KANSAS FERTILIZER RESEARCH 2009

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KANSAS STATE UNIVERSITY

KANSAS FERTILIZER RESEARCH 2009

Contents

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Introduction

The 2009 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.

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Precipitation Data

Month	Manhattan	SWREC Tribune	SEARC Parsons	ECK Exp. Field Ottawa	HC Exp. Field Hesston S
	--------------------	--------------------	in.	--------------------	--------------------
2008					
August	5.29	4.79	4.79	2.82	5.17
September	5.42	0.83	6.80	6.93	4.92
October	2.78	2.95	3.32	4.49	4.28
November	1.34	0.37	3.44	1.62	1.93
December	0.64	0.33	2.18	1.57	0.35
Total 2008	43.25	15.37	61.69	44.70	37.61
Departure from normal	+8.45	-2.07	+19.60	+5.49	+4.54
2009					
January	0.04	0.30	0.13	1.25	0.03
February	0.65	0.46	1.70	1.41	0.33
March	3.01	0.93	4.10	4.09	2.20
April	5.25	2.17	9.95	4.37	5.79
May	0.98	1.00	6.17	6.81	3.11
June	8.53	1.23	4.67	9.75	5.26
July	6.55	2.83	7.30	8.61	5.25
August	4.50	2.22	5.56	1.01	2.04
September	2.03	2.66	12.61	3.71	4.29

Month	NCK Exp. Field Belleville	KRV Exp. Field	SCK Exp. Field Hutchinson	ARC-Hays
	--------------------	--------------------	in.	--------------------
2008				
August	3.67	1.40	2.29	3.40
September	4.28	5.51	5.73	1.42
October	8.63	3.43	5.10	6.02
November	0.01	0.62	1.06	0.70
December	0.41	1.06	0.37	0.24
Total 2008	44.18	26.52	38.59	33.70
Departure from normal	+14.86	-5.89	+8.27	+11.07
2009				
January	0.02	0.03	0.04	0.45
February	0.25	0.15	0.23	1.30
March	0.09	2.61	1.78	0.41
April	2.36	3.90	5.94	1.95
May	1.93	1.25	3.91	6.85
June	6.23	5.85	4.58	1.85
July	4.35	5.93	2.05	4.02
August	4.28	4.00	4.13	3.40
September	3.00	1.41	6.79	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.

Soybean Response to Foliar Application of Manganese and Zinc

N. Nelson, L. Maddux, M. Davis, and A. Bontrager

Summary

There is increased interest in applying micronutrients to soybean. The objective of this study was to determine if soybean responded to foliar applications of manganese (Mn) and zinc (Zn) applied in various forms. The study was conducted in a randomized complete block design at the Ashland Bottoms and Rossville experiment fields. Treatments included different rates of Mn and Zn foliar applied to soybean at approximately the V6 growth stage. Treatments did not increase tissue or grain concentrations of Mn or Zn. Treatments did not affect yield, moisture, or test weight. Although soil test Zn was near the critical limit for recommended Zn application, tissue Zn concentrations were above the critical value for plant growth.

Introduction

Interest in foliar micronutrient applications on soybean has recently increased. Application of these fertilizer products can potentially be combined with routine glyphosate applications, which saves on application costs. However, additional research needs to be done to determine the yield benefits from these micronutrient applications as well as the potential for antagonistic effects of the herbicide on nutrient absorption by the plant. The objective of this study was to determine if soybean responded to foliar applications of Mn and Zn supplied in three different forms. A secondary objective was to determine if application of micronutrient sources in conjunction with glyphosate affected product performance.

Procedures

The study was conducted at the Ashland Bottoms and Rossville agronomy experiment fields near Manhattan and Topeka, KS, respectively. Two studies—full and reduced—were implemented at Rossville. The growing season was very good; it had adequate moisture and cool temperatures. Harvest was delayed, but this did not affect yield. Although irrigation water was available, irrigation was not applied because of frequent rains throughout the summer. Soil analyses for the locations are in Table 1.

Cultural practices for each location are listed in Table 2. All locations were conventionally tilled with 30-in. rows. Plot sizes at each location were 10 ft wide by 30 ft long. Treatments were arranged in a randomized complete block design with four replications (Table 3). For the Ashland Bottoms and Rossville2 studies, treatments were tank mixed with glyphosate unless otherwise noted. Glyphosate was applied 2 days before treatment application at the Rossville1 study. Glyphosate was applied at 0.75 lb ae/a with 1.5% ammonium sulfate. Glucoheptonate micronutrient product was supplied by Brandt Consolidated, Inc., and the phosphate micronutrient product was supplied by Agro-K Corporation.

Leaf samples were collected from the uppermost fully developed trifoliate at R3 (July 24, 2009 and July 25, 2009 at Manhattan and Rossville2, respectively) and analyzed for total nutrient content. The center two rows of each plot were harvested, and seed samples were analyzed for total nutrient content by standard methods.

Results

Treatments did not significantly affect yield, test weight, moisture, or plant analysis (Tables 4, 5, and 6). Lack of yield response does not necessarily indicate poor performance of the applied nutrient source. Critical limits for Mn and Zn in soybean tissue are 17 and 21 ppm, respectively (Bell et al., 1995). As indicated by the nutrient concentrations in plant leaves at R3, the soybean plants were not deficient in either Mn or Zn. Therefore, plant response would not have been expected in these conditions. The soil test Zn at Ashland Bottoms was right at the critical level for Zn (1 ppm); however, micronutrient availability can be influenced by multiple factors. Therefore, a combination of soil analysis and tissue analysis is recommended for guidance on micronutrient applications.

References

Bell, P.F., W.B. Hallmark, W.E. Sabbe, and D.G. Dombeck. 1995. Diagnosing nutrient deficiencies in soybean, using M-dris and critical nutrient level procedures. Agronomy Journal 87:859-865.

Table 1. Selected analysis for soils used in the study

Location	Organic matter	pH	SMP buffer pH	Mehlich III-P	NH_4-OAc K	DTPA Zn	DTPA Fe	DTPA Mn
	%			--------------	--------------	ppm	--------------	--------------
Manhattan	1.5	5.1	6.7	48	330	1.0	69.4	39.2
Rossville	1.3	6.7	na[1]	16	154	na	na	na

[1] na, not available.

Table 2. Cultural and experimental details for the three study locations

Study	Variety	Planting date	Treatments[1]	Treatment application date	Harvest date
Ashland Bottoms	NK S39-A3	5/22/09	all	7/2/09	10/19/09
Rossville1	Taylor 398	5/23/09	all	7/2/09	10/07/09
Rossville2	Taylor 398	5/23/09	1, 3, 4, 5, 7	7/9/09	10/07/09

[1] See Table 3 for treatment descriptions.

Table 3. Micronutrient products, application rates, and timing

Treatment	Timing: Glyphosate[1]	Timing: Treatment	Product application	Mn	Zn
			qt/a	lb/a	lb/a
1. Control	V6	V6	0	0	0
2. Mn/Zn - Glucoheptonate	V6	V6	1	0.125	0.175
3. Mn/Zn - Phosphite	V6	V6	1	0.05	0.075
4. Delayed Mn/Zn - Phosphite	V6	10 days later	1	0.05	0.075
5. Experimental product	V6	V6	4		
6. High Mn/Zn - Glucoheptonate	V6	V6	1.5	0.2	0.3
7. High Mn/Zn - Phosphite	V6	V6	4	0.2	0.3
8. Delayed Mn/Zn - Glucoheptonate	V6	10 days later	1	0.125	0.175

[1] For the Ashland and Rossville2 locations, glyphosate was tank mixed with all treatments except 4 and 8.

Table 4. Soybean leaf tissue analysis at growth stage R3, seed analysis at harvest, seed moisture, test weight, and yield as affected by treatments at Ashland Bottoms study location

Treatment[1]	Plant analysis: Mn	Plant analysis: Zn	Seed analysis: Mn	Seed analysis: Zn	Moisture	Test weight	Yield[2]
	ppm	ppm	ppm	ppm	%	lb/bu	bu/a
1	89.3	35.4	26.8	29.3	13.0	na[3]	66.0
2	84.9	35.6	21.8	24.3	12.7	na	67.9
3	82.8	33.9	25.5	27.5	12.4	na	68.6
4	78.3	33.9	18.0	20.3	12.6	na	68.0
5	81.0	34.7	19.5	22.8	12.8	na	70.6
6	86.1	37.2	24.8	27.3	12.7	na	70.0
7	83.3	38.5	23.8	27.0	12.9	na	67.8
8	81.3	34.3	21.0	23.0	12.7	na	67.6
P-value[4]	0.469	0.951	0.332	0.650	0.737		0.802
LSD	10.1	8.9	8.1	10.5	0.7		6.2
CV (%)	8.2	15.8	33.8	34.7	3.5		6.3

[1] Treatment numbers correspond to those listed in Table 3.
[2] Corrected to 13% moisture.
[3] na, not available.
[4] From ANOVA F-test for treatment effects.

Table 5. Soybean moisture, test weight, and yield as affected by treatments at the Rossville1 study location

Treatment[1]	Moisture	Test weight	Yield[2]
	%	lb/bu	bu/a
1	12.1	54.8	43.3
2	12.4	55.0	47.9
3	12.8	55.0	48.5
4	12.2	55.0	47.3
5	12.3	54.6	45.8
6	12.3	54.9	46.3
7	12.1	53.8	42.6
8	12.3	54.0	46.2
P-value[3]	0.485	0.122	0.875
LSD	0.8	1.1	9.3
CV (%)	3.9	1.5	13.0

[1] Treatment numbers correspond to those listed in Table 3.
[2] Corrected to 13% moisture.
[3] From ANOVA F-test for treatment effects.

Table 6. Soybean leaf tissue analysis at growth stage R3, seed analysis at harvest, seed moisture, test weight, and yield as affected by treatments at Rossville2 study location

	Plant analysis		Seed analysis				
Treatment[1]	Mn	Zn	Mn	Zn	Moisture	Test weight	Yield[2]
	----------- ppm			----------	%	lb/bu	bu/a
1	54.8	28.5	19.0	18.0	11.3	54.5	54.6
3	54.0	29.8	19.3	18.3	11.0	54.3	55.5
4	54.8	29.5	21.3	23.0	11.7	50.6	52.2
5	52.8	31.8	21.0	22.0	11.3	54.1	59.4
7	55.5	31.0	20.0	20.0	11.1	54.3	55.2
P-value[3]	0.872	0.547	0.944	0.606	0.191	0.285	0.867
LSD	5.9	4.4	7.3	8.2	0.6	4.3	14.1
CV (%)	8.4	9.7	29.0	36.7	3.3	5.6	15.6

[1] Treatment numbers correspond to those listed in Table 3.
[2] Corrected to 13% moisture.
[3] From ANOVA F-test for treatment effects.

Fertilization Strategies for Iron-Deficiency Chlorosis in Soybean Production

A. M. Liesch, D. A. Ruiz Diaz, and K. L. Martin

Summary

Iron-deficiency chlorosis is a common yield-limiting factor for soybean grown on calcareous soil with high pH and has been reported by many researchers in the Great Plains and north central United States. A particular challenge to studying and managing iron-deficiency expression is the high level of temporal and spatial variability. In some years, chlorosis develops during early growth stages and disappears as the plants mature. In more severe cases, chlorosis can persist throughout the entire season. Chlorosis generally occurs in localized areas of fields and frequently occurs in low areas. This study evaluated seed coating and foliar fertilization with chelated iron (Fe) sources as well as variety selection. Preliminary results indicate that foliar treatment seemed to effectively increase plant greenness, but seed coating increased yield across locations. Selection of a soybean variety that is tolerant to iron-deficiency chlorosis seems to provide significant improvements for chlorosis management. Future studies should evaluate effectiveness of the seed coating approach for iron fertilization management from an agronomic and especially an economic perspective.

Introduction

Soil properties associated with iron-deficiency chlorosis have been studied for many years. However, it is not yet clear which factors affect iron-deficiency chlorosis. Recent research has shown that iron-deficiency chlorosis may not always occur in a pattern consistent with changes in soil types. Previous studies indicated several soil factors as potential contributors of iron-deficiency chlorosis symptoms including soil pH, carbonates, iron oxide concentration in the soil, DTPA-extractable iron, soil electrical conductivity, and soil water content.

Iron is crucial to the photosynthesis process, and a deficiency creates severe chlorosis. In mild cases, soybeans are stunted and yield is diminished. In severe cases, many chlorotic patches in the field become necrotic and result in plant death. The causes of iron chlorosis are complex, and determining the best management practices to address the problem is not easy. Soybean lines are bred to have varietal resistance to iron chlorosis. Other control practices can include in-field foliar application of iron chelates after chlorosis has appeared. The purpose of this study was to evaluate the effectiveness of different management scenarios in reducing the prevalence of iron chlorosis at four field locations in western Kansas.

Specific objectives for this study were to (1) evaluate the effect of different iron fertilizer application strategies on soybean yield on soils with potential for iron-deficiency chlorosis, (2) determine interactions between soil properties and iron fertilizer applications on soybean yield, and (3) evaluate economic returns due to iron fertilizer applications and varietal resistance selection.

Procedures

This study was initiated in 2009 at the Southwest Research-Extension Center in Garden City, KS, and two locations at cooperator fields in Lane County, KS. The soil in Garden City was a Ulysses silt loam (mesic Aridic Haplustolls) with 2.22% organic matter and pH 8.12. The soybean crop in Garden City was not regularly irrigated and received only 1 acre-inch of water. Soil at the Lane County locations was a Richfield silt loam (mesic Aridic Argiustolls) with 1.87% organic matter and pH 8.23 (Table 1). The Lane County locations received regular irrigation as needed.

Plots were arranged in the field in a randomized complete block design with four replications. Two soybean varieties with different genetic tolerance to iron chlorosis were grown: AG2905 has very good chlorosis tolerance, and AG3205 has low tolerance. Chelated iron (FeEDDHA 6%) was used for seed coating. One of two iron chelates (Fe-EDDHA or Fe-HEDTA) was applied as a foliar treatment at 0.1 lb/a iron at approximately at the 2- to 3-trifoliate growth stage, and a second application was applied approximately 2 to 4 weeks later if deficiency symptoms reappeared. Water used included 17 lb of ammonium sulfate additive per 100 gal of spray solution.

Soil samples from the 0- to 6- and 6- to 12-in. depths were taken from each individual plot and analyzed for routine soil properties. Several measurements were made to document the relative effectiveness of each treatment. Overall established plant population was recorded in July along with the first SPAD meter reading; these measurements were followed by the first foliar application treatment. On August 21, a second SPAD reading was taken before the second foliar application. Total plant height was taken at maturity. Plants were harvested and threshed by hand, and yield was adjusted to 15.5% moisture. Analysis included soil organic matter, soil test phosphorus, soil test potassium, extractable calcium and magnesium, total organic carbon, total nitrogen, soil pH, carbonates, electrical conductivity/soluble salts, and DTPA-extractable iron. Study areas were characterized by soil map units.

Results

At location 1, there were no significant differences in SPAD readings due to variety, seed coating, foliar application, or plant population (Table 2). There was a significant difference in plant height due to seed coating and variety. The AG3205 variety is a taller variety and, on average, is 10 cm taller than AG2905. Coated seeds resulted in a much taller plant height than nontreated seeds. In AG2905, treated seeds resulted in plants that were 15 cm taller than plants from nontreated seeds. In AG3205, treated seeds resulted in plants that were 10 cm taller than plants from nontreated seeds. Seed coating strongly affected total yield for both varieties. Foliar application did not significantly increase any of the crop control parameters.

At location 2, there were no significant differences between the foliar treatments and the control, but seed coating and variety selection affected crop parameters (Table 3). Plants from coated seeds had a significantly higher SPAD reading than plants from nontreated seeds (Table 2). Like location 1, there was a significant difference in height between seed treatments and between varieties. In AG2905, plants from treated seeds were 12 cm taller than plants from nontreated seeds, and in AG3205, plants from treated seeds were 15 cm taller. Seed coating also significantly increased yield. The seed coating increased yield by an average of 18 bu/a in AG2905 and by 11 bu/a in AG3205.

At location 3, plants from nontreated seeds from AG2905 had a higher SPAD reading than plants from treated seeds, but for AG3205, which is the less tolerant variety, the seed coating significantly increased chlorophyll readings (Table 4). Plants of AG2905 were 5 cm shorter than plants of AG3205, which was expected because AG2905 is a shorter variety. Yield for AG3205 was only 5 bu/a greater than that for AG2905. The seed coating decreased yield of AG2905 by 14 bu/a but increased yield of AG3205 by 10 bu/a. This result could be due to a lack of population stand in the south end of the plots, which was damaged by animals. Partial ANOVA across locations is shown in Table 5.

Acknowledgements
This project is funded by the Kansas Soybean Commission.

Table 1. Preliminary soil test results at four field locations at the beginning of the project in 2009

Location	County	pH	P	K	Fe	Ca	$CaCO_3$
			-----------------	ppm	-----------------		%
1	Lane	8.3	19	1050	3.5	3336	4.0
2	Lane	8.4	20	1018	2.9	4429	7.0
3	Finney	8.4	27	822	3.2	4628	9.0
4	Riley	7.8	82	372	3.9	4028	8.8

Table 2. Grain yield, plant population, plant height, and SPAD meter readings for location 1

Variety	Seed coating	Foliar application	Yield	Population per 25-ft row	Height	SPAD readings
			bu/a		cm	
AG2905	Yes	EDDHA	60.43	73.75	64.79	36.38
		HEDTA	65.22	77.50	66.25	36.23
		No treatment	58.09	79.88	68.83	35.20
	No	EDDHA	31.45	76.00	50.92	35.58
		HEDTA	29.82	76.38	51.79	35.20
		No treatment	35.20	75.75	50.75	35.48
AG3205	Yes	EDDHA	59.87	79.13	75.25	35.83
		HEDTA	56.48	74.13	76.04	34.20
		No treatment	58.69	79.13	76.29	36.80
	No	EDDHA	43.92	72.88	64.58	34.53
		HEDTA	37.42	81.25	63.58	35.38
		No Treatment	44.92	81.13	64.00	35.95

Table 3. Grain yield, plant population, plant height, and SPAD meter readings for location 2

Variety	Seed coating	Foliar application	Yield	Population per 25-ft row	Height	SPAD readings
			bu/a		cm	
AG2905	Yes	EDDHA	56.28	79.38	64.92	31.95
		HEDTA	71.24	78.63	65.67	32.28
		No treatment	64.87	78.50	62.58	32.35
	No	EDDHA	44.09	70.63	50.83	28.65
		HEDTA	54.46	73.88	55.42	28.93
		No treatment	39.76	73.75	48.67	28.70
AG3205	Yes	EDDHA	67.33	80.75	77.67	32.43
		HEDTA	60.03	81.50	75.00	33.38
		No treatment	54.38	80.75	75.08	31.53
	No	EDDHA	46.18	73.88	61.00	29.58
		HEDTA	54.04	77.50	59.58	29.20
		No Treatment	48.79	76.13	59.58	29.55

Table 4. Grain yield, plant population, plant height, and SPAD meter readings for location 3

Variety	Seed coating	Foliar application	Yield	Population per 25-ft row	Height	SPAD readings
			bu/a		cm	
AG2905	Yes	EDDHA	19.28	45.50	29.33	31.73
		HEDTA	24.72	51.50	29.22	33.05
		No treatment	28.54	48.17	34.67	36.23
	No	EDDHA	37.58	71.75	35.08	36.37
		HEDTA	36.46	65.63	34.50	38.40
		No treatment	41.71	66.75	36.17	38.57
AG3205	Yes	EDDHA	44.62	72.63	42.63	37.23
		HEDTA	38.70	70.00	39.58	37.47
		No treatment	41.19	71.50	40.42	36.28
	No	EDDHA	38.34	69.75	33.50	32.50
		HEDTA	23.20	63.125	33.75	34.55
		No Treatment	29.67	68.375	35.21	35.28

Table 5. Partial ANOVA for effect of variety, seed coating, and foliar iron application on grain yield, SPAD readings, and plant height across locations

Effect	Yield	SPAD	Height
	----------------------------	P > F	-------------------------
Variety	0.1399	0.3622	<0.0001
Seed coating	<0.0001	0.0942	<0.0001
Variety × Seed	0.7917	0.0176	0.1384
Foliar	0.9839	0.7961	0.9866
Variety × Foliar	0.1298	0.7240	0.7160
Seed × Foliar	0.9467	0.5577	0.9322
Variety × Seed × Foliar	0.6810	0.3980	0.8868

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

H. S. Weber 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 the 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. A project was initiated in 2008 and continued in 2009 to quantify how a number of currently marketed products and commonly used management practices performed at supplying N to no-till corn. Conditions in 2009 at these locations were conducive for N loss from ammonia volatilization, immobilization, and denitrification. A significant response to N fertilizer as well as a significant difference in performance among N fertilizers, enhancement products, and application practices was observed. Using currently available tools to protect N from volatilization, immobilization, and denitrification loss significantly increased yields in these experiments.

