Kansas Fertilizer Research 2010

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KANSAS FERTILIZER RESEARCH 2010

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KANSAS FERTILIZER RESEARCH 2010

Introduction

The 2010 edition of the Kansas Fertilizer Research Report of Progress is a compilation of data collected by researchers across Kansas. Information was contributed by faculty and staff from the Department of Agronomy, Kansas agronomy experiment fields, and agricultural research and research-extension centers.

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

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Precipitation Data

Month	Manhattan	SWREC Tribune	SEARC Parsons	ECK Exp. Field Ottawa
	--------------------	--------------------	in. --------------------	--------------------
2009				
August	4.50	2.66	5.56	5.96
September	2.03	0.78	12.61	6.03
October	4.00	2.48	7.45	4.59
November	1.21	0.93	2.30	2.57
December	1.89	0.52	2.31	2.72
Total 2009	38.69	17.28	54.30	45.57
Departure from normal	+3.89	-0.16	+12.21	+6.36
2010				
January	0.41	0.47	2.08	0.57
February	0.56	0.53	1.19	1.95
March	2.78	2.07	2.85	1.79
April	3.45	1.49	1.45	4.69
May	3.95	3.48	6.91	5.32
June	7.68	1.92	6.98	5.73
July	3.83	4.09	9.42	7.48
August	4.04	3.79	0.82	1.38
September	3.52	0.34	5.89	6.55

continued

Precipitation Data

Month	NCK Exp. Field Belleville	KRV Exp. Field	SCK Exp. Field Hutchinson	ARC-Hays
	--	in.	--	
2009				
August	4.28	4.00	4.13	5.10
September	3.00	1.41	6.79	1.67
October	3.37	1.71	3.18	2.08
November	0.81	1.83	0.58	1.02
December	1.09	1.13	0.39	1.19
Total 2009	27.78	29.80	33.60	21.72
Departure from normal	-3.11	-5.84	+3.28	-1.77
2010				
January	0.07	0.19	0.49	0.18
February	0.42	1.13	1.03	0.42
March	3.44	1.11	1.30	2.01
April	4.05	2.83	1.86	1.60
May	2.61	4.55	5.44	3.60
June	8.07	6.32	8.37	3.77
July	2.71	3.98	6.55	2.75
August	3.58	1.02	4.75	5.40
September	5.10	3.74	1.31	2.11

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.

Chelated Iron Fertilizer Application Rate for Iron Chlorosis in Soybean[1]

A.L. Liesch, D.A. Ruiz Diaz, and B. Olson

Summary
Iron deficiency in soybean can limit plant growth and grain yield dramatically under conditions of high soil pH. The objective of this study was to evaluate various rates of seed-applied iron (Fe) fertilizer for soybean. For all of the different agronomic parameters except plant population, results indicate that a level of 0.14 lb/a can be just as effective as the high level (0.28 lb/a). The addition of only 0.07 lb/a was also beneficial, but not to the level of the higher application. Without iron application, plants failed to grow. The increase in yield was dramatic; therefore, using a chelated Fe source is economically effective. Regression analysis suggests a minimum application rate of 0.2 lb/a in contact with the seed.

Introduction
In semi-arid calcareous soils with low organic matter such as those in western Kansas, inadequate amounts of Fe are available for plant growth. These conditions result in iron deficiency, a nutrient disorder that presents as interveinal leaf yellowing. This widespread problem costs millions of dollars' worth of yield loss each year. Several solutions can reduce chlorosis: producers can choose an appropriate variety, apply either inorganic or chelated forms of Fe to the furrow at planting time, use chelated Fe as a seed coating, or apply foliar Fe.

A 2009 study at three locations in western Kansas showed a 50% average yield increase in response to the addition of a 0.28 lb/a coating of chelated FeEDDHA (6% iron) iron applied to the seed before planting. One of the major limitations of using chelated iron seed coating is the cost, which makes lower application rates desirable. However, researchers in other regions have found that lower application rates do not have a sustained success rate. The objective of this study was to evaluate various rates of seed-applied Fe fertilizer.

Procedures
The experiment was conducted in 2010 on a Ulysses silt loam (Aridic Haplustolls) at the Northwest Research and Extension Center in Colby, KS, where soybean had exhibited severe Fe chlorosis in the past. Soil samples were collected from each block to a 0- to 6-in depth, and analyzed for pH using a 1:1 soil:water ratio. Soil organic matter (SOM) was measured using the Walkley-Black method. Iron was extracted using DTPA solution. Extractable potassium was determined by an ammonium acetate extraction. Nitrate-N was measured with a 1 M KCl extraction. Exchangeable calcium carbonates were measured adding dilute HCl to calcareous soil and measuring gas displacement.

[1] This project was supported by the Kansas Soybean Commission.

Soybean was planted at 30-in. row spacing with a seeding rate of 125,000 plants/a. Postemergence control of weeds was completed as needed. The plots were 6.1 m wide by 15.2 m long and set up in a randomized complete block design with three replications. Asgrow 3803 variety seeds, a non-tolerant variety to iron chlorosis, were selected for this study. Chelated FeEDDHA fertilizer was mixed into a slurry with water and a protective seed coating adhesive polymer and applied at four different rates: 0, 0.07, 0.14, and 0.3 lb/a Fe.

Plant population was counted at V3 growth stage. Chlorophyll meter readings were recorded at V3 and V6 growth stages with a SPAD 502 (Minolta, Ramsey, NJ) in 20 leaflets per plot, and averaged into one value to ascertain the effectiveness of seed coating. Plant height was recorded at the R7 growth stage. Grain yields were determined by harvesting the two center rows by hand then threshing. Moisture content of plot samples was recorded and used to adjust grain yields to a moisture content of 13%. Data were analyzed in PROC GLIMMIX in SAS 9.1. ANOVA was run using Fe fertilizer rate as a fixed variable and blocks as a random variable. Values were deemed significant if the P-value was <0.05. Agronomic parameters were regressed using PROC REG against the different levels of Fe applied, and fit to a polynomial line. The optimum rate was determined when the slope of the Fe level was maximized or stabilized.

Results

Chlorosis developed shortly after emergence. Plant population varied based on the concentration of iron applied to the seed. The highest overall germination occurred in the 0.3 lb/a, which was 38% higher than the treatment without Fe (Figure 1). The 0.07 and 0.14 lb/a application rates had equal germination rates. This higher plant population density may impact plant "greenness" early.

At V3 stage, the lowest chlorophyll meter (SPAD) value was the control (Figure 2). The application of iron fertilizer caused the strongest increase in SPAD units at 0.07 lb/a (increasing 6.4 SPAD units, or 26% response). Between 0.07 and 0.14, only a 5% increase occurred in reponse to a higher fertilizer application, which is not statistically significant. Between 0.14 and 0.28, a larger increase occurred, but it is only half the response to the low level of iron application (12%), and this response was not significant. Early in the season, the 0.14 and 0.28 lb/a applications were successful at raising CM readings to equally high levels, even though the 0.28 lb/a rate was slightly higher. At V6, SPAD values declined overall compared to V3, indicating a possibly worsening chlorosis (Figure 2).

Plant height was also indicative of seed Fe coating. The more Fe that was added, the taller the plant at maturity. Without seed coating, plantings did not yield any viable plants, and the stubble was less than 5 cm tall. The largest increase in plant height came after the addition of 0.07 lb/a, which added 30 cm to plant height (Figure 3). Plants in both of the high levels of application (0.28 and 0.14 lb/a) were equally tall, indicating that the increased application over 0.14 may not be as effective as the lower application; however, regression analysis gives the optimum Fe value of 0.21 lb/a.

The 0.14 lb/a application rate was the highest overall yield (Figure 4); even though it was statistically the same as the 0.28 lb/a, the 0.14 lb/a rate outyielded the 0.28 lb/a rate, which may have economic significance. Several reasons may explain why the highest seed coating rate did not continue to respond over the 0.14 lb/a Fe level. The 0.07 lb/a treatments did not differ significantly from the control. Regression analysis suggests optimum Fe levels of 0.2 lb/a.

Table 1. Soil parameters for optimum Fe rate study in Colby, KS

Block	pH	SOM[1]	ECC[2]	P[3]	Fe[4]	NO_3-N	Ca	Mg	EC
		-------- g/kg -------		------------------------ ppm ------------------------					mS/cm
1	8.1	19	137	62.0	1.5	6.7	5554	358	0.5
2	8.3	18	126	26.6	1.4	3.7	5867	338	0.5
3	8.3	23	136	35.0	1.5	3.7	5857	351	0.5
4	8.2	21	104	103.6	1.9	4.7	5508	347	0.5

[1] Soil organic matter.
[2] Effective calcium carbonate.
[3] Soil test P and K: Soil test P determined by Mehlich-3 test.
[4] Soil-available Fe determined by DTPA extraction.

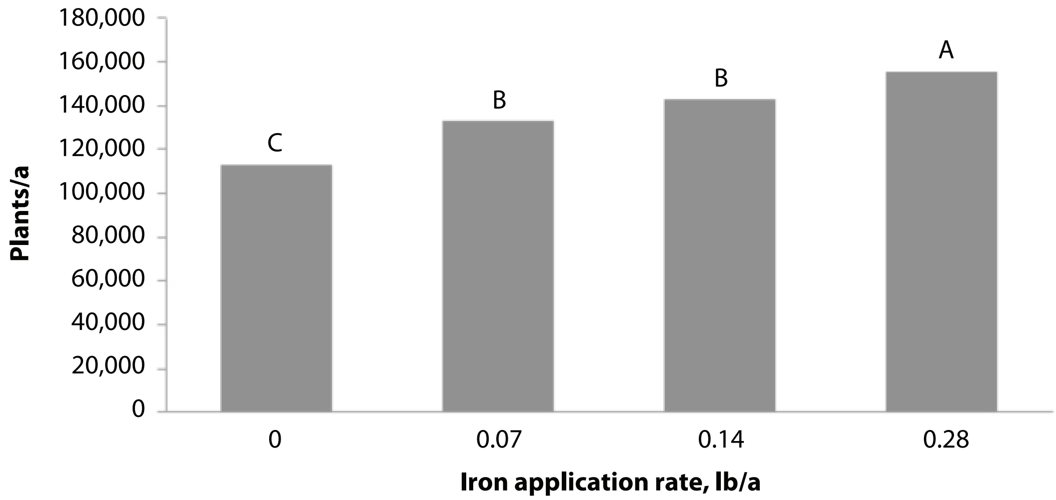

Figure 1. Plant population in response to different levels of seed coating at V3 growth stage. Means with different letters indicate statistically significant differences.

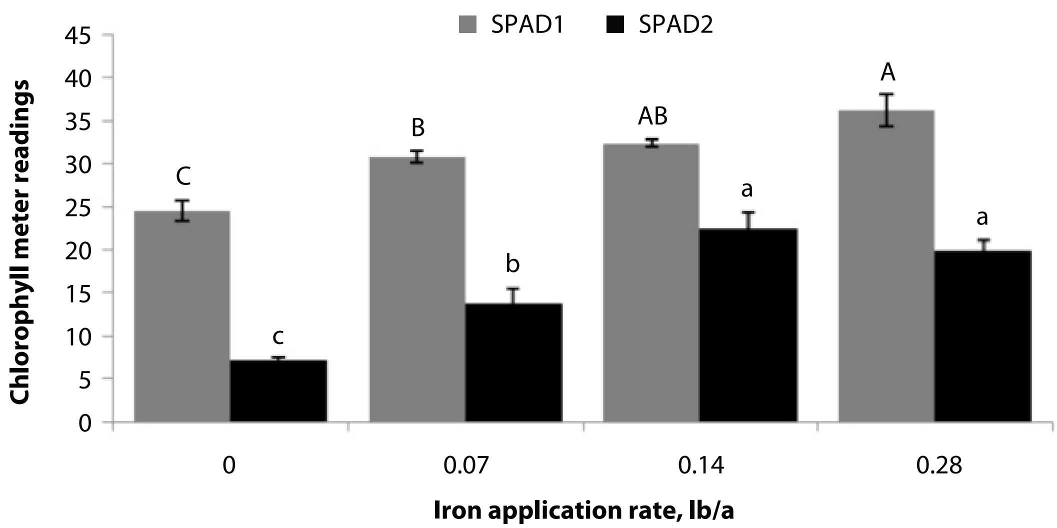

Figure 2. SPAD chlorophyll meter (CM) readings in response to increasing iron application at V3 and V6 stages. Capital letters represent CM values at V3 stage; small letters represent values at V6 stage. Means with different letters indicate statistically significant differences.

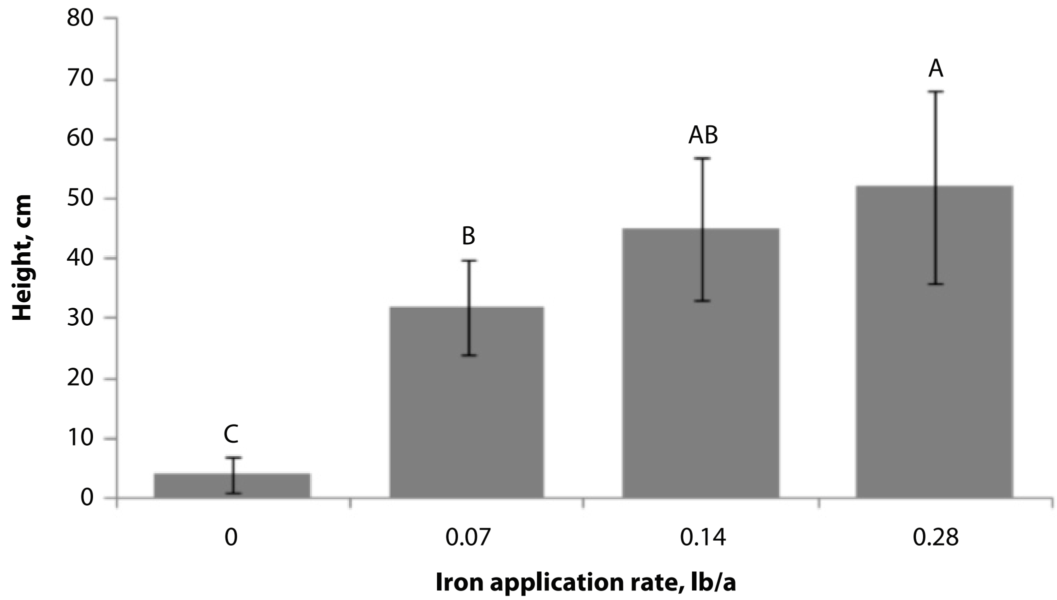

Figure 3. Plant height in response to seed coating at maturity (R7 stage). Means with different letters indicate statistically significant differences. Error bars indicate standard error of the mean.

