatments are also applied prior to planting of wheat.

Results

Winter Wheat

The fall of 2000 was wet and followed a very hot, dry August and September. Thus, wheat planting was delayed. Fall temperatures were warm, which allowed wheat to tiller into late December. January and February had above-normal precipitation. Precipitation and temperature in April, May, and June were slightly below normal. Wheat yields reflect the presence of the winter pea treatments as well as the reduced grain sorghum yields for the no-pea treatment plots. Test weight of the grain and percentage of N in the seed at harvest were not affected by pea or fertilizer treatment but were affected by rainfall at harvest time. Weed pressure is a concern. The April-termination pea plus 90 lb/a N treatment had significantly more weeds than other treatments. Except for this treatment, there were no differences noted for weed pressure. Grain yield data are presented in Table 1. Because of earlier planting for the 2004 crop, wheat should have had a better chance to tiller, but the wet, cold fall limited growth. Wheat yields were considerably greater than those of 2002 (Table 1). As with all other wheat plots, yields in 2007 were adversely affected by the April freeze. The 2007 yields are presented in Table 1, but fertility and lack of winter pea presence in the rotation caused differences in stage of growth at the time of the freeze. Plots (treatments) that were further along were affected more; thus, the higher fertility plots had lower yields.

Grain Sorghum

The first increment of N resulted in the greatest change in yield, and yields tended to peak at the 60 lb/a N rate treatment regardless of the presence or lack of winter pea. Grain sorghum yields for 2002 are presented in Table 2. These yields reflect the later planting date (June 22). The 2002 growing season favored the later planted summer crops. These emerged after the June 15 hail storm and were not as mature for the August wind storm; thus, they had less lodging and stock damage, resulting in less secondary tillering and fewer sucker heads. This allowed the main head to fill and produce a quality grain. The 2008 yields (Table 2) express the presence of the winter pea cover crop. For the April termination for which there was no pea planted and no N added, treatments yielded about half as much as treatments that had peas and no additional N. This difference diminished as N rate increased and for treatments in which peas were terminated in May.

The 2008 data indicates that as this rotation continues and the soil system adjusts, the rotation will reveal the true effects of the winter cover crop. It is important to remember that in the dry (normal) years, soil water (precipitation) during the growing season most likely will not be as favorable as it was in 1999, and water use by the cover crop will be the main influence on yield of the succeeding crop.

Table 1. Winter wheat yield after grain sorghum as affected by nitrogen rate, winter pea cover crop, and termination date in a winter wheat/winter pea cover crop/grain sorghum rotation, South Central Kansas Experiment Field, Hutchinson

Termination Date	N Rate[1]	Grain Yield 2001	Grain Yield 2004	Grain Yield 2007	Grain N 2001	Grain N 2004	Grain N 2007	Grain P 2001	Grain P 2004	Grain P 2007
	lb/a		bu/a				-------%-------			
April[2] N/pea	0	37	58	15	2.32	1.73	2.14	0.38	0.38	0.46
	30	40	56	15	2.43	1.94	2.14	0.36	0.36	0.45
	60	39	51	11	2.30	2.23	2.25	0.38	0.34	0.46
	90	37	44	12	2.24	2.27	2.23	0.38	0.35	0.45
April[2] /pea	0	39	58	14	2.38	1.89	2.18	0.35	0.38	0.48
	30	42	55	13	2.33	1.97	2.26	0.37	0.34	0.47
	60	36	50	8	2.22	2.23	2.28	0.40	0.33	0.47
	90	37	47	8	2.18	2.46	2.40	0.37	0.32	0.47
May[3] N/pea	0	38	57	16	2.30	1.79	2.09	0.37	0.36	0.45
	30	38	53	15	2.32	2.13	2.17	0.37	0.34	0.45
	60	34	46	11	2.42	2.30	2.29	0.35	0.35	0.47
	90	38	44	11	2.24	2.37	2.29	0.35	0.35	0.46
May[3] /pea	0	42	60	14	2.37	1.91	2.14	0.40	0.36	0.47
	30	37	50	10	2.38	2.19	2.28	0.38	0.35	0.47
	60	35	45	6	2.38	2.33	2.35	0.37	0.33	0.46
	90	37	45	6	2.34	2.42	2.40	0.38	0.34	0.46
LSD[4] (0.05)		5	6	4	0.18	0.12	0.14	0.03	0.03	0.01

[1] Nitrogen applied as 34-0-0 before planting winter wheat.
[2] Early April termination.
[3] Early May termination.
[4] Unless two yields in the same column differ by at least the least significant difference (LSD), little confidence can be in one being greater than the other

.

Table 2. Grain sorghum yield as affected by nitrogen rate, winter pea cover crop, and termination date in a winter wheat/winter pea cover crop/grain sorghum rotation, South Central Kansas Experiment Field, Hutchinson

		Flag leaf 1996		Grain 1996			Grain 1999			Grain 2002			Grain 2005			Grain 2008		
Date	N Rate[1]	N	P	N	P	Yield	N	P	Yield	N	P	Yield	N	P	Yield	N	P	Yield
	lb/a	--%--		--%--		bu/a	--%--		bu/a	--%--		bu/a	--%--		bu/a	--%--		bu/a
April[2]	0	2.5	0.38	1.6	0.26	86.5	1.1	0.32	72.6	1.5	0.38	78.4	1.0	0.31	54	1.2	0.32	36.0
	30	2.7	0.44	1.6	0.27	93.9	1.2	0.29	90.9	1.6	0.40	87.5	1.1	0.29	76	1.3	0.34	50.8
	60	2.8	0.43	1.7	0.27	82.6	1.5	0.32	06.4	1.8	0.40	82.8	1.4	0.31	94	1.4	0.34	59.3
	90	2.8	0.44	1.7	0.25	90.4	1.7	0.34	01.8	1.8	0.35	92.5	1.5	0.31	96	1.4	0.35	61.7
April[2] /pea	0	2.4	0.40	1.5	0.29	80.2	1.3	0.31	93.5	1.6	0.37	79.9	1.4	0.29	102	1.2	0.35	68.9
	30	2.7	0.39	1.6	0.26	85.7	1.3	0.32	97.4	1.7	0.38	91.1	1.4	0.31	107	1.3	0.32	72.8
	60	2.7	0.38	1.7	0.27	90.0	1.5	0.33	05.1	1.8	0.40	87.5	1.5	0.31	107	1.4	0.33	73.1
	90	2.9	0.41	1.8	0.23	83.8	1.8	0.32	97.9	2.0	0.37	77.2	1.6	0.32	98	1.4	0.33	68.9
May[3]	0	2.1	0.39	1.4	0.30	81.4	1.1	0.34	40.5	1.6	0.41	56.4	1.1	0.31	67	1.3	0.34	47.1
	30	2.4	0.39	1.5	0.28	88.1	1.1	0.32	66.6	1.7	0.40	71.6	1.1	0.30	92	1.3	0.33	73.2
	60	2.6	0.40	1.6	0.27	90.7	1.2	0.30	93.3	1.8	0.40	71.4	1.2	0.31	95	1.3	0.33	66.8
	90	2.6	0.40	1.6	0.26	89.6	1.4	0.31	05.9	1.9	0.40	82.6	1.4	0.33	95	1.4	0.34	65.7
May[3] /pea	0	2.3	0.40	1.4	0.29	85.0	1.2	0.31	92.4	1.7	0.39	74.8	1.4	0.31	95	1.3	0.33	74.5
	30	2.5	0.40	1.5	0.31	92.4	1.3	0.31	97.7	1.8	0.38	81.5	1.5	0.30	98	1.3	0.33	78.9
	60	2.6	0.38	1.6	0.26	92.9	1.5	0.30	12.3	1.9	0.36	86.8	1.6	0.30	91	1.4	0.34	77.8
	90	2.7	0.41	1.6	0.25	90.5	1.5	0.32	08.7	1.8	0.39	90.3	1.6	0.31	98	1.4	0.34	87.6
LSD		0.2	0.02	0.1	NS	8.9	0.2	0.04	16.0	0.14	0.05	14.0	0.11	0.02	15	0.1	0.03	24