Introduction
The purpose of this study was to evaluate the performance of different N fertilizer products, fertilizer additives, and application practices used in Kansas and determine whether specific combinations improved yield and N use efficiency of no-till corn. The long-term goal of the study was to quantify some of these relationships to assist farmers in selecting specific combinations of fertilizer products, additives, and application techniques that could enhance yield and profitability on their farm. In this study, five tools for preventing N loss were examined: (1) fertilizer placement, or putting N below surface residue to reduce ammonia volatilization and/or immobilization; (2) use of the commercial urease inhibitor Agrotain to block the urease hydrolysis reaction that converts urea to ammonia and potentially could reduce ammonia volatilization; (3) use of the commercially available additives Agrotain Plus and Super U, which contain both a urease inhibitor and a nitrification inhibitor to slow the rate of ammonium conversion to nitrate and subsequent denitrification or leaching loss; (4) use of a commercial product, NutriSphere-N, that claims urease and nitrification inhibition; and (5) 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
This study was initiated in 2008 at the Agronomy North Farm near Manhattan, KS. The study was continued in 2009 at the Agronomy North Farm near Manhattan, the East Central Kansas Experiment Field near Ottawa, KS, and the South Central Kansas Experiment Field near Hutchinson, KS. Important facts concerning the studies, including soils, planting dates, and hybrids used, are summarized in Table 1. Plots were arranged in the field in a randomized complete block design with four replications.

Starter fertilizer was applied to all treatments, including the no-N control, at a rate of 20 lb/a N as urea ammonium nitrate (UAN). Starter N was applied using a 2 × 2 placement at Manhattan and as a surface band at Ottawa and Hutchinson. Winter applications of broadcast urea and broadcast ESN were applied February 4 at Manhattan, February 6 at Ottawa, and February 27 at Partridge to determine the efficiencies of N applications at such an early timing. Nitrogen management treatments were applied in late May at Manhattan; this was approximately the V-2 growth stage. At Ottawa and Hutchinson, planting was delayed because of moist soils and spring applications were applied at the time of planting. Treatments were applied at a rate of 60 lb/a N for a total N application with starter of 80 lb/a N. Treatments applied at all locations consisted of a check plot (no N applied); broadcast granular urea; broadcast granular urea treated with Agrotain; broadcast granular urea treated with Super U (a combination of Agrotain and dicyandiamide, a nitrification inhibitor); broadcast-sprayed UAN; broadcast-sprayed UAN + NutriSphere-N; broadcast-sprayed UAN + Agrotain Plus; broadcast granular ESN urea (urea coated with polyurethane); a 50/50 ESN/urea blend; surface-band treatments of UAN, UAN + NutriSphere-N, and UAN + Agrotain Plus; and a nonvolatile N source of UAN coulter banded or ammonium nitrate. At Manhattan, this consisted of Coulter-banded UAN placed approximately 2 in. below the soil surface in the row middles on 30-in. centers; at Ottawa and Hutchinson, ammonium nitrate was broadcast as the nonvolatile N source. Broadcast urea treatments of 90, 120, and 150 lb/a N were also applied to determine the N response function at each location.

Several measurements were made to document the relative effectiveness of each treatment. Ear leaves were collected at silking to determine relative N content. Firing ratings (number of green leaves remaining below the ear) were made to evaluate N stress to the plants approximately 10 days after pollination. Whole plant samples were taken to measure plant/stover N content at maturity. Ten plants were selected at random from the plot and cut off at ground level. Ears were removed, remaining vegetative portions of the plants were weighed and chopped, and a subsample was collected to determine N and dry matter content. At Manhattan and Hutchinson, plots were hand harvested, corn was shelled, and samples were collected for grain moisture and grain N content. At the Ottawa location, corn was mechanically harvested. Yield was adjusted to 15.5% moisture.

Results

Results from these experiments are summarized in Tables 2 and 3.

Relatively low levels of N in the ear leaf (less than 2.7% N, which is suggested as critical) suggest the 80 lb/a N application was not adequate at these sites (Table 2). This suboptimal N rate was selected to ensure that differences in efficiencies between products were not masked by overapplication of N. The potential for N loss through ammonia volatilization or immobilization loss of surface-applied N was high at all three sites because of moist soil at the time of application, good drying conditions, and a large amount of crop residue on the soil surface. This is typical of conditions in eastern Kansas most years, especially where corn is grown in rotations that include wheat.

At Manhattan, the broadcast treatment of urea applied at planting performed significantly better than the same treatment applied in winter but was less effective than some of the alternative products, such as ESN applied at planting (Table 2). Use of urease inhibitors with urea or UAN did not improve performance, though weather conditions were present for ammonia volatilization. Granular urea was more effective than broadcast UAN at Manhattan, likely because the high level of surface residue was capable of immobilizing the uniformly applied UAN. Surface banding did not improve UAN performance, though coulter banding did. The broadcast urea/ESN blend and the urea + Agrotain Plus treatments were the highest yielding at Manhattan. High-intensity rainfall events occurred 30 to 40 days after fertilizer application, which created conditions for denitrification loss. Winter applications of ESN were not as effective as planting time applications of ESN or an ESN/urea blend. NutriSphere-N was not beneficial at this location when added to broadcast or surface-banded UAN.

Results from the Ottawa location are summarized in Table 2. Yields were lower than those at Manhattan, likely a result of delayed planting due to heavy spring rains and significant greensnap of plants that occurred with a thunderstorm shortly after tasseling. Approximately 30% of the plants were lost because of stalk breakage. Potential for N loss due to ammonia volatilization, immobilization, and denitrification was also high. Ear leaf N at Ottawa was well below the 2.7% suggested critical level. Ammonia volatilization was likely high at this site as indicated by the excellent performance of the ammonium nitrate application (nonvolatile N source). Conditions were excellent for N loss from volatilization and denitrification as well as immobilization following N applications. Soil conditions at the time of N application were moist, followed by a 5-day period of no rainfall and high temperatures. In the 3 weeks following fertilization, there were several rainfall events (<1.0 in.) followed by a period of heavy rainfall (>4 in.) that created conditions with potential for denitrification. In general, UAN applications of N seemed to be less effective than urea applications regardless of additive products used. Use of additives increased yields only slightly at Ottawa in 2009. This was likely a result of the high denitrification loss potential over an extended period and the reduced effective plant stand due to greensnap.

Results from Hutchinson are also summarized in Table 2. Yields were good at this location; however, plant stands were variable because of lack of seed closure and affected plant maturity throughout the growing season. Though field variability in stand and denitrification likely were responsible for the differences in yields, the winter-applied urea and ESN were less effective than the spring-applied urea and ESN treatments. No difference among N treatments was observed.

Relative effectiveness of different N treatments are shown in comparison to the standard planting time broadcast application of urea for each location in Figures 1, 2, and 3. The N response curve from broadcast applications of urea is shown for each location. The 60-lb urea application rate and resulting yield is marked with a broken line. The resulting yield from selected other treatments is then shown on the response curve to estimate the amount of urea that would have needed to be applied at planting to obtain similar yields.

Nitrogen use efficiency (NUE), estimated by N recovery, for each site is shown in Table 2. Worldwide, NUE in cereal production is estimated at 35%; In Kansas, an NUE of 50% is used to make fertilizer recommendations. At Manhattan, NUE ranged from a low of 30% to a high of 63%. Practices such as broadcast urea, urea + Super U, Agrotain, Agrotain Plus and use of ESN or a urea/ESN blend all gave NUE >50%, whereas broadcast or surface-banded UAN with or without additives gave NUE <50%.

At Ottawa, N uptake and NUE were extremely low, likely because of the low yield and high N loss potential. Recoveries of N at Hutchinson were intermediate.

Table 1. Summary of experimental conditions

Item	Manhattan 2009	Ottawa 2009	Hutchinson 2009
Soil type	Smolan silt loam	Woodson silt loam	Ott loam
Previous crop	Double-crop soybean after canola	Double-crop soybean after wheat	Soybean after wheat
Corn hybrid	DKC52-59VT3	DKC52-59-VT3	DKC50-44
Plant population	23,500	26,000	19,330
Planting date	Apr. 23	May 20	May 21
Winter application	Feb. 4	Feb. 6	Feb. 27
Spring application	May 18	May 20	May 21
Green leaves counted	July 24	July 22	Aug. 4
Whole plant sampling	Aug. 24	Sept. 1	Sept. 15
Harvest	Sept. 14	Oct. 7	Sept. 15

Table 2. Effect of nitrogen product and method of application on corn yields

		Manhattan 2009			Ottawa 2009			Hutchinson 2009		
Treatment	Total N	Yield	Ear leaf N	GL[1]	Yield	Ear leaf N	GL	Yield	Ear leaf N	GL
	lb/a	bu/a	%		bu/a	%		bu/a	%	
Control	20	104	2.10	3.15	72	1.40	3.35	120	2.16	3
Urea at winter	80	138	2.32	4	76	1.60	4.25	125	2.13	3.25
Broadcast ESN-coated urea at winter	80	154	2.36	4.1	84	1.62	5.25	129	2.15	3.8
Urea	80	165	2.53	5.15	87	1.56	5.3	141	2.22	3.8
Broadcast urea + Agrotain	80	169	2.56	5.75	89	1.61	4.95	133	2.19	4.35
Broadcast urea + Super U	80	173	2.38	4.8	91	1.81	5.4	138	2.16	3.4
Broadcast ESN-coated urea	80	167	2.36	5.55	88	1.71	5.85	140	2.13	4
Broadcast 50% urea + 50% ESN urea	80	174	2.40	5.2	82	1.80	5.3	121	2.19	3.4
Broadcast UAN	80	148	2.37	4.3	81	1.49	3.8	135	2.23	4.05
Broadcast UAN + Agrotain Plus	80	142	2.36	4.5	79	1.55	4.35	138	2.19	4.2
Broadcast UAN + NutriSphere-N	80	149	2.34	3.65	71	1.50	4.05	143	2.29	3.55
Surface band UAN	80	148	2.28	4.3	79	1.59	4.1	126	2.03	3.95
Surface band UAN + Agrotain Plus	80	157	2.44	5.05	78	1.69	4.5	139	2.09	4
Surface band UAN + NutriSphere-N	80	148	2.39	4.15	80	1.64	4.3	125	2.15	3.45
Coulter band UAN	80	162	2.35	5.35	106	1.82	5.8	145	2.22	4.65
Broadcast urea	110	181	2.61	5.45	92	1.66	5.1	138	2.18	4.45
Broadcast urea	130	179	2.60	6.1	96	1.76	5.8	127	2.27	4.2
Broadcast urea	170	196	2.62	60	108	1.78	6.2	147	2.27	4.5
LSD (0.10)		19	0.16	0.81	10	0.25	0.62	20	0.19	0.157

[1] GL, green leaves below the ear leaf.

Table 3. Effect of nitrogen product and method of application on nitrogen uptake

		Manhattan 2009			Ottawa 2009			Hutchinson 2009		
Treatment	Total N	Grain N	Total N Uptake	NUE[1]	Grain N	Total N Uptake	NUE	Grain N	Total N Uptake	NUE
	lb/a	%	lb	%	%	lb	%	%	lb	%
Control	20	0.93	66	na	0.86	44	na	1.35	95	na
Urea at winter	80	1.04	89	30	0.85	50	7	1.42	111	30
Broadcast ESN-coated urea at winter	80	1.02	98	41	0.87	54	13	1.46	116	25
Urea	80	1.13	114	61	0.87	56	14	1.54	137	49
Broadcast urea + Agrotain	80	1.12	117	63	0.89	59	19	1.57	130	44
Broadcast urea + Super U	80	1.10	114	60	0.87	53	11	1.57	129	42
Broadcast ESN-coated urea	80	1.08	111	56	0.90	59	18	1.47	122	51
Broadcast 50% urea + 50% ESN urea	80	1.08	111	57	0.91	52	13	1.53	115	22
Broadcast UAN	80	1.04	101	44	0.88	53	11	1.58	129	42
Broadcast UAN + Agrotain Plus	80	1.03	93	34	0.85	52	10	1.51	128	41
Broadcast UAN + NutriSphere-N	80	0.97	81	20	0.87	48	6	1.51	127	40
Surface band UAN	80	0.99	92	33	0.85	52	9	1.46	111	31
Surface band UAN + Agrotain Plus	80	1.04	100	43	0.90	55	13	1.50	129	41
Surface band UAN + NutriSphere-N	80	0.99	92	33	0.82	50	7	1.48	110	31
Coulter band UAN	80	1.07	106	46	0.89	66	27	1.58	133	47
Broadcast urea	110	1.20	130	55	0.86	60	15	1.62	145	45
Broadcast urea	130	1.22	129	42	0.85	60	9	1.55	129	36
Broadcast urea	170	1.29	149	47	0.91	69	13	1.66	164	40
LSD (0.10)		0.08	14	19	0.05	7	9	0.14	20	29

[1] NUE, nitrogen use efficiency.

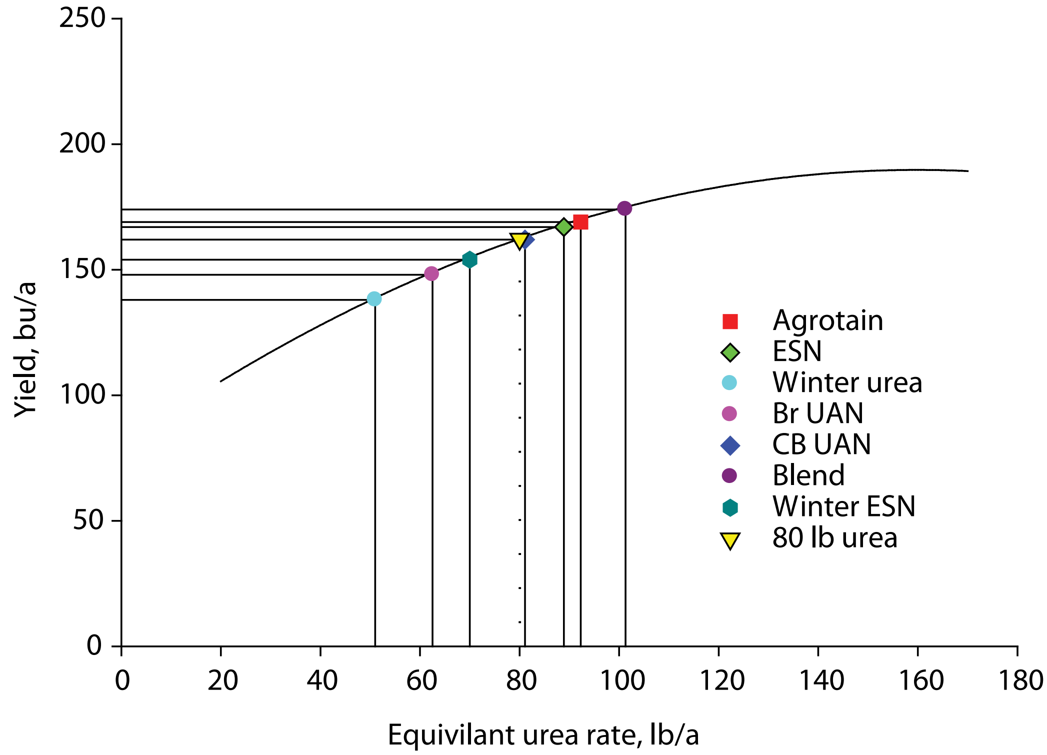

Figure 1. Response of no-till corn to 80 lb nitrogen applied using different products and application methods, Manhattan, 2009.

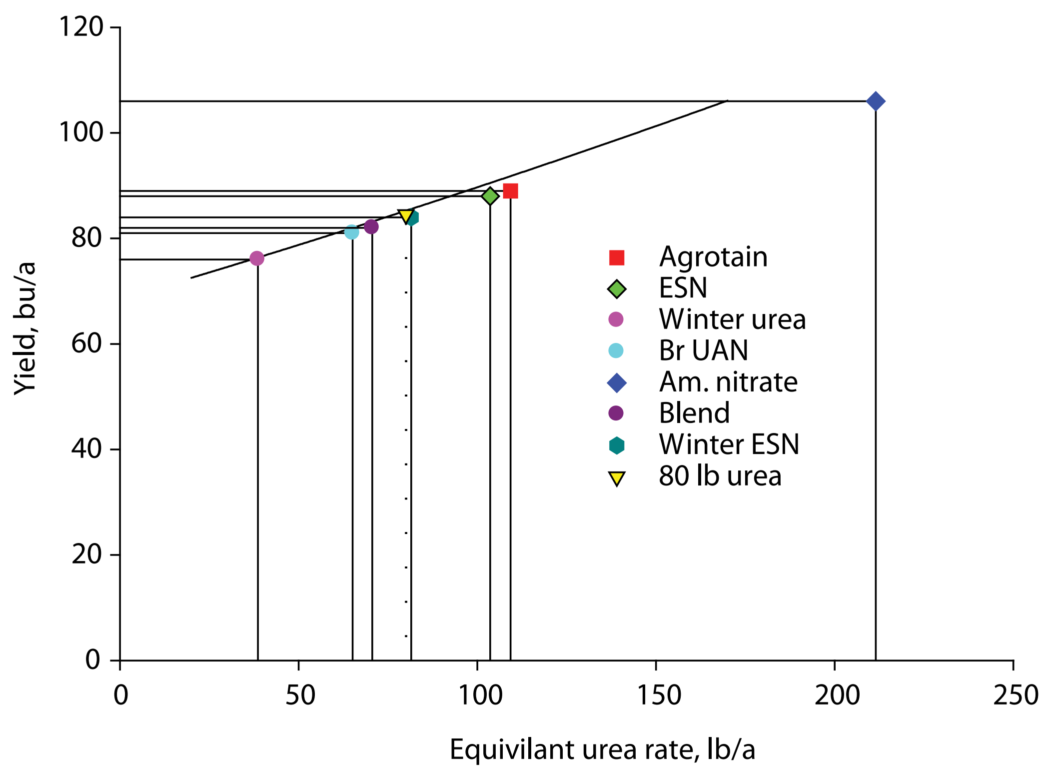

Figure 2. Response of no-till corn to 80 lb nitrogen applied using different products and application methods, Ottawa, 2009.

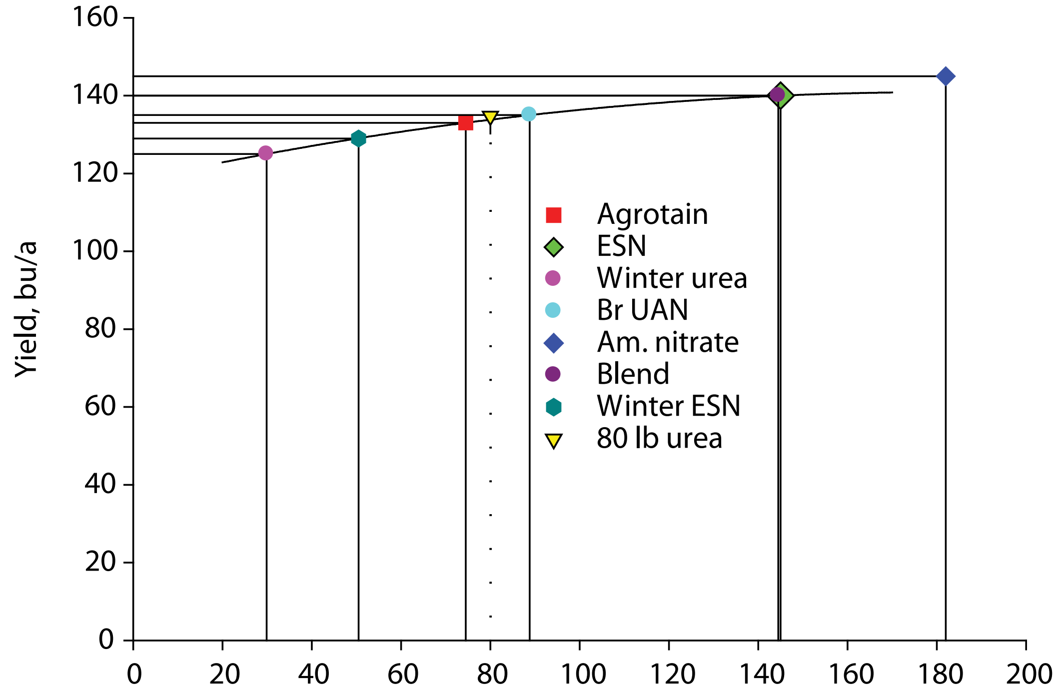

Figure 3. Response of no-till corn to 80 lb nitrogen applied using different products and application methods, Hutchinson, 2009.