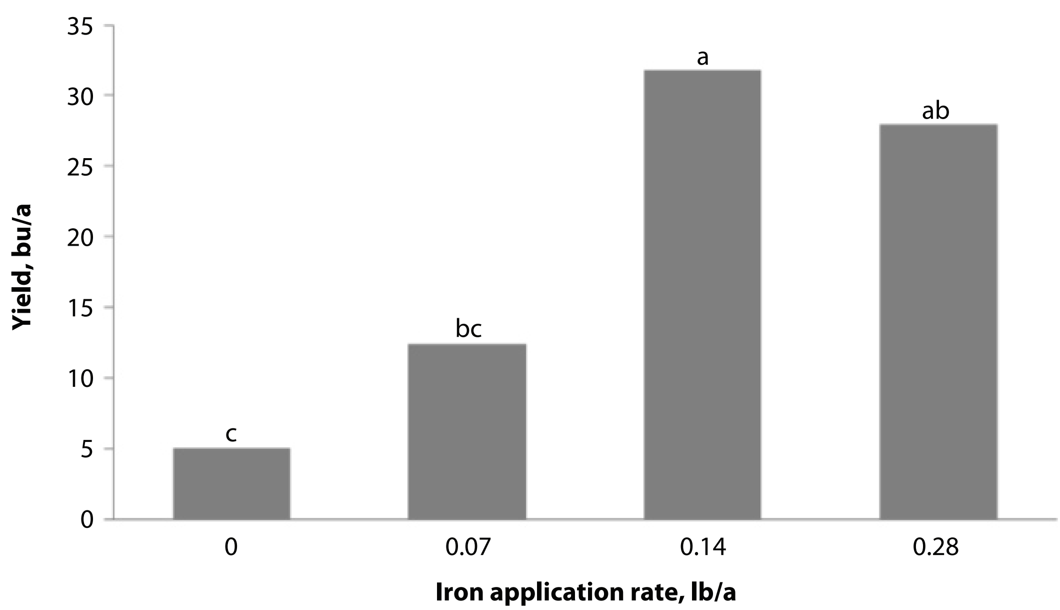

Figure 4. Grain yield in bu/a based on the different levels of iron seed coating. Means with different letters indicate statistically significant differences.

Phosphorus Recovered from Feedlot Manure as Fertilizer Source for Corn and Soybean[1]

D.A. Ruiz Diaz, N.D. Mueller, K. Heller, and N.O. Nelson

Summary

Wastewater from animal feeding operations can be treated to precipitate excess phosphorus (P) in the form of magnesium ammonium phosphate, also known as struvite. Evaluation of struvite as a source of P fertilizer for corn and soybean is limited. The objectives of the study were (1) to evaluate plant P uptake from commercial P fertilizer sources and struvite and their effects on final grain yield, and (2) to determine optimum application rates for corn and soybean. Based on our results and under these soil conditions, struvite should supply a similar amount of P to corn and soybean during the growing season when compared to monoammonium polyphosphate (MAP) or triple superphosphate (TSP).

Introduction

Excessive manure applications to agricultural land on fields surrounding Concentrated Animal Feeding Operation (CAFO) facilities can, in some cases, result in high soil test P levels. Overapplication of P can be detrimental to surrounding ecosystems and contamination of surface water. Animal waste treatments for phosphorus recovery from manure are a management option that could resolve problems of excess manure P on some regions. In addition, this can provide the opportunity to utilize P where needed for optimum crop production.

Wastewater from CAFOs can be treated to precipitate P in the form of magnesium ammonium phosphate, known as struvite. Evaluation of struvite as a P fertilizer source for corn and soybean is limited.

Procedures

The study was conducted at the Kansas State University North Central Experiment Field in Scandia, KS, using soybean and corn. P fertilizer sources were applied at planting. Four P application rates (0, 10, 20, and 40 lb/a) were placed near the seed. The struvite source generated from wastewater was evaluated at these different rates along with commercial fertilizers TSP and MAP. The experimental design consisted of a factorial in a randomized complete block, with a factorial combination of 3 fertilizer sources, 4 rates, and 3 replications.

Soil samples from the 0- to 6-in. depth were collected from each replication and analyzed for routine soil properties. Soil test P levels were determined by Mehlich-3; soil pH in a 1:1 suspension; soil test potassium (K) with ammonium acetate extraction; and organic matter with dry combustion. Plant leaf tissue samples were collected from 15 plants per plot and analyzed for P uptake via wet digestion. Plant growth and final grain yields were collected. Statistical analysis was completed using the PROC GLIMMIX procedure in SAS 9.2.

[1] This project was supported by the Kansas Livestock Foundation using USDA-NRCS funding.

Results

Soil test analysis from the two locations indicated low soil test P and optimum soil test K and pH (Table 1). Corn P uptake and yield showed a significant response to P application rate (Figure 1, Table 2). However, fertilizer source carried no significant effect, indicating a similar P supply from MAP, TSP, and struvite during the growing season. Soybean tissue P concentration and yield showed a significant increase with P application rate (Figure 2, Table 3). Similar to corn, fertilizer source was not significant for any of the measured parameters, indicating similar supply of P from MAP, TSP, and struvite for soybean.

Based on these results and under these soil conditions, struvite should supply a similar amount of P to corn and soybean during the growing season when compared to MAP or TSP.

Table 1. Soil test results from the corn and soybean study. Samples were collected at the 0- to 6-in. depth before planting

Study	pH	STP[1]	STK[1]	OM[2]
		--------------- ppm	---------------	%
Corn	6.7	9.4	524	2.8
Soybean	6.3	8.2	465	3.0

[1] Soil test P and K: Soil test P determined by Mehlich-3 test.
[2] Organic matter.

Table 2. Statistical probability of treatment effects for corn[1]

Effect	P uptake	Yield
	----------------------- P-value	-----------------------
Fertilizer	0.4817	0.1720
P rate	0.0011	0.0418
Fertilizer × rate	0.7344	0.7850

[1] $P<0.05$ is considered significant for this study.

Table 3. Statistical probability of treatment effects for soybean[1]

Effect	Tissue P	Yield
	----------------------- P-value	-----------------------
Fertilizer	0.8041	0.7854
P rate	0.0248	0.0053
Fertilizer × rate	0.6829	0.7599

[1] $P<0.05$ is considered significant for this study.

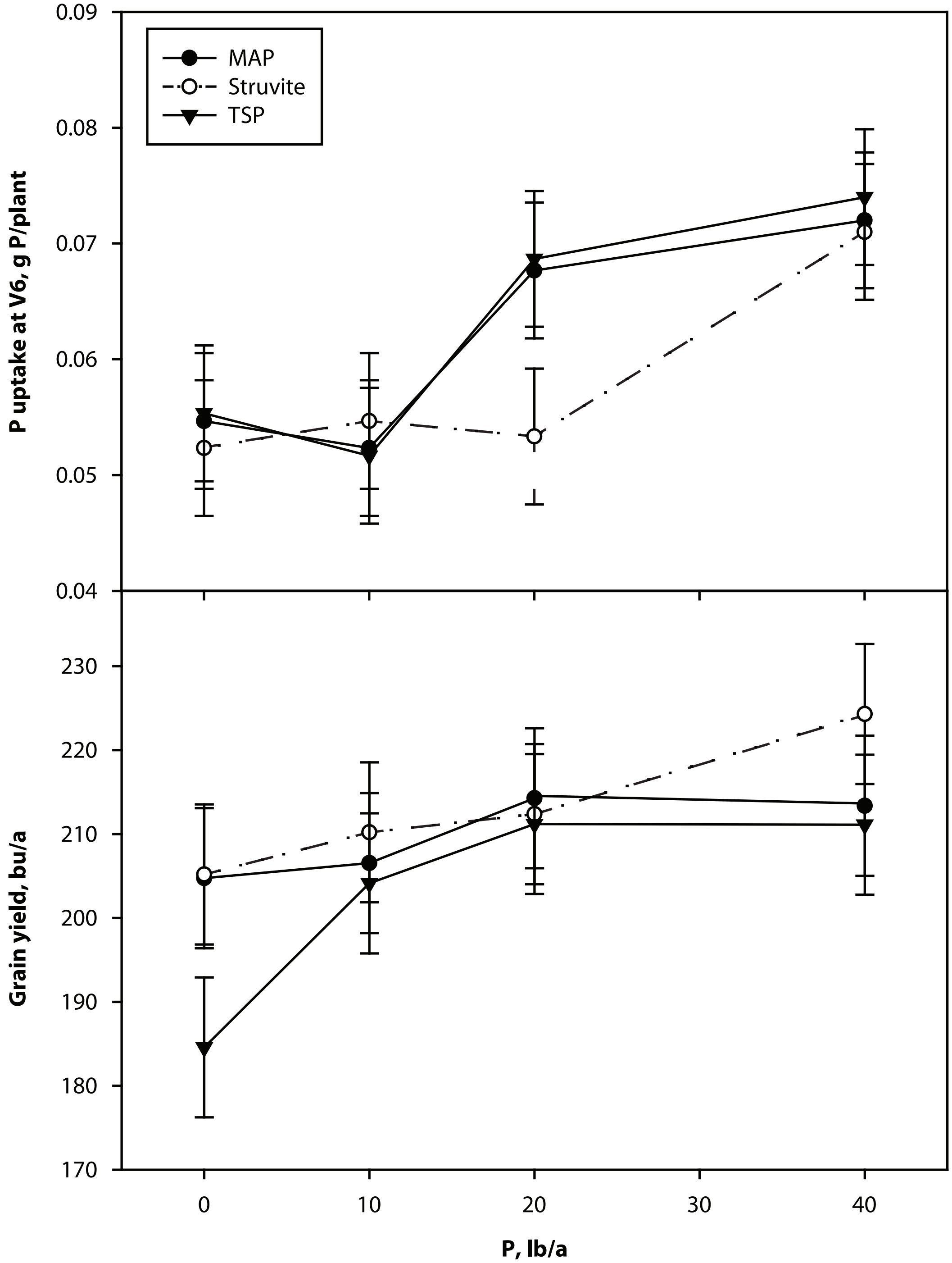

Figure 1. Corn grain yield and early season phosphorus uptake with MAP, struvite, and TSP.

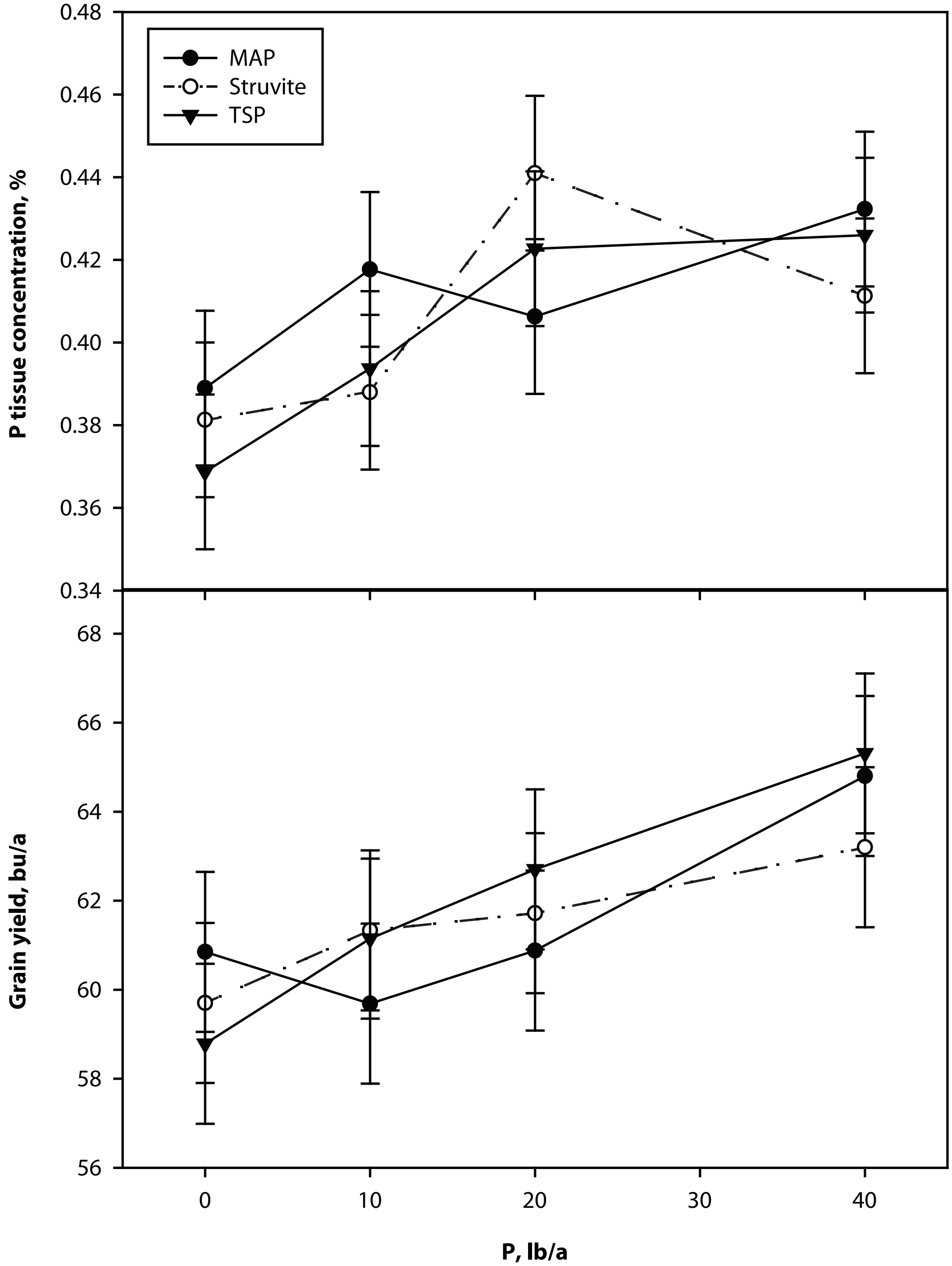

Figure 2. Soybean grain yield and leaf tissue phosphorus concentration with MAP, struvite, and TSP.