[1] Nitrogen applied after winter pea termination prior to planting grain sorghum.

[2] Early April termination. Actual termination: May 16, 1996, April 21, 1999, April 13, 2002, and April 27, 2005.

[3] Early May termination. Actual termination: June 4, 1996, May 19, 1999, May 25, 2002, and May 18, 2005.

Effects of Nitrogen Fertilizer Rate and Time of Application on Corn and Grain Sorghum Yields

K. W. Kelley and D. W. Sweeney

Summary
Effects of various rates of fertilizer nitrogen (N) applied preplant or side-dressed have been evaluated with corn and grain sorghum in southeastern Kansas since 2005. Averaged over 3 years, fertilizer N rate has influenced both corn and grain sorghum yields more than time of N application when these crops follow double-crop soybean in a 2-year cropping rotation.

Introduction
Because of recent increases in N fertilizer prices, producers are looking to reduce production costs for feed-grain crops, such as corn and grain sorghum. There is renewed interest in applying some of the fertilizer N requirement after the crop has emerged, referred to as side-dressing. Some research has shown that a subsurface application of banded N after the crop has emerged results in more efficient N use and often increases net return. In southeastern Kansas, excessive spring rainfall also increases the potential for greater N loss where fertilizer N is applied preplant.

Procedures
Studies were established at the Columbus Unit of the Southeast Agricultural Research Center in 2005 to evaluate effects of time and rate of N fertilizer application on both corn and grain sorghum. Fertilizer (28% liquid N) treatments consisted of different N rates applied preplant or side-dressed. Preplant N fertilizer was subsurface applied before planting on 15-in. centers at a depth of 4 to 6 in. Side-dress N also was subsurface applied between 30-in. rows. All plots received 30 lb/a N preplant as 18-46-0. In 2008, corn was planted in late April and grain sorghum near May 20. Side-dress N was applied June 18 for both crops. The previous crop was double-crop soybean.

Results
Corn and grain sorghum yield responses to fertilizer N for 2008 and 3-year averages are shown in Table 1. In the spring of 2008, above-normal rainfall (28 in.) occurred during the 3-month period from April through June. Even though soil moisture was excessive during early spring, water did not pond on the soil surface. Corn yields in 2008 showed no increase above the 120 lb/a N rate, but 3-year corn yield averages were greater for the 150 lb/a N rate. Corn yields responded more to rate than time of fertilizer N application. Under conditions in this study, in which denitrification N loses were likely small, corn yields were greater when fertilizer N was applied preplant than when it was side-dressed, although grain yield differences were not large over the 3-year period.

Similar to corn, grain sorghum yields generally increased with increasing N rates, although 3-year average yields showed the 120 lb/a N rate was most efficient. Time of fertilizer N application did not have a significant effect on grain sorghum yields.

Table 1. Effects of nitrogen fertilizer rate and time of application on corn and grain sorghum yields, Southeast Agricultural Research Center, Columbus Unit

Rate of fertilizer N[1]		Grain yield			
		Corn		Grain sorghum	
Preplant	Side-dress	2008	3-year avg.	2008	3-year avg.
---------lb/a---------		---------------------------bu/a---------------------------			
30	0	77.2	77.8	70.2	88.4
60	0	89.6	92.0	94.8	108.7
90	0	111.8	111.1	110.4	118.1
120	0	129.6	122.0	121.8	130.2
150	0	130.4	128.5	133.1	132.0
30	30	84.2	89.1	97.5	109.5
30	60	103.3	107.3	110.0	121.3
30	90	116.7	118.7	121.7	132.6
30	120	113.4	126.6	130.1	135.0
LSD (0.05)		6.4	6.1	4.4	6.4

[1] 30 lb/a N applied as 18-46-0 to all treatments.

Effects of Phosphorus and Potassium Fertilizer Rate and Time of Application in a Wheat Double-Cropping System

K. W. Kelley and D. W. Sweeney

Summary
Neither rate nor timing of phosphorus (P) and potassium (K) fertilizer application significantly affected grain yields of grain sorghum, wheat, and double-crop soybean during initial stages of this long-term study.

Introduction
Timing and rate of fertilizer P and K application are important crop production management decisions. In southeastern Kansas, producers often plant wheat following harvest of a feed-grain crop, such as grain sorghum or corn, and then plant double-crop soybean after wheat, giving three crops in 2 years. In these multiple-crop systems, producers typically apply fertilizer P and K only to the feed-grain and wheat crops. Because fertilizer costs are increasing, this research seeks to determine direct and residual effects of rate and timing of P and K fertilizer application on grain yields in a double-cropping system.

Procedures
This study was established in 2004 at the Columbus Unit of the Southeast Agricultural Research Center. Crop rotation consists of grain sorghum/(wheat – double-crop soybean), giving three crops in a 2-year period. Grain sorghum is planted with conventional tillage, and wheat and double-crop soybean are planted with no-till. Different P and K fertilizer rates are applied preplant to the grain sorghum crop only or to both the grain sorghum and wheat crops. Initial soil test values before study establishment were 23 ppm Bray-1 P and 160 ppm exchangeable K for the 0- to 6-in. soil depth. Soil has been sampled each year since study establishment for nutrient availability following the double-crop soybean harvest.

Results
Effects of various P and K fertilizer treatments on grain sorghum, wheat, and double-crop soybean yields are shown in Table 1. Fertilizer treatments have affected grain yields very little during initial years of study establishment. The nonsignificant yield response was not unexpected because initial soil test values indicated soil P and K values were sufficient for expected yield goals.

Nutrient removal in harvested grain for 100 bu/a grain sorghum, 50 bu/a wheat, and 25 bu/a double-crop soybean is 87 lb/a P_2O_5 and 72 lb/a K_2O. Thus, this study will continue for several cropping cycles to monitor residual effects of P and K fertilizer treatments on grain yields and soil nutrient concentrations of P and K.