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

H. S. Weber 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 in no-till production systems. These systems leave a large amount of 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. A project was initiated in 2008 and expanded in 2009 to quantify the effect of a number of commercially available products marketed to enhance N utilization by sorghum. Conditions at the sites used varied widely in 2009. Conditions that could lead to ammonia volatilization and immobilization of N were present at most sites, and conditions at some sites could lead to denitrification and leaching. At locations where N loss limited yield (i.e., Manhattan and Ottawa) use of these products and practices enhanced yield. However, at locations where N loss was minimal or low yields unrelated to N fertilization limited N response (i.e., Tribune and Partridge), use of these practices was not helpful.

Introduction
The purpose of this study was to evaluate different N fertilizers, products, and application practices used in Kansas and determine whether specific combinations improved yield and N use efficiency in 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, under their conditions. In this study, five tools for preventing N loss were examined: (1) fertilizer placement, or placing N in bands on the residue-covered soil surface to reduce immobilization; (2) use of a urease inhibitor (Agrotain) that blocks the urease hydrolysis reaction that converts urea to ammonia and potentially could reduce ammonia volatilization; (3) use of an additive (Agrotain Plus or Super U) that contains both a nitrification inhibitor and a urease inhibitor to slow the rate of ammonium conversion to nitrate and subsequent denitrification or leaching loss; (4) use of a commercial product (NutriSphere-N) that claims both nitrification inhibition and urease inhibition; and (5) 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
This study was initiated in 2008 and continued in 2009 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. An additional site at the Southwest Research-Extension Center near Tribune, KS, was added in 2009. Previ-

ous crops on these sites were soybean at Manhattan, double-crop soybean after wheat at Ottawa and Partridge, and wheat at Tribune. Sorghum hybrids DKSA54-00, P54G62, P84G62, and P86G32 were planted May 18, May 21, June 25, and June 1 at Manhattan, Ottawa, Partridge, and Tribune, respectively. Winter applications of broadcast urea and broadcast ESN were applied February 4 at Manhattan, February 6 at Ottawa and February 27 at Partridge to determine the efficiencies of N applications at such an early timing. Tribune did not receive winter-applied treatments. Nitrogen management treatments were applied from late May to mid-June at approximately the same time as planting. Treatments applied at all locations consisted of a check plot (no N applied); broadcast granular urea; broadcast granular urea treated with Agrotain; broadcast granular urea treated with Super U (a combination of Agrotain and dicyandiamide, a nitrification inhibitor); broadcast-sprayed urea ammonium nitrate (UAN); broadcast-sprayed UAN + NutriSphere-N; broadcast-sprayed UAN + Agrotain Plus; broadcast granular ESN urea (urea coated with polyurethane); a 50/50 ESN/urea blend; surface-band treatments of UAN, UAN + NutriSphere-N and UAN + Agrotain Plus; and a nonvolatile N source. At Manhattan, this consisted of coulter-banded UAN placed approximately 2 in. below the soil surface in the row middles on 30-in. centers. At Ottawa, Partridge, and Tribune, ammonium nitrate was broadcast as the nonvolatile N source. Broadcast urea treatments of 30, 90, and 120 lb/a N were applied to define the N response curve at each 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 location to determine nutrient status of the site. Flag leaves were collected at half bloom at all locations except Partridge as a measure of plant N content.

The middle two rows of each plot were machine harvested at Ottawa and Tribune. A 17.3-ft segment of the middle two rows of each plot was hand harvested at Manhattan and Partridge. Harvest dates were October 5 at Manhattan, November 6 at Ottawa, November 24 at Partridge, and December 1 at Tribune. Grain samples were collected from each plot for grain moisture and N content. Yields were adjusted to 13% moisture.

Results

Results from these experiments are summarized in Table 1. A significant response to N was obtained in this study at Manhattan, Ottawa, and Tribune. No response to N was seen at Partridge, probably because of the low yields that resulted from a late planting date as well as herbicide damage at emergence. Relatively low levels of N in the flag leaf (less than 2.7% N, which is suggested as critical) were observed at Manhattan and Ottawa, which suggests the 60 lb/a N application was not adequate at these sites. However, increasing the amount of broadcast urea applied at planting did not resolve the issue.

At Manhattan, no significant yield increases over the standard practice of broadcasting granular urea were seen with the use of nitrogen products, except for the use of ESN at both winter and planting time applications. Broadcast and surface-banded UAN treatments were not statistically different; however, the surface-banded UAN + Agrotai Plus and NutriSphere-N treatments were significantly higher than the broadcast UAN + Agrotain Plus or NutriSphere-N treatments.

At Ottawa, winter-applied broadcast ESN yielded significantly higher than winter-applied urea. Yields for the broadcast ESN at planting, broadcast ESN/urea blend, and nonvolatile N treatment of ammonium nitrate were all significantly higher than yields from the 60-lb urea treatment applied at planting.

At Partridge, yields were low, and there were no differences in treatment yields. At the Tribune location, no difference among N treatments was observed.

Figures 1, 2, and 3 demonstrate efficiencies of the N products and application timings compared with the standard treatment of broadcasting urea at planting.

These data clearly show that in conditions where N loss is occurring, such as at Manhattan and Ottawa in 2009, use of products that enhance N use can enhance yield while minimizing total N inputs. Using this type product to address specific concerns or loss mechanisms can be more efficient, and potentially more cost-effective, than simply increasing N application rate.

Table 1. Effect of nitrogen product and method of application on sorghum flag leaf percentage nitrogen and yield, 2009

Treatment	Total N	Manhattan Flag leaf N	Manhattan Grain N	Manhattan Yield	Ottawa Flag leaf N	Ottawa Grain N	Ottawa Yield	Partridge Grain N	Partridge Flag leaf N	Partridge Yield	Tribune Flag leaf N	Tribune Grain N	Tribune Yield
	lb/a	-----%-----		bu/a	-----%-----		bu/a	-----%-----		bu/a	-----%-----		bu/a
Control	0	2.12	0.89	104	1.78	0.93	70	1.30	---	41	2.64	1.1925	89
Broadcast urea at winter	60	2.13	0.91	123	1.84	0.92	86	1.27	---	51	---	---	---
Broadcast ESN at winter	60	2.32	0.92	138	2.00	0.94	101	1.30	---	43	---	---	---
Broadcast urea	60	2.31	0.92	137	1.93	0.94	96	1.29	---	42	2.82	1.42	113
Broadcast urea + Agrotain	60	2.50	0.96	144	1.98	0.94	105	1.31	---	49	2.76	1.43	116
Broadcast urea + Super U	60	2.26	0.91	140	1.88	0.94	105	1.31	---	46	2.75	1.42	109
Broadcast ESN-coated urea	60	2.45	0.94	151	2.06	0.95	110	1.33	---	45	2.80	1.38	105
Broadcast 50% urea + 50% ESN urea	60	2.34	0.92	133	1.93	0.94	108	1.25	---	42	2.82	1.40	113
Broadcast UAN	60	2.16	0.88	117	1.87	0.92	89	1.24	---	55	2.91	1.41	112
Broadcast UAN + Agrotain Plus	60	2.26	0.88	109	1.93	0.91	98	1.29	---	56	2.88	1.39	111
Broadcast UAN + NutriSphere-N	60	2.33	0.89	120	1.87	0.95	85	1.31	---	56	2.90	1.39	109
Surface band UAN	60	2.47	0.90	121	1.91	0.90	86	1.26	---	40	2.73	1.39	106
Surface band UAN + Agrotain Plus	60	2.35	0.92	126	1.91	0.95	84	1.35	---	43	2.89	1.38	110
Surface band UAN + NutriSphere-N	60	2.43	0.93	139	1.94	0.94	89	1.28	---	39	2.85	1.35	109
Nonvolatile N	60	2.58	0.96	141	2.06	0.97	110	1.34	---	49	2.78	1.39	107
Broadcast 30 Urea	30	2.14	0.89	114	1.84	0.90	83	1.29	---	52	2.80	1.35	104
Broadcast 90 Urea	90	2.47	0.95	147	2.00	0.94	110	1.25	---	53	2.85	1.50	111
Broadcast 120 Urea	120	2.43	1.03	156	2.05	0.96	104	1.24	---	54	3.05	1.55	109
LSD (0.10)		0.17	0.04	10	0.16	0.05	12	0.09	---	NS	0.13	0.08	9

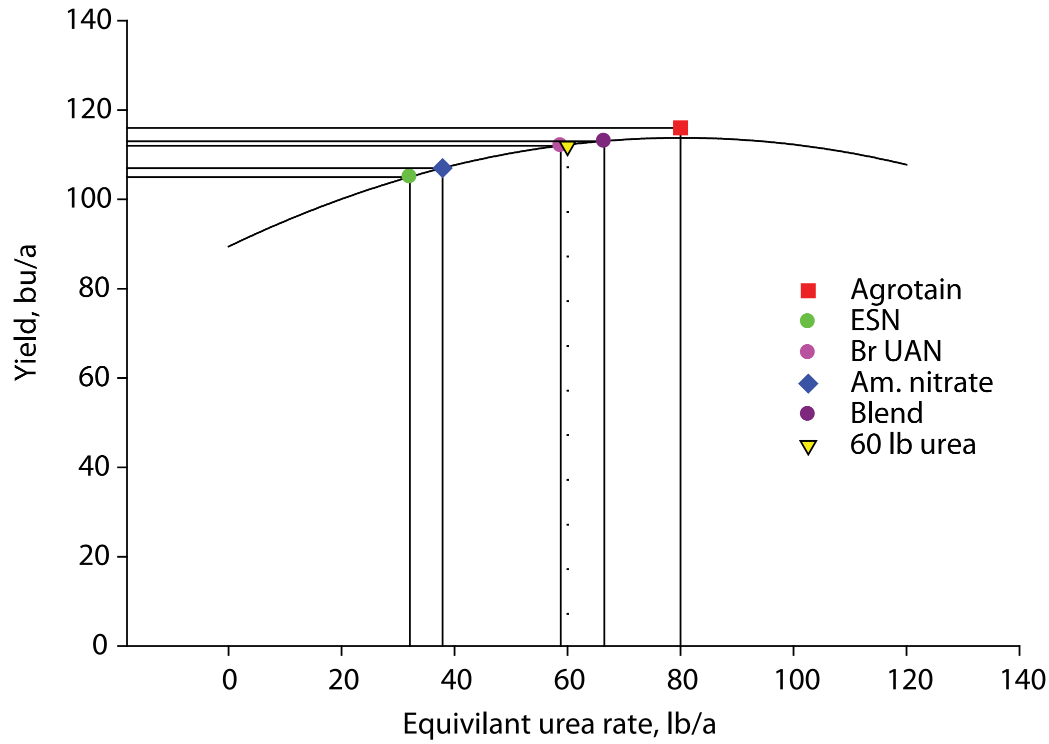

Figure 1. Response of no-till grain sorghum to 60 lb N applied using different products and application methods, Tribune, 2009.

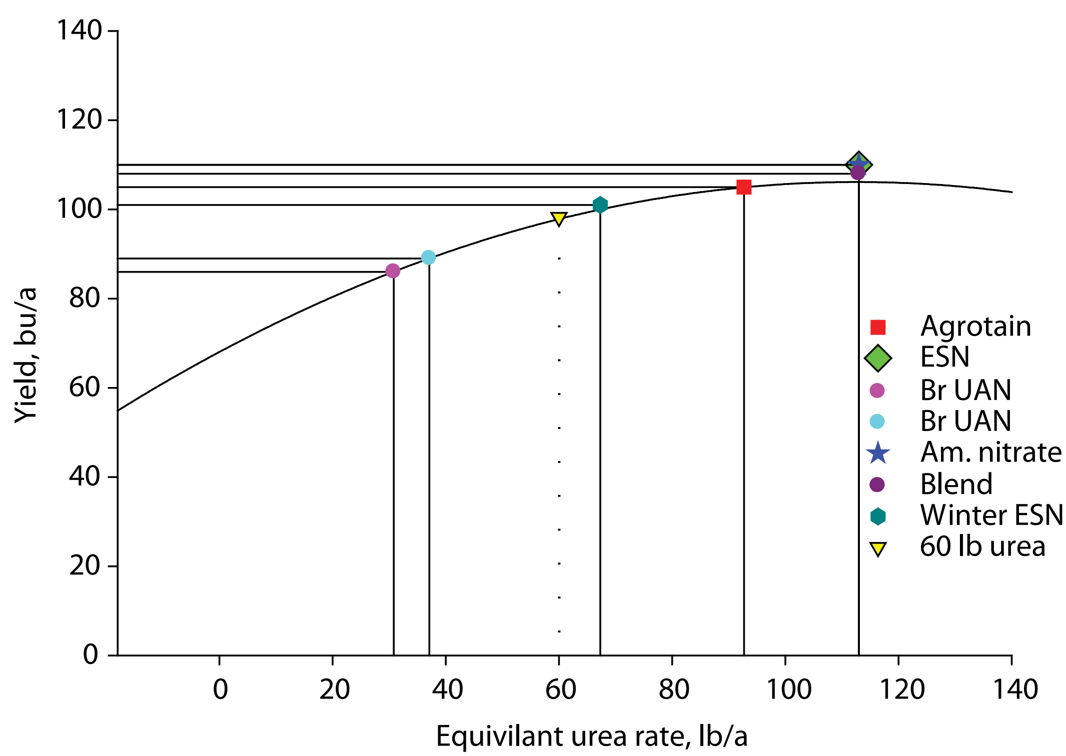

Figure 2. Response of no-till grain sorghum to 60 lb N applied using different products and application methods, Ottawa, 2009.

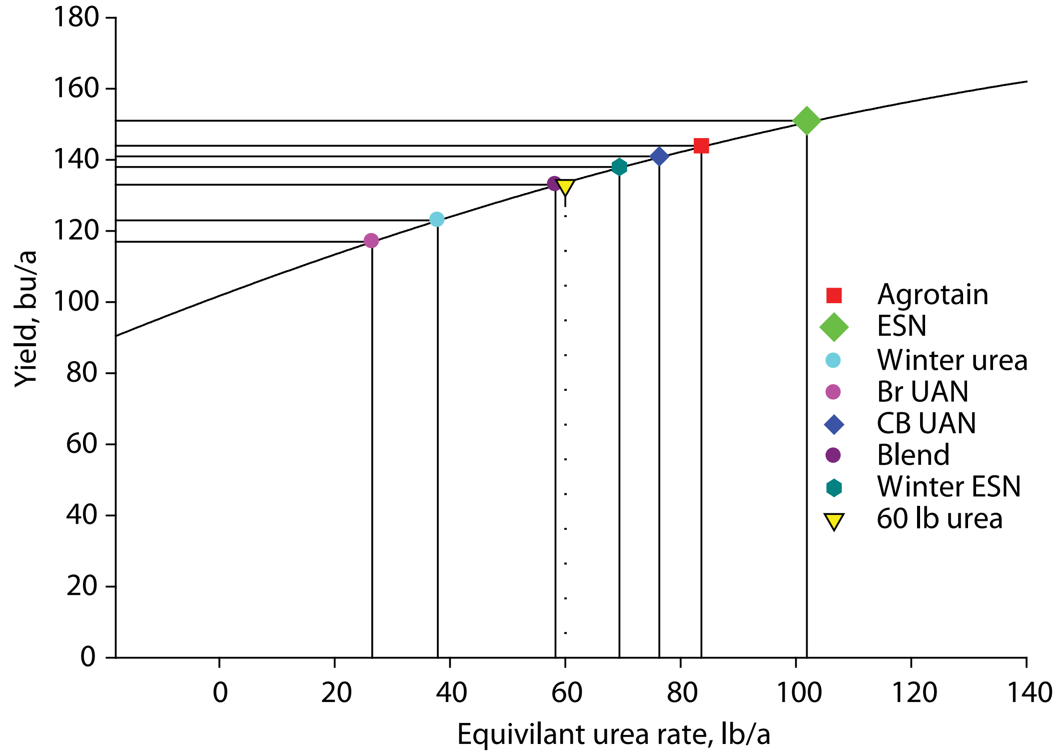

Figure 3. Response of no-till grain sorghum to 60 lb N applied using different products and application methods, Manhattan, 2009.

Correction of Potassium Deficiency in Soybean Production in Kansas

J. D. Matz, A. Tran, and D. B. Mengel

Summary
This report covers the first year of a multiyear project designed to address issues with potassium (K) fertilization of soybean and rotational crops. During 2009, four field research studies were established, all on fields in which soil test K levels were below the current critical level of 130 ppm. Later soil testing during the growing season revealed that K levels had unexpectedly increased well above the standard critical level. By harvest time, however, the K soil test levels had fallen back down to the range of the initial K baseline, well below the critical level of 130 ppm. Our data, together with data collected by farmers and crop consultants, show significant fluctuation in exchangeable K levels of up to 50% on a yearly and even monthly basis. This raises questions about how reliable lab procedures are in extrapolating exchangeable K.

In a study designed to assess the effect of sample drying and temperature (factors that influence K availability), field-moist samples were collected and prepared for analysis and then air dried and oven dried at 40°C, 60°C, 80°C, and 100°C for various lengths of time. Results showed less than a 10% decrease in exchangeable K due to high-temperature drying (Figure 1) but a 50% change in exchangeable K in the field over time. Potassium uptake was monitored by using tissue analysis. Results showed that broadcast and high-rate surface-band applications increased K uptake slightly in 2009; the majority of the treatments, including control treatments, were within the normal concentration range of 1.7% to 2.3%, indicating no K deficiencies during late vegetative and early reproductive growth. No clear effects of K fertilization rate or placement on soybean yield were observed. This research will continue in 2010.

Introduction
Within the last decade, K deficiency in soybean has become a tremendous concern in the eastern half of Kansas. The K content of many Kansas soils that had naturally elevated K availability has declined because of continuous cropping and planting high-K-extracting crops such as soybean without replacing the K removed. The more weathered soils in the southeastern part of the state, which have lower cation exchange capacity and exhausted K reserves, are encountering increased occurrence of K deficiency. In addition, the increased popularity of no-till systems has raised additional concerns of vertical stratification and positional unavailability due to dry soil conditions that result in increased K fixation and reduced diffusion rates.

This study was initiated in 2009 to determine the overall impact of K deficiencies on soybean yields and what management practices could be implemented to overcome any adverse effects. A main focus was to determine which fertilizer application methods, including broadcast and surface banding, efficiently corrected the problem.

Procedures

The project was conducted on cooperating farmers' fields in southeast Kansas. Four sites were selected near Hallowell, KS, in Cherokee County. The predominant soil type at all four locations was a Cherokee silt loam with an average K exchangeable level of 145 ppm. Plots were arranged in the field in a randomized complete block design with four replications. Maturity group 5 soybeans were planted on June 25 following the harvest of a wheat crop at a seeding rate of 110,000 seeds/a. Fertilizer was applied shortly after planting on July 1 using KCl as the fertilizer source.

Ten different treatments were applied to double-crop soybean: an unfertilized check; annual broadcast application at the rate recommended by Kansas State University; annual broadcast application of 30 and 60 lb/a K_2O; biannual broadcast application of 60, 120, and 180 lb/a K_2O; and biannual surface-band application of 60, 120, and 180 lb/a K_2O. Surface banding consisted of applying all the KCl in a concentrated band 4 to 5 in. wide immediately adjacent to the crop row.

Measurement of treatment effects included soil sampling every 1 to 2 months to track K levels, leaf K levels at pod set and pod fill, soybean yield, and grain K levels. Residual effects of the biannual applied treatments will be measured by continuing the study for a second year. Similar measurements will be made on the rotational corn crop.

Results

Potassium soil test levels in the field were substantially higher than expected from routine field soil tests conducted in the winter of 2007–2008 (Table 1). All sites showed K levels approximately 50% higher than those in 2007 and well above the accepted critical level of 130 ppm exchangeable K. The fertilizer program practiced by the grower was the traditional K-State nutrient sufficiency program. Therefore, fertilizer added on the basis of the 2007 soil tests would have been substantially less than crop removal and would not explain the significant increases. Sampling through the growing season showed that these high levels remained until mid-October, when soil tests again dropped to levels at or approaching those found in 2007.

Potassium uptake in the leaf was generally high and was significantly increased in many treatments when KCl fertilizer was applied broadcast or surface banded at a higher rate (Table 2). The relatively high levels found in the leaf tissue are consistent with soil test K levels above the critical level, which were observed throughout the growing season.

No consistent response to K fertilization or placement was observed in the yield data (Table 3). The SW Brown and SE Brown locations yield data did show some significant differences that we are attributing to harvest lost due to soybean lodging issues rather than to a treatment effect (Table 3).

The significant findings of this first years' data relate to the large change in soil test K levels seen between 2007 and 2009 and at the final sampling in 2009. It will be important to understand the mechanism responsible for these changes and what triggers these changes before routine management recommendations can be developed.