Winter Annual Weeds' Effects on Corn Response to Nitrogen

N.D. Mueller, D.A. Ruiz Diaz, D.G. Hallauer, and D. Shoup

Summary

Field studies were established in fall of 2009 at seven locations in Kansas to determine what effect winter annual weed (WAW) burndown timing has on nitrogen (N) and water availability for no-till, rainfed corn following soybean. High-density stands of WAWs contained 10 to 27 lb N/a at maturity. Early growth and N uptake was reduced by delay of burndown until planting or after. In early June, gravimetric water content was higher as a result of delaying burndown, but soil nitrate-nitrogen was not significantly different among burndown timings. N status at the silking to blister stage of corn was reduced only if burndown was delayed until May after the emergence of corn. Grain yield was not significantly affected by burndown timing, but neared significance with a 5 bu/a decrease if burndown was delayed until after corn emergence. Corn responded early in the growing season to various WAW burndown timings, but the effects diminished by harvest.

Introduction

When to control winter annual weeds (WAWs) is a management concern for producers. Reduced tillage, lack of winter crops, herbicide programs, and late spring weed control are some factors contributing to the increased prevalence of WAWs. Evidence suggests that dense stands of WAWs slow the warming and drying of soil in the spring, interfere with planting equipment, cause allelopathic effects, and increase damage from lepidopteron in corn. However, the effects of WAWs' use of nitrogen and water prior to corn production are two additional factors that may negatively affect yield. The objective of this study was to determine the importance of the timing of WAW control for no-till, rainfed corn production following soybean by assessing soil water and nitrate, early growth and N uptake of corn, N status at silking and blister stages, and grain yield.

Procedures

Field research was conducted in 2010 at seven locations in Kansas under no-till, rainfed corn production conditions following soybean. Locations were at producers' fields in Jackson, Jefferson, Marshall, and Osage Counties in Kansas and Department of Agronomy Experiment Fields in Manhattan, Hutchinson, and Ottawa, KS. Experimental design was a two-factor factorial arrangement in a randomized complete block design with three replications. Plot size was 15 by 50 ft. There were four different burndown times: fall, early preplant (2 to 4 weeks prior to planting), planting (within one week of planting), and emerged (at V2 growth stage, two visible leaf collars). Burndown treatments consisted of glyphosate with or without 2,4-D. After the last burndown treatment, five N rates of 0, 15, 30, 60, and 120 lb N/a were applied via broadcast urea. Corn was planted April 12 through April 20. Two locations (Franklin and Riley counties) are being analyzed separately given late planting dates of June 1 and May 25 and are not part of this analysis. Weed density and composition was determined prior to each burndown treatment application. The percent of weed control was determined during subsequent visits. Aboveground biomass collection was taken prior to the last burndown treatment and tissue was analyzed for total carbon and nitrogen. Soil gravimetric water content and soil nitrate-nitrogen were collected from 0- to 24-in. depth during early corn growth (V5 to V8, 5 to 8 leaf collars), and aboveground corn biomass was analyzed for N content. Chlorophyll content values to determine N status were taken on the ear leaf at the silking/blister stage (R1/R2) and recorded with a SPAD meter (Minolta, Ramsay, NJ). Final corn yield was determined by hand harvesting the middle two rows for 25 ft of each plot. Grain yield was corrected for moisture at 15.5%.

Results

The most common WAWs were henbit and field pennycress. Burndown control was excellent at all locations and timings. Average WAW density per site ranged from 11 to 35 plants/ft^2. Average WAW dry biomass at maturity in May range from 500 to 1,000 lb/a, resulting in 10 to 27 lb N/a uptake in aboveground WAW biomass. The C:N ratios ranged from 16:1 to 28:1. The time by N rate interaction was not significant for any dependent variables measured. Delayed emergence was visually observed with burndown after early preplant. Delaying burndown until after corn emergence did not reduce corn plant populations. Early growth was significantly affected by burndown timing (Figure 1) and was maximized by an early preplant burndown. N concentration in corn tissue was not significantly different for burndown timings. Therefore, N uptake was mostly due to difference in early biomass accumulation. Soil nitrate-nitrogen was not significantly different among burndown timings. Soil gravimetric water content increased with delayed burndown with 0.26, 0.26, 0.27, and 0.27 for fall, early preplant, planting, and emerged, respectively. Any excessive water use by WAWs with later burndown control was alleviated in 2010 by above-average rainfall in May and June, reduced soil surface evaporation from increased residue cover, and reduced water use by smaller corn plants. Delaying burndown until May after the corn had emerged significantly lowered the chlorophyll meter reading at R1 to R2 growth stages over early preplant control (Figure 2). This suggests that the N mobilized into aboveground WAW biomass by mid-May in 2010 could significantly reduce cumulative corn N uptake by July (R1 to R2). Grain yield was not significantly affected by burndown timing, but neared significance (P=0.14) with a 5 bu/a yield decrease for the last treatment timing (Figure 3), and it trended toward a similar pattern as the chlorophyll meter reading data.

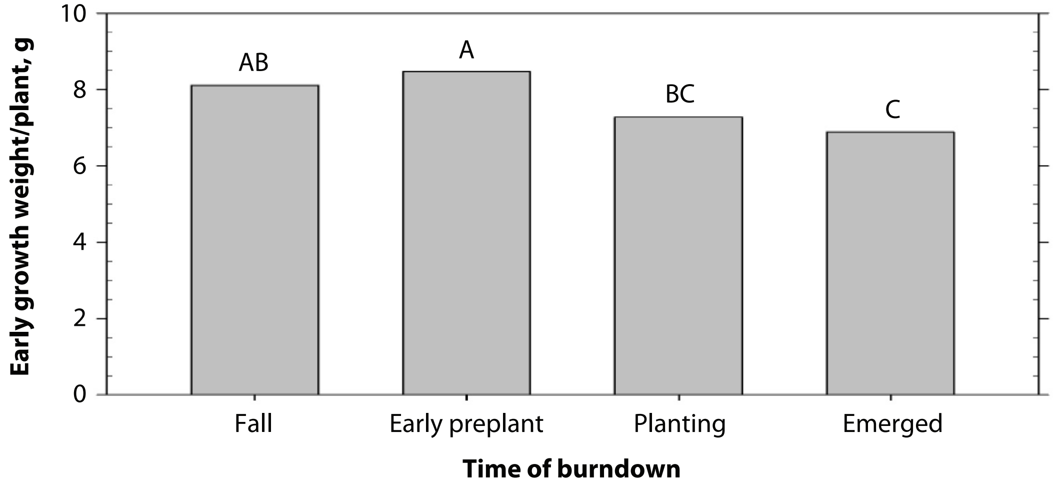

Figure 1. Early growth (V5 to V8 growth stage) of corn as affected by different burndown times. Means with different letters indicate statistically significant differences.

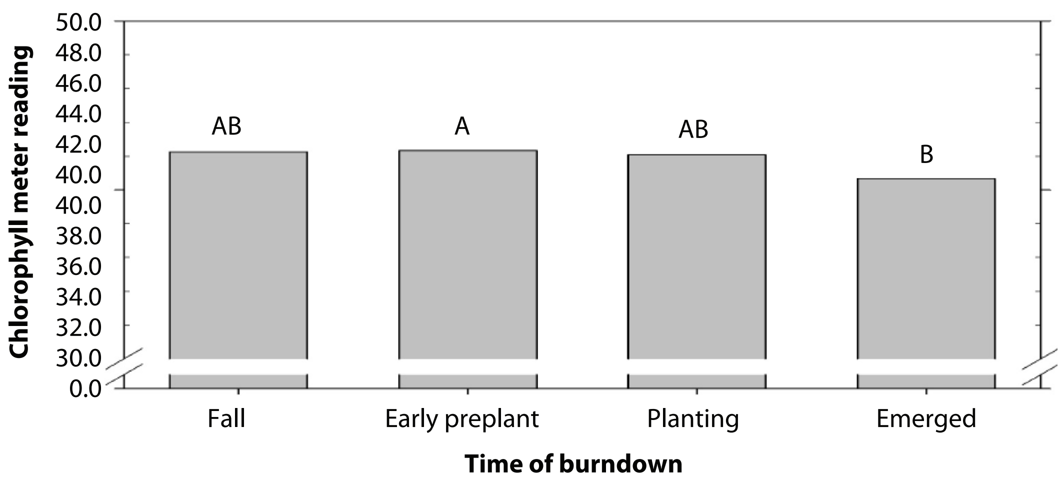

Figure 2. Chlorophyll meter readings at R1 to R2 as affected by different burndown times. Means with different letters indicate statistically significant differences.

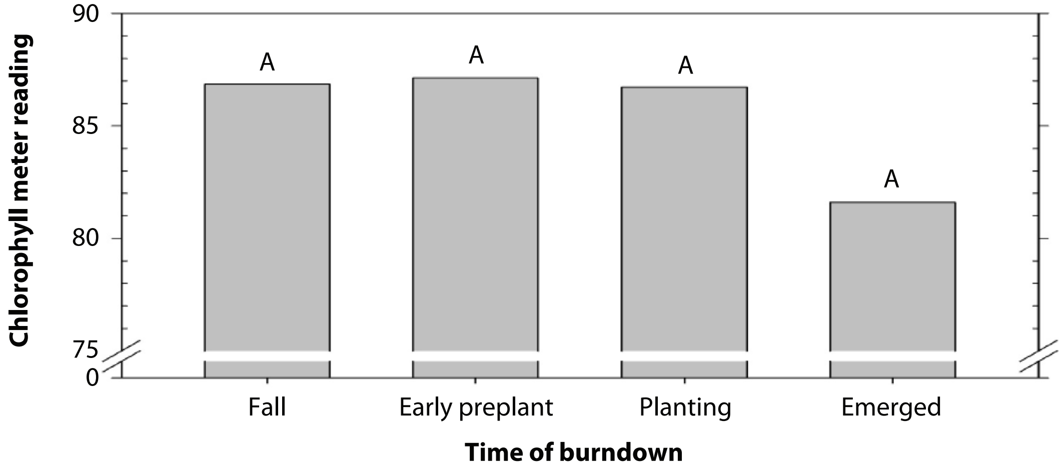

Figure 3. Corn grain yield as affected by different burndown times. Means with different letters indicate statistically significant differences.

Grain Sorghum Response to Side-Dress Chloride Applications

N.D. Mueller and D.A. Ruiz Diaz

Summary

Field studies were established in spring 2010 at two locations near Abilene, KS, to validate current Kansas State University recommendations for chloride application on sorghum. The current Kansas State soil test chloride interpretation suggested fertilizer application for 75% of the plots. Chloride (Cl^-) side-dress application of 20 lb/a near growth stage 1 increased tissue concentration later in the growing season; however, tissue chloride concentrations from control plots suggested that these soils provided adequate amounts of chloride in 2010 without additional fertilizer chloride. Thus, sorghum yield was not significantly increased in this study. The current recommendation for using soil test chloride (0- to 24-in. depth) to make fertilizer applications appears to require further research to develop more robust preseason guidelines for chloride fertilizer use in sorghum, which may include additional soil parameters.

Introduction

In Kansas, previous research on chloride fertilization of sorghum has found that positive yield responses often exist when soil chloride at a depth of 0 to 24 in. is below 6 ppm (Table 1) and whenever leaf chloride concentration is below 0.10 to 0.12%. Plants take up chlorine as the anion chloride (Cl^-). The anion is very mobile in the soil and can leach below rooting depth. The objective of this study was to test current recommendations utilizing side-dress applications of chloride near growth stage 1.

Procedures

Two locations were established near Abilene, KS. Research was conducted on producers' fields. The experimental design was a factorial arrangement in a randomized complete block design with four replications. Plot size was 4.6 m wide by 15.2 m long. A control (0 lb Cl/a) and one application rate of 20 lb Cl/a with fluid magnesium chloride fertilizer was dribbled 4 in. to the side of the row near growth stage 1 (third leaf collar visible).

Soil samples were collected from 0- to 24-in. depth after planting for analysis of chloride. Aboveground biomass was collected at growth stage 4 (final leaf visible in whorl) and tissue was analyzed for chloride. Final sorghum yield was determined by hand harvesting the middle two rows for 7.6 m of each plot. Grain yield was corrected for moisture at 13.0%.

Results

The current Kansas State University soil test chloride interpretation suggested fertilizer application for 75% of the plots (Table 1). Of soil test chloride concentrations, 75% were categorized as medium and 25% as high. Total plant biomass at growth stage 4 was not significantly increased (Table 2). Chloride tissue concentrations were significantly increased by chloride applications at both sites. Plant uptake of chloride was significantly increased at site 1. Grain yield at site 1 was not significantly different. Due to cooperator error, site 2 yield data was lost. All control plots had plant tissue chloride concentrations above 0.37% (Table 1), which suggest soil chloride was adequate this year on these soils (Crete and Irvin silty clay loam). The results of this study support the current use of Kansas State University chloride recommendations for sorghum. The current recommendation for using soil test chloride (0- to 24-in. depth) to make fertilizer applications appears to provide a good baseline for identification of potential responses to Cl fertilization.