Table 1. Effects of phosphorus and potassium fertilizer rate and time of application on grain yield in a double-cropping system, Southeast Agricultural Research Center, Columbus Unit

Fertilizer rate						Grain yield		
Grain sorghum			Wheat					
N	P_2O_5	K_2O	N	P_2O_5	K_2O	Grain sorghum	Wheat	Soybean
lb/a						bu/a		
120	0	0	120	0	0	88	42	31
120	45	45	120	45	45	91	46	32
120	90	90	120	0	0	94	44	32
120	60	60	120	60	60	93	46	32
120	120	120	120	0	0	94	46	31
120	75	75	120	75	75	94	46	32
LSD (0.05)						NS	NS	NS

2-year crop rotation: grain sorghum/(wheat – double-crop soybean).
Initial soil test values before study establishment were 23 ppm Bray-1 P and 160 ppm exchangeable K for the 0- to 6-in. soil depth.
Grain yields represent averages from 2005 through 2008, except no grain yields were reported for wheat in 2007 because of early April freeze damage.

Effect of Soil pH on Crop Yield

K. W. Kelley

Summary
Grain yields of grain sorghum, soybean, and wheat increased as soil acidity decreased with lime application. This study has completed five cropping cycles.

Introduction
In southeastern Kansas, nearly all topsoils are naturally acidic (pH less than 7.0). Agricultural limestone is applied to correct soil acidity and improve nutrient availability, but applying too much lime can result in alkaline soil conditions (pH greater than 7.0), which also reduces nutrient availability and increases persistence of some herbicides. This research evaluated crop yield responses to different soil pH levels.

Procedures
Beginning in 1989, five soil pH levels ranging from 5.5 to 7.5 were established on a native grass site at the Parsons Unit of the Southeast Agricultural Research Center in a 3-year crop rotation: grain sorghum/soybean/(wheat – double-crop soybean). Soil samples (0- to 6-in. depth) have been taken yearly to assess soil pH values. In the fall of 2008, soil samples also were collected at three different depths (0 to 3 in., 3 to 6 in., and 6 to 12 in.) to determine the influence of lime application on soil pH.

Results
Grain yield responses for the various soil pH treatments after five complete crop rotations are shown in Table 1. Yields of all crops increased as soil acidity decreased, although yield response to pH was generally low for wheat. Yields were greatest when soil pH was near the neutral range of 7.0. Soil data will be summarized following analysis of soil results taken after the fall harvest in 2008.

Table 1. Effects of soil pH on crop yields, Southeast Agricultural Research Center, Parsons Unit, 5-year averages

	Grain yield[1]			
Soil pH[2]	Grain sorghum	Full-season soybean	Double-crop soybean	Winter wheat
	----------	---------- bu/a	----------	----------
5.4	82.3	30.7	22.7	41.8
6.0	87.8	32.4	26.0	43.0
6.3	92.8	35.2	26.8	44.1
7.0	95.7	35.7	28.3	45.1
7.3	95.3	36.4	27.5	44.4
	4.0	1.5	1.5	1.8

[1] Grain yields represent 5-year averages.
[2] Average soil pH from 2005 through 2007 (0- to 6-in. depth).

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

D. W. Sweeney and K. W. Kelley

Summary

In 2007, corn yields were greater with conventional tillage than with reduced tillage or no-till. Overall, adding nitrogen (N) fertilizer greatly increased yields, especially when knifed.

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 rotation.

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 consists of chiseling, disking, and field cultivation. Chiseling 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 4 in. deep. The N rate for the corn crop grown in odd years was 125 lb/a.

Results

In 2007, adding fertilizer N, in general, greatly increased corn yields compared with the no-N controls (Figure 1). Overall yield was greater with knifed application than with broadcast or dribble application. Although this trend did not appear as prevalent in conventional tillage as in reduced tillage and no-till, there was no significant interaction between tillage and N fertilization treatment. Additionally, overall corn yields were greatest with conventional tillage compared with the other two tillage treatments.

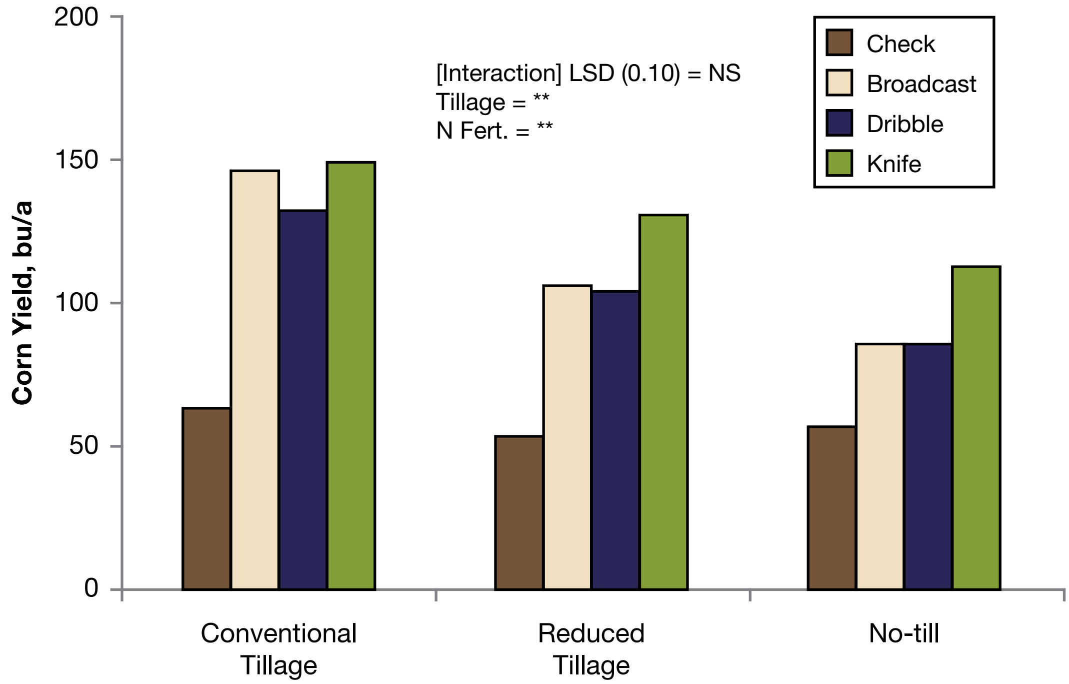

Figure 1. Effect of tillage and nitrogen placement on short-season corn yield in 2007.
**Significant at P=0.01. NS = not significant.

Surface Runoff Nutrient Losses from Cropland Receiving Fertilizer and Turkey Litter

D. W. Sweeney and G. M. Pierzynski

Summary

Phosphorus (P) losses were greater when turkey litter was applied on the basis of crop nitrogen (N) needs. Applying turkey litter on the basis of crop P needs reduced P losses. Nitrogen losses appeared to follow a similar trend. Incorporating turkey litter with conventional tillage did not result in greater sediment loss; however, losses were small on this soil, which is typical of southeastern Kansas.