Table 1. Soil test exchangeable potassium results at different sampling dates by site

Location	Nov. 30, 2007	July 30, 2009	Aug. 31, 2009	Oct. 13, 2009
	-----------------------------	ppm	-----------------------------	
SW Jennings	90	140	136	104
SE Brown	88	155	162	109
SW Brown	106	155	165	112
Delmont	99	157	144	96

Table 2. Potassium in soybean leaf tissue at pod set (early) and pod fill (late) by treatment and site

	SW Jennings		SE Brown		SW Brown		Delmont	
Treatment[1]	Early	Late	Early	Late	Early	Late	Early	Late
		------------------	------------------	%	------------------	------------------		
Control	1.68	0.99	1.75	0.99	1.79	1.03	1.76	1.00
BR K-State	1.75	1.09	1.75	0.95	1.82	1.11	1.75	1.02
BR 30	1.75	1.05	1.78	0.98	1.85	1.10	1.78	1.10
BR 60	1.79	1.10	1.79	1.02	1.87	1.09	1.78	1.09
BR 60, biannual	1.74	1.11	1.80	1.00	1.86	1.09	1.80	1.09
BR 120, biannual	1.77	1.14	1.84	1.03	1.85	1.15	1.76	1.16
BR 180, biannual	1.85	1.11	1.95	1.03	1.96	1.20	1.94	1.21
SB 60, biannual	1.82	1.20	1.80	0.98	1.84	1.09	1.85	1.07
SB120, biannual	1.80	1.11	1.83	1.01	1.91	1.14	1.77	1.17
SB 180, biannual	1.81	1.19	1.84	1.06	1.87	1.15	1.88	1.14
LSD (0.05)	0.10	0.11	0.19	0.09	0.13	0.11	0.15	0.15

[1] Treatments: annual broadcast (BR) application at the K-State-recommended rate and 30 and 60 lb/a K_2O; biannual application at 60, 120, and 180 lb/a K_2O; and biannual surface band (SB) application of 60, 120, and 180 lb/a K_2O.

Table 3. Influence of potassium fertilizer rate and treatment on soybean yield by location, 2009

Treatment[1]	SW Jennings	SE Brown	SW Brown	Delmont
	------------------------------	------------------------------bu/a	------------------------------	------------------------------
Control	39	36	29	38
BR K-State	37	32	36	38
BR 30	39	37	34	37
BR 60	39	31	35	36
BR 60, biannual	41	39	36	34
BR 120, biannual	38	32	34	36
BR 180, biannual	41	33	30	38
SB 60, biannual	39	36	31	38
SB120, biannual	40	33	34	39
SB 180, biannual	39	31	36	34
LSD (0.05)	NS	8	6	NS

[1] Treatments: annual broadcast (BR) application at the K-State-recommended rate and 30 and 60 lb/a K_2O; biannual application at 60, 120, and 180 lb/a K_2O; and biannual surface band (SB) application of 60, 120, and 180 lb/a K_2O.

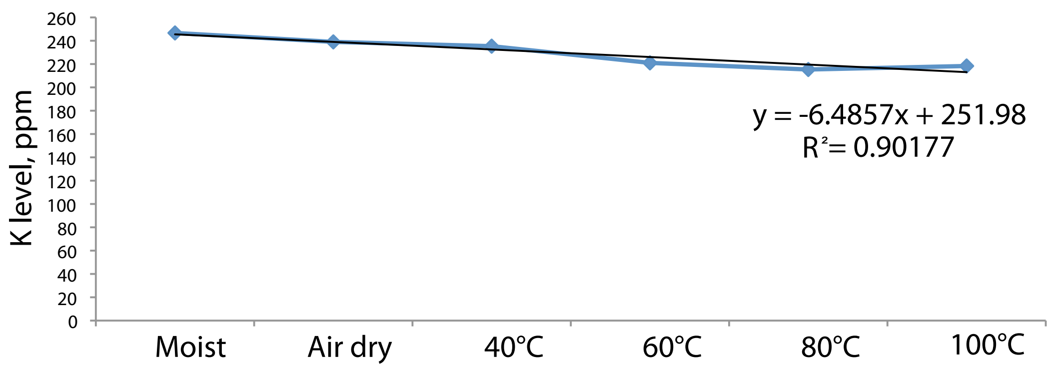

Figure 1. Effect of drying and drying temperature on exchangeable potassium, SW Brown location, 2009.

Nitrogen Fertilization of Corn Using Sensor Technology

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 and nitrogen demand can be highly variable from year to year. Also, optimum N rates are variable because of differences in residual soil N levels, variations in N mineralization from soil organic matter and previous crop residue, N loss, and grain yield. During the period of this study (2007–2009), optimum N rates varied from location to location. 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 2007 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 winter wheat, grain sorghum, and cotton. However, work with corn has been less successful.

Procedures
The study was conducted at the Kansas River Valley Experiment Field near Rossville, KS, from 2007 to 2009, Southwest Research–Extension Center near Tribune, KS, from 2007 to 2009, and Northwest Research–Extension Center near Colby, KS, from 2008 to 2009. 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. In addition, three variable rate treatments developed on the basis of recently developed crop sensor technologies (GreenSeeker; NTech Industries, Ukiah, CA) and/or a chlorophyll meter were used. The Rossville location had additional treatments developed by using the Crop Circle sensor (Holland Scientific, Lincoln, NE) with and without a chlorophyll meter. A total preplant N application of 120 lb/a N was used with these sensor-based treatments, the optical sensors (GreenSeeker and Crop Circle) were used to estimate yield potential at the V8 or V9 growth stage, and additional N was applied accordingly on the basis of the Oklahoma State University sensor-based N-rate calculator for the U.S. Grain Belt.

The chlorophyll meter was used to measure greenness of the plot relative to that of the highest preplant N plots. When the plot of interest had a relative greenness less than 95% or 90% of the reference, an additional 30 or 60 lb/a N, respectively, was applied. All preplant N treatments were applied immediately before planting, whereas side-dress treatments were applied 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 all locations, a 200 lb/a N 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 was collected with a GreenSeeker sensor at the V9 growth stage.

The center two rows of each plot were harvested after physiological maturity. Grain yield was adjusted to 15.5% moisture.

Additional studies were conducted on farmers' fields near St. Marys, KS. Sensor-based nitrogen treatments were applied near the V16 growth stage with a high-clearance sprayer equipped with GreenSeeker sensors and operated by J.B. Pearl of St. Marys. These fields were split in half with half managed according to the sensor-based treatments and the other half managed by the farmer. Fields were harvested with a combine equipped with yield monitors after physiological maturity.

Data from all experiments were analyzed statistically using SAS version 9.1 and the PROC GLM procedure with an alpha level of 0.05 for all mean separations.

Results

Fertilizing according to sensor technology resulted in good performance at Colby, Rossville, and Tribune and on the farmers' fields near St. Marys (Tables 1, 2, 3, and 4). At all locations, sensor-based treatments performed statistically as well as the highest preplant N rate but applied significantly less N. These results indicate sensor technology has potential to make appropriate midseason N recommendations for corn from the V8 to V16 growth stages.

Acknowledgments

We thank Drs. Robert Aiken, Larry Maddux, and Alan Schlegel for their help with this project and the Corn Commission and Kansas Fertilizer Research Fund for financial support of this work. We also thank Howard Parr, Jim Gentry, and Francis Kelsey for hosting experiments on their farms and J.B. Pearl and Co. for sharing data on their recent experiences with sensor technology.

Table 1. Effect of nitrogen fertilization on corn grain yields, Colby, 2008–2009

Preplant	Starter	Side-dress	Total	Yield
------------------	------------------	lb/a	------------------	bu/a
0	20	0	20	139b
100	20	0	120	171a
140	20	0	160	178a
180	20	0	200	176a
40	20	60	120	163a
60	20	80	160	182a
80	20	100	200	187a
100	20	GreenSeeker	136	170a
100	20	Crop Circle	133	175a
100	20	SPAD	128	166a
100	20	GreenSeeker + SPAD	148	168a
100	20	Crop Circle + SPAD	140	167a

Means followed by the same letter are not significantly different at $P<0.05$.

Table 2. Effect of nitrogen fertilization on corn grain yields, Rossville, 2007–2009

Preplant	Starter	Side-dress	Total	Yield
----------------------------------lb/a----------------------------------				bu/a
0	20	0	20	102d
100	20	0	120	214c
140	20	0	160	218bc
180	20	0	200	230ab
40	20	60	120	219bc
60	20	80	160	229ab
80	20	100	200	229ab
100	20	GreenSeeker	145	222ab
100	20	Crop Circle	149	235a
100	20	SPAD	133	215bc
100	20	GreenSeeker + SPAD	126	225abc
100	20	Crop Circle + SPAD	145	222abc

Means followed by the same letter are not significantly different at $P<0.05$.

Table 3. Effect of nitrogen fertilization on corn grain yields, Tribune, 2007–2009

Preplant	Starter	Side-dress	Total	Yield
----------------------------------lb/a----------------------------------				bu/a
0	20	0	20	139f
100	20	0	120	190de
140	20	0	160	222a
180	20	0	200	195cde
40	20	60	120	180e
60	20	80	160	209abc
80	20	100	200	212ab
100	20	GreenSeeker	133	198bcd
100	20	SPAD	139	202bcd
100	20	GreenSeeker + SPAD	125	190de

Means followed by the same letter are not significantly different at $P<0.05$.

Table 4. Effect of nitrogen fertilization on corn grain yields, farmers' fields, St. Marys, 2009

Field comparison	GreenSeeker total N	Farmer total N	GreenSeeker yield	Farmer yield
	----------lb/a----------		----------bu/a----------	
1	106	160	209	172
2	118	160	190	190
3	124	160	197	202

Timing of Nitrogen Fertilization of Corn

A. N. Tucker and D. B. Mengel

Summary
Nitrogen (N) loss is an important problem in corn production in eastern Kansas. Many farmers question whether corn will respond to addition of N fertilizers late in the growing season. In 2009, a series of field plots was established to address this question. Results indicate that good response from N application during the late vegetative growth stage (V16, the 16-leaf stage or just prior to tassel) can be obtained. This provides new opportunities to make N applications to correct N deficiencies that can develop because of denitrification or leaching during wet years. It also suggests that use of optical sensors mounted on high-clearance sprayers could be effectively used to make site-specific N application late in the growing season to fine tune N application systems.

Introduction
Research has shown that N fertilizer is generally needed to optimize corn yields in Kansas, though the optimum rate varies widely across locations and years. Optimum N rates vary for a number of reasons, including crop yield and N uptake, residual N from previous crops present in the soil at planting, variations in organic N mineralized from soil organic matter and crop residue, and N loss during the growing season.

During the past few years, a large amount of corn in the eastern part of Kansas has been deficient in N because of in-season N loss. This study was initiated in 2009 to determine the effectiveness of N application timing on corn grain yields and, in particular, whether corn will respond to late-season N fertilizer applications.

Procedures
This study was conducted at the Kansas State University Agronomy North Farm in Manhattan, KS, the Kansas River Valley Experiment Field near Rossville, KS, and on two farmers' fields near St. Marys, KS. Initial applications of 60 lb/a N were made at or shortly before planting (urea at Manhattan and Rossville and anhydrous ammonia at the St. Marys sites). Corn was planted in late April or early May with a hybrid adapted to that area. Nitrogen fertilizer treatments consisted of four rates of N (0 to 90 lb/a N) as urea applied at the V8 and V16 growth stages at Manhattan and only at the V16 growth stages at the Rossville and St. Marys locations.

Plots were arranged in the field in a randomized complete block design with four replications. The center two rows of each plot were harvested by hand after physiological maturity, and corn was dried and shelled. Grain yield was adjusted to 15.5% moisture.

Data were analyzed statistically with SAS version 9.1 and the PROC GLM procedure with an alpha level of 0.05 for all mean separations.

Results
Significant N responses were seen at the Manhattan and Rossville sites, but the farmers' fields did not respond to additional N (Tables 1 and 2). At Manhattan, delaying N

fertilization to the V16 growth stage produced higher grain yields than applying N at the V8 growth stage at the two highest N rates. This is likely due to denitrification loss that occurred after the V8 growth stage. Delaying applications an additional 30 days reduced N loss, resulting in higher yields.

At Rossville, corn was N stressed at the time of N application. Although a portion of this stress was overcome by the late-season fertilizer application, yields were still substantially lower than those of adjacent corn that received adequate N earlier in the growing season and did not demonstrate N stress.

At the two farmers' fields, no N stress was observed throughout the season, and no response to late-season N was observed. This demonstrates that considerable N can be supplied by the soil, even on sandy soils with relatively low organic matter.

Applying N late in the vegetative growth period of corn can be a useful tool for overcoming early season N deficiency and minimizing N loss during earlier periods of vegetative growth on soils with high potential for N loss. However, for this practice to be successful, adequate N must be available during key early growth stages to support ear and kernel differentiation.

Acknowledgments
We thank Dr. Larry Maddux, Kelsey Farms, Gentry Farms, and J.B. Pearl Co. for their help with this project.

Table 1. Effect of timing of nitrogen fertilization on corn grain yields, Manhattan, 2009

Starter N	Preplant N	V10 N	V16 N	Total N	Grain yield
	------------------------------lb/a------------------------------				bu/a
20	0	0	0	20	95f
20	40	0	0	60	133e
20	40	30	0	90	158d
20	40	60	0	120	173cd
20	40	90	0	150	185bc
20	40	0	30	90	166d
20	40	0	60	120	192ab
20	40	0	90	150	207a

Means followed by the same letter are not significantly different at P<0.05.

Table 2. Effect of late-season nitrogen fertilization on corn grain yields, Rossville and St. Marys farmers' fields, 2009

Treatment			Yield		
Preplant N	V16 N	Total N	Rossville	Field 1	Field 2
---------------lb/a---------------			---------------bu/a---------------		
60	0	60	102d	182a	173a
60	30	90	131c	178a	179a
60	60	120	158b	189a	180a
60	90	150	196a	180a	174a

Means followed by the same letter are not significantly different at P<0.05.

Nitrogen Fertilization of Nitrogen-Stressed Soybean

A. N. Tucker and D. B. Mengel

Summary
Planting soybean without inoculation into soils where soybean has never been grown can result in poor nodulation and nitrogen (N) deficiency. Similar problems can occur when inoculation fails or severely acid soils limit nodulation. In these situations, farmers often wonder if soybean will respond to N fertilizers. In 2009, an opportunity arose to study this situation because of a failure of inoculation in a field with no history of soybean production. Significant and economic responses to N fertilizer were obtained, up to the maximum rate of 120 lb/a N applied.

Introduction
When adequate levels of active, appropriate rhizobia bacteria are present in the soil, soybean plants will nodulate and fix nitrogen and normally not respond to applications of N fertilizer. When soybean is planted into ground that has no history of soybean production or a long interval between soybean crops, natural levels of rhizobia may not be present for successful nodulation and N fixation, and the crop will be N deficient. Commercial inoculants are usually applied to the seed to supply needed rhizobia and provide adequate nodulation.

In 2009, soybean planted into "virgin" soybean ground or returned conservation reserve program ground in north central Kansas fields was observed to be poorly nodulated and N deficient, even though the seed was properly inoculated with commercial inoculants. A field study was established in one of those fields to determine whether the unnodulated soybean plants would respond to applied N fertilizers and, if so, how much could successfully be used.

Procedures
This study was conducted on a farmer's field near Solomon, KS, that had a noticeably N-deficient soybean crop. Soybean variety NKS 39-A3 was planted no-till into sorghum residue from the previous year on May 20, 2009, at 140,000 seeds/a. A liquid inoculant was sprayed on the soybean seeds as they were loaded into the planter. This field had no history of soybean production. Nitrogen fertilizer was applied on July 20, 2009, to soybean displaying N-deficiency symptoms at the R1 to R2 growth stages. A simple N-rate study with five N rates ranging from 0 to 120 lb/a N was laid out in the field in a randomized complete block design with four replications. The N was applied as urea by surface banding the material between the soybean rows. Rainfall occurred within a few hours of N application.

The two center rows of the four row plots were machine harvested at maturity. Grain moisture was adjusted to 13% moisture content. Data were analyzed statistically with SAS version 9.1 and the PROC GLM procedure with an alpha level of 0.05 for all mean separations.

Results

Results are summarized in Table 1. There was a near-linear significant response to N at this location. The 120 lb/a N rate had a 21 bu/a yield advantage over the unfertilized check. Fertilization was clearly economical in this situation. Additional research will be conducted to further refine appropriate N rates if opportunities develop in the future.

Acknowledgments

We thank Tom Maxwell, agriculture and natural resources agent in the K-State Research and Extension Central Kansas District, for his help with this project.

Table 1. Effect of nitrogen fertilization on yield of nitrogen-deficient soybean, 2009

N Rate	Yield
lb/a	bu/a
0	28d
30	37c
60	42b
90	43b
120	49a

Means followed by the same letter are not significantly different at $P<0.05$.

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 grain yield and protein content at locations where wheat was planted with and without fall-applied starter N. Grain yields for this study ranged from 49 to 84 bu/a, whereas protein content ranged from 9.3% to 13.3%. In general, slight decreases in yield and increases in protein content were observed as N application was delayed.

Introduction
This study was conducted in 2009 at the Kansas State University Agronomy North Farm near Manhattan, KS. The objective was to evaluate the response of wheat to N fertilization at Feekes 4, 5, 7, and 9 growth stages at locations where fall N had been applied and where no fall N had been applied. Grain yield and protein levels were used to measure the response to N application timing.

Procedures
Hard red winter wheat variety Santa Fe was no-till planted into soybean stubble at 90 lb/a in late October with a CrustBuster no-till drill. Forty pounds of P_2O_5 were applied with the drill in furrow at seeding. Nitrogen was applied by treatment. Actual treatments used are listed in Table 1, but these included 0 or 30 lb N in the fall and topdress rates applied in the spring at Feekes 4, 5, 7, or 9. The center 5 ft of each plot was machine harvested after physiological maturity with a plot combine, and grain yield was adjusted to 12.5% moisture.

Data were analyzed using SAS version 9.1 and the PROC GLM procedure with an alpha level of 0.05 for all mean separations.

Results
Grain yield and protein values were increased with N fertilizer (Table 1), but the response was limited. Increasing N rates above 30 lb/a N generally was not productive at this site. However, protein content increased with increasing N rate and with later applications. The highest protein levels were found with 90 lb total N with 60 lb applied at Feekes 7 or Feekes 9.

Table 1. Effect of nitrogen timing and rate on wheat grain yield and protein content, 2009

Fall N	Feekes 4 N	Feekes 5 N	Feekes 7 N	Feekes 9 N	Total N	Yield	Protein
---------------------------------lb/a---------------------------------						bu/a	%
0	0	0	0	0	0	49h	9.3h
120	0	0	0	0	120	78abcd	12.3bcd
0	30	0	0	0	30	70defg	10.3g
0	60	0	0	0	60	84ab	10.5fg
0	90	0	0	0	90	77bcde	11.6cde
0	0	30	0	0	30	83ab	11.2ef
0	0	60	0	0	60	85a	11.6de
0	0	90	0	0	90	81abc	12.4bc
30	0	0	0	0	30	80abc	10.5fg
30	30	0	0	0	60	74cdef	10.2g
30	60	0	0	0	90	83ab	11.5e
30	0	0	60	0	90	79abc	12.9ab
30	0	0	0	30	60	70efg	11.7cde
30	0	0	0	60	90	65g	13.3a

Means followed by the same letter are not significantly different at $P<0.05$.

Effects of Phosphorus Fertilizer Enhancement Products on Corn

N. C. Ward and D. B. Mengel

Summary

Field studies were established in spring 2008 to evaluate the performance of two widely marketed products that claim to enhance availability of soil or fertilizer phosphorus (P): Avail, a P fertilizer enhancer added to commercial fertilizer, and JumpStart, a seed inoculant that infects corn roots and enhances availability of native soil P. This study was continued in 2009 at five locations across north central and northeastern Kansas. All five sites had soil test P levels below the current critical level of 20 ppm and would have been expected to respond to application of P fertilizers.

Excellent corn yields, above 200 bu/a, were obtained at four of the five sites. However, significant responses to applied P were obtained only at Scandia. No significant increase in yield due to the use of Avail or JumpStart was seen at any site where P response was observed.

Introduction

In recent years, the volatile price of P fertilizers has created interest among producers in using products to enhance the 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 *Penicilliam bilaii* seed inoculant that increases availability of native soil P to plant roots.

Procedures

This study was established at five locations in northeastern and north central Kansas: Manhattan (Reading silt loam), Scandia (Crete silt loam), Rossville (Eudora sandy loam), Ottawa (Woodson silt loam), and Silver Lake (Rossville silt loam). The Rossville, Scandia, and Silver Lake locations received supplemental irrigation during the growing season. Mehlich-3 P soil tests at each site were: Manhattan, 13 ppm; Scandia, 14 ppm; Rossville, 15 ppm; Ottawa, 11 ppm; and Silver Lake, 13 ppm.

All locations were planted with hybrids adapted to the area at populations appropriate to the respective soils and cropping systems.