Table 1. Soil test values and tissue chloride for sorghum

Cl^- rate	Block	Soil Cl	Tissue Cl	Soil pH	M3-P	K	Organic matter
lb/a		ppm	%	1:1	ppm	ppm	%
Site 1							
20	1	5.9	0.635	5.5	34.7	265	2.8
0			0.374				
0	2	5.7	0.385	5.6	23.3	252	2.9
20			0.527				
0	3	4.2	0.500	5.4	23.2	222	2.6
20			0.671				
20	4	7.1	0.799	5.7	21.8	247	3
0			0.724				
Site 2							
0	1	4.5	0.550	7.3	80.3	457	2.7
20			0.662				
20	2	5.8	0.601	7.1	77.8	484	2.6
0			0.512				
0	3	4.7	0.518	7.2	68.9	446	2.6
20			0.563				
20	4	9.2	0.601	7.3	80.2	489	2.5
0			0.577				

Table 2. Response of sorghum to chloride application

	Site 1				Site 2			
Rate	Tissue Cl	Dry biomass	Cl uptake	Yield	Tissue Cl	Dry biomass	Cl uptake	Yield
lb/a	%	g/plant	lb/a	bu/a	%	g/plant	lb/a	bu/a
0	0.4964	45.2	18.1	104.8	0.5399	57.8	-	-
20	0.6584	46.4	24.8	108.9	0.6071	57.5	-	-
LSD (0.05)	0.1224	NS	4.9	NS	0.0637	NS	-	-

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

A.R. Asebedo and D.B. Mengel

Summary
Immobilization, ammonia volatilization, denitrification, and leaching are all common nitrogen (N) loss mechanisms corn producers face in Kansas. These N loss mechanisms cause a reduction in N uptake and yield, and increase costs for Kansas corn producers. In 2010, a project was initiated at five locations in Kansas to evaluate N management products and application methods. Conditions in the eastern half of Kansas in 2010 were very conducive to N loss. A significant response to N fertilizer, performance differences between N fertilizers, and application methods were observed.

Introduction
The use of N fertilizer generally is required to optimize corn yields in Kansas; however, N loss mechanisms such as immobilization, ammonia volatilization, denitrification, and leaching reduce the efficiency of N fertilizer applications, and often result in lower yields. In 2010 a number of products and practices for preventing N loss were evaluated. These included: (1) fertilizer placement — surface broadcast, surface banding, or subsurface banding; (2) the addition of Agrotain, a urease inhibitor, to granular urea or urea-ammonium nitrate (UAN) solutions; (3) the addition of Instinct, a nitrification inhibitor, to UAN solutions; (4) the use of urease inhibitors in combination with nitrification inhibitors Agrotain Plus, Super U, or NutriSphere-N; and (5) controlled-release urea fertilizer, polyurethane coated urea (ESN). The objective of the study was to determine under what conditions these products or application practices would enhance N uptake in corn and increase yield.

Procedures
This study was initiated in 2008 and conducted in 2010 at five locations: The Agronomy North Farm near Manhattan, KS; the Clark Woodworth farm near Sterling, KS; the East Central Kansas Experiment Field near Ottawa, KS; the North Central Kansas Experiment Field near Scandia, KS; and the Kansas River Valley Experiment Field near Rossville, KS. Plots were arranged at all locations in a randomized complete block design with four replications. Soil samples were taken within the study area at each location to determine residual N levels and additional nutrient needs. Important information for each location is summarized in Table 1. Starter fertilizer was applied to all treatments at all locations at a rate of 20 lb N/a using a mixture of UAN and 10-34-0. All treatments were applied at approximately the V2 growth stage at each location, at a rate of 80 lb N/a for a total of 100 lb N/a including the starter fertilizer. The N response curve was established using broadcast urea at rates of 20, 70, 100, 130, and 160 lb/a to determine the N response function at each location. Refer to Table 2 for a complete list of treatments, products, and application methods used.

Multiple measurements were taken to evaluate the performance of each treatment. Ear leaves were collected at the R1 growth stage and whole plant samples were taken at maturity to measure N content. Leaf counts and leaf firing notes were taken at various growth stages to establish a visual evaluation of plant N status. Yield data were recorded at harvest and grain samples were analyzed for grain N content.

Results

Results from these experiments are summarized in Table 2. Rainfall was unusually high in the 60 to 90 days after planting at all locations. At Sterling, only 1.13 in. of precipitation fell in the first 30 days after planting, but over 14 in. of rain fell in the next 60 days. This resulted in extreme N loss due to leaching and denitrification, and high levels of variation (CV > 25%); consequently, data from this site are not reported.

At Ottawa, heavy rainfall and constant wet conditions made planting difficult. The site was planted three times between April 18 and May 29. The stand from the final planting was good; however, as is often the case with late-planted corn in Kansas, the plot received only 11 in. of rainfall for the balance of the year, resulting in low yield. Nitrogen loss from leaching and/or denitrification also was low. Optimum yields were obtained at N rates between 100 and 130 lb N/a; thus, the potential for a response to a nitrification inhibitor or controlled-release fertilizer was low. A 0.41-in. rain shower occurred less than 48 hours after application of N treatments at Ottawa. A number of studies across the United States have shown that 0.25 to 0.30 in. of rainfall are sufficient to incorporate nitrogen fertilizers and mitigate any threat of ammonia volatilization. This explains why urease inhibitor products (Agrotain, Agrotain Plus, Super U, or NutriSphere-N), which are designed to reduce the threat of N loss from ammonia volatilization, prompted no observable response.

Immobilization was, however, a significant problem at the Ottawa site. The difference in performance between granular urea products and surface-broadcast or dribble-banded UAN is likely the result of immobilization. Significantly higher yields were obtained from coulter banding of UAN, or placing the N below the residue and reducing potential for utilization of the N by soil organisms degrading the residue, as compared to any of the surface-broadcast or dribble-banded treatments. This is a clear indication of the role immobilization played at this site.

At Manhattan and Rossville, 10 to 15 in. of rainfall occurred between planting in late April and July 4, resulting in extremely high rates of N loss at these sites. At both sites yields were low, but CV was higher than desired (16 and 18%, respectively). At Manhattan, 0.23 in. of rain fell 48 hours after N application, and an additional 0.63 in. fell four days later. Although slightly less than the 0.25 in. suggested as needed to reduce ammonia volatilization, the rainfall was probably adequate to move the majority of N below the surface and minimize any loss; this explains why urease inhibitors promoted no observable response. At Rossville, however, 0.08 in. of rain fell on May 26, and 0.19 in. fell on May 30. This would have been inadequate to incorporate the fertilizer for at least 6 days, and significant ammonia volatilization likely occurred. Trends toward higher yield where urease inhibitors were used with granular urea products were observed but were nonsignificant due to the high CV at the site.

At both Manhattan and Rossville, as with Ottawa, placement of N below the residue with coulter banding gave significantly higher yields than when the N solution was placed on top of the residue with surface broadcasting or surface banding.

The high rainfall after treatment application at Manhattan and Rossville led to significant N loss and to the crop responding to the highest level of N applied. In addition, the use of ESN controlled-release fertilizer enhanced yield compared to conventional fertilizer products. No consistent, significant response to the use of nitrification inhibitors was observed; however, a trend existed toward higher yields where applied. Multiple denitrification events occurred at both sites, and N loss conditions likely were too severe for these products to perform well.

At Scandia, rainfall was modest after treatments were applied and N loss was relatively low, resulting in high yield considering the low N rate applied. Results from the N rate portion of the study showed optimum N rate was approximately 130 lb N/a, less than the highest rate applied. Like several other locations, rain fell within 24 hours of treatment application, which reduced the potential for ammonia volatilization. Therefore, no response to the use of a urease inhibitor was expected or observed.

With the low levels of surface residue following soybean, and the narrow C:N ratio of soybean residue compared to wheat or corn stubble, the potential for immobilization of N at this site was low. As a result, little difference was observed between N sources or methods of N application, unlike the results from Manhattan and Rossville.

The variation in results across sites emphasizes the site-specific nature of N loss and the variability from site to site and year to year. One clear trend, however, was the role immobilization played in reducing N availability and yield at sites where wide C:N ratios were present. Clearly, developing management systems to place N fertilizers below these residues (wheat straw, corn stalks, and sorghum stubble) could be expected to pay significant benefits.

Acknowledgments

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Table 1. Location information, 2010

Location	Manhattan	Ottawa	Scandia	Rossville	Sterling
Soil type	Smolan silt loam	Woodson silt loam	Crete silt loam	Eudora sandy loam	Pratt-Turon fine sands
Previous crop	Wheat/double-cropped soybean	Wheat/double-cropped soybean	Soybean	Corn	Wheat/double-cropped sunflowers
Corn hybrid	DKC52-59VT3	DKC52-59-VT3	Garst 83x61 3000GT	DK C 61-05 VT3	P 35F40
Plant population	26,000	26,000	31,000	31,000	20,400
Planting date	April 20	May 28	April 29	April 20	April 1
Treatment application date	May 24	June 21	June 1	May 24	May 19
Green leaves counted date	July 8	July 26	July 15	June 7	June 29
Whole plant sampling date	August 25	September 13	August 31	August 30	n/a
Harvest date	September 27	September 28	October 13	September 23	August 23

Table 2. Yields from the 2010 nitrogen management and product evaluation studies in Kansas

Treatment	Ottawa	Manhattan	Rossville	Scandia	Mean across sites
	bu/a				
Control, starter only	34	44	55	129	65
Broadcast Urea	87	95	91	160	108
Urea+Agrotain	88	87	111	158	108
Super U	87	103	107	158	114
Urea+NutriSphereN	83	93	102	162	112
100% ESN	86	115	118	171	120
½ ESN, ½ urea	85	104	104	164	114
Broadcast UAN	61	67	89	163	95
Broadcast UAN + Agrotain Plus	65	62	93	170	98
Broadcast UAN + NutriSphereN	70	83	83	160	98
Broadcast UAN + Instinct	62	68	89	148	91
Surface band UAN	61	76	90	179	103
Surface band UAN + Agrotain Plus	65	87	93	165	104
Surface band UAN + NutriSphereN	67	77	97	159	100
Surface band UAN + Instinct	63	96	97	170	106
Coulter band UAN	90	105	119	169	120
Coulter band UAN + Agrotain Plus	97	118	126	170	124
Coulter band UAN + Instinct	91	102	121	177	122
Broadcast Urea @ 70 total N	67	-	68	166	-
Broadcast Urea @ 130 total N	92	116	95	172	119
Broadcast Urea @ 160 total N	98	130	103	158	122
CV (%)	5.7	15.8	17.9	7.5	13.3
LSD (0.1)	5 bu	20 bu	24 bu	14 bu	10 bu

All treated plots received a total of 100 lb N/a, 20 lb N/a as starter, and 80 lb N/a as designated treatment, unless otherwise noted.
Surface banded = 20-in. centers using a sprayer with solid stream fertilizer nozzles. Coulter banded = 60-in. centers (every other row middle) approximately 2 in. deep.
Agrotain = NBPT urease inhibitor.
Agrotain Plus = NBPT plus DCD urease and nitrification inhibitors.
Super U = Urea cogranulated with NBPT urease inhibitor and DCD nitrification inhibitor.
Nutrasphere = Nitrogen fertilizer manager product.
Instinct = Nitrapyrin-based nitrification inhibitor.

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

A.R. Asebedo and D.B. Mengel

Summary
Ammonia volatilization, denitrification, immobilization, and leaching are common nitrogen (N) loss mechanisms grain sorghum producers face in Kansas. These N loss mechanisms cause a reduction in N availability and yield and increase costs for Kansas grain sorghum producers. In 2010 a project was conducted at four locations in Kansas to evaluate a number of products to manage N availability as well as N application methods. Conditions in 2010 varied at each location. Growing conditions following a mid-June replant at Belleville were near ideal, whereas the Salina location experienced heavy rains and severe N loss. The Randolph and Ottawa locations had wet conditions early but late-season heat and drought stress. A significant response to N was seen at all locations, but little difference between treatments was observed, especially at Belleville and Salina.

Introduction
Nitrogen fertilizer is generally required to optimize grain sorghum yields in Kansas, but N loss mechanisms such as ammonia volatilization, denitrification, immobilization, and leaching reduce the efficiency of N fertilizer applications, often resulting in lower yields or higher N needs. In 2010 five tools for preventing N loss were evaluated: (1) fertilizer placement; (2) timing of fertilizer application; (3) the urease inhibitor NBPT, present in Agrotain, Super U, and Agrotain Plus; (4) a urease inhibitor in combination with the nitrification inhibitor DCD as Agrotain Plus and Super U; and (5) a controlled-release polyurethane coated urea, ESN. The goal of the project was to determine under what conditions these products or practices would enhance N uptake in grain sorghum and increase yield.

Procedures
This study was conducted in 2010 at four locations: the North Central Kansas Experiment Field near Belleville, KS; the Bill Came farm near Salina, KS; the Mengel farm near Randolph, KS; and the East Central Kansas Experiment Field near Ottawa, KS. Plots were arranged in the field using a randomized complete block design with four replications. Soil samples were taken within the study area at each location prior to planting to estimate residual N and other nutrients needed. Initial treatments were applied at approximately the three- to four-leaf stage of growth at each location at a rate of 60 lb N/a. The N response curve was established using broadcast urea at rates of 0, 30, 60, 90, 120, and 150 lb N/a to determine the N response function at each location. Refer to Tables 1 and 2 for specific treatments used at each location. At the Came farm, a second application of the N response curve was made at GS3, or approximately the 8-leaf growth stage.

Multiple measurements were taken to evaluate the performance of each treatment. Leaf samples consisting of 15 third leaves from the top were collected at heading (GS5), and whole plant samples were taken at maturity to measure total N uptake. Leaf counts and leaf firing notes were taken at various growth stages to establish a visual evaluation of plant N status. Yield data were recorded at harvest and grain samples were collected to measure grain N content.

Results

Results from these experiments are summarized in Tables 1 and 2. Statistical analysis was conducted with the PROC GLM procedure in SAS, with an alpha level of 0.05.

Results from the Salina location are summarized in Table 1. This site experienced several sequential periods of high rainfall, which together with the poor drainage of the Crete silt loam soil created exceptionally favorable conditions for denitrification. The crop responded to the highest rates of N, 150 lb N/a, applied at both the four-leaf and eight-leaf growth stages. Even at these high N rates, symptoms of N deficiency were observed. Due to the extremely high N loss at this site, no response to any of the N-enhancing products was observed.

Results from the Ottawa, Randolph, and Belleville locations are summarized in Table 2. At all of these locations a response to N was observed, although it was limited at Belleville. The Belleville site was originally planted in mid-May and was replanted in mid-June; although significant N loss could have been expected earlier in the season, conditions were good for crop growth with little excess moisture leading to N loss after replanting or N application. A significant response occurred to the first 30 lb of N applied at Belleville in 2010, but higher rates brought little or no additional response. With this limited response to N, no response was seen or expected to placement or N-enhancing products.