Introduction

Nutrient and sediment losses due to surface runoff are significant threats to surface water quality. Little information is available on losses of nutrients from animal wastes relative to losses from commercial fertilizers, especially in southeastern Kansas. Current nutrient management guidelines in Kansas require P-based, rather than N-based, applications of animal wastes when risk of offsite P movement is high, but water quality benefits from this strategy are not known. Objectives of this study were to: (1) compare surface runoff losses of nutrients and sediment from fertilizer and turkey litter manure nutrient sources and (2) determine the influence of tillage on nutrient and sediment losses in surface runoff from use of fertilizer and turkey litter.

Procedures

The experiment was initiated in 2005 near Girard, KS, on the Greenbush educational facility grounds. Soil at this site is a Parsons silt loam overlying a claypan B horizon. Five treatments were replicated twice:

1. Control – no fertilizer or turkey litter applied
2. Fertilizer – only commercial fertilizer to supply N and P with no turkey litter
3. Turkey litter (N-based) – turkey litter applications to supply all N (that also provides excess P)
4. Turkey litter (P-based) – turkey litter applications to supply all P with supplemental fertilizer N
5. Turkey litter (P-based) – same as Treatment 4 but with incorporation of litter and fertilizer

Treatments 1 through 4 were planted with no-till, but Treatment 5 was planted after chisel and disk incorporation of litter and fertilizer. Individual plot size was one acre. In 2007, fertilizer was applied on June 22, turkey litter was applied on June 25, and Treatment 5 was chiseled on June 25 and disked the next day. Yield was collected from a 5 × 50-ft area within each plot. ISCO-brand samplers were used to determine runoff volume and sample runoff water. Water samples were analyzed for NH_4-N, NO_3-N, ortho-P, bioavailable P, total N, total P, and total suspended solids by using standard methods.

Runoff was measured, and samples were obtained for several events before fertilizer and litter application and for three events after application in 2007. Three events prior to application were selected to represent expected nutrient and sediment losses from measured runoff: March 30, May 7, and June 12. The three events after fertilizer and turkey litter application were June 29, July 1, and July 30. Rainfall amounts were 1.38 in. (March 30), 2.04 in. (May 7), 5.23 in. (June 10 to 12), 1.69 in. (June 29), 5.17 in. (June 30 to July 1), and 1.62 in. (July 30).

Results

With a few exceptions, average runoff volume and concentrations as well as total volume and loadings of three runoff events that occurred in spring 2007 prior to fertilizer and turkey litter applications in late June were not statistically affected by previous treatments (Table 1). Only ortho-P concentrations were affected by previous treatments. Where litter was applied on the basis of N needs of the crop (which overapplies P), concentration of ortho-P was nearly threefold greater than the next highest concentration from the fertilizer-only treatment. Other concentrations and average flow were not statistically affected by previous treatments. The litter N-based treatment also resulted in greater NO_3-N and bioavailable P loadings than the other treatments, except for the litter P-based treatment.

For the three runoff events in 2007 after turkey litter and fertilizer application, average concentrations of most measured N and P parameters were affected by amendment treatment (Table 2). Ammonium-N concentration was greatest in runoff from the N-based treatment. Also, NH_4-N concentration was greater in runoff from the fertilizer treatment than from the control or litter P-based treatment when incorporated. Nitrate-N concentration was unaffected by amendment. Phosphorus concentrations generally were greatest in runoff from the N-based turkey litter treatment followed by the fertilizer treatment. Incorporating turkey litter did not significantly reduce the various P concentrations in runoff compared with runoff from the no-till, P-based treatment. Phosphorus loadings, however, were greater from the N-based turkey litter treatment with no differences in loadings from the other treatments. Total suspended solids (i.e., sediment) and runoff water flow were unaffected by amendments.

In its third year, this field study demonstrates P losses that can occur if a producer applies turkey litter on the basis of crop N needs. Applying turkey litter on the basis of crop P needs reduced P losses. Nitrogen losses appeared to follow a similar trend. In this third year, incorporation by conventional tillage did not result in significantly greater sediment loss; however, losses were small on this soil, which is typical of southeastern Kansas.

Table 1. Average concentrations and total loadings of selected chemical parameters in runoff water of three events in 2007 prior to application of turkey litter and fertilizer

	Concentrations							
Amendment	NH_4-N	NO_3-N	Total N	Ortho-P	Bioavailable P	Total P	TSS[1]	Avg. flow
	ppm						mg/L	ft^3/a
Control	0.3	1.2	3.2	0.42	0.44	0.71	143	2180
Fertilizer	2.6	0.7	6.6	1.16	1.19	1.70	78	3940
Litter–N based	0.6	0.4	3.6	3.15	2.56	3.36	69	7140
Litter–P based	6.3	0.2	12.5	0.83	1.65	2.06	420	8290
Litter–P based, CT[2]	1.1	0.4	3.7	0.59	0.78	0.97	121	3090
LSD (0.20)	NS	NS	NS	0.62	NS	NS	NS	NS

	Loadings							
Amendment	NH_4-N	NO_3-N	Total N	Ortho-P	Bioavailable P	Total P	TSS	Total flow
	lb/a							ft^3/a
Control	0.1	0.1	0.7	0.14	0.12	0.22	30	6500
Fertilizer	0.4	0.1	1.6	0.45	0.38	0.60	22	10500
Litter–N based	0.4	0.6	4.3	3.48	2.62	3.86	74	21400
Litter–P based	11.3	0.2	22.1	1.30	1.49	3.46	788	24900
Litter–P based, CT	0.6	0.1	2.2	0.44	0.48	0.74	49	9000
LSD (0.20)	NS	0.3	NS	NS	1.22	NS	NS	NS

NS = nonsignificant.
[1] TSS = total suspended solids.
[2] CT = conventional tillage, litter and fertilizer incorporated.

Table 2. Average concentrations and total loadings of selected chemical parameters in runoff water of the first three events in 2007 after application of turkey litter and fertilizer

	Concentrations							
Amendment	NH_4-N	NO_3-N	Total N	Ortho-P	Bioavailable P	Total P	TSS[1]	Avg. flow
	ppm						mg/L	ft^3/a
Control	0.1	0.1	3.1	0.24	0.23	0.61	140	1670
Fertilizer	5.0	7.2	14.2	5.19	4.35	5.72	41	2200
Litter–N based	13.6	2.4	29.6	9.45	7.52	9.92	75	6300
Litter–P based	2.9	6.8	12.3	1.87	1.50	2.23	388	7500
Litter–P based, CT[2]	0.2	7.1	11.8	1.29	1.18	1.99	326	2720
LSD (0.20)	4.1	NS	5.6	2.00	1.68	2.21	NS	NS

	Loadings							
Amendment	NH_4-N	NO_3-N	Total N	Ortho-P	Bioavailable P	Total P	TSS	Total flow
	lb/a							ft^3/a
Control	0.1	0.2	0.8	0.05	0.05	0.17	55	5000
Fertilizer	3.8	9.2	20.3	5.10	4.27	5.63	109	23400
Litter–N based	17.3	2.2	35.5	12.54	10.19	13.51	107	18900
Litter–P based	3.0	6.0	11.2	2.09	1.72	2.42	218	22500
Litter–P based, CT	0.1	5.0	8.1	0.68	0.62	1.22	264	7700
LSD (0.20)	NS	NS	21.8	6.80	5.62	7.66	NS	NS

NS = nonsignificant.
[1] TSS = total suspended solids.
[2] CT = conventional tillage, litter and fertilizer incorporated.