Plots were arranged in the field in a randomized complete block design with four replications. There were 14 total treatments consisting of four rates of P fertilizer (0, 10, 20, and 40 lb/a P_2O_5 broadcast applied as monoammonium polyphosphate; MAP) with and without addition of Avail P enhancer with each of the fertilizer/Avail treatments planted with or without the JumpStart seed treatment. No JumpStart treatments were applied at Silver Lake. Broadcast fertilizer treatments were applied by hand before planting using MAP and MAP commercially impregnated with Avail, obtained locally. All P treatments were balanced for nitrogen with urea, which was broadcast before planting. A total of 160 lb/a N was applied.

Whole plant samples were taken at approximately the V4 growth stage, and ear leaf samples were taken at green silk. 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. At harvest, yield, moisture, and P content of the grain were measured. All yields were corrected to 15.5% grain moisture.

At Ottawa, significant damage to all plots occurred because of greensnap from a severe thunderstorm that occurred at the V16-V18 growth stage. Nearly all plants were lodged, and approximately 30% were broken at the base. The unbroken plants "goose-necked" back up and produced ears.

Results

Individual treatment means for each location and statistical analyses using planned comparisons and contrasts are reported in Table 1. Initial preplant soil tests indicated low available P at all locations. A response to applied P, as indicated by the contrast no P vs. P, was observed only at Scandia. No response to applied P was observed at the other locations, even though the soil tests were below the critical 20 ppm level. One possible explanation for this lack of response to applied P is the good growing conditions and adequate soil moisture throughout the growing season. Phosphorus is known to move to the root for uptake through the soil solution by diffusion. Increasing soil moisture results in a greater portion of soil pores filled with water; this creates continuous water films from soil particle surfaces to the root surface, reducing the distance P ions must diffuse or move and increasing the rate of P supply. Thus, in soils that test lower in P, the rate of P supply will be higher with good soil moisture than under water stress conditions. A recent summary of P soil test correlation and calibration data from Kansas shows that a response to P is expected only about 50% of the time when the soil test is in the range of 13 to 20 ppm, which was the case for most of these sites.

The response to additives was examined using the contrasts no Avail vs. Avail across P rates, no JumpStart vs. JumpStart across rates, no JumpStart vs. JumpStart with no P applied, and no additives vs. both Avail and JumpStart across P rates. Little response to P additives was seen in 2009. At Ottawa, a significant positive response to addition of Avail was observed, using the contrast no Avail vs. Avail across P rates, even though no response to P was seen. No other responses to Avail were seen, even at sites where significant, large responses to P were observed.

No responses to JumpStart alone or JumpStart in combination with P fertilizer were observed. A statistically significant yield reduction due to addition of both Avail and JumpStart in combination across P rates was seen at Scandia.

In summary, response to P fertilizers was limited in 2009, even at sites where soil tests were below the established critical level. No additional response to use of P-enhancing additives was observed, with the exception of a response to addition of Avail at Ottawa.

Table 1. Corn yield response to phosphorus fertilizer with and without the use of phosphorus-enhancing additives

Treatment and rate		Enhancing product	Ottawa	Manhattan	Scandia	Rossville	Silver Lake
	lb/a P_2O_5		-----------------------------	-----------------------------	-bu/a-	-----------------------------	-----------------------------
1.	0	None	78	217	191	230	231
2.	0	JumpStart	95	223	196	231	---
3.	10	None	68	220	210	226	226
4.	10	JumpStart	83	199	209	225	---
5.	10	Avail	78	220	201	223	220
6.	10	JumpStart + Avail	86	193	187	233	---
7.	20	None	89	214	215	233	209
8.	20	JumpStart	82	225	218	226	---
9.	20	Avail	95	214	209	231	209
10.	20	JumpStart + Avail	81	198	204	245	---
11.	40	None	71	198	225	230	223
12.	40	JumpStart	86	201	228	223	---
13.	40	Avail	103	218	225	233	222
14.	40	JumpStart + Avail	94	201	230	231	---
Statistical analysis using planned comparisons/contrasts							
No P vs. P, 1 vs. 3, 7, 11			NS	NS	<.0001	NS	NS
No JumpStart vs. JumpStart at no P, 1 vs. 2			NS	NS	NS	NS	---
Low P rate vs. High P rate, 3, 4, 5, 6 vs. 11, 12, 13, 14			NS	NS	<.0001	NS	NS
Low P rate vs. Middle P rate, 3, 4, 5, 6 vs. 7, 8, 9, 10			NS	NS	0.0034	0.041	NS
Middle P rate vs. High P rate, 7, 8, 9, 10 vs. 11, 12, 13, 14			NS	NS	<.0001	NS	NS
No JumpStart vs. JumpStart across P rates 3, 7, 11 vs. 4, 8, 12			NS	NS	NS	NS	---
No Avail vs. Avail across P rates 3, 7, 11 vs. 5, 9, 13			0.0275	NS	NS	NS	NS
Avail vs. JumpStart 5, 9, 13 vs. 4, 8, 12			NS	NS	NS	NS	---
No product vs. Avail + JumpStart 3, 7, 11 vs. 6, 10, 14			NS	NS	0.0186	NS	---
Standard error (bu)			9	9	7	6	10

Impact of Planting at Different Distances from the Center of Strip-Tilled Fertilized Rows on Early Growth and Yield of Corn

K. A. Janssen

Summary
Corn growers who have automatic guidance systems technology (e.g., GPS and auto-steer) can plant corn directly on top of previously established strip-tilled fertilized rows, but this might not be the best location for planting. The objective of this study was to determine the effects of planting corn at different distances from strip-tilled fertilized rows. The locations evaluated were planting directly on top of the strip-tilled fertilized rows and 3.75, 7.5, and 15 in. off the center of the rows. Planting corn directly on top of freshly tilled strip-tilled fertilized rows negatively impacted yield. Planting at distances greater than 3.75 in. from strip-tilled fertilized rows reduced early season corn growth, uptake of nutrients, and yield. The best location for planting was within 3.75 in. of the strip-till fertilized rows and where the seedbed was firm and moist.

Introduction
Corn growers who have automatic guidance systems technology, such as GPS and auto steer, have the capability to plant corn in precise locations relative to previously established strip-tilled fertilized rows. However, depending on the amount of time that has elapsed between the strip-till fertilizer operations and planting and the rate and forms of fertilizers applied, the best location for planting may not be directly on top of the strip-tilled fertilized rows. For example, strip-tilled fertilized rows could have air pockets under the row, might be dry or cloddy, or could have excessive levels of fertilizer salts or free ammonia. On the other hand, planting too far away from the strip-tilled fertilized rows might reduce benefits from residue management including warmer loosened soil and rapid root-to-fertilizer contact. The objective of this study was to determine the effects of planting corn at various distances from the center of previously established strip-tilled fertilized rows on fine-textured soils in eastern Kansas.

Procedures
Field experiments were conducted on an Osage silty clay loam soil at a field site near Lane, KS, in 2006 and 2008 and on a Woodson silt loam soil at the East Central Kansas Experiment Field at Ottawa, KS, in 2009. The planting distances evaluated were directly on top of strip-tilled fertilized rows and 3.75, 7.5, and 15 in. off the center of the rows. The experiment was designed as a randomized complete block with three to four replications. Plot size ranged from 0.14 to 0.55 acres depending on the site year. The strip-till fertilization application was performed 1 day before planting in 2006, 2 weeks before planting in 2008, and 2.5 months before planting in 2009. Fertilizer was applied at a standard rate (120-30-10 lb/a). The fertilizer source was a mixture of dry urea, diammonium phosphate, and muriate of potash. Depth of the strip-till fertilizer application was 5 to 6 in. below the row. The planting treatments were evaluated for effects on plant population, early season corn growth, nutrient uptake, and grain yield.

Results

In 2006 and 2008, plant populations were higher for corn planted 3.75 in. off the center of the strip-tilled fertilized rows than for corn planted directly on top of the rows (Figure 1). This was expected in 2006 because the strip-till fertilization operation was performed only 1 day before planting and the soil was loose and had air pockets under the row. In 2008, when there were 2 weeks between the strip-till operation and planting, plant population was still increased by planting just slightly off the strip-tilled fertilized rows. No differences in plant populations occurred in 2009, when the strip-till operation was performed 2.5 months before planting.

Early season corn growth at the 2- to 3- and 6- to 7-leaf growth stages tended to be better for corn planted directly on top of the strip-tilled fertilized rows or just slightly off (3.75 in. off) than for corn planted 7.5 and 15 in. off the center of the rows (Figures 2A and 2B). Planting corn 7.5 in. from the center of the strip-tilled fertilized rows reduced early season corn growth 12% on average, and planting 15 in. away reduced early season growth 38%. Uptake of plant nutrients (i.e., nitrogen, phosphorus, and potassium) followed a pattern similar to that for plant growth (data not shown).

In 2006, yield of corn planted directly on top of the strip-tilled fertilized rows was 8% less that that of corn planted 3.75 in. off the center of the rows (Figure 3). This was a result of the reduced plant population. In 2008, corn planted 3.75 in. off the center of the strip-tilled fertilized rows had the highest plant population and the highest numerical grain yield. In 2009, when the strip-till operation was performed 2.5 months before planting and there was plenty of time for the strip-tilled seedbed to settle and become firm, there were no differences in plant population and no differences in yield between planting directly on the strip-tilled rows and planting 3.75 in. off the rows.

These results indicate that the best location for planting will vary depending on the condition of the strip-tilled fertilized seedbed and the amount of time between planting and when the strip-till fertilizer operation was performed. Corn should be planted in a moist, firm seedbed to obtain good stands and within 3.75 in. of strip-tilled fertilized rows to ensure quick contact between corn roots and fertilizer.

Additional years testing are needed to determine if these guidelines might also apply to strip-tilled fertilized corn planted on course-textured soils and when higher rates of fertilizer and other sources of nitrogen are applied.

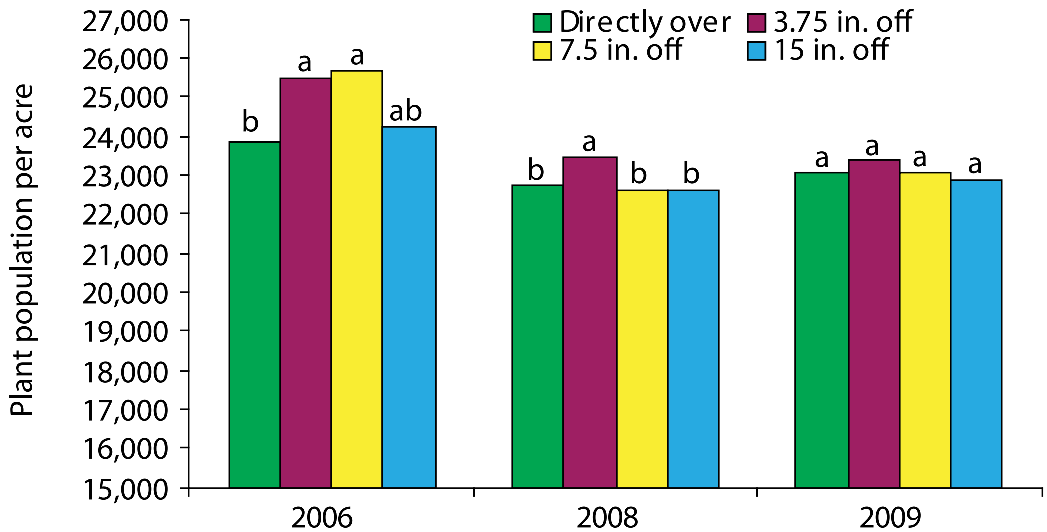

Figure 1. Impact of planting at different distances from the center of strip-tilled fertilized rows on corn plant population.
Means with the same letter within years are not significantly different at P<0.05.

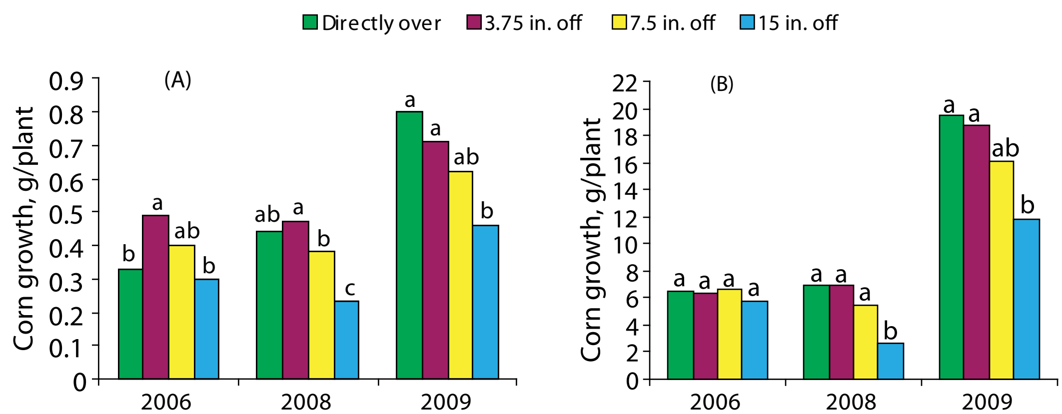

Figure 2. Impact of planting at different distances from the center of strip-tilled fertilized rows on corn growth at the (A) 2- to 3-leaf growth stage and (B) 6- to 7-leaf growth stage.
Means with the same letter within years are not significantly different at P<0.05.

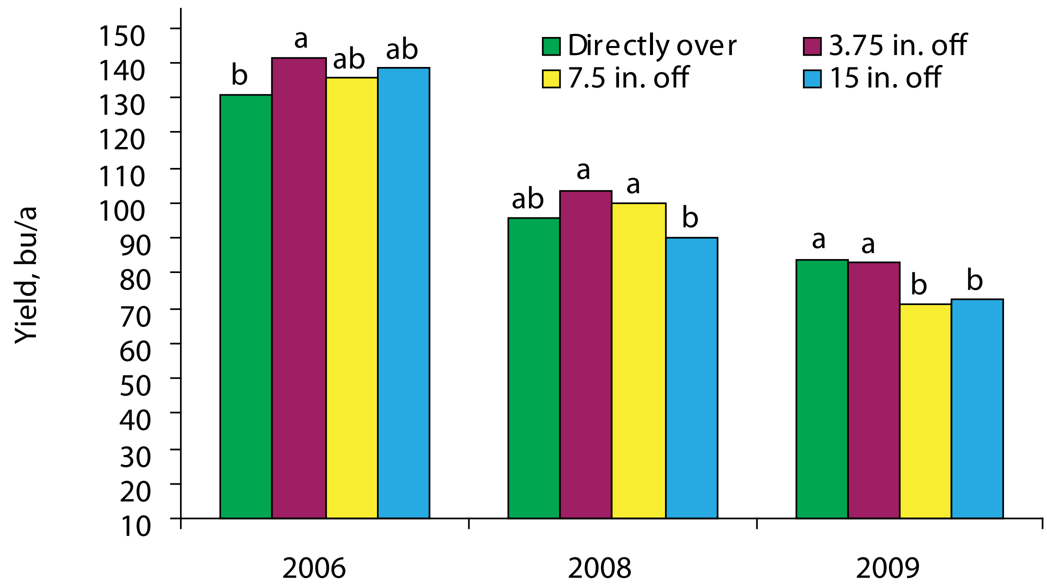

Figure 3. Impact of planting at different distances from the center of strip-tilled fertilized rows on corn grain yield.

Means with the same letter within years are not significantly different at $P<0.05$.

Effect of Various Fertilizer Materials on Dryland Grain Sorghum

L. D. Maddux

Summary
A lower-than-optimal nitrogen (N) rate (60 lb/a) applied to dryland grain sorghum in 2009 resulted in yields equal to those obtained with the same N rate plus calcium thiosulfate (CaTs), Trisert NB, and magnesium thiosulfate (MagThio). All treatments yielded more than the no-N check, with the 90 lb/a N treatments yielding about 20 bu/a more than the 60 lb/a N treatments. No significant differences were observed in flag leaf phosphorus (P) or grain N content. All treatments had higher leaf N content and lower grain P content than the no-N check. The 90 lb/a N treatments had higher leaf N content and lower grain P content than the 60 lb/a N treatments.

Introduction
This study was funded by a grant provided by Tessenderlo Kerley, Inc., a producer of specialty products used in the agriculture, mining, and process chemical industries. The Tessenderlo Kerley products tested were CaTs (0-0-0-10S-6Ca), Trisert NB (26-0-0 with 33% slow-release N), and MagThio (0-0-0-10S-4Mg). A lower-than-optimal N rate (60 lb/a) was used to evaluate the effectiveness of Trisert NB at supplying foliar N to sorghum plants to increase grain yield. Applications of CaTs and MagThio with urea-ammonium nitrate (UAN) solution were also evaluated for their effect on grain yield at the lower N rate.

Procedures
This study was conducted in 2009 on no-till dryland grain sorghum following soybean on a Woodson silt loam soil at the East Central Kansas Experiment Field near Ottawa, KS. Treatments were: a no-N check; 90 and 60 lb/a N; 60 lb/a N + 5 or 10 gal/a CaTs; 60 lb/a N + 5 gal/a CaTs + 4 gal/a foliar N; 60 lb/a N + 4 gal/a foliar N; and 60 lb/a N + 1.0, 1.5, or 2.0 gal/a MagThio. Urea-ammonium nitrate solution was used as the N source and knifed 6 to 8 in. deep on 30-in. centers. Grain sorghum hybrid Pioneer 84G62 was planted no-till into soybean stubble at 65,000 seeds/a on May 18. The UAN, CaTs, and MagThio treatments were applied on 30-in. centers between the planted rows on May 19. The Trisert NB treatments were applied in 20 gal/a solution to 10-leaf sorghum on July 13. Herbicides were applied as needed for weed control. Flag leaf samples were taken at boot stage of growth for N and P analyses. Plots were harvested with a John Deere 3300 plot combine, and grain samples were saved for N and P analyses.

Results
Nitrogen content of sorghum leaf tissue at boot stage responded to N rate (Table 1). The check plot had the lowest N content, the 90 lb/a N rate had the highest, and the treatments with the 60 lb/a N rate were intermediate. Phosphorus content of the grain was the reverse of the leaf N content; the check plot had the highest P content, the 90 lb/a N rate had the lowest, and the treatments with the 60 lb/a N rate were again

intermediate. However, there were no significant differences in leaf tissue P content or grain N content. All treatments increased yield of dryland sorghum over that of the no-N check. The 90 lb/a N rate yielded 20 bu/a more than most of the other 60 lb/a N treatments, but there were no significant differences among the treatments receiving 60 lb/a N as UAN.

Table 1. Effect of calcium thiosulfate, magnesium thiosulfate, and Trisert NB rate on nitrogen and phosphorus content in the flag leaf and grain, test weight, and grain yield of sorghum, East Central Kansas Experiment Field, 2009

Treatment[1]	Leaf N	Leaf P	Grain N	Grain P	Test weight	Yield
	-----------------%			-----------------	lb/bu	bu/a
Check	1.65	0.257	1.02	0.722	56.7	49.2
UAN 90	2.41	0.264	1.05	0.435	55.6	96.8
UAN 60	2.03	0.254	0.98	0.649	54.9	76.0
UAN 60; CaTs, 5 gal	1.82	0.263	0.97	0.636	55.8	69.0
UAN 60; CaTs, 10 gal	1.97	0.252	0.94	0.635	55.6	74.9
UAN 60; CaTs, 5 gal; Trisert NB	2.09	0.251	1.01	0.667	55.4	78.4
UAN 60; Trisert NB, 4 gal foliar	2.19	0.254	1.03	0.616	55.6	79.6
UAN 60; MagThio, 1.0 gal	1.94	0.254	0.99	0.665	56.0	78.3
UAN 60; MagThio,1.5 gal	2.10	0.253	1.01	0.617	55.8	74.4
UAN 60; MagThio, 2.0 gal	1.97	0.255	0.99	0.647	55.0	75.2
LSD (0.05)	0.17	NS	NS	0.142	0.8	10.9

[1] UAN, urea-ammonium nitrate solution; CaTs, calcium thiosulfate; MagThio, magnesium thiosulfate.

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 2009 (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 14 years of this test. Potassium fertilization increased corn yield an average of 6 bu/a from 1983 to 1995, but no significant differences have been observed since then.

Introduction
This study was initiated in 1972 at the Paramore 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. In 2002, sprinkler irrigation with a linear move irrigation system replaced the furrow irrigation. 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 (1976–2009), 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 (1997–2009). Nitrogen rates included a factorial arrangement of 0, 40, and 160 lb/a 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, 1999–2009).

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), Asgrow RX785 (2007), and DeKalb DKC63-42 (2009). Corn was planted in mid-April, 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 2009. A plot combine was used to harvest grain yields.