At Randolph and Ottawa, a response to 90 to 120 lb of N was observed, although yields were somewhat limited at around 100 bu/a due to heat and dry weather. No response to the use of N-enhancing products was observed at either site, nor did placement of UAN below the soil enhance yield as compared to surface-broadcasting UAN.

Acknowledgments

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Table 1. Yields from N products and practices study conducted near Salina, KS, 2010

	Salina	
Treatment	lb N/a	bu/a
Control	0	30
Urea	30	48
Urea	60	66
Urea	90	77
Urea	120	89
Urea	150	92
Agrotain	60	67
Super U	60	66
NutraSphere-N	60	66
ESN 100%	60	67
ESN/Urea 75%/25%	60	61
ESN/Urea 50%/50%	60	68
ESN/Urea 25%/75%	60	68
Urea-8 leaf	30	49
Urea-8 leaf	60	66
Urea-8 leaf	90	66
Urea-8 leaf	120	81
Urea- 8 leaf	150	90
CV		12.74%
LSD		12 bu

Agrotain = NBPT urease inhibitor.
Super U = Urea cogranulated with NBPT urease inhibitor and DCD nitrification inhibitor.
Nutrasphere-N= Nitrogen fertilizer management product.

Table 2. Yields from N product and practices studies located near Ottawa, Randolph, and Belleville, KS, 2010

Treatment	lb N/a	Ottawa	Randolph	Belleville
Control	0	29	60	82
Urea	30	49	92	111
Urea	60	74	97	116
Urea	90	91	105	119
Urea	120	100	99	110
Urea	150	108	n/a	121
Agrotain	60	77	93	104
Super U	60	74	107	122
NutraSphere-N	60	68	89	118
ESN 100%	60	73	89	105
ESN/Urea 50%/50%	60	68	82	108
Broadcast UAN	60	49	83	113
Broadcast UAN/Agrotain	60	58	n/a	110
Broadcast UAN/Agrotain Plus	60	48	87	98
Broadcast UAN/Nsphere	60	47	87	101
Surface band UAN	60	57	85	111
Surface band UAN/Agrotain	60	56	n/a	119
Surface band UAN/Agrotain Plus	60	53	83	109
Surface band UAN/Nsphere	60	57	n/a	114
Coulter band UAN	60	72	79	117
Coulter band UAN/Agrotain Plus	60	68	n/a	88
CV		9.53%	15.62%	11.36%
LSD		9 bu	20 bu	18 bu

Surface band = 20-in. centers using a sprayer with solid stream fertilizer nozzles.
Coulter band = 60-in. centers (every other row middle) approximately 2 in. deep.
Agrotain = NBPT urease inhibitor.
Agrotain Plus = NBPT plus DCD urease and nitrification inhibitors.
Super U = Urea cogranulated with NBPT urease inhibitor and DCD nitrification inhibitor.
Nutrasphere-N = Nitrogen fertilizer manager product.

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

M.R. Wyckoff and D.B. Mengel

Summary

Long-term research has shown that nitrogen (N) fertilizer usually is needed to optimize wheat production in Kansas. With increasing environmental concerns and the volatile price of N, using every pound of N efficiently is more important than ever. This project was initiated to quantify the most efficient management practices and the efficacy of several products sold to enhance yield and N uptake in no-till wheat. Five sites were harvested in 2010 from eastern to far western Kansas with a range of weather and soil conditions. Although few large yield advantages to any treatments were apparent, top-dressed dry N fertilizer sources consistently tended to do better than broadcast liquid UAN in no-till conditions.

Introduction

The goal of this study was to determine efficient and profitable N management options for Kansas farmers growing no-till wheat. Combinations of five common N management options were evaluated in this study: (1) fertilizer placement, banding N vs. broadcasting; (2) timing, top-dressing at Feekes 4 compared to applying the entire N application at planting; (3) using commercial fertilizer additives such as a urease inhibitor, Agrotain (NBPT, N-(n-butyl) thiophosphoric Triamid), to prevent the urease enzyme from converting urea to volatile ammonia, or Super U, which has both a urease inhibitor and a nitrification inhibitor (DCD, dicyandiamide) to slow the conversion of ammonium to nitrate, which is subject to denitrification and leaching; (4) using polyurethane-coated urea (ESN) to control the release of the urea into the soil system ultimately intended to protect the N until the plant needs it; and (5) using different forms of N fertilizers (liquid urea-ammonium nitrate [UAN], urea, and ammonium nitrate [AN]). The objective of the study was to identify management options that provide the most efficient N management system in a given setting to produce more yield with less N fertilizer.

Procedures

In 2010 this study was carried out in five locations. Four locations were on cooperator farm fields at Yates Center, Lindsborg, Marquette, and Johnson City, KS. The Manhattan site was on the Kansas State University North Agronomy Farm. These sites had a wide range of climates, soils, and rainfall totals. All sites were no-till, but at Lindsborg, the residue was burned prior to planting to reduce ammonia volatilization or immobilization potential. Nitrogen was applied by treatments listed in Table 1 and included a zero-N control, urea, Agrotain-treated urea, Super U-treated urea, 50/50 urea/ESN blend, and ESN, all at planting. All top-dress treatments had 20 lb/a N as urea broadcast at planting as starter. Spring top-dress treatments included broadcast UAN, streamer bar UAN, streamed UAN with Agrotain Plus, urea, 50/50 urea/ESN blend, ESN, ammonium nitrate, Agrotain-treated urea, and Super U-treated urea applied at

Feekes 4. The plots were placed in the field using a randomized complete block design with four replications. The center 5 ft of each plot was harvested at physiological maturity with a plot combine and grain yield was adjusted to 12.5% moisture.

Results

Results for these experiments are summarized in Table 1. The Manhattan site was planted into fairly heavy wheat stubble on a Smolan silt loam soil. This site had a marginal stand and was hit very hard by disease due to large amounts of rain throughout the spring. This is reflected by the 20 bu/a plot yield average. With the low yields and variability across the site, little difference can be noted as a result of treatment.

The Yates Center site had many of the same issues as Manhattan, with poor stands and heavy disease pressure creating a great deal of variability in stand and yield. The plot was located on a Woodson silt loam soil and received large amounts of rain throughout the spring. The results were messy and difficult to explain. We saw a response to N, although it was limited to the lower N rates. Fall-applied N treatments tended to yield higher than the spring top-dressed treatments. This may be due to the cooperator applying no starter at planting and the site's extremely low residual N levels. The top-dressed ESN treatment was one of the poorest yielding treatments, likely because it did not release the N in time for crop uptake.

The Lindsborg and Marquette sites were within a few miles of each other and were farmed by the same cooperator. The Marquette field was a lighter and flatter Hord silt loam whereas the Lindsborg site was a heavier textured, sloping, Bridgeport silt loam. The Lindsborg site had substantially more soil variability across the plot area. Although yields were higher at the Marquette location, both sites responded to a total application rate of 60 lb N/a. Limited rainfall from planting to heading created little potential for loss at these sites, so response to or need for these N enhancement products was low.

Excellent yields were obtained at the Johnson City site in 2010, but no response to applied N was observed. Initial preplant soil samples suggested that a response to N would have been expected; however, above-average precipitation in the drier portions of western Kansas can cause large amounts of N to mineralize from soil organic matter and accumulated crop residue.

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Table 1. Effects of nitrogen products and methods of application on wheat yields

Treatment	N applied at planting	N applied at Feekes 4	N source	Additive	Application method	Manhattan	Yates Center	Lindsborg	Marquette	Johnson City	All sites combined
	(lb/a)	(lb/a)				Yield (bu/a)					
1	0	0	Control	na	na	12.5b	17.3c	33.5d	57.1e	61.6a	36.4c
2	20	40	UAN		Broadcast	21.4a	32.4ab	47.5ab	73.6abcd	64.4a	47.8ab
3	20	40	UAN		Streamer Bars	19.7ab	28.6ab	49.3ab	72.1cd	65.1a	46.9ab
4	20	40	UAN	Agrotain	Streamer Bars	21.4a	27.1ab	43 9abc	73.0abcd	60.1a	45.1b
5	20	40	Urea		Broadcast	22.2a	31.7ab	51.5a	74.2abcd	64.4a	48.8a
9	20	40	Urea	Agrotain	Broadcast	19.8ab	29.7ab	49.8ab	79.5a	62.7a	48.3ab
10	20	40	Urea	Super U	Broadcast	19.7ab	32.4ab	46.2ab	72.7bcd	64.7a	47.1ab
8	20	40	AN		Broadcast	22.4a	33.1a	44.8ab	75.1abcd	65.4a	48.2ab
6	20	40	Urea/ESN		Broadcast	22.3a	30.4ab	42.2abc	78.0abc	62.3a	47.0ab
7	20	40	ESN		Broadcast	19.1ab	25.4b	45.6abc	73.1abcd	65.4a	45.7ab
11	60	0	Urea		Broadcast	20.3ab	33.5a	49.3ab	69.0d	60.7a	46.6ab
12	60	0	Urea	Agrotain	Broadcast	20.9a	33.2a	46.0ab	71.8cd	61.4a	46.7ab
13	60	0	Urea	Super U	Broadcast	19.4ab	33.6a	46.9ab	74.1abcd	65.5a	47.9ab
14	60	0	ESN		Broadcast	22.4a	33.9a	47.3ab	74.2abcd	61.2a	47.8ab
15	60	0	Urea/ESN		Broadcast	17.1ab	29.3ab	47.3ab	71.6cd	65.5a	46.2ab
16	20	20	Urea		Broadcast		25.3b	47.9ab	69.6d		
17	20	60	Urea		Broadcast		33.6a	47.7ab	73.1abcd		
18	20	80	Urea		Broadcast		33.0a	39.1bc	78.8ab		
					Site averages	20	30.2	45.9	72.8	63.4	

Values followed by the same letter are not statistically different at P=0.05.

Managing Variations in Soil Test K Levels in Southeast Kansas

J.D. Matz and D.B. Mengel

Summary
Potassium (K) deficiency has increased significantly in southeast Kansas in the past decade. Likely contributors to this problem are the use of more intense crop rotations (i.e. corn/wheat/double-cropped soybean) and an increase in K-extracting crops (i.e. soybean) together with a tradition of using sufficiency-type fertilizer recommendations and not fertilizing each crop in the rotation, which results in a failure to replace K lost through crop removal. Because of these practices, many soils that had naturally elevated K availability 25 years ago have declined in K content. More troubling is the extreme yearly variation of exchangeable K soil test levels in the region, which has many producers and consultants concerned about proper K management. To address these issues, a series of studies was initiated in 2007 and carried through 2010 in Franklin, Anderson, and Cherokee Counties in southeast Kansas. The studies, funded by the Kansas Soybean Commission, were designed to look at the impact of K deficiency on soybean in the region, to compare methods of correcting the perceived problem, and to examine the effects of residual K fertilizer on rotational crops.

The preliminary study, conducted in 2007 and 2008, compared broadcast and deep band applications at multiple rates with and without starter as alternative corrective measures. The current study, initiated in 2009, compares broadcast vs. surface banding K fertilizer at varying rates to determine which more effectively resolves K deficiency. No clear effect of K fertilization or placement for soybean and corn yields was observed to date. However, soybean leaf samples have revealed that when a high rate of K fertilizer was applied, regardless of placement, plants contain increased K concentrations. In 2007, increased soybean K leaf level also was observed with deep banding. In 2010, soybean tissue samples were below the normal concentration range of 1.7 to 2.3%, yet no visible deficiency symptoms were documented. In 2009 soybean and 2010 corn studies, leaf K concentrations were within the normal range.

Soil samples taken on a monthly basis during the growing season at every location indicated that K levels did indeed change dramatically. These 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 work will continue.

Introduction
Implementing a sound K management system is essential to maximizing crop yields as well as seed quality. Potassium is an element long recognized for its role in improving the oil content in soybean and increasing kernel weight and kernels/ear in corn. Maintaining adequate K fertility levels in the soil is vital, but unfavorable conditions can make K management difficult. Soil moisture and temperature are vital factors affecting K availability because a majority of the K that reaches the plant root moves through the soil via diffusion. During hot and dry conditions, diffusion rates are greatly reduced and plant K uptake decreases substantially. Potassium availability also is affected directly by

the type and amount of clay minerals in the soil. Certain clay minerals trap K and hold it in an unavailable form, thus reducing plant uptake. Cation exchange capacity (CEC) from clay and organic matter are important sites of K storage in soils. Soils with low CEC can exhibit K leaching and reduced K availability. Combining all these factors can result in plant K uptake as well as K soil test levels that fluctuate tremendously over a season.

Evaluation of different K fertilizer rates and application methods is critical when determining the best K management practices. A major objective of our research is to try to identify the mechanism(s) driving changes in soil test K levels and K availability to crops during the growing season. The long-term goal is to be able to design a soil sampling system and develop alternative K fertilizer recommendation strategies that can alleviate K deficiency impacts on crop yield.

Procedures

The project was conducted on cooperating farmers' fields in southeast Kansas. Five sites were established in Anderson and Franklin Counties in 2007 and 2008. In 2007, experiments were established on the John Wray farm near Ottawa, Rex Lizer Farm near Garnett, and Grant Corley farm near Westphalia. In 2008, additional experiments were established on the Clyde Parks farm near Welda and the Wray farm. In 2009 and 2010 the research shifted to Cherokee county near Hallowell on the John and Mark Epler farm. Sites are identified by the individual landowners' names. Dominant soil types were Woodson and Cherokee silt loams. The climate of the region is characterized by a long growing season, >200 days, with high summer temperatures and high rainfall. Rainfall distribution, given in Table 1, is not uniform and is highest in the spring and lowest in winter, with a typical summer dry period in July and August and fall rains in September and October. Variability from year to year is high and periodic dry and wet periods are common.