Nitrogen Management for Seed and Residual Forage Production of Endophyte-Free and Endophyte-Infected Tall Fescue

D. W. Sweeney and J. L. Moyer

Summary
In 2007, greater clean seed yields were obtained with 100 to 150 lb/a nitrogen (N) from endophyte-free fescue; lower yields were obtained with endophyte-infected fescue, even at N rates up to 200 lb/a. Forage aftermath yield tended to maximize at about 100 lb/a N for endophyte-free fescue. Forage yields of endophyte-infected fescue continued to increase with greater N rates. Nitrogen fertilizer timing had little effect on clean seed or aftermath forage yield in 2007.

Introduction
Nitrogen fertilization is important for fescue and other cool-season grasses, but N management for seed production is less defined. Endophyte-free tall fescue may need better management than infected stands. Nitrogen fertilization has been shown to affect forage yields, but data on yield and quality of the aftermath remaining after seed harvest are lacking. The objective of this study was to determine the effects of timing and rate of N applied to endophyte-free and endophyte-infected tall fescue for seed and aftermath forage production.

Procedures
The experiment was established as a split-plot arrangement of a completely randomized block design with three replications. Whole plots were endophyte-free and endophyte-infected tall fescue. Subplots were a 3 × 5 factorial arrangement of fertilizer N timing and N rate. The three N timings were 100% in late fall (Dec. 1, 2003, Dec. 17, 2004, Dec. 13, 2005, and Dec. 14, 2006), 100% in late winter (Feb. 26, 2004, Mar. 7, 2005, Feb. 28, 2006, and Mar. 6, 2007), and 50% in late fall and 50% in late winter. The five N rates were 0, 50, 100, 150, and 200 lb/a. In all treatments, N fertilizer was broadcast applied as urea-ammonium nitrate (UAN) solution. All plots received broadcast applications of 40 lb/a P_2O_5 and 70 lb/a K_2O each fall. Seed harvest was on June 7, 2004, June 15, 2005, June 16, 2006, and June 20, 2007; forage aftermath was harvested on June 14, 2004, June 20, 2005, June 20, 2006, and June 22, 2007.

Results
In 2007, fescue clean seed yield and aftermath forage yields were affected by an interaction between N rate and endophyte infection, with little effect due to fertilizer timing. Clean seed yields were moderate but exceeded 100 lb/a for endophyte-free fescue fertilized with 100 or 150 lb/a N (Figure 1). Endophyte-infected fescue seed yields, however, were lower and never exceed 75 lb/a, even at the highest N rate. Aftermath forage yields of endophyte-free tall fescue tended to maximize at about 100 lb/a N. Forage yields of endophyte-infected fescue continued to increase with N rates up to 200 lb/a.

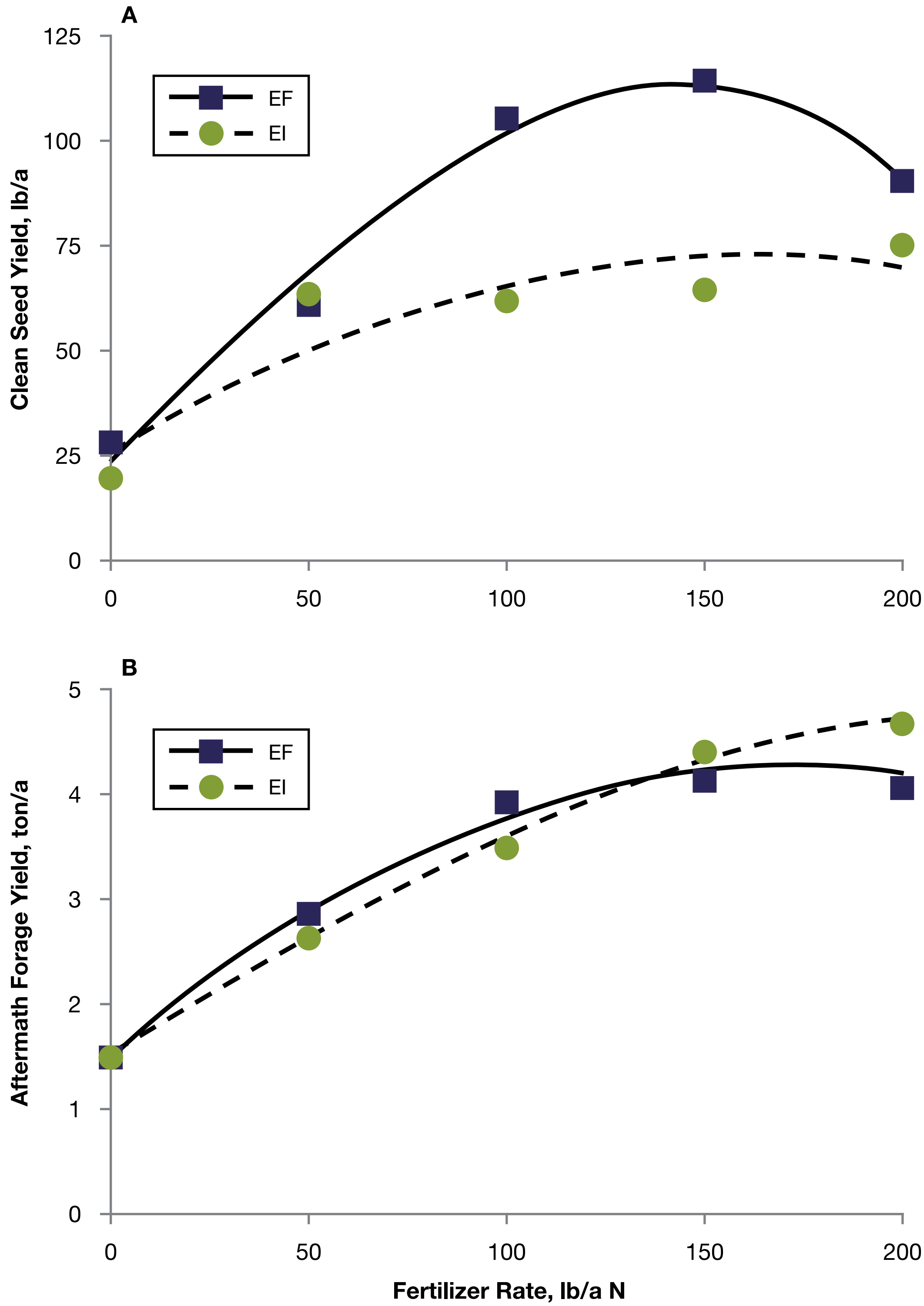

Figure 1. Effects of nitrogen fertilizer rate on clean seed yield and aftermath forage yield of endophyte-infected (EI) and endophyte-free (EF) tall fescue during 2007.