Results

Average corn yields for the 7-year period from 1983 to 1995 and yields for 1997 to 2009 are shown in Table 1. Yields were maximized with 160 lb/a N in most years. Fertilization at 240 lb/a N did not significantly increase corn yield. From 1997 to 2009, 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 11 to 19 bu/a). A yield response to P fertilization was obtained in 1985 and 1993 (yearly data not shown), but 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 7-year average from 1997 to 2009 showed a nonsignificant 7 bu/a yield increase for the 60 lb/a P_2O_5 treatment 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 2009. No significant interactions between N, P, and/or K were observed. However, in 2005 and 2009, the years with the highest corn yields, the 160-60-150 treatment had the highest grain yield. This suggests a balanced fertility program is necessary for best yields in good production years.

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

Fertilizer[1]			Corn yield							
N	P_2O_5[2]	K2O	1983–1995	1997	1999	2001	2003	2005	2007	2009
----------lb/a----------			-----------------------------------bu/a---------------------------------							
0	0	0	87	93	88	119	88	92	126	141
0	0	60/150	86	95	106	123	84	83	101	132
0	30	0	93	101	115	124	107	114	120	154
0	30	60/150	86	87	90	115	102	80	108	136
0	60	0	84	86	76	110	101	102	100	157
0	60	60/150	92	89	79	115	106	105	104	139
40/120	0	0	129	200	202	183	174	171	191	208
40/120	0	60/150	126	181	195	173	167	189	201	216
40/120	30	0	123	189	188	168	188	179	187	192
40/120	30	60/150	138	208	181	192	198	200	189	223
40/120	60	0	117	195	159	183	202	194	194	201
40/120	60	60/150	132	190	213	182	195	201	194	232
160	0	0	171	203	171	171	188	196	197	217
160	0	60/150	177	177	206	168	175	194	206	211
160	30	0	168	184	189	174	184	174	168	193
160	30	60/150	181	205	209	190	211	200	184	216
160	60	0	167	191	199	205	205	203	196	218
160	60	60/150	178	204	203	198	193	213	201	242
80	30	60/150	151	187	177	167	167	167	202	219
240	30	60/150	182	206	219	192	192	192	197	220
LSD (0.05)			15	27	46	26	34	28	26	41
Nitrogen means										
0			88	92	92	118	98	96	110	143
40/120			127	194	190	180	187	189	193	212
160			174	194	196	184	193	197	192	216
LSD (0.05)			8	19	19	13	17	13	13	11
Phosphorus means										
	0		129	158	161	156	146	154	170	187
	30		131	162	162	160	165	158	159	186
	60		128	159	155	166	167	170	165	198
LSD (0.05)			NS	NS	NS	NS	17	NS	NS	NS
Potassium means										
		0	127	160	154	160	160	158	164	187
		60/150	133	159	165	162	159	163	165	194
LSD (0.05)			6	NS	NS	NS	NS	NS	NS	NS

[1] Fertilizer applied to corn in odd years from 1983 to 2009 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] Potassium treatments were 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). Nitrogen and potassium treatments were applied to corn in 1997.

Effect of Various Foliar Fertilizer Materials on Irrigated Soybean

L. D. Maddux

Summary
Various fertilizer materials were foliar applied to soybean at V5 to R3 growth stages depending on the fertilizer material being applied. Manganese thiosulfate was also applied with the 2 × 2 starter. None of the fertilizer materials significantly affected grain yield.

Introduction
This study was conducted with a grant provided by Tessenderlo Kerley, Inc., a producer of specialty products used in the agriculture, mining, and process chemical industries. Treatments varied in 2008 and 2009. The Tessenderlo Kerley products tested included calcium thiosulfate (CaTs; 0-0-0-10S-6Ca), Trisert K+ (5-0-20-13S), Trisert CB (26-0-0-0.5B), magnesium thiosulfate (MagThio; 0-0-0-10S-4Mg) and manganese thiosulfate (MnThio; analyses unknown). 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 the Rossville Unit and in 2009 at the Paramore Unit. 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 MnThio at 2.5 and 5.0 gal/a applied with starter in a 2 × 2 band and 8 days after glyphosate was applied (about R3 growth stage). A starter of 10 gal/a of 10-34-0 was applied to all plots at planting in a 2 × 2 band. Soybean varieties NK S37-F7 and Pioneer 94Y01 were planted at 139,000 seeds/a on May 16, 2008, and June 5, 2009, respectively. The foliar treatments were applied as follows: V5 – June 30, 2008; R1 – July 2, 2008 and July 10, 2009; R2 – July 14, 2008 and July 17, 2009; and R3 – July 27, 2009. In 2008, glyphosate (0.75 lb ae/a) + Intrro (2.0 qt/a) was applied on June 17 and glyphosate was applied on June 30. In 2009, glyphosate + Select + Resource was applied on June 29, and glyphosate was applied on July 19. Plots were harvested with a John Deere 3300 plot combine.

Results
Soybean yields are shown in Table 1. Yields for the untreated check were 59.9 and 69.6 bu/a in 2008 and 2009, respectively. Although yield increases of up to 4.0 bu/a in 2008 and 6.0 bu/a in 2009 were observed with some treatments, these yield increases were not statistically significant.

Table 1. Effect of various fertilizer applications on soybean yield, Kansas River Valley Experiment Field, Rossville, 2008 and 2009

Fertilizer	Rate	Growth stage 2008/2009	Soybean yield 2008	Soybean yield 2009
	gal/a		-----bu/a-----	
Check			59.9	69.6
Trisert K+	2.5	V5/NA	60.6	
Trisert K+	5.0	V5/NA	59.3	
MagThio	1.0	V5/NA	60.7	
MagThio	1.5	V5/R1	61.0	70.0
MagThio	2.0	V5/R1	63.9	71.3
Trisert CB	1.0	R2/NA	60.9	
Trisert CB	1.5	R2/NA	57.5	
CaTs	3.0	R1/R2	61.1	70.6
CaTs	5.0	R1/R2	63.2	73.0
MnThio, 2 × 2 with starter	2.5	NA/at planting		72.9
MnThio, 2 × 2 with starter	5.0	NA/at planting		71.3
MnThio, glyphosate application 8 days after treatment	2.5	NA/R3		68.9
MnThio, glyphosate application 8 days after treatment	5.0	NAR3		75.6
LSD (0.05)			NS	NS

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 yields of winter wheat and alternative crops 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 predominant dryland cropping systems. A 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 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 and in 2007 to a wheat/grain sorghum/canola cropping system. The second alternative cropping system, established in 1990, has winter wheat following soybean. Both cropping systems are seeded NT 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 is 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 and 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 plots 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 spring 1994. Fertility rates were maintained, and the oat crop was harvested in July. Winter wheat has been planted in mid-October each year in the plots since fall 1994. New herbicides have helped control cheat in the NT treatments. These plots were seeded to canola in fall 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. Hail adversely affected wheat yields in 2008, but wheat yields were average in 2009.

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, Kansas Agricultural Experiment Station 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 fall 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 similar to yield of wheat after soybean.

Results

Unlike 2008 wheat yields, which were affected by hail, 2009 wheat yields reflected the favorable moisture conditions in the spring. Wheat yields in 2009 were closer to average yields for the time period of these studies.

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, Kansas Agricultural Experiment Station 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, Kansas Agricultural Experiment Station 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 fall 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 (2007 harvest) 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. The continuous wheat plots were not harvested for yield data in 2008 because of the severe hail damage from the May 5 storm. Yields in 2009 were excellent because moisture and temperatures during grain filling were ideal for winter wheat.

Wheat After Soybean

Wheat yields after soybean also reflect differences in N rate. However, wheat yields from this cropping system are compared 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, Kansas Agricultural Experiment Station 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. An 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. Wheat yields for 2009 continued to reflect the N added by the soybean crop in the cropping sequence. 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 hail on May 5, 2008, and, therefore, were not harvested for yield data in 2008. 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, Kansas Agricultural Experiment Station 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 such as 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. Because of 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 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. The canola did not survive the winter; thus, wheat yields in 2009 do not reflect the presence of a canola crop in the cropping sequence.

Other Observations

Nitrogen application significantly increased grain N content 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. Planting was again delayed because of above-average rains in April. 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 are 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 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 (2007-2009) 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		2009	
N Rate	CT[2]	NT	CT	NT	CT	NT	CT	NT	CT	NT	CT	NT[3]	CT	NT	CT	NT
lb/a	----------------------------								bu/a	----------------------------						
0	50	11	26	8	54	9	66	27	47	26	10	0	15	14	37	13
25	53	26	34	9	56	9	68	41	63	36	19	0	13	16	44	31
50	54	35	32	8	57	22	65	40	68	38	26	0	12	14	45	22
75	58	36	34	7	57	42	63	37	73	43	28	0	12	14	44	26
100	54	34	35	5	56	35	64	43	73	40	31	0	9	13	43	22
125	56	36	32	5	57	38	63	31	69	35	31	0	9	16	44	14
LSD[4] (0.01)	10	10	6	NS	NS	18	NS	9	14	14	6	0	6	NS	NS	15

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, Kansas Ag. Exp. Stn. Report of Progress 854. Data for the years 1996 through 2000 can be found in Agronomy Field Research 2006, Kansas Ag Exp. Stn. 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	2009
lb/a	--bu/a--								
0	12	9	31	40	30	29	15	9	26
25	16	10	48	46	43	38	21	15	29
50	17	9	59	48	49	46	23	19	37
75	17	7	65	46	52	46	24	23	41
100	20	8	67	43	50	52	23	23	44
125	21	8	66	40	48	50	20	23	41
LSD[3] (0.01)	7	4	3	5	5	3	3	3	6
CV (%)	23	24	4	6	6	5	9	11	9

[1] Data for the years 1991 through 2000 can be found in Agronomy Field Research 2006, Kansas Ag. Exp. Stn. 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	2009
lb/a	--bu/a--							
0	45	10	9	47	59	38	10	7
HV[3]	45	10	5	36	63	58	13	16
50	41	8	4	35	56	61	15	26
WP[3]	41	9	8	37	60	64	13	30
100	39	5	5	32	55	58	14	29
SC[3]	42	6	6	36	55	55	11	33
LSD[4] (0.01)	5	3	NS	8	6	5	2	5
CV (%)	6	20	70	12	6	7	10	12

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

[1] Data for the years 1997 through 2000 can be found in Agronomy Field Research 2006, Kansas Ag. Exp. Stn. 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	2009
lb/a	bu/a													
0	16	26	22	33	25	7	22	5	53	20	18	15	36	33
25	17	29	23	35	21	8	22	6	50	19	18	16	39	33
50	18	30	23	36	23	9	22	6	50	18	18	14	37	35
75	20	29	24	36	24	8	21	7	51	18	18	15	37	34
100	22	31	25	37	21	9	21	7	51	19	18	16	39	34
125	20	25	24	34	22	8	22	7	49	19	19	14	39	34
LSD[2] (0.01)	3	NS	NS	NS	NS	NS	NS	1.4	NS	NS	1	NS	NS	NS
CV (%)	10	12	6	12	15	13	7	17	6	11	5	11	8	9

[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	2009
lb/a	bu/a													
0	32	13	57	52	55	15	34	10	86	86	19	---	39	92
25	76	29	63	67	56	15	41	10	112	90	18	---	43	92
50	93	40	61	82	54	13	43	9	129	97	16	---	54	96
75	107	41	60	84	49	9	43	8	136	95	14	---	56	87
100	106	65	55	77	50	7	46	8	141	101	12	---	61	82
125	101	54	55	82	49	7	47	9	142	95	12	---	74	87
LSD[2] (0.01)	8	13	NS	13	NS	NS	8	NS	9	12	4	---	16	NS
CV (%)	5	18	10	9	10	58	11	24	4	7	18	---	17	18

[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	2009
lb/a	--------	--------	--------	--------	--------	--------	--------	bu/a	--------	--------	--------	--------	--------	--------
0	73	26	69	81	68	17	22	21	92	84	20	37	70	118
25	99	36	70	106	54	17	21	16	138	93	21	50	85	127
50	111	52	73	109	66	13	25	15	135	90	28	48	98	129
75	93	35	72	95	51	19	23	17	138	101	23	52	96	131
100	109	54	67	103	45	12	25	14	136	89	27	52	100	122
125	94	21	72	92	51	19	19	19	94	80	28	53	101	129
LSD[3] (0.01)	13	14	NS	21	16	6	NS	5	19	16	6	16	18	NS
CV (%)	8	22	13	12	16	21	20	22	9	10	19	18	11	8

[1] In years 1996–2007, the 25, 75, and 125 lb/a N rates were replaced with hairy vetch, winter pea, and sweet clover, 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.

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

Overall in 2008, adding nitrogen (N) increased wheat yields, but the advantage of knifing compared with broadcast and dribble placement was apparent only in no-till. Double-crop soybean yields were slightly decreased with no-till but unaffected by the residual from N placement treatments.

Introduction

Many crop rotation systems are used in southeastern Kansas. This experiment is 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) continues in the same areas used during the previous 22 years. The conventional system consists of chiseling, disking, and field cultivation. Chiseling occurs in the fall preceding corn or wheat crops. The reduced-tillage system consists of disking and field cultivation prior to planting. Glyphosate (Roundup) is applied to the no-till areas. The four N treatments for the crop are: 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-numbered years is 125 lb/a. The N rate of 120 lb/a for wheat is split as 60 lb/a applied preplant as broadcast, dribble, or knifed UAN. All plots except the controls are top-dressed in the spring with broadcast UAN at 60 lb/a N.

Results

In 2008, adding fertilizer N, in general, doubled wheat yields compared with the no-N controls (Figure 1). Wheat yield was affected by an interaction between tillage and N placement. With conventional and reduced tillage, there were no differences in yield due to placement method. In no-till, knife application of fertilizer N resulted in nearly 50% greater yield than broadcast or dribble applications but did not fully compensate for yield reduction with no-till. Although double-crop soybean yields were not affected by the residual effect of N placement or an interaction of N placement with tillage (data not shown), no-till soybean yield was 3 to 4 bu/a less than yields with conventional or reduced tillage (Figure 2).

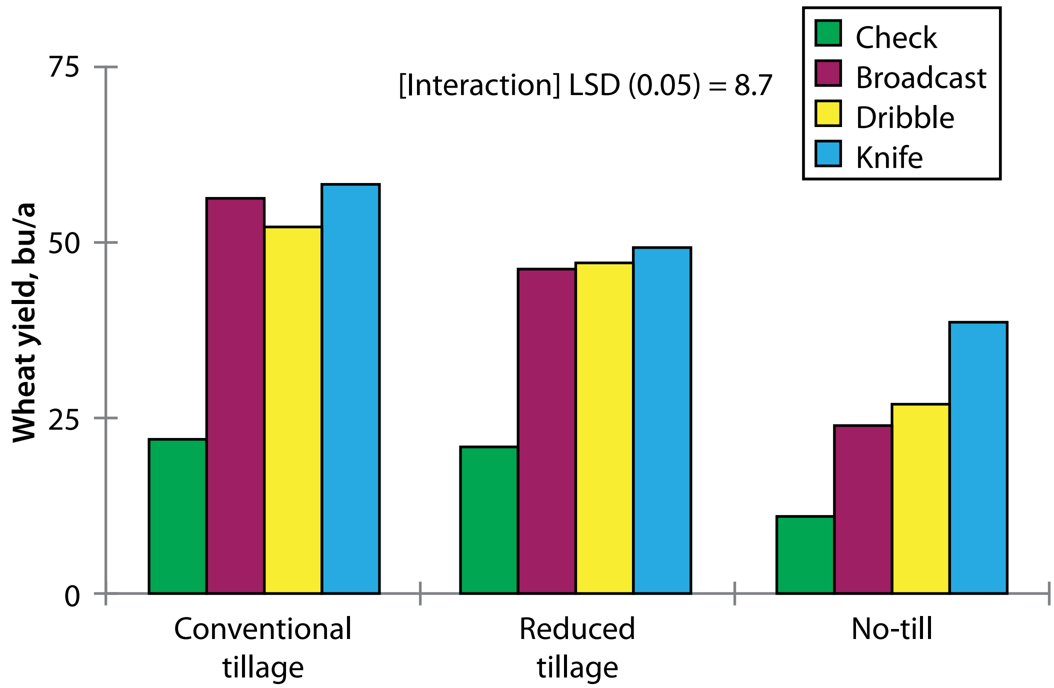

Figure 1. Effect of tillage and nitrogen placement on wheat yield, Southeast Agricultural Research Center, 2008.

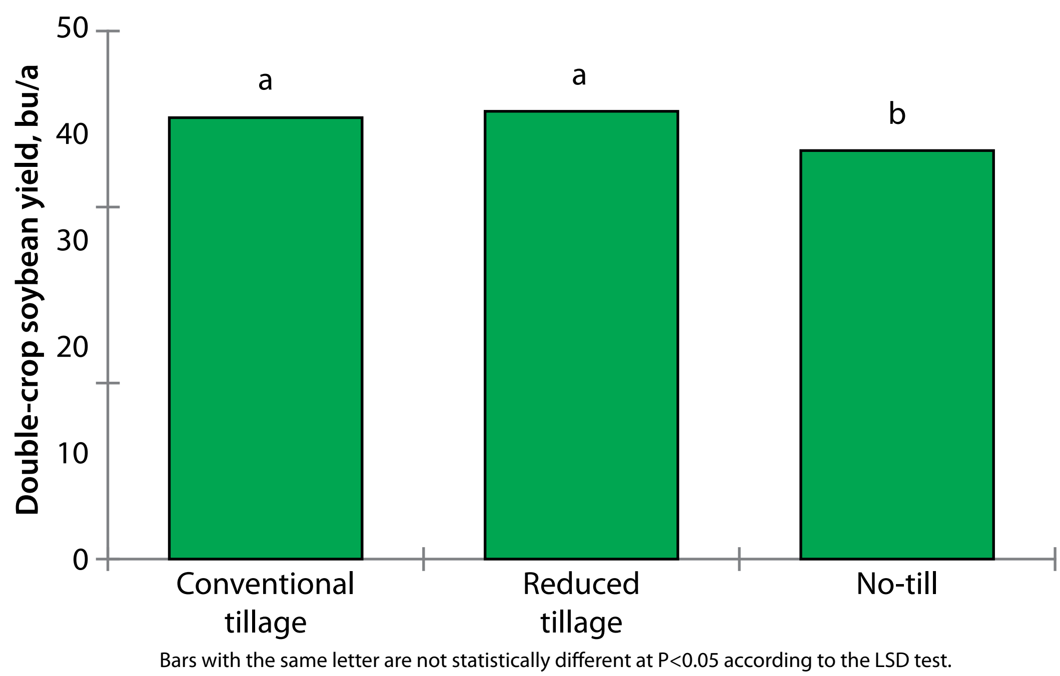

Figure 2. Effect of tillage on soybean yield planted as a double crop after wheat, Southeast Agricultural Research Center, 2008.

Effect of Nitrogen and Phosphorus Starters on Short-Season Corn Grown in Conservation-Tillage Systems

D. W. Sweeney, D. B. Mengel, and K. W. Kelley

Summary
Overall corn yields in 2008 averaged near 150 bu/a. Corn yields were not improved by use of starters. Even though early corn growth appeared to be improved with the highest phosphorus (P) rate in the starter, this effect did not persist by the reproductive stages of growth.

Introduction
Corn acreage has increased in southeastern Kansas in recent years because of the introduction of short-season cultivars that enable producers to plant in the upland, claypan soils typical of the area. Short-season hybrids reach reproductive stages earlier than full-season hybrids and thus may partially avoid midsummer droughts, which are often severe on these claypan soils that have limited plant-available moisture storage.

Optimum corn production results from proper management of soil fertility, tillage, and other practices. However, ideal soil fertility and other management options have not been well defined for short-season corn production in southeastern Kansas. Reducing tillage has the potential to reduce soil and nutrient losses to the environment, and maintaining proper plant nutrition is critical for crop production. Starter fertilizers have been used to improve early plant growth in no-till or reduced-tillage systems, and this often translates to additional yield. However, data are limited regarding the effect of starter fertilization on yield of short-season corn grown on the claypan soils found in areas of the eastern Great Plains. The objective of this study was to determine the effect of nitrogen (N) and P rates in starter fertilizers on short-season corn planted with reduced tillage or no-till.

Procedures
The experiment was conducted in 2008 at the Kansas State University Southeast Agricultural Research Center at Parsons, KS. The soil was a Parsons silt loam with a claypan subsoil. Selected background soil chemical analyses in the 0- to 6-in. depth were pH 6.5 (1:1 soil:water), 5 ppm P (Bray-1), 65 ppm K (1 M $NH_4C_2H_3O_2$ extract), 5.3 ppm NH_4-N, 6.4 ppm NO_3-N, and 2.8% organic matter. The experimental design was a split-plot arrangement of a randomized complete block with three replications. The whole plots were tillage system (reduced tillage and no-till), and subplots were starter N-P combinations. Nine of the subplots were starter fertilizer combinations in which N rates were 20, 40, and 60 lb/a and P rates were 0, 25, and 50 lb/a P_2O_5. In addition, there were two reference subplot treatments: a no-starter treatment (all N and P applied preplant) and a control with no N or P. All plots except the no N-P control were balanced to receive a total of 120 lb/a N and 50 lb/a P_2O_5. The N and P fertilizer sources were 28-0-0 and 10-34-0 fluids. All plots received 60 lb/a K_2O as solid KCl broadcast preplant. Pioneer 35F37 Roundup Ready corn was planted at 25,000 seeds/a

on Apr. 16, 2008. Starter solutions were applied 2 × 2 with the planter. Grain was harvested for yield on Sept. 19, 2008, with a small-plot combine equipped with a corn head.