The experimental design used at each location was a randomized complete block design with four replications. Maturity group 4 soybean was planted in May in 2007 and 2008 and group 5 soybean was planted in June following the harvest of a wheat crop at a seeding rate of 110,000 seeds/a in 2009 and 2010. All fields were no-till planted. Corn was planted in March or April as appropriate at a seeding rate of 20,000 to 24,000 seeds/a. Fertilizer was applied shortly following planting when soybean was at the V3 to V5 growth stage and to corn at the V5 growth stage.

Eight treatments were applied to the 2007 and 2008 experiments: an unfertilized check, an application of 10 lb/a K2O with liquid starter fertilizer, broadcast applications of 60 or 120 lb/a K2O as potash, deep banding of 60 or 120 lb/a K2O (6 to 7 in. deep) under the row with a strip till operation, and combinations of starter with the lower rate of K broadcast or deep banded.

Measurement of treatment effects on the initial study included soil sampling in the fall and spring to track K levels at 0- to 3-in. and 3- to 6-in. depths, leaf K levels for soybean at pod set and pod fill and for corn at silking, soybean/corn yield, and grain K levels.

Ten different treatments were applied to double-cropped soybean in 2009 and 2010: an unfertilized check; annual broadcast applied at the Kansas State University recommendation rate; annual broadcast application of 30 and 60 lb/a K2O; biannual broadcast application of 60, 120, and 180 lb/a K2O and biannual surface band application of 60, 120, and 180 lb/a K2O. Only the three annual fertilizer treatments were applied to corn, and residual effects of the other treatments that were applied the year before to soybean were analyzed as well. Surface banding consisted of applying 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 at a 0- to 6-in. depth, leaf K levels for soybean at pod set and pod fill and corn at silking, soybean/corn yield, and grain K levels.

Results

Preliminary study, 2007–2008

2007 in Eastern Kansas was characterized by an extremely wet May and June followed by an extremely dry summer and fall. Approximately 25 in. of precipitation fell during the growing season, with over 22 in. received in May and June. Initial soil test results at all three sites in 2007 showed K levels below 100 ppm, which is below the established critical level of 130 ppm. Increases in leaf K levels due to broadcast K application and deep placement of K were observed, but no increase due to starter application was observed. Deep banding was more effective at supplying K to the plant, as measured by leaf K, than broadcasting. Similar trends were seen at all three sites. No effects of any K fertilizer treatments were observed on soybean yields, likely due to the extremely dry weather during pod fill, thus limiting yields. The results from 2007 averaged across locations are summarized in Table 2.

Two additional sites were established in 2008 based on fall 2007 field soil tests. However, when individual plot samples were pulled in spring 2008, soil test K levels had increased dramatically to levels well above the critical levels. A similar shift in soil test values occurred at two of the 2007 experiments when retested in 2008. Control plots receiving no K in 2007 showed an increase in K soil test of 50 to 100 ppm.

2009 studies

Due to the apparent variation in K soil test levels observed in 2007 and 2008, efforts were made to monitor soil test levels more closely on sites established in 2009 and 2010. Sites were again selected based on previous soil testing information available from farmers and crop consultants. All sites selected for use in 2009 had been soil-tested in the late fall of 2007 and all had soil test K levels below 100 ppm. The soil test levels from these four sites established in 2009 are summarized in Figure 1. Low-testing sites as indicated by fall sampling were found to have high soil test K levels the following spring/summer when double-cropped soybean plots were established. Exchangeable K soil test levels at these locations appear to be changing significantly throughout the growing season. Levels seem to demonstrate seasonal changes: rates are higher in the spring months and then decline in the summer and fall. K soil test levels also appear to follow a similar trend with precipitation. During wet months, soil test levels tend to increase and then decline during drier months; however, this is not a perfect relationship, and other factors are also likely to be involved in regulating K soil test levels.

Potassium (K) uptake in the leaf by soybean planted on these sites was generally high, and was significantly increased in many treatments when KCl fertilizer was either broadcast or surface banded at a high rate (Table 3). 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 2009 growing season. No consistent response to K fertilization or placement was observed in the yield data at these sites (Table 4).

2010 studies
Corn was planted on these sites in 2010 to consider the residual effects of multiyear K applications made in 2009 and to continue to monitor soil test levels. As evidenced in Figure 1, soil test K levels rebounded in the spring of 2010, with all four sites achieving soil test levels near or above the critical level of 130 ppm by planting. Soil test levels dropped again during the summer, and were below the critical level by silking. Corn leaf samples collected at greensilk in mid-June were all above the established critical levels of 1.7%, and we observed no effects of treatments on yield.

Four additional sites were established in 2010. Similar trends in soil test levels with season were initially observed: They were high in spring and lower in summer. However, soil test levels at three of the sites rebounded in the summer during an extended dry period. K levels in the soybean leaves were more variable in 2010 and tended to reflect soil test levels of the individual sites and applied treatments at the two sites with lowest soil test levels. Soybean yields in 2010 were good due to timely fall rains and we could see no clear impacts of treatments (Table 6).

Thus far, maintaining soil test K levels above 130 ppm using a spring soil test appears to be successful strategy for avoiding K deficiency, but this is contrary to current practices and traditional Kansas State University fertilizer recommendations. Farmers traditionally sample soil in midsummer after wheat or corn harvest or in late fall after soybean harvest, when soil conditions are generally dry. Spring sampling can be difficult to do in a timely fashion. In addition, prior to 2003, KSU made only nutrient sufficiency recommendations. Build-and-maintain approaches that maintain K levels above the critical level were frowned upon by many extension personnel.

Adopting a build-and-maintain fertilizer recommendation philosophy, together with basing fertilizer rates on spring sampling, is proving a successful approach to resolving this issue; however, this will require a significant change in mindset among farmers and agronomists in the region. Work will continue in 2011 on this problem. Sites established in 2010 will be continued and new sites are currently being identified with spring soil test levels well below the current 130 ppm critical level.

Table 1. Rainfall distribution and variability in Cherokee County KS, 2000–2010 (in.)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean	1.7	2.2	3.8	3.6	6.5	6.9	4.0	2.9	4.2	3.5	2.1	2.2	43.5
High	4.2	5.2	6.8	7.7	12.1	18.0	7.9	7.0	11.5	7.8	5.8	4.9	61.3
Low	0.3	0.2	1.0	0	0.4	3.2	1.9	0	1.6	1.3	0.5	0.1	30.6

Table 2. Average percentage potassium in soybean leaf tissue at pod set (early) and pod fill (late) and yield by treatment combined across sites, 2007

Treatment	Early	Late	Yield
	------------------ % K	-------------------	bu/a
Check	1.30%	0.72%	26
60 Broadcast	1.38	0.78	30
120 Broadcast	1.52	0.81	25
60 Band	1.68	0.90	28
120 Band	1.79	1.08	29
Starter	1.35	0.68	26
Broadcast + Start	1.49	0.75	27
Band + Start	1.73	0.89	31
LSD (0.05)	0.15	0.11	NS

Table 3. Average percentage potassium in soybean leaf tissue at pod set (early) and pod fill (late) by treatment and site, 2009

	Farm or location							
	SW Jennings		SE Brown		SW Brown		Delmont	
Treatment	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
KSU broadcast recommendation	1.75	1.09	1.75	0.95	1.82	1.11	1.75	1.02
Broadcast 30, annual	1.75	1.05	1.78	0.98	1.85	1.10	1.78	1.10
Broadcast 60, annual	1.79	1.10	1.79	1.02	1.87	1.09	1.78	1.09
Broadcast 60, every other year	1.74	1.11	1.80	1.00	1.86	1.09	1.80	1.09
Broadcast 120, every other year	1.77	1.14	1.84	1.03	1.85	1.15	1.76	1.16
Broadcast 180, every other year	1.85	1.11	1.95	1.03	1.96	1.20	1.94	1.21
Surface band 60, every other year	1.82	1.20	1.80	0.98	1.84	1.09	1.85	1.07
Surface band 120, every other year	1.80	1.11	1.83	1.01	1.91	1.14	1.77	1.17
Surface band 180, every other year	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

Table 4. Soybean yield by treatment and site, 2009

Treatment	SW Jennings	SE Brown	SW Brown	Delmont
	bu/a			
Control	39	36	29	38
KSU broadcast recommendation	37	32	36	38
Broadcast 30, annual	39	37	34	37
Broadcast 60, annual	39	31	35	36
Broadcast 60, every other year	41	39	36	34
Broadcast 120, every other year	38	32	34	36
Broadcast 180, every other year	41	33	30	38
Surface band 60, every other year	39	36	31	38
Surface band 120, every other year	40	33	34	39
Surface band 180, every other year	39	31	36	34
LSD (0.05)	NS	8	6	NS

Table 5. Average percentage potassium in soybean leaf tissue at pod set (early) and pod fill (late) by treatment and site, 2010

	Farm or Location							
	NW of Dads		Marks		Krantz		Spieth	
Treatment	Early	Late	Early	Late	Early	Late	Early	Late
	%							
Control	1.11	0.69	1.23	0.95	1.52	1.11	1.78	1.18
KSU broadcast recommendation	1.20	0.78	1.39	0.97	1.49	1.07	1.77	1.26
Broadcast 30, annual	1.24	0.80	1.30	0.93	1.51	1.14	1.74	1.20
Broadcast 60, annual	1.24	0.79	1.37	0.97	1.62	1.15	1.82	1.26
Broadcast 60, every other year	1.26	0.79	1.36	1.07	1.58	1.18	1.75	1.23
Broadcast 120, every other year	1.39	0.94	1.49	1.06	1.57	1.22	1.78	1.22
Broadcast 180, every other year	1.39	0.98	1.41	1.13	1.66	1.30	1.96	1.29
Surface band 60, every other year	1.29	0.81	1.37	1.04	1.59	1.17	1.84	1.23
Surface band 120, every other year	1.34	0.90	1.43	1.04	1.65	1.28	1.84	1.28
Surface band 180, every other year	1.37	0.88	1.42	1.09	1.63	1.28	1.71	1.30
LSD (0.05)	0.11	0.09	0.21	0.10	0.15	0.08	0.23	0.09

Table 6. Soybean yield by treatment and site, 2010

Treatment	NW of Dads	Marks	Krantz	Spieth
	bu/a			
Control	39	52	55	46
KSU broadcast recommendation	40	52	58	41
Broadcast 30, annual	41	47	59	46
Broadcast 60, annual	40	51	57	47
Broadcast 60, every other year	41	52	58	44
Broadcast 120, every other year	40	46	59	49
Broadcast 180, every other year	40	49	58	42
Surface band 60, every other year	40	47	57	50
Surface band 120, every other year	41	52	56	47
Surface band 180, every other year	41	49	58	49
LSD (0.05)	NS	NS	3	7

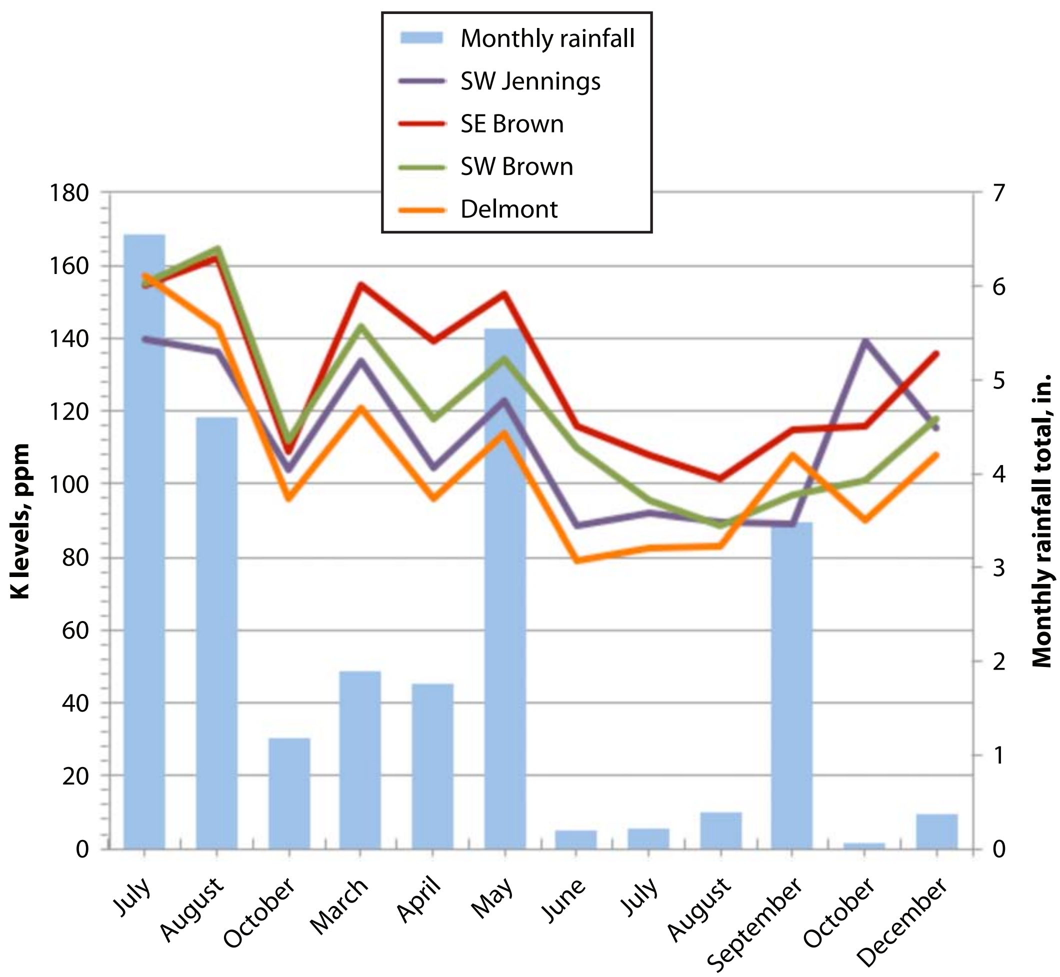

Figure 1. Seasonal changes in exchangeable potassium (K) levels of the control plots at four locations in SE Kansas (2009–2010).