Nitrogen Fertilization of Bermudagrass

J. L. Moyer and K. W. Kelley

Summary
Bermudagrass forage yield response to nitrogen (N) fertilization was measured for rates up to 300 lb/a N in 2006 and 2008. Total yield of bermudagrass cultivar 'Midland 99' from two cuttings was higher in 2006 than in 2008, reaching an optimum at about 250 lb/a N. In 2008, yield was still increasing linearly at 300 lb/a. Nutrisphere applied at the higher rates in 2008 had no effect on yield.

Introduction
Bermudagrass can be a high-producing, warm-season perennial forage for hay or pasture in eastern Kansas when sufficient N is applied. Newer, high-yielding cultivars may have different N responses than older varieties, so optimum rates of N need to be determined for newer cultivars.

Split applications of N are generally recommended for bermudagrass. However, use of N stabilizers may make single applications more efficient. Nutrisphere, a urease inhibitor, may preserve N for uptake throughout the summer.

Procedures
Established Midland 99 bermudagrass plots received one of six rates (0, 60, 120, 180, 240, and 300 lb/a) of N as urea on Apr. 12, 2006, and May 23, 2008. In 2008, some urea was treated with Nutrisphere and applied to additional plots at 240 and 300 lb/a N. Plots were 20 × 6 ft in 2006, and 40 × 6 ft in 2008, arranged in randomized complete blocks with four replications each year.

Plots were harvested on June 21 and Aug. 16, 2006, and June 25 and Aug. 18, 2008 from 3-ft strips of varying length; subsamples were collected to determine moisture content of forage.

Results
In 2006, first-cut yield was higher for each 60-lb increment of N applied up to the 180 lb/a rate (Table 1). Second-cut yield was higher for the 300 lb/a rate than for the 120 through 240 lb/a rates, which were, in turn, higher than the check and 60 lb/a rate. Trends of total yield reflected those of the second cutting, in that yield responses continued to occur up to the highest N rates.

In 2008, first-cut yield was higher for each of the first two 60-lb increments of N applied (Table 1). However, yield from the 180 lb/a rate was not significantly (P=0.05) greater than yield from the 120 lb/a rate, and none of the higher rates increased yield beyond that achieved with the 180 lb/a rate. Second-cut yield was not increased compared with the check by the first two 60-lb increments of N applied but was increased by the 180 and 240 lb/a rates. The 300 lb/a rate resulted in a further yield increase compared with the lower rates. Total 2008 yield was higher for each 60-lb increment of N applied up to the 180 lb/a rate. Yield from the 240 lb/a rate with Nutrisphere was significantly higher than yield from the 180 lb/a rate of urea alone. This was the only case in which Nutrisphere resulted in a significant yield difference. The 300 lb/a rate resulted in a further yield increase compared with the lower rates, regardless of whether Nutrisphere was added (Table 1).

Rainfall in the 3-month growing season of 2006 was about 80% of normal, whereas rainfall in the 2008 growing season was 155% of the 30-year average. In April through September of 2008, more than 42 in. of rainfall were received; this is near the average annual precipitation and 15 in. above average for the period. This hindered efficient use of applied N and contributed to the lower yield in 2008 compared with the drier year of 2006 (Table 1).

Table 1. Forage yield in 2006, 2008, and total annual yields for Midland 99 bermudagrass, Southeast Agricultural Research Center, Columbus Unit

	2006			2008		
Nitrogen rate	Cut 1	Cut 2	Total	Cut 1	Cut 2	Total
lb/a	ton/a at 12% moisture					
0	0.95	0.39	1.34	0.90	0.55	1.45
60	2.37	0.47	2.83	1.96	0.74	2.69
120	4.28	0.98	5.26	2.78	0.90	3.68
180	4.86	0.97	5.83	3.12	1.44	4.55
240	5.03	1.39	6.42	3.35	1.56	4.91
300	5.08	1.92	7.00	3.33	2.73	6.06
240 + Nutrisphere	–	–	–	3.39	1.82	5.21
300 + Nutrisphere	–	–	–	3.41	2.47	5.88
Average	3.76	1.02	4.78	2.78	1.53	4.30
LSD (0.05)	0.60	0.44	0.88	0.37	0.42	0.49

Management Practices to Improve Productivity of Degraded/Eroded Soils

M. M. Mikha, P. W. Stahlman, J. G. Benjamin, and P. W. Geier

Summary
Productivity of degraded/eroded soils can be restored by using organic amendment, such as manure, and improved soil management. A study is being conducted near Hays, KS, to investigate and compare restorative potential of two nitrogen (N) sources. Dried beef manure and urea fertilizer were each applied at rates of 60 and 120 lb/a N to an eroded upland soil farmed with two tillage practices, no-till (NT) and conventional tillage (CT). Winter wheat yields in 2008 were significantly higher for the manure N source than for fertilizer N. Wheat yield was not significantly different between the two tillage practices. Preliminary data suggest manure addition increases productivity of eroded soils in the central Great Plains Region.

Introduction
Farmlands in the central Great Plains have lost topsoil through wind and water erosion induced by tillage and poor soil management. These soils are now degraded (i.e., low soil quality and productivity). Productivity and quality of degraded/eroded soils can be restored by using manure and improved management. Using manure as a fertilizer source is a management practice that can improve nutrient status of the soil and increase soil organic carbon levels. Continuous manure applications over several years can reduce soil bulk density. Reduction in soil bulk density and greater soil porosity are clear indicators of reduced soil compaction, improved aeration, greater infiltration, and improved conditions for plant root penetration. This study evaluates crop yield improvement associated with management of dryland eroded soils with manure vs. chemical fertilizer.

Procedures
This field experiment is being conducted at the Kansas State University Agricultural Research Center near Hays, KS. The experiment was established in 2006 on low-productivity, eroded soil. Treatments consist of two tillage systems (CT, chisel disk and NT) and two N sources (manure and commercial fertilizer) applied at low (normal N rate for crop need) and high (2X the normal N rate) rates. The crop sequence is typical of the region. The crop in rotation each year is chosen according to weather pattern (temperature and precipitation). The current rotation is grain sorghum (2006)/forage oat (2007)/winter wheat (2008). Individual experimental units (plots) are 21 ft wide and 45 ft long. The experimental design is a split plot with tillage as the main plot and N source and rate as subplots. A control treatment with no added N is also included. Treatments are replicated four times. In September 2007 before planting winter wheat, dried beef manure and commercial urea fertilizer were applied at 60 lb/a N (low rate) and 120 lb/a N (high rate). Winter wheat variety Dandy was seeded Oct. 13, 2007, at 59 lb/a by using a Sunflower 9711 drill with 7.5-in. row spacing. Grain was harvested on July 5, 2008, by using a Massey MF8 plot combine. Grain yields were determined at 12.5% moisture.