Results

Although rainfall was variable, environmental conditions were more favorable than in the past 2 years, resulting in overall corn yields in 2008 near 150 bu/a. However, corn yields were not improved by use of starters in 2008. Average corn yield with starters was 8 bu/a less than with all N and P fertilizer applied broadcast prior to planting (Table 1). This yield difference appeared to be due to a greater number of kernels per ear in the treatment with all N and P broadcast prior to planting. Even though early growth appeared to be improved with the highest P rate in the starter, this effect did not persist by the reproductive stages of growth (Table 2). A rate of 40 lb/a N in the starter resulted in greater dry matter production at R1 compared with 20 lb/a N, but this effect was not apparent at any other growth stage. At the R4 (dough) growth stage, dry matter production was not significantly affected by any treatment including the control.

Table 1. Effect of conservation-tillage systems and nitrogen and phosphorus starter rates on yield and yield components of short-season corn, Southeast Agricultural Research Center, 2008

Treatments	Yield	Population	Kernel weight	Kernels/ear
	bu/a	plants/a	mg	
Tillage[1]				
Reduced	153	27700	284	589
No-till	146	28500	281	577
LSD (0.05)	NS	NS	NS	NS
Starter N Rate, lb/a				
20	147	28100	286	580
40	153	28000	281	595
60	149	28200	282	577
LSD (0.05)	NS	NS	NS	NS
Starter P_2O_5 rate, lb/a				
0	153	28100	284	581
25	150	27500	284	583
50	147	28600	280	588
LSD (0.05)	NS	NS	NS	NS
All N-P preplant	158	28200	285	601
Control (No N or P)	140	28100	278	533

[1] Means for tillage include all treatments.

Table 2. Effect of conservation-tillage systems and nitrogen and phosphorus starter rates on corn dry matter accumulation at the V6, V12, R1 (silk), and R4 (dough) growth stages, Southeast Agricultural Research Center, 2008

Treatments	V6	V12	R1	R4
	--------	-------- lb/a	--------	--------
Tillage[1]				
Reduced	480	3750	6230	12900
No-till	490	3610	6150	13300
LSD (0.05)	NS	NS	NS	NS
Starter N Rate, lb/a				
20	490	3520	5930	12900
40	530	3780	6720	13300
60	520	3820	6370	13300
LSD (0.05)	NS	NS	490	NS
Starter P_2O_5 rate, lb/a				
0	490	3720	6370	13500
25	470	3490	6100	12800
50	590	3930	6560	13200
LSD (0.05)	60	330[†]	NS	NS
All N-P preplant	450	4000	5860	13700
Control (No N or P)	270	3060	5150	12000

[1] Means for tillage include all treatments.
[†] Significant at the 0.10 probability level.

Effects of Planting Date, Nitrogen Placement, and Timing of Supplemental Irrigation on Sweet Corn

D. W. Sweeney and M. B. Kirkham

Summary

In 2008, irrigation applied at both the VT and R2 growth stages increased total fresh weight but not number of ears or individual ear weight. Earlier planting increased total ears, total fresh weight, and individual ear weight. Knife application increased total sweet corn fresh weight, but nitrogen (N) placement had no effect on number of ears or individual ear weight.

Introduction

Sweet corn is a possible value-added, alternative crop for producers in southeastern Kansas. Corn responds to irrigation, and timing of water deficits can affect yield components. Even though large irrigation sources, such as aquifers, are lacking in southeastern Kansas, supplemental irrigation could be supplied from the substantial number of small lakes and ponds in the area. However, there is a lack of information on effects of irrigation management, N placement, and planting date on performance of sweet corn, which may hinder producers' adoption of this crop.

Procedures

The experiment was established on a Parsons silt loam in spring 2008 as a split-plot arrangement of a randomized complete block with three replications. The whole plots included two planting dates (targets of late April and mid-May) and four irrigation schemes: (1) no irrigation, (2) 1.5 in. at VT (tassel), (3) 1.5 in. at R2 (blister), and (4) 1.5 in. at both VT and R2. Subplots were three N treatments consisting of no N and 100 lb/a N applied broadcast or as a subsurface band (knife) at 4 in. Sweet corn was planted on Apr. 22 and May 19, 2008. Sweet corn from the first planting date was picked on July 14 and 18, and corn from the second planting date was picked on Aug. 1 and 6, 2008.

Results

The total number of ears was 15% greater from sweet corn planted in April than sweet corn planted in May (Table 1), and there was a similar difference in individual ear weight. As a result, total fresh weight was more than 30% greater for sweet corn planted in April than in May. Limited irrigation applied at both the VT and R2 growth stages resulted in more than 10% greater total fresh weight than no irrigation or irrigation at only one growth stage. Irrigation did not increase number of ears per acre or individual ear weight. Nitrogen placement did not affect number of ears or individual ear weight, but knifing increased total fresh weight by about 10% above broadcast N or no N fertilizer. The minimal response to fertilizer N may be a result of the plot area being fallowed the previous year.

Table 1. Effects of planting date, irrigation scheme, and nitrogen placement on sweet corn, Southeast Agricultural Research Center, 2008

Treatment	Total ears	Total fresh weight	Individual ear weight
	ears/a	ton/a	g/ear
Planting date			
Date 1	17100	6.08	323
Date 2	14900	4.54	278
LSD (0.05)	1000	0.29	13
Irrigation scheme			
None	15600	5.07	293
VT (1.5 in.)	15500	5.17	303
R2 (1.5 in.)	15900	5.17	296
VT-R2 (1.5 in. at each)	17000	5.81	310
LSD (0.10)	NS	0.41	NS
N Placement			
None	15800	5.20	297
Broadcast	15500	5.19	301
Knife	16600	5.54	303
LSD (0.05)	NS	0.28†	NS
Interactions	NS	NS	NS

† Significant at the 0.10 probability level.

Effects of Nitrogen Fertilizer and Previous Double-Cropping Systems on Subsequent Corn Yield

K. W. Kelley and J. L. Moyer

Summary
In 2009, corn yields were highest following double-crop soybean, double-crop sunflower, chemical fallow, or summer fallow interseeded with sweet clover. Corn yields were lowest following double-crop grain sorghum. Corn yield response to nitrogen (N) fertilizer differed among previous wheat/double-crop systems, but yields increased with increasing N rate.

Introduction
In southeastern Kansas, producers typically double-crop soybean after wheat, but other double-crop options are suitable for the growing conditions of this region. Grain sorghum can be grown successfully as a double-crop option if planted by early July. If wet conditions follow wheat harvest, double-crop sunflower can be planted as late as mid- to late July. Small-seeded legumes, such as lespedeza or sweet clover, typically are seeded into wheat in late winter. Lespedeza commonly is grown for seed or cut for hay, and sweet clover is planted primarily for soil amendment purposes. Fewer producers summer fallow land after wheat harvest. Previous wheat and double-crop systems likely affect growth of subsequent crops, such as corn. In addition, N fertilizer requirements for corn might need to be adjusted depending on the previous wheat and double-crop system used.

Procedures
The study was conducted at the Parsons Unit of the Southeast Agricultural Research Center. The experimental design was a split-plot arrangement with three replications. Main plots consisted of six different systems: (1) wheat/double-crop soybean, (2) wheat/double-crop grain sorghum, (3) wheat/double-crop sunflower, (4) wheat/sweet clover, (5) wheat/lespedeza, and (6) wheat/chemical fallow.

Double-crop grain sorghum and sunflower plots each received 75 lb/a N. Subplots consisted of six preplant fertilizer N rates (0, 30, 60, 90, 120, and 150 lb/a) for corn following wheat/double-crop options. The nitrogen source was 28% N solution preplant applied with a coulter-knife applicator. Because residual soil test values were relatively high, neither phosphorus nor potassium fertilizer was applied. Corn was planted with conventional tillage.

Results
Corn yields in 2009 were highest following wheat/double-crop soybean, wheat/double-crop sunflower, chemical summer fallow, or summer fallow interseeded with sweet clover (Table 1). Corn yields were lowest following wheat/double-crop grain sorghum. Similar corn yield trends in response to wheat/double-crop options are shown in the

3-year averages (Table 1). The higher N fertilizer requirement following wheat/double-crop grain sorghum likely is the result of greater immobilization of N fertilizer following the high-residue sorghum crop. In addition, sweet clover growth was reduced in 2 of the 3 years because of dry soil conditions during midsummer, which likely affected subsequent corn yield responses.

Table 1. Effects of nitrogen and previous wheat/double-crop options on subsequent corn production, Parsons Unit, Southeast Agricultural Research Center

Previous wheat/double-crop system	N rate	Corn yield	
		2009	3-year avg.
	lb/a	--------------bu/a --------------	
Chemical fallow	0	57.0	57.8
	30	83.0	86.2
	60	93.5	119.3
	90	107.5	128.4
	120	113.6	144.2
	150	123.6	153.7
Soybean	0	62.6	79.0
	30	75.9	101.2
	60	88.5	116.3
	90	105.3	132.4
	120	109.7	140.9
	150	133.4	153.0
Grain sorghum	0	49.1	40.5
	30	51.7	61.9
	60	65.5	80.1
	90	78.3	100.9
	120	82.3	119.8
	150	106.6	131.2
Sunflower	0	47.9	57.4
	30	76.6	82.5
	60	98.0	122.0
	90	113.2	134.0
	120	117.7	144.0
	150	126.8	154.4
Sweet clover	0	57.7	61.4
	30	66.2	74.8
	60	89.0	111.0
	90	107.0	126.6
	120	121.3	143.7
	150	123.6	146.3

continued

Table 1. Effects of nitrogen and previous wheat/double-crop options on subsequent corn production, Parsons Unit, Southeast Agricultural Research Center

Previous wheat/double-crop system	N rate	Corn yield	
		2009	3-year avg.
		---------------bu/a ---------------	
Lespedeza	0	50.0	61.3
	30	55.8	74.5
	60	66.5	98.6
	90	99.4	125.0
	120	120.6	139.7
	150	125.7	145.4
LSD (0.05)			
Same cropping system		6.8	5.6
Different system		7.3	7.1
Mean values:			
Chemical fallow		96.4	115.0
Soybean		95.9	120.5
Grain sorghum		72.2	89.1
Sunflower		96.7	115.7
Sweet clover		94.1	110.7
Lespedeza		86.3	107.4
LSD (0.05)		4.4	5.3

Effects of Fertilizer Nitrogen 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. However, the yield differences between preplant N and side-dress N have been small. Grain yields have been influenced more by fertilizer N rate than time of N application.

Introduction

Because of recent increases in fertilizer N prices, producers are looking for ways to reduce production costs for feed-grain crops, such as corn and grain sorghum. One method that has gained renewed interest is 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 conducted at the Columbus Unit of the Southeast Agricultural Research Center from 2005 through 2009 to evaluate the effects of time and rate of fertilizer N application for both corn and grain sorghum. Fertilizer N (28% liquid N) treatments consisted of different N rates applied preplant or side-dressed. Preplant fertilizer N was subsurface applied in mid-March on 15-in. centers at a depth of 4 to 6 in. Side-dress N also was subsurface applied between 30-in. rows during the early growing season. All plots received 30 lb/a N preplant as 18-46-0. The previous crop was double-crop soybean.

Results

Wet soil conditions in early spring prevented corn from being planted in 2009. Corn yields for 2008 and 3-year averages are shown in Table 1. Grain sorghum yield results for 2009 and 4-year averages also are included in Table 1. In this study, both corn and grain sorghum yields responded more to rate than time of fertilizer N application. Even though soil moisture was excessive during early spring in several years, denitrification loses evidently were small at this silt loam site, where water did not pond on the soil surface.

Table 1. Effects of fertilizer nitrogen rate and time of application on corn and grain sorghum yields, Southeast Agricultural Research Center, Columbus Unit, 2006 to 2009

Rate of fertilizer N[1]		Grain yield			
		Corn		Grain sorghum	
Preplant	Side-dress	2008	3-year avg.	2009	4-year avg.
--------------lb N/a --------------		---------------------------bu/a ---------------------------			
30	0	77.2	77.8	106.1	92.8
60	0	89.6	92.0	129.3	113.9
90	0	111.8	111.1	138.0	123.1
120	0	129.6	122.0	142.4	133.3
150	0	130.4	128.5	148.2	136.0
30	30	84.2	89.1	126.3	113.7
30	60	103.3	107.3	138.6	125.6
30	90	116.7	118.7	147.3	136.3
30	120	113.4	126.6	151.4	139.1
LSD (0.05)		6.4	6.1	6.7	3.4

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

Effect of Previous Crop, Nitrogen Placement Method, and Time of Nitrogen Application on No-Till Wheat Yield

K. W. Kelley and D. W. Sweeney

Summary

Previous crop, fertilizer nitrogen (N) method, and time of N application significantly influenced no-till wheat yields. In 2009, yields were significantly greater for wheat following soybean than for wheat following corn or grain sorghum. Yield responses to N method and time of N application varied with previous crop. Yield potential was reduced because of excessive rainfall in April and May, which also resulted in severe scab disease infection after heading.

Introduction

In southeastern Kansas, wheat is commonly planted after a summer crop, such as corn, grain sorghum, or soybean, to diversify crop rotation. Improved equipment technology has made no-till planting of wheat more feasible in high-residue conditions. The benefits of planting wheat no-till are reduced labor and tillage costs and less soil erosion. Leaving crop residues near the soil surface, however, affects fertilizer N management for no-till wheat.

Procedures

The experiment was a split-plot design, in which main plots were previous crops (corn, grain sorghum, and soybean) and subplots were three fertilizer N methods and three N application times. Application methods were: (1) subsurface knife of 28% N (coulter-knife on 15-in. spacing at a depth of nearly 4 in.), (2) surface strip-band of 28% N (15-in. strip bands on soil surface), (3) surface broadcast of 28% N using TeeJet streamer nozzles, and (4) surface broadcast of urea (46% N). The N application times were: (1) ⅓ of the N in fall followed by ⅔ in late winter, (2) ⅔ of the N in fall followed by ⅓ in late winter, and (3) all N applied in fall. All plots also received 100 lb/a of 18-46-0 and 100 lb/a of 0-0-60. Wheat was planted on October 21 with a no-till drill in 7.5-in. spacing at a seeding rate of 100 lb/a.

Results

In 2009, wheat yields were reduced because of excessive rainfall in April and May, which resulted in a severe scab disease infection after wheat heading. Wheat yields were highest following soybean, and yields generally were similar following either corn or grain sorghum (Table 1). However, fertilizer N responses varied with previous crop. When wheat followed grain sorghum, N application method and time of N application resulted in more significant yield responses compared with wheat following soybean or corn.

Table 1. Effect of previous crop, nitrogen application method, and time of nitrogen application on no-till wheat yield, Southeast Agricultural Research Center, Parsons Unit, 2009

Fertilizer N application method and N source	Time of N application: Fall	Time of N application: Late winter	Wheat yield following: Corn	Wheat yield following: Grain sorghum	Wheat yield following: Soybean
	-------- lb/a --------		--------------- bu/a ----------------		
Subsurface knife	33	67	45.4	52.4	59.8
(28% liquid N)	67	33	44.5	49.4	58.8
	100	0	46.6	44.5	58.7
Surface strip-band	33	67	44.8	46.0	57.2
(28% liquid N)	67	33	46.3	46.6	59.5
	100	0	42.9	40.1	55.2
Surface broadcast	33	67	44.9	45.2	54.8
(28% liquid N)	67	33	46.6	46.1	58.6
	100	0	41.7	41.2	54.2
Surface broadcast	33	67	45.2	48.5	59.0
(46% urea)	67	33	46.1	45.1	59.0
	100	0	45.5	41.1	56.7
Control			14.3	16.8	33.5
Means (without control)			Avg. yield		
Corn			45.0		
Grain sorghum			45.5		
Soybean			57.6		
LSD (0.05)			2.5		
Subsurface-knife	28% N		51.1		
Surface strip-band	28% N		48.7		
Surface broadcast	28% N		48.1		
	Urea		49.6		
LSD (0.05)			1.5		
Fall (⅓) – Late winter (⅔)			50.3		
Fall (⅔) – Late winter (⅓)			50.5		
Fall (all)			47.3		
LSD (0.05)			1.3		

Comparison of Fertilizer Nitrogen Sources Applied in Late Winter for No-Till Winter Wheat

K. W. Kelley

Summary
This study compared the effects of various fertilizer nitrogen (N) sources applied in late winter to no-till wheat following corn. Although grain yields were reduced because of moderate scab disease infection after heading, yields were still significantly affected by fertilizer N source and method of application. Including a urease inhibitor with 28% N solution resulted in greater yield compared with surface-applied urea.

Introduction
More producers are planting winter wheat no-till into previous crop residues as a means of reducing labor and tillage costs. However, the large amount of crop residue left on the soil surface in no-till systems can make N management difficult. Loss of N as ammonia (NH_3) is a concern in no-till crop production when urea-containing fertilizers are applied to the soil surface. The use of urease inhibitors, such as Agrotain and Nutrisphere, applied with urea-containing fertilizers has been shown to reduce ammonia volatilization losses. In addition, a slow-release polymer-coated urea (ESN) has become available as an N management product. Ammonium thiosulfate (ATS) also has the ability to slow soil urease activity and delay urea hydrolysis. This study compared the effects of various fertilizer N sources and urease inhibitors applied in late winter to no-till wheat following corn.

Procedures
Winter wheat was planted in mid-October 2008 following corn harvest at the Parsons Unit of the Southeast Agricultural Research Center. Wheat was planted no-till in 7.5-in. spacing at a seeding rate of 100 lb/a. All plots received a preplant broadcast application of 100 lb/a of 18-46-0. Various fertilizer N sources were applied in late February at a rate of 75 lb/a N. Fertilizer N treatments were ESN, Nutrisphere-N + urea-ammonium nitrate solution (UAN; 28%N), Agrotain + UAN, UAN + ATS, UAN alone, urea, and ammonium nitrate. Liquid UAN treated with urease inhibitors was broadcast on the soil surface using TeeJet nozzle streamers. In addition, effects of UAN as a broadcast application on the soil surface and as a subsurface treatment applied on 15-in. centers with a coulter-shank applicator were compared.

Results
Grain yields were reduced because of excessive rainfall in April and May, which resulted in moderate scab disease infection after wheat headed. However, wheat yields were significantly affected by fertilizer N source. Applying a urease inhibitor with UAN generally increased wheat yield compared with UAN alone and surface-applied urea. Additional research conducted under various environmental conditions is needed to evaluate the effectiveness of urease inhibitors with urea-containing N fertilizer sources.

Table 1. Comparison of fertilizer nitrogen sources applied in late winter to no-till winter wheat, Southeast Agricultural Research Center, Parsons Unit, 2009

Fertilizer N source[1]	N rate	N application method	Yield
	lb/a		bu/a
UAN (28% N)	75	Broadcast	42.1
UAN + Nutrisphere	75	Broadcast	45.8
UAN + Agrotain	75	Broadcast	44.2
UAN + ATS	75	Broadcast	41.6
UAN	75	Subsurface-knife	41.8
UAN	75	Surface-band	41.0
ESN-polymer	75	Broadcast	39.4
Urea	75	Broadcast	37.8
Ammonium nitrate	75	Broadcast	44.5
Control	0		13.5
LSD (0.05)			4.8

[1] UAN, urea-ammonium nitrate solution (28% N); Nutrisphere and Agrotain are urease inhibitors; ATS, ammonium thiosulfate (12% N); ESN-polymer, environmentally smart nitrogen (43% N) with a polymer coating; Urea, 46% N; ammonium nitrate, 34% N.

All plots also received 100 lb/a of 18-0-46 as a preplant application.

Late-winter N treatments were applied on Feb. 24, 2009.

Previous crop was corn.

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

K. W. Kelley

Summary
Neither rate nor timing of fertilizer phosphorus (P) and potassium (K) application significantly affected grain yields of grain sorghum, wheat, and double-crop soybean during the first two cropping cycles 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 P and K fertilizer rate and time of 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. The 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 no-till. Different fertilizer P and K 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.

Results
Effects of various fertilizer P and K treatments on grain sorghum, wheat, and double-crop soybean yields are shown in Table 1. Fertilizer treatment has affected grain yields very little during first two cropping cycles. The nonsignificant yield response to fertilizer P and K was not unexpected because initial soil test values indicated that soil values of P and K were sufficient for the expected yield goals. Results of soil analyses after two complete cropping cycles are shown in Table 2. Soil P and K levels are beginning to change from initial values. Soil sampling will continue over time to monitor changes in soil nutrient levels.