Evaluation of Application Methods of Anhydrous Ammonia in Wheat

M.R. Wyckoff and D.B. Mengel

Summary
Previous work has shown that nitrogen (N) fertilizer is needed in most years to optimize winter wheat yields in Kansas. Anhydrous ammonia (NH_3) has proven to be a reliable and economical source of N for preplant application, particularly in the western half of Kansas in summer fallow ground using tillage sweeps or knife applicators. However, availability of application equipment to apply ammonia at the relatively narrow spacing needed for wheat has limited its use in eastern Kansas. Many Kansas farmers also have elected not to use ammonia preplant because of the high soil disturbance associated with the application process, particularly in no-till systems. The soil disturbance issue and resulting damage to wheat stands using traditional knife-type applicators also has limited the use of ammonia for topdressing.

The development of John Deere's 2510 high-speed, low-draft NH_3 applicator has renewed interest in using ammonia as an N source for both preplant and topdressing applications in the no-till systems of the High Plains. This low disturbance is achieved through a coulter-type soil injection system instead of a conventional knife apparatus. Yield data from this study showed that applying ammonia preplant was as effective as topdressing with urea and that application row spacing made little difference between 15, 20, and 30 in. Topdressing wheat with the 2510 applicator with little or no yield reduction relative to the traditional practice of topdressing with urea also is possible.

Introduction
The purpose of this study was to determine if using the JD 2510 HSLD anhydrous ammonia applicator for preplant or topdress applications of N for wheat was a viable option, particularly in high-residue no-till systems. Two separate experiments were conducted. The first experiment evaluated the effects of ammonia row spacing on N uptake and yield of wheat, and compared a total preplant NH_3 to a traditional split urea treatment. The objectives of the second experiment were to: (1) compare topdressing with NH_3 to the traditional urea system, (2) evaluate the impact of speed of ammonia application on crop injury and yield, and (3) assess the effect of application with the crop row compared to across the row on injury and yield.

Procedures
The studies were initiated at the Kansas State Agronomy North Farm in Manhattan, KS, on highly productive bottom ground in the fall of 2009. Preplant applications of ammonia at 60 and 90 lb N/a were applied in 15-, 20-, and 30-in. application spacings, with the ammonia applied approximately 4.5 in. deep in late October. Additional topdress treatments at equivalent N rates also were established. All topdress plots received 20 lb N/a as urea preplant with the remaining 40 or 70 lb N topdressed as urea at Feekes 4 in early spring. The experiment was no-till drilled in 7.5-in. rows into soybean stubble in early November using the variety Sante Fe, at a seeding rate of 100

lb/a. Forty pounds of P_2O_5 was applied as a starter fertilizer to all plots with the drill at planting.

A second experiment was established simultaneously to determine if topdressing with ammonia could be done using the low-disturbance applicator. Sante Fe wheat was no-till planted at a 100 lb/a seeding rate. All plots received 20 lb N/a as urea and 40 lb P_2O_5 as 0-46-0 (triple super phosphate) applied prior to planting as starter. Topdress treatments consisting of a no N control, 60 lb N as urea, and 60 lb N as ammonia applied at 4, 6, and 8 mph with the applicator running parallel to the rows or at a 20 to 30° angle to the row, at Feekes 4.

Plot size used in both experiments was 10 ft by 80 ft. Leaves sampled for N analysis were collected at heading. Plots were end-trimmed to a uniform length of 40 ft, and the center 5 ft was harvested using a Hege 125B plot combine at physiological maturity. Grain yield was adjusted to 12.5% moisture. Grain samples were collected from each plot and analyzed for N content and test weight.

Statistical analysis was performed using the PROC GLM procedure of SAS version 9.1, with an alpha level of 0.05 for all mean separations.

Results

The results from experiment one, the preplant spacing study, are summarized in Table 1. A good response to applied N was noted, with highest leaf N content and yields obtained at the highest N rate, 90 lb N/a. No significant difference in yield or leaf N content was observed due to preplant application spacing or between topdressing or preplant ammonia application.

The results for experiment two, the topdressing experiment, are reported in Table 2. As in experiment one, a significant positive response to N was observed. However, no significant impact of application speed or application direction in relation to row direction was found. Although higher application speeds caused more soil disturbance and initial damage to the wheat plants, cool temperatures and timely rainfall led to quick recovery. Under higher temperatures and drier conditions, this increased damage with the highest application speeds could have had a negative impact on yield. Using wider wheat row spacings, which is common in western Kansas, along with auto-steer guidance systems would allow running the applicator units between rows, minimizing any potential injury.

These experiments will be repeated at multiple locations in 2011.

Acknowledgments

We wish to thank Deere & Company for providing a JD 2510 HSLD ammonia applicator for our use, and for providing funds to support this project.

Table 1. Experiment 1: Impact of N application row spacing and N rate on leaf N content, yield, and grain protein content of wheat fertilized prior to planting with a John Deere 2510 ammonia applicator

Treatment: Time, spacing, and rate	Leaf N	Yield	Grain protein content
	%N	bu/a	%
No N control	1.99d	19.9e	11.2a
Split-applied; 20 fall, 40 spring topdress	2.16bcd	36.2cd	10.4ab
60 preplant as ammonia on 15-in. spacings	2.11cd	34.1d	10.0b
60 preplant as ammonia on 20-in. spacings	2.38abc	39.1bc	10.6ab
60 preplant as ammonia on 30-in. spacings	2.31abc	34.5d	9.9b
Split-applied; 20 fall, 70 spring topdress	2.36abc	43.8a	10.7ab
90 preplant as ammonia on 15-in. spacings	2.40ab	41.5ab	10.0b
90 preplant as ammonia on 20-in. spacings	2.44a	41.7ab	10.6ab
90 preplant as ammonia on 30-in. spacings	2.44a	40.2abc	10.8ab

Values followed by the same letter are not statistically different at P=0.05.

Table 2. Experiment 2: Impact of application speed and row approach

Treatment: Time, spacing, and rate	Leaf N	Yield	Grain protein content
	% N	bu/a	%
No N control	2.33d	30.3b	11.9abc
Split-applied; 20 fall 60 spring topdress as urea	2.48cd	49.5a	11.5bc
60 topdress ammonia running at angle to rows at 4 mph	2.83ab	46.1a	11.3c
60 topdress ammonia running with the rows at 4 mph	2.64bc	47.1a	11.8abc
60 topdress ammonia running at angle to rows at 6 mph	3.00a	48.5a	12.4a
60 topdress ammonia running with the rows at 6 mph	2.82ab	47.3a	11.3c
60 topdress ammonia running at angle to rows at 8 mph	2.92ab	43.8a	12.1ab
60 topdress ammonia running with the rows at 8 mph	2.83ab	44.1a	11.5bc

Values followed by the same letter are not statistically different at P=0.05.

Nitrogen Fertilization of Nitrogen-Stressed Soybean

A.R. Asebedo and D.B. Mengel

Summary
As soybean acres expand into soils where soybean has never been grown, inoculation of the seed is critical to ensure nodulation and nitrogen (N) fixation. If inoculation is not done or fails to result in adequate nodulation, this work shows that fertilization with 120 lb of N/a can supply the N needed for a normal crop.

Introduction
When adequate levels of active, appropriate rhizobia bacteria are present in the soil, soybean plants will nodulate and fix N and normally will 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, adequate rhizobia may not be present for successful nodulation and N fixation, and the crop will be N-deficient. Commercial inoculants usually are applied to the seed to supply needed rhizobia and provide adequate nodulation; however, these inoculants are not always successful. Poorly nodulated, N-deficient soybean can result

In both 2009 and 2010, a number of fields planted into "virgin" soybean ground or into returned conservation reserve program ground in north central Kansas were observed to be poorly nodulated and N-deficient even though the seed was commercially inoculated. A field study was conducted in 2009 and continued at a new location in 2010 to determine whether these poorly nodulated, N-deficient soybean would respond to applied N fertilizers, and, if so, how much N could successfully be used.

Procedures
This study was conducted on a farmer's field near Solomon, KS, that had noticeably N-deficient soybean. 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 cogranulated with a urease inhibitor and nitrification inhibitor (Super-U) by surface banding the material between the soybean rows. Rainfall occurred within a few hours of N application.

This study was repeated in 2010 on a farmer's field near Gypsum, KS, that had poorly nodulated, N-deficient soybean. The soybean variety P93Y70 was planted into conventional tilled soil at 130,000 seeds/a on June 19, 2010. Soybean seed was treated with Optimize Inoculant prior to planting. This field had no history of soybean production. A simple N-rate study with six N rates ranging from 0 to 150 lb N/a was laid out in the field in a randomized complete block design with four replications. The N was again broadcast-applied as urea co-granulated with a urease inhibitor and nitrification inhibitor (Super U) on July 22, 2010. Rainfall did not occur until 14 days after treatments were applied.

The two center rows of the four row plots were machine harvested at maturity both years. 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

The results from both studies for 2009 and 2010 are summarized in Table 1. In 2009, response to the highest rate, 120 lb N/a, was near-linear and highly significant, with a 21 bu/a advantage over the control.

Yields at Gypsum in 2010 were lower due to dry weather; however, similar results were obtained, with an 11-bu response to the first 120 lb of N/a compared to the control. No additional response was obtained to the 150-lb rate applied in 2010 compared to 120 lb N/a in 2009. When pooled across years, the data show a clear linear response to N, with highest yields obtained at 120 lb N/a.

The data from these studies show that applying N fertilizer to poorly nodulated, N-deficient soybean enhances yield. Applying up to 120 lb N/a has been effective in each of the past two years. At current fertilizer and commodity prices these responses would provide a good return on investment, even on the modest yields obtained in 2010. 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 and 2010

	Solomon, KS 2009	Gypsum, KS 2010	Pooled
N rate	Yield	Yield	Yield
lb/a	----------------------------------	bu/a	----------------------------------
0	28d	18c	23d
30	37c	23b	30c
60	42b	26ab	33cb
90	43b	26ab	34b
120	49a	29a	39a
150	n/a	29a	n/a
CV	7.17%	10.89%	11.96%
LSD (0.05)	4.36 bu	4 bu	3.9 bu

Treatments followed by the same letter are not statistically different.

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

K.A. Janssen

Summary
Effects of nitrogen (N) rates and starter fertilizer were evaluated for nonirrigated, strip-till fertilized corn on a Woodson silt loam soil at the East Central Kansas Experiment Field at Ottawa, KS, in 2006 through 2010. Because of below-average seasonal rainfall in 2006 and 2007 and above-average rainfall in 2008, 2009, and 2010, 80 to 160 lb/a N were required to maximize yields. Starter fertilizer placed beside and below the seed row at planting increased early season corn growth four out of five years but did not increase grain yield in any year. Highest grain yields were produced when the starter fertilizer nutrients (nitrogen-phosphorus-potassium; NPK) were included along with the rest of the fertilizer in the strip-till zone. These findings suggest that starter fertilizer applied in the strip-till zone may be as or more effective at increasing yield as placement beside and below the seed row at planting. These data also suggest that not knowing the amount of rainfall that will occur prior to fertilization makes precise N application difficult. One strategy might be to apply an intermediate rate of N (between 80 and 160 lb/a). Other strategies might be to apply some or all of the N with a safener to help minimize potential N losses or to side-dress some of the N to better match the N rate with variable seasonal needs.

Introduction
Corn growers in eastern Kansas might benefit from more accurate N rate applications when growing strip-till corn. The high cost of N fertilizer and potential for increased N losses with over application demand prudent use. Research also is needed to determine whether growers need to apply starter fertilizer at planting for strip-tilled fertilized corn with under-the-row banded fertilizers. Such research could help strip-till corn growers make better decisions about the amount of N fertilizer to apply, whether purchasing costly planter fertilizer-banding equipment is worthwhile, and whether to apply starter fertilizer at planting.

Procedures
This was the fifth year of this study. Six N rates and three starter fertilizer options were studied. Nitrogen rate treatments were 0, 60, 80, 100, 120, 140, and 160 lb/a applied in the spring before planting in the strip-till zone. Starter fertilizer treatments were (1) placement of all starter fertilizer 5 to 6 in. below the row in the strip-till zone, (2) placement of the starter fertilizer 2.5 in. to the side and 2.5 in. below the seed row at planting, and (3) half of the starter fertilizer applied in the strip-till zone and half applied beside and below the seed row at planting. In all cases, 30 lb/a N was included with the phosphorus (P) and potassium (K) starter fertilizers and balanced for total N. Research by Barney Gordon at the North Central Kansas Experiment Field at Scandia, KS (Field Research 2002, Report of Progress 893), showed that at least a 1:1 ratio of N-P fertilizer mix should be used for best starter P benefits.

Experiment design was a randomized complete block with four replications. No-till soybean was grown prior to the strip-till corn studies each year. For preplant weed control, 1 qt/a atrazine 4L plus 0.66 pint/a 2,4-D LVE, plus 1 qt/a crop oil concentrate was applied. Pioneer 35P17 corn was planted April 6, 2006; May 19, 2007; May 13, 2008; May 20, 2009; and May 5, 2010. Plantings in 2007, 2008, 2009, and 2010 were delayed because of wet weather. Corn was planted at a rate of 24,500 seeds/a in 2006 and at 26,500 seeds/a in 2007, 2008, 2009, and 2010. Preemergence herbicides containing 0.5qt/a atrazine 4L plus 1.33 pint/a Dual II Magnum were applied the day after planting each year for in-season weed control. Effects of the N rates and starter fertilizer treatments were evaluated by measuring early season growth at the V6- toV7-leaf corn growth stage and grain yield at physiological maturity.

Results

Seasonal moisture for corn was below average in 2006 and 2007 and above average in 2008, 2009, and 2010. Under these conditions and with corn following soybean, 80 lb/a N maximized corn grain yields in 2006 and 2007, 100 to 140 lb/a N maximized corn grain yields in 2008 and 2009, and 160 lb/a N was required to obtain the highest yield in 2010 (Table 1). Increased demand for N in 2008 and 2009 was due to increased seasonal rainfall and higher yield potential. Extreme need for N in 2010 was because of major losses of N from 7.5 in. of rain from mid-April through mid-May. Even at the 160 lb/a N rate, N was insufficient and yield was over 30 bu/a below the yield level obtained the two previous years with lower N rates. Application of starter fertilizer placed 2.5 in. to the side and 2.5 in. below the seed row at planting increased early season growth of corn in 2006, 2008, 2009, and 2010, but not in 2007 (Table 1). The combination application of half the starter fertilizer applied at planting and half applied in the strip-till zone produced intermediate early season plant growth effects (Figure 1).