Results

Nitrogen source, N rate, and their interaction (source by rate) significantly affected ($P \le 0.05$) winter wheat grain yield (Table 1). Tillage practices had no significant effect on grain yield. Addition of manure significantly ($P \le 0.05$) increased wheat yield compared with the urea fertilizer treatment. No differences in wheat yield were observed between commercial fertilizer treatments (at either N rate) and the no-N control. Data suggest addition of organic material, such as manure, improves many aspects of soil quality at this eroded site, which is reflected in the increased crop yield. In addition, the slow release of nutrients in the manure treatment could also have improved soil nutrient status compared with commercial fertilizer. Analysis of soil quality (physical, chemical, and biological) as affected by manure amendments is being conducted and will be reported in the future.

Table 1. Effect of tillage, nitrogen source, and nitrogen rate on wheat production on eroded soil in Hays, KS, 2008

Tillage treatment	N source	N rate	Wheat yield
		lb/a	bu/a
No-till	Control[1]	0	24
	Manure	120	60
		60	47
	Fertilizer	120	25
		60	24
Tillage	Control	0	20
	Manure	120	61
		60	52
	Fertilizer	120	25
		60	22
Tillage (means)			NS
No-till			39
Conventional tillage			40
Nitrogen source (means)			0.004*
Fertilizer			24b
Manure			55a
Nitrogen rate (means)			0.01*
High[2]			43a
Low[3]			36b
N source × N rate (means)			0.03*
High fertilizer			25c
Low fertilizer			24c
High manure			61a
Low manure			49b

[1] Control was not included with the statistical analysis.
[2] High rate (120 lb/a N)
[3] Low rate (60 lb/a N)
* Significant at $P<0.05$.
NS = not significant.
Values followed by a different letter are significantly different.

Nitrogen and Phosphorus Fertilization of Irrigated Corn

A. J. Schlegel

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 2008, N applied alone increased yields about 60 bu/a, whereas P applied alone increased yields about 20 bu/a. When N and P were applied together, however, yields were increased up to 120 bu/a. Averaged over the past 9 years, corn yields were increased up to 130 bu/a by N and P fertilization. Application of 120 lb/a N (with P) was sufficient to produce >90% of maximum yield in 2008, which was similar to the 9-year average. In 2008, P increased corn yields more than 50 bu/a when applied with at least 120 lb/a N. Application of 80 instead of 40 lb/a P_2O_5 increased yields only 3 bu/a.

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 was 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
Initial fertilizer treatments in 1961 were 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. 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 prior to planting. The soil is a Ulysses silt loam. Corn hybrids Pioneer 33A14 (2000), Pioneer 33R93 (2001 and 2002), DeKalb C60-12 (2003), Pioneer 34N45 (2004 and 2005), Pioneer 34N50 (2006), Pioneer 33B54 (2007), and Pioneer 34B99 (2008) were planted at about 30,000 to 32,000 seeds/a in late April or early May. Hail damaged the 2005 and 2002 crops. Corn was irrigated to minimize water stress. Furrow irrigation was used in 2000, and sprinkler irrigation has been used since 2001. The center two rows of each plot were machine harvested after physiological maturity. Grain yields were adjusted to 15.5% moisture.

Results
Corn yields in 2008 were less than the 9-year average (Table 1). Nitrogen alone increased yields by 60 bu/a, whereas P alone increased yields by 20 bu/a. However, N and P applied together increased corn yields up to 120 bu/a. Only 120 lb/a N with P was required to obtain >90% of maximum yield, which is similar to the 9-year average. Corn yields (averaged across all N rates) were only 3 bu/a greater with 80 than with 40 lb/a P_2O_5 in 2008, which is less than the 9-year average.

Table 1. Effect of nitrogen and phosphorus fertilization on irrigated corn yield, Tribune, KS, 2000-2008

Fertilizer		Yield									
N	P_2O_5	2000	2001	2002	2003	2004	2005	2006	2007	2008	Mean
---------- lb/a ----------		---------- bu/a ----------									
0	0	131	54	39	79	67	49	42	49	36	60
0	40	152	43	43	95	97	60	68	50	57	74
0	80	153	48	44	93	98	51	72	51	52	74
40	0	150	71	47	107	92	63	56	77	62	81
40	40	195	127	69	147	154	101	129	112	105	126
40	80	202	129	76	150	148	100	123	116	104	128
80	0	149	75	53	122	118	75	79	107	78	95
80	40	205	169	81	188	209	141	162	163	129	161
80	80	211	182	84	186	205	147	171	167	139	166
120	0	143	56	50	122	103	66	68	106	65	87
120	40	204	177	78	194	228	162	176	194	136	172
120	80	224	191	85	200	234	170	202	213	151	186
160	0	154	76	50	127	136	83	84	132	84	103
160	40	203	186	80	190	231	170	180	220	150	179
160	80	214	188	85	197	240	172	200	227	146	185
200	0	165	130	67	141	162	109	115	159	99	127
200	40	207	177	79	197	234	169	181	224	152	180
200	80	218	194	95	201	239	191	204	232	157	192

continued

Table 1. Effect of nitrogen and phosphorus fertilization on irrigated corn yield, Tribune, KS, 2000-2008

Fertilizer		Yield									
N	P_2O_5	2000	2001	2002	2003	2004	2005	2006	2007	2008	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
Linear		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
Phosphorus		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
Quadratic		0.001	0.001	0.007	0.001	0.001	0.001	0.001	0.001	0.001	0.001
N × P		0.008	0.001	0.133	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Means											
Nitrogen, lb/a											
0		145	48	42	89	87	53	61	50	48	69
40		182	109	64	135	132	88	103	102	91	112
80		188	142	73	165	178	121	137	146	115	141
120		190	142	71	172	188	133	149	171	118	148
160		190	150	71	172	203	142	155	193	127	156
200		197	167	80	180	212	156	167	205	136	167
LSD (0.05)		10	15	8	9	11	10	15	11	9	8
P_2O_5, lb/a											
0		149	77	51	116	113	74	74	105	71	92
40		194	147	72	168	192	134	149	160	122	149
80		204	155	78	171	194	139	162	168	125	155
LSD (0.05)		7	10	6	6	8	7	11	8	6	5

Land Application of Animal Wastes for Irrigated Corn[1]

A. J. Schlegel, L. R. Stone, H. D. Bond, and M. Alam

Summary
Animal wastes are routinely applied to cropland to recycle nutrients, build soil quality, and increase crop productivity. This study evaluates established best management practices for land application of animal wastes on irrigated corn. Swine (effluent water from a lagoon) and cattle (solid manure from a beef feedlot) wastes have been applied annually since 1999 at rates to meet estimated corn phosphorus (P) or nitrogen (N) requirements along with a rate double the N requirement. Other treatments were N fertilizer (60, 120, and 180 lb/a N) and an untreated control. Corn yields were increased by application of animal wastes and N fertilizer. Overapplication of cattle manure has not had a negative effect on corn yield. Overapplication of swine effluent has not reduced corn yields, except in 2004 when the effluent had a much greater salt concentration than in previous years; this caused reduced germination and poor early growth.

Introduction
This study was initiated in 1999 to determine the effect of land application of animal wastes on crop production and soil properties. The two most common animal wastes in western Kansas were evaluated: solid cattle manure from a commercial beef feedlot and effluent water from a lagoon on a commercial swine facility.