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 P205 and 72 lb/a K20. Thus, this study will continue for several cropping cycles to monitor residual effects of fertilizer P and K treatments on grain yields and soil nutrient concentrations of P and K. Additional treatments, such as starter fertilizer effects, likely will be imposed in the study as soil test values change with time.

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						Average grain yield		
Grain sorghum			Wheat					
N	P_2O_5	K_2O	N	P_2O5	K_2O	Grain sorghum	Wheat	Soybean
--------------------------------lb/a--------------------------------						---------------bu/a---------------		
120	0	0	120	0	0	90	42	32
120	45	45	120	45	45	92	46	34
120	90	90	120	0	0	95	44	33
120	60	60	120	60	60	93	46	33
120	120	120	120	0	0	95	46	33
120	75	75	120	75	75	94	46	33
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 yield averages: Grain sorghum = 6 years (2004–2009); Wheat = 3 years (2005, 2006, and 2008); No wheat data in 2007 because of freeze damage or in 2009 because of severe scab disease infection; Double-crop soybean = 5 years (2005–2009).

Table 2. Effects of phosphorus and potassium fertilizer rate and time of application on soil phosphorus and potassium in a double-cropping system, Southeast Agricultural Research Center, Columbus Unit

Fertilizer rate						Soil test values			
Grain sorghum			Wheat			Site 1		Site 2	
N	P_2O_5	K_2O	N	P_2O_5	K_2O	P	K	P	K
----------------------------------lb/a----------------------------------						---------- ppm ----------			
120	0	0	120	0	0	13	94	12	83
120	45	45	120	45	45	23	123	22	107
120	90	90	120	0	0	22	119	20	96
120	60	60	120	60	60	27	128	24	105
120	120	120	120	0	0	26	124	22	101
120	75	75	120	75	75	32	147	31	123

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.
Soil test values after two complete cropping cycles.

Nitrogen Management for Crabgrass Hay Production

J. L. Moyer and D. W. Sweeney

Summary
Fertilizing crabgrass with 100 lb/a nitrogen (N) resulted in more forage than fertilizing with 50 lb/a N, but additional 50-lb increments did not result in further increases. Forage fertilized with more than 100 lb/a N generally had a higher N concentration than forage that received less N. Split application usually resulted in less forage with a lower N concentration in the first cutting but more in the second cutting than a single N application. Responses to N application as urea versus ammonium nitrate varied with cutting, N rate, and timing.

Introduction
Warm-season grass is needed to fill a production void left in forage systems by cool-season grasses. Crabgrass could fill this niche by providing high-quality forage in summer. Although crabgrass is an annual species, it is a warm-season grass that has the capacity to reseed itself. Crabgrass requires N for optimum production, but little is known about its needs or responses to different nitrogen management alternatives.

Procedures
The plot area at the Mound Valley Unit of the Southeast Agricultural Research Center was fertilized with 0-60-60 lb/a N-P_2O_5-K_2O beginning in May 2005. Shortly thereafter, the plot was seeded with 5 lb/a pure live seed of 'Red River' crabgrass [*Digitaria ciliaris* (Retz.) Koel.] with a Brillion seeder. In addition to natural reseeding, another 3 lb/a pure live seed was broadcast each spring thereafter, another 0-60-60 lb/a N-P_2O_5-K_2O was applied, and the plot area was rotary hoed.

The three N treatments (rates, sources, and timing) and a check were arranged in a 4 × 2 × 2 factorial design in four replications. Rates were 50, 100, 150, and 200 lb/a N per year, sources were urea and ammonium nitrate, and timing was either all N applied in a single application at the beginning of the growing season or split, with half applied initially and half in midsummer.

Nitrogen was applied for the initial spring applications on Apr. 12, 2006; May 22, 2007; and Apr. 15, 2008. Plots were harvested on June 26, 2006; June 21, 2007; and July 14, 2008. The split N applications were made on June 26, 2006; July 17, 2007; and July 15, 2008. The second cuttings were made on Sept. 18, 2006; Aug. 27, 2007; and Sept. 18, 2008. In 2007, some plots that emerged late because of uneven drainage from heavy rain were not harvested or sampled. Plots were harvested with a Carter flail cutter at a height of 2 to 3 in. The remainder of the area was clipped at each harvest to the same height. A forage subsample was taken from each plot for moisture determination and analysis of forage N.

Results

Forage yields responded to N fertilizer treatments somewhat differently in the 3 years, so these results are shown by year (Table 1). Nitrogen rate significantly ($P<0.05$) affected first-cut and total yield in 2006 and all yields in 2007; the 50-lb rate yielded less than the higher rates (factorial means not shown). The split N application produced less forage in cut 1 of 2006 and 2008 but more in cut 2 of 2007and 2008 compared with a single application. The only effect of source in the first 2 years was in cut 2 of 2007, when urea resulted in more forage than ammonium nitrate.

In 2008, a significant N rate by N source interaction for first-cut and total yield resulted from the sources having similar yields for all except the 200 lb/a rate, for which urea produced more than ammonium nitrate (factorial means not shown). Further, yield with ammonium nitrate seemed to peak at the 150 lb/a rate because that treatment yielded as much as the 200 lb/a rate of urea. Otherwise, treatment with 50 lb/a N yielded significantly less first-cut and total forage than th e 100 and 150 lb/a N rates regardless of source. In the second cutting, yield from ammonium nitrate application increased between 50 and 100 lb/a N but declined at the 200 lb/a N rate, whereas urea application rates from 100 to 200 lb/a N were similar. Also, increasing N rate from 50 to 100 lb/a increased yield with ammonium nitrate, but urea required 150 lb/a N to increase yield above that of the 50 lb/a rate (Table 1).

Forage N concentrations responded to N fertilizer treatments somewhat differently in the 2 years that subsamples were assayed, so these results are shown by year (Table 2). Nitrogen rate significantly ($P<0.05$) affected forage N concentration but interacted with application timing in cut 2 of 2008 (factorial means not shown). Increasing the N rate from 50 to 100 lb/a resulted in an increase of forage N concentration in 2006 but not in 2008. In 2006, forage N concentration of cut 1increased as application rate increased from 100 to 150 lb/a N but not with the addition of another 50-lb increment. In cut 2, N concentration was similar with 100 and 150 lb/a N applied, and 200 lb/a N provided a further increase. In both cuttings of 2008, average forage N concentration increased as N rate increased from 100 to 150 lb/a and increased again as N rate increased to 200 lb/a.

The single N application increased forage N concentration in cut 1 of both years, but there was an interaction of timing and N rate in 2008 because the difference occurred only at the two higher N rates. In cut 2, an effect of N timing appeared only in 2006 as an interaction with N rate, wherein split applications resulted in an increase of N concentration only at the 200 lb/a N rate (Table 2). Use of ammonium nitrate as an N source increased forage N concentration in 2008 but not in 2006.

Table 1. Forage yields of crabgrass in response to nitrogen management, Southeast Agricultural Research Center, Mound Valley Unit

Year	N Rate	N Source	N Timing	Cut 1	Cut 2	Total
				---------------ton/a---------------		
2006	0	---	---	0.90	0.89	1.79
	50	Urea	1X	1.23	0.93	2.16
			2X	1.16	1.16	2.32
		NH_4NO_3	1X	1.29	0.92	2.22
			2X	0.80	1.06	1.86
	100	Urea	1X	1.90	0.91	2.81
			2X	1.28	1.26	2.53
		NH_4NO_3	1X	1.95	0.92	2.87
			2X	1.50	1.20	2.70
	150	Urea	1X	2.04	0.90	2.95
			2X	1.85	1.16	3.01
		NH_4NO_3	1X	1.91	0.98	2.89
			2X	1.65	1.07	2.72
	200	Urea	1X	1.64	1.13	2.77
			2X	1.79	0.88	2.66
		NH_4NO_3	1X	1.72	1.06	2.77
			2X	1.80	0.96	2.75
			LSD	0.52	NS	0.47
2007	0	---	---	0.24	1.96	2.16
	50	Urea	1X	0.87	2.50	3.37
			2X	0.27	2.96	3.33
		NH_4NO_3	1X	0.86	2.28	3.14
			2X	0.37	2.41	2.77
	100	Urea	1X	1.40	3.20	4.58
			2X	0.40	3.92	4.32
		NH_4NO_3	1X	1.80	2.49	4.29
			2X	1.26	3.60	5.08
	150	Urea	1X	1.87	2.52	4.39
			2X	1.49	3.92	5.41
		NH_4NO_3	1X	1.75	2.98	4.73
			2X	1.48	3.44	4.85
	200	Urea	1X	1.21	3.03	4.24
			2X	1.97	3.28	4.80
		NH_4NO_3	1X	2.05	2.80	4.66
			2X	2.03	2.75	4.63
			LSD	0.79	0.52	0.64

continued

Table 1. Forage yields of crabgrass in response to nitrogen management, Southeast Agricultural Research Center, Mound Valley Unit

Year	N Rate	N Source	N Timing	Cut 1	Cut 2	Total
				---------------ton/a---------------		
2008	0	---	---	1.51	1.20	2.71
	50	Urea	1X	2.97	1.23	4.20
			2X	2.37	1.82	4.19
		NH_4NO_3	1X	3.24	1.50	4.74
			2X	2.10	2.22	4.32
	100	Urea	1X	4.10	1.65	5.75
			2X	3.56	1.91	5.48
		NH_4NO_3	1X	3.79	1.90	5.69
			2X	3.82	2.46	6.28
	150	Urea	1X	3.99	1.55	5.54
			2X	3.67	2.47	6.13
		NH_4NO_3	1X	4.00	1.79	5.79
			2X	4.00	2.26	6.26
	200	Urea	1X	4.28	1.74	6.02
			2X	4.32	2.28	6.60
		NH_4NO_3	1X	3.98	1.44	5.42
			2X	3.52	2.00	5.52
LSD				0.50	0.44	0.63

Table 2. Forage nitrogen concentration of crabgrass in response to nitrogen management, Southeast Agricultural Research Center, Mound Valley Unit

Year	N Rate	N Source	N Timing	Cut 1	Cut 2
				----------%----------	
2006	0	---	---	1.66	1.41
	50	Urea	1X	1.99	1.71
			2X	1.73	1.74
		NH_4NO_3	1X	2.26	1.76
			2X	1.65	1.67
	100	Urea	1X	2.14	1.91
			2X	2.19	1.84
		NH_4NO_3	1X	2.35	1.83
			2X	2.15	1.76
	150	Urea	1X	2.55	1.87
			2X	2.53	1.93
		NH_4NO_3	1X	2.52	1.88
			2X	2.36	1.95
	200	Urea	1X	2.60	1.95
			2X	2.44	2.11
		NH_4NO_3	1X	2.68	1.91
			2X	2.50	2.06
			LSD	0.35	0.15
2008	0	---	---	1.21	1.15
	50	Urea	1X	1.06	0.99
			2X	1.09	1.04
		NH_4NO_3	1X	1.07	1.08
			2X	1.33	1.07
	100	Urea	1X	1.02	0.96
			2X	1.03	1.19
		NH_4NO_3	1X	1.31	1.05
			2X	0.93	1.30
	150	Urea	1X	1.61	1.49
			2X	1.29	1.36
		NH_4NO_3	1X	1.75	1.47
			2X	1.32	1.63
	200	Urea	1X	1.79	1.51
			2X	1.28	1.68
		NH_4NO_3	1X	1.95	1.79
			2X	1.77	1.80
			LSD	0.28	0.30

Long-Term Nitrogen and Phosphorus Fertilization of Irrigated Grain Sorghum

A. Schlegel

Summary
Long-term research shows that phosphorus (P) and nitrogen (N) fertilizer must be applied to optimize production of irrigated grain sorghum in western Kansas. In 2009, N and P applied alone increased yields about 45 and 6 bu/a, respectively, whereas N and P applied together increased yields up to 75 bu/a. Averaged across the past 9 years, N and P fertilization increased sorghum yields up to 65 bu/a. Application of 40 lb/a N (with P) was sufficient to produce about 85% of maximum yield in 2009. Application of potassium (K) has had no effect on sorghum yield throughout the study period.

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

Procedures
This field study is conducted at the Tribune Unit of the Southwest Research-Extension Center. Fertilizer treatments initiated in 1961 are N rates of 0, 40, 80, 120, 160, and 200 lb/a N without P and K; with 40 lb/a P_2O_5 and zero K; and with 40 lb/a P_2O_5 and 40 lb/a K_2O. All fertilizers are broadcast by hand in the spring and incorporated before planting. The soil is a Ulysses silt loam. Sorghum (Pioneer 8500/8505 from 1998–2007 and Pioneer 85G46 in 2008–2009) is planted in late May or early June. Irrigation is used to minimize water stress. Furrow irrigation was used through 2000, and sprinkler irrigation has been used since 2001. The center two rows of each plot are machine harvested after physiological maturity. Grain yields are adjusted to 12.5% moisture.

Results
Grain sorghum yields in 2009 were similar to the average of the past 9 years (Table 1). Nitrogen alone increased yields about 45 bu/a, and P alone increased yields only about 5 bu/a. However, N and P applied together increased yields up to 75 bu/a. Averaged across the past 9 years, N and P applied together increased yields up to 65 bu/a. In 2009, 40 lb/a N (with P) produced about 85% of maximum yields, which is about 5% less than the 9-year average. Sorghum yields were not affected by K fertilization, which has been the case throughout the study period.

Table 1. Effect of nitrogen, phosphorus, and potassium fertilizers on irrigated sorghum yield, Tribune, KS, 2001–2009

Fertilizer			Sorghum yield									
N	P_2O_5	K_2O	2001	2002	2003	2004	2005	2006	2007	2008	2009	Mean
lb/a			bu/a									
0	0	0	76	73	80	57	58	84	80	66	64	71
0	40	0	81	81	93	73	53	102	97	60	70	80
0	40	40	83	82	93	74	54	95	94	65	76	81
40	0	0	92	82	92	60	63	102	123	92	84	89
40	40	0	124	120	140	112	84	133	146	111	118	123
40	40	40	119	121	140	117	84	130	145	105	109	120
80	0	0	110	97	108	73	76	111	138	114	115	106
80	40	0	138	127	139	103	81	132	159	128	136	129
80	40	40	134	131	149	123	92	142	166	126	108	132
120	0	0	98	86	97	66	77	101	138	106	113	99
120	40	0	134	132	135	106	95	136	164	131	130	131
120	40	40	135	127	132	115	98	139	165	136	136	133
160	0	0	118	116	122	86	77	123	146	105	108	113
160	40	0	141	137	146	120	106	145	170	138	128	138
160	40	40	136	133	135	113	91	128	167	133	140	133
200	0	0	132	113	131	100	86	134	154	120	110	122
200	40	0	139	136	132	115	108	143	168	137	139	137
200	40	40	142	143	145	123	101	143	170	135	129	138
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	0.018	0.005	0.004	0.001	0.001	0.001	0.001
P-K			0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Zero P vs. P			0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
P vs. P-K			0.619	0.920	0.694	0.121	0.803	0.578	0.992	0.745	0.324	0.975
N × P-K			0.058	0.030	0.008	0.022	0.195	0.210	0.965	0.005	0.053	0.010

continued

Table 1. Effect of nitrogen, phosphorus, and potassium fertilizers on irrigated sorghum yield, Tribune, KS, 2001–2009

Fertilizer			Sorghum yield									
N	P_2O_5	K_2O	2001	2002	2003	2004	2005	2006	2007	2008	2009	Mean
-------------------- lb/a --------------------			---------- bu/a ----------									
Means												
Nitrogen, lb/a												
0			80	79	88	68	55	93	91	64	70	77
40			112	108	124	96	77	121	138	103	104	111
80			127	119	132	100	83	128	155	123	120	122
120			122	115	121	96	90	125	156	124	126	121
160			132	129	134	107	92	132	161	125	125	128
200			138	131	136	113	98	140	164	131	126	132
LSD (0.05)			8	9	10	11	10	11	9	7	11	6
P_2O_5-K_2O, lb/a												
0			104	94	105	74	73	109	130	101	99	100
40-0			126	122	131	105	88	132	151	117	120	123
40-40			125	123	132	111	87	130	151	117	116	123
LSD (0.05)			6	6	7	7	7	7	6	5	7	4

Long-Term Nitrogen and Phosphorus Fertilization of Irrigated Corn

A. 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 2009, N applied alone increased yields about 60 bu/a, whereas P applied alone increased yields about 25 bu/a. However, N and P applied together increased yields up to 150 bu/a. Averaged across the past 9 years, N and P fertilization increased corn yields up to 140 bu/a. Application of 120 lb/a N (with P) was sufficient to produce greater than 90% of maximum yield in 2009, which was similar to the 9-year average. In 2009, P increased corn yields more than 80 bu/a when applied with at least 120 lb/a N. Application of 80 instead of 40 lb P_2O_5/a increased yields 11 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 is conducted on a Ulysses silt loam soil with an inherently high K content. No yield benefit to corn from K fertilization was observed in 30 years, and soil K levels remained high, so the K treatment was discontinued in 1992 and replaced with a higher P rate.

Procedures
This field study is conducted at the Tribune Unit of the Southwest Research-Extension Center. Fertilizer treatments initiated in 1961 are N rates of 0, 40, 80, 120, 160, and 200 lb/a without P and K; with 40 lb/a P_2O_5 and zero K; and with 40 lb/a P_2O_5 and 40 lb/a K_2O. The treatments were changed in 1992; the K variable was replaced by a higher rate of P (80 lb/a P_2O_5). All fertilizers are broadcast by hand in the spring and incorporated before planting. The soil is a Ulysses silt loam. The corn hybrids [Pioneer 33R93 (2001 and 2002), DeKalb C60-12 (2003), Pioneer 34N45 (2004 and 2005), Pioneer 34N50 (2006), Pioneer 33B54 (2007), Pioneer 34B99 (2008), and DeKalb 61-69 (2009)] were planted at about 30,000 to 32,000 seeds/a in late April or early May. Hail damaged the 2002 and 2005 crops. The corn is 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 are machine harvested after physiological maturity. Grain yields are adjusted to 15.5% moisture.

Results
Corn yields in 2009 were greater than the 9-year average (Table 1). Nitrogen alone increased yields 60 bu/a, whereas P alone increased yields 25 bu/a. However, N and P applied together increased corn yields up to 150 bu/a. Only 120 lb/a N with P was required to obtain greater than 90% of maximum yield, which is similar to the 9-year average. Corn yields in 2009 (averaged across all N rates) were 11 bu/a greater with 80 than with 40 lb/a P_2O_5, which is greater than the 9-year average.

Table 1. Effect of nitrogen and phosphorus fertilization on irrigated corn yield, Tribune, KS, 2001–2009

N	P_2O_5	2001	2002	2003	2004	2005	2006	2007	2008	2009	Mean
--------- lb/a ---------		---------- bu/a ----------									
0	0	54	39	79	67	49	42	49	36	85	55
0	40	43	43	95	97	60	68	50	57	110	69
0	80	48	44	93	98	51	72	51	52	106	68
40	0	71	47	107	92	63	56	77	62	108	76
40	40	127	69	147	154	101	129	112	105	148	121
40	80	129	76	150	148	100	123	116	104	159	123
80	0	75	53	122	118	75	79	107	78	123	92
80	40	169	81	188	209	141	162	163	129	179	158
80	80	182	84	186	205	147	171	167	139	181	162
120	0	56	50	122	103	66	68	106	65	117	84
120	40	177	78	194	228	162	176	194	136	202	172
120	80	191	85	200	234	170	202	213	151	215	185
160	0	76	50	127	136	83	84	132	84	139	101
160	40	186	80	190	231	170	180	220	150	210	180
160	80	188	85	197	240	172	200	227	146	223	186
200	0	130	67	141	162	109	115	159	99	155	126
200	40	177	79	197	234	169	181	224	152	207	180
200	80	194	95	201	239	191	204	232	157	236	194
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	0.007	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
N × P		0.001	0.133	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001

continued

Table 1. Effect of nitrogen and phosphorus fertilization on irrigated corn yield, Tribune, KS, 2001–2009

N	P_2O_5	2001	2002	2003	2004	2005	2006	2007	2008	2009	Mean
--------- lb/a ---------		---------- bu/a ----------									
Means											
Nitrogen, lb/a											
0		48	42	89	87	53	61	50	48	100	64
40		109	64	135	132	88	103	102	91	138	107
80		142	73	165	178	121	137	146	115	161	137
120		142	71	172	188	133	149	171	118	178	147
160		150	71	172	203	142	155	193	127	191	156
200		167	80	180	212	156	167	205	136	199	167
LSD (0.05)		15	8	9	11	10	15	11	9	12	8
P_2O_5, lb/a											
0		77	51	116	113	74	74	105	71	121	89
40		147	72	168	192	134	149	160	122	176	147
80		155	78	171	194	139	162	168	125	187	153
LSD (0.05)		10	6	6	8	7	11	8	6	9	6

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