Neither of the planter starter fertilizer options increased grain yield (Figure 2). Grain yields were highest when all starter fertilizer nutrients (i.e., N, P, and K) were included in the strip-till zone along with the rest of the strip-till fertilizer. These data suggest that placing starter fertilizer preplant under the row in the strip-till zone may be as good as or better than placing starter fertilizer beside and below the seed row at planting. Also, application of starter fertilizer at planting may be unnecessary when growing strip-till fertilized corn when starter fertilizer nutrients are included in the strip-till zone. Not knowing the amount of rainfall and N loss that will occur prior to fertilization makes precise N application difficult. One strategy might be to apply an intermediate rate of N (between 80 and 160 lb/a). Some years an intermediate N rate would be too low and other years too high. Other strategies might be to apply a safener with some or all the N to help minimize potential N losses or side-dress some of the N to match better the N rate with variable seasonal needs. More research is needed to determine the most efficient N application for strip-till corn.

Table 1. Effects of nitrogen rates and starter fertilizer on V6- to V7-plant dry weights and grain yields of strip-till corn, East Central Kansas Experiment Field, Ottawa, 2006-2010

Fertilizer treatments		V6-V7 dry weights					Grain yields				
Strip-till	Starter 2.5 × 2.5 in.	2006	2007	2008	2009	2010	2006	2007	2008	2009	2010
---- N-P2O5-K2O, lb/a ----		g/plant					bu/a				
Check 0-0-0		2.1	5.3	7.1	5.1	6.0	47	37	63	61	16
60-40-20		5.5	9.5	10.9	7.3	11.4	101	89	121	108	61
80-40-20		4.2	9.8	11.4	8.3	12.7	109	95	134	118	66
100-40-20		4.4	8.3	11.4	7.6	12.9	103	93	138	132	73
120-40-20		4.3	9.4	9.7	7.0	11.3	108	99	138	136	89
140-40-20		3.9	9.0	10.5	6.7	12.3	109	98	147	136	90
160-40-20		4.0	8.9	10.1	6.7	11.9	108	101	145	142	106
Evaluation of starter at three N levels											
80-40-20		4.2	9.8	11.4	8.3	12.7	109	95	134	118	66
50-20-10 +	30-20-10	6.4	9.5	12.8	9.8	13.3	101	88	124	96	62
50 +	30-40-20	6.6	9.7	12.9	10.0	13.7	103	90	121	92	62
120-40-20		4.3	9.4	9.7	7.0	11.3	108	99	138	136	89
90-20-10 +	30-20-10	6.2	9.5	11.8	9.3	12.4	105	102	140	133	83
90 +	30-40-20	7.6	9.2	12.2	10.9	13.9	102	95	136	124	75
160-40-20		4.0	8.9	10.1	6.7	11.9	108	101	145	142	106
130-20-10 +	30-20-10	5.3	9.2	12.4	8.8	12.6	106	99	150	140	103
130 +	30-40-20	6.8	8.7	14.5	9.6	13.0	100	98	143	131	100
LSD (0.05)		1.0	1.4	0.9	1.3	0.8	6	9	7	11	5

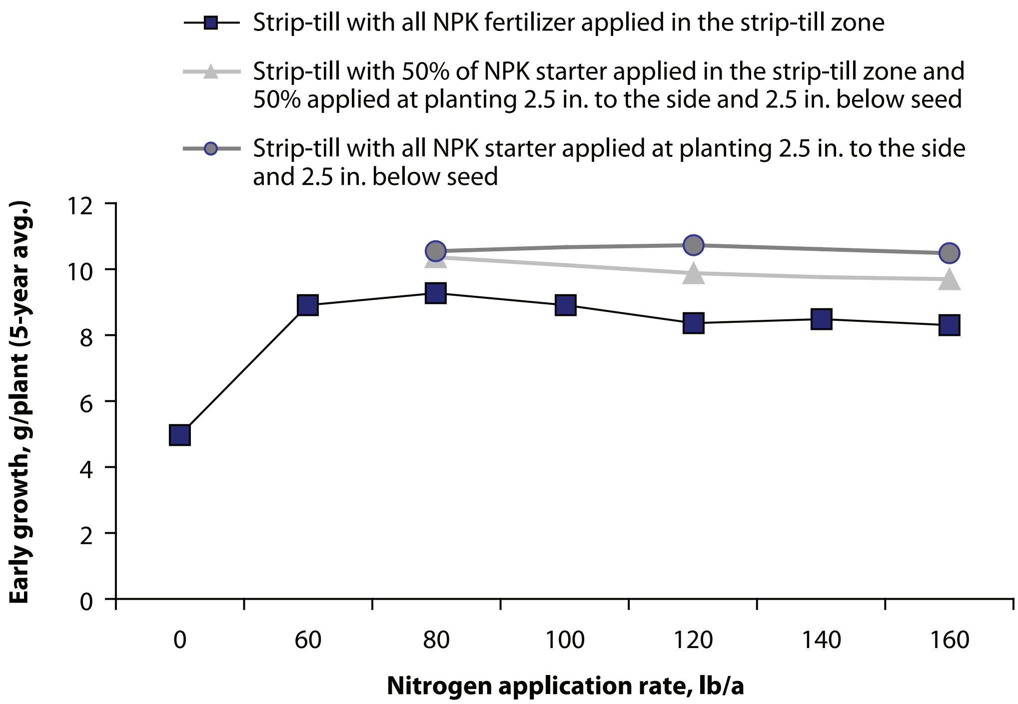

Figure 1. Nitrogen rate and starter fertilizer placement effects on V6- to V7-leaf stage growth of strip-till corn.

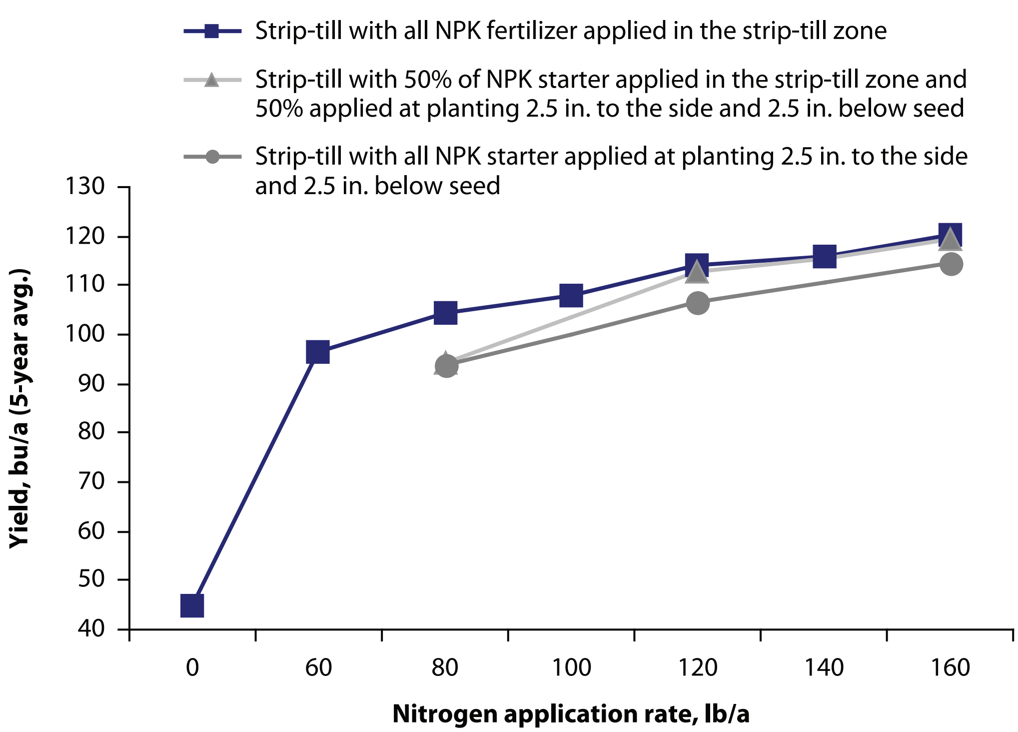

Figure 2. Nitrogen rates and starter NPK fertilizer placement effects on yield of strip-till corn.

Effect of Calcium Thiosulfate on Irrigated Corn

L.D. Maddux

Summary
Calcium thiosulfate was applied as a 2 × 2 starter to corn at 5, 10, and 20 gal/a. No significant differences in grain yield or in percent N, P, or K were observed.

Introduction
This study was conducted with a grant provided by Tessenderlo Kerley, Inc. (TKI), a producer of specialty products used in the agriculture, mining, and process chemical industries. This study was conducted to evaluate the effect of applications of calcium thiosulfate (CaTs, 0-0-0-10S-6Ca) applied at three rates as a 2 × 2 starter to irrigated glyphosate-resistant corn.

Procedures
This study was conducted in 2010 on a Eudora silt loam soil previously cropped to soybean at the Paramore Unit of the Kansas River Valley Experiment Field near Topeka, KS. Prior to planting, 240 lb/a of 5.5-26-30 fertilizer was broadcast and incorporated. Anhydrous ammonia was applied April 1 at 150 lb N/a. CaTs was applied at 5, 10, and 20 gal/a as a 2 × 2 starter application at planting. Corn hybrid DeKalb DKC 61-69 was planted April 13 at 29,600 seeds/a. Harness Xtra (2.4 qt/a) + Trophy Gold (1 qt/100 gal) was applied April 28. Honcho Plus (1.0 qt/a) + Callisto (1.5 oz/a) + Trophy Gold (1 qt/100 gal) + UAN (2.5 gal/100 gal) was applied June 4. Sprinkler irrigation was applied July 23 (1.02 in.), July 26 (1.12 in.), and August 4 (1.24 in.). Plots were harvested September 14 with a plot combine.

Results
Corn yields are shown in Table 1. No significant differences in grain yield or percent N, P, or K were observed, although grain yield with 20 gal/a CaTs yielded almost 8 bu/a more than the check. A non-significant trend toward increased N content in the grain with increasing CaTs rates was also observed.

Table 1. Effect of CaTs applications on corn yield and grain nutrient content, Kansas River Valley Experiment Field, Topeka, KS, 2010

Fertilizer	Rate	Application	Corn yield	Grain N	Grain P	Grain K
	gal/a		bu/a	%	%	%
Check			190.8	1.32	.382	.423
CaTs	5	2 × 2	192.5	1.33	.386	.425
CaTs	10	2 × 2	190.1	1.35	.361	.400
CaTs	20	2 × 2	198.5	1.43	.373	.410
LSD (0.05)			NS	NS	NS	NS

Effect of Calcium Thiosulfate, Manganese Thiosulfate, and Magnesium Thiosulfate on Irrigated Soybean

L.D. Maddux

Summary

Calcium thiosulfate was applied to irrigated soybean as a 2 × 2 starter at 5, 10, and 20 gal/a, and manganese thiosulfate and magnesium thiosulfate were applied as foliar treatments at R3 growth stage. No significant yield differences were observed.

Introduction

This study was conducted with a grant provided by Tessenderlo Kerley, Inc. (TKI), a producer of specialty products used in the agriculture, mining, and process chemical industries. The TKI products tested included calcium thiosulfate (CaTs, 0-0-0-10S-6Ca), manganese thiosulfate (MnThio), and magnesium thiosulfate (MagThio, 0-0-0-10S-4Mg). This study was conducted to evaluate the effect of applications of these materials on irrigated soybean yield.

Procedures

This study was conducted in 2010 on a Eudora silt loam soil previously cropped to corn at the Paramore Unit of the Kansas River Valley Experiment Field near Topeka, KS. Prior to planting, 240 lb/a of 5.5-26-30 fertilizer was broadcast and incorporated. CaTs was applied at 5, 10, and 20 gal/a as a 2 × 2 starter application at planting. Foliar treatments included MnThio at 2.5 gal/a and MagThio at 1.5 gal/a applied at R3. Soybean variety Asgrow 4005 was planted June 1 at 139,000 seeds/a. The R3 growth stage foliar treatments were applied July 30. Roundup Weathermax (22 oz/a) plus Dual II Magnum (1.0 pt/a) plus Shadow (4.5 oz/a) plus AMS (17 lb/100 gal) was applied June 25. Sprinkler irrigation was applied July 23 (1.01 in.), July 26 (0.99 in.), August 5 (1.24 in.), August 13 (0.93 in.), August 23 (1.00 in.), and August 30 (1.04 in.). Plots were harvested October 7 with a plot combine.

Results

Soybean yields are shown in Table 1. Yields ranged from 65.7 to 71.0 bu/a, but no significant differences were observed. Research conducted at the North Central Kansas Experiment Field near Scandia has shown some yield increases to foliar application ofnmanganese (Mn), but previous research on Mn applications on soybean conducted at the Rossville Unit showed no yield increase.

Table 1. Effect of various fertilizer applications on soybean yield, Kansas River Valley Experiment Field, Topeka, KS, 2010

Fertilizer	Rate	Application	Soybean yield
	gal/a		bu/a
Check			71.0
CaTs	5.0	2 × 2	67.3
CaTs	10.0	2 × 2	64.4
CaTs	20.0	2 × 2	65.7
MnThio	2.5	Foliar-R3	68.6
MagThio	1.5	Foliar-R3	66.7
LSD (0.05)			NS

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

D.W. Sweeney and K.W. Kelley

Summary
In 2009, overall corn yields were greater with conventional and reduced tillage than with no-till. Adding nitrogen (N) fertilizer greatly increased yields. The effect of N placement on yield was nonsignificant in conventional and reduced tillage, but knife N application resulted in greater yields than dribble application in no-till.

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

Procedures
A split-plot design with four replications was initiated in 1983 with tillage system as the whole plot and N treatment as the subplot. In 2005, the rotation was changed to begin a short-season corn/wheat/double-crop soybean sequence. Use of three tillage systems (conventional, reduced, and no-till) 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 a depth of 4 in. The N rate for the corn crop grown in odd years is 125 lb/a. Planting was delayed until May 22, 2009, because of wet weather.

Results
In 2009, adding fertilizer N greatly increased corn yields in general compared with the control (Figure 1). Overall