Procedures
The rate of waste application was based on the amount needed to meet estimated crop P requirement, N requirement, or twice the N requirement (Table 1). The Kansas Department of Agriculture Nutrient Utilization Plan Form was used to calculate animal waste application rates. Expected corn yield was 200 bu/a. Allowable P application rates for the P-based treatments were 105 lb/a P_2O_5 because soil test P levels were less than 150 ppm Mehlich-3 P. The N recommendation model uses yield goal less credits for residual soil N and previous manure applications to estimate N requirements. For the N-based swine treatment, residual soil N levels after harvest in 2001, 2002, 2004, and 2006 were great enough to eliminate the need for additional N the following year. So, no swine effluent was applied to the 1X N treatment in 2002, 2003, 2005, and 2007 or to the 2X N requirement treatment because it is based on the 1X treatment (Table 1). The same situation occurred for the N-based treatments using cattle manure in 2003. Nutrient values used to calculate initial applications of animal wastes were 17.5 lb available N and 25.6 lb available P_2O_5 per ton of cattle manure and 6.1 lb available N and 1.4 lb available P_2O_5 per 1000 gal of swine effluent (actual analysis of animal wastes as applied varied somewhat from the estimated values, Table 2). Subsequent applications were based on previous analyses. Other nutrient treatments were three rates of N fertilizer

[1] This project has received support from the Kansas Fertilizer Research Fund, Kansas Department of Health and Environment, and the Ogallala Aquifer Initiative.

(60, 120, and 180 lb/a N) and an untreated control. The N fertilizer treatments also received a uniform application of 50 lb/a P_2O_5. The experimental design was a randomized complete block with four replications. Plot size was 12 rows wide by 45 ft long.

The study was established in border basins to facilitate effluent application and flood irrigation. Swine effluent was flood-applied as part of a preplant irrigation each year. Plots not receiving swine effluent were also irrigated at the same time to balance water additions. Cattle manure was hand broadcast and incorporated. The N fertilizer (granular NH_4NO_3) was applied with a 10-ft fertilizer applicator. The entire study area was uniformly irrigated during the growing season with flood irrigation from 1999 through 2000 and sprinkler irrigation from 2001 through 2008. The soil is a Ulysses silt loam. Corn was planted at about 33,000 seeds/a in late April or early May each year. Grain yields are not reported for 1999 because of severe hail damage. Hail also damaged the 2002 and 2005 crops. The center four rows of each plot were machine harvested after physiological maturity with yields adjusted to 15.5% moisture.

Results

Corn yields were increased by all animal waste and N fertilizer applications in 2008, as has been the case for all years except 2002, when yields were greatly reduced by hail damage (Table 3). Type of animal waste affected yields in 7 of the 9 years, with higher yields achieved with cattle manure than with swine effluent. Averaged over the 9-year period, corn yields following application of cattle manure were 18 bu/a greater than yields following application of swine effluent on an N application basis. Overapplication (2X N) of cattle manure has had no negative effect on grain yield in any year. In one year (2004), overapplication of swine effluent reduced corn yield. However, no adverse residual effect from the overapplication has been observed.

Table 1. Application rates of animal wastes, Tribune, KS, 1999-2008

	Cattle manure									
Application basis[1]	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
	ton/a									
P requirement	15.0	4.1	6.6	5.8	8.8	4.9	3.3	6.3	5.9	7.6
N requirement	15.0	6.6	11.3	11.7	0	9.8	6.8	6.3	9.8	10.2
2X N requirement	30.0	13.2	22.6	22.7	0	19.7	13.5	12.6	19.6	20.4
	Swine effluent									
	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
	1000 gal/a									
P requirement	28.0	75.0	61.9	63.4	66.9	74.1	73.3	66.0	70.9	50.0
N requirement	28.0	9.4	37.8	0	0	40.8	0	16.8	0	17.6
2X N requirement	56.0	18.8	75.5	0	0	81.7	0	33.7	0	35.2

[1] Animal waste applications are based on the estimated requirement of nitrogen (N) and phosphorus (P) for a 200 bu/a corn crop.

Table 2. Analysis of animal waste as applied, Tribune, KS, 1999-2008

	Cattle manure									
Nutrient content	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
	lb/ton									
Total N	27.2	36.0	33.9	25.0	28.2	29.7	31.6	38.0	18.8	26.0
Total P_2O_5	29.9	19.6	28.6	19.9	14.6	18.1	26.7	20.5	11.7	17.2
	Swine effluent									
	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
	1000 gal/a									
Total N	8.65	7.33	7.83	11.62	7.58	21.42	13.19	19.64	10.09	13.22
Total P_2O_5	1.55	2.09	2.51	1.60	0.99	2.10	1.88	2.60	1.09	1.47

Table 3. Effect of animal waste and nitrogen fertilizer on irrigated corn, Tribune, KS, 2000-2008

Nutrient source	Rate basis[1]	Grain yield									
		2000	2001	2002	2003	2004	2005	2006	2007	2008	Mean
		------------------------------ bu/a ------------------------------									
Cattle manure	P	197	192	91	174	241	143	236	232	169	186
	N	195	182	90	175	243	147	217	230	165	183
	2X N	195	185	92	181	244	155	213	228	156	183
Swine effluent	P	189	162	74	168	173	135	189	217	128	159
	N	194	178	72	167	206	136	198	210	128	165
	2X N	181	174	71	171	129	147	196	216	128	157
N fertilizer	60 lb/a	178	149	82	161	170	96	178	112	99	136
	120 lb/a	186	173	76	170	236	139	198	195	144	169
	180 lb/a	184	172	78	175	235	153	200	225	146	174
Control	0	158	113	87	97	94	46	123	45	53	91
LSD (0.05)		22	20	17	22	36	16	18	15	18	10
ANOVA											
Treatment		0.034	0.001	0.072	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Selected contrasts											
Control vs. treatment		0.001	0.001	0.310	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Manure vs. fertilizer		0.089	0.006	0.498	0.470	0.377	0.001	0.001	0.001	0.001	0.001
Cattle vs. swine		0.220	0.009	0.001	0.218	0.001	0.045	0.001	0.001	0.001	0.001
Cattle 1X vs. 2X		0.900	0.831	0.831	0.608	0.973	0.298	0.646	0.730	0.316	0.936
Swine 1X vs. 2X		0.237	0.633	0.875	0.730	0.001	0.159	0.821	0.399	0.977	0.102
N rate linear		0.591	0.024	0.639	0.203	0.001	0.001	0.021	0.001	0.001	0.005
N rate quadratic		0.602	0.161	0.614	0.806	0.032	0.038	0.234	0.001	0.006	0.005

No yields reported for 1999 because of severe hail damage. Hail reduced corn yields in 2002 and 2005.

[1] Rate of animal waste applications are based on the amount needed to meet estimated crop phosphorus requirement (P), nitrogen requirement (N), or twice the N requirement (2X N).

KANSAS FERTILIZER RESEARCH 2008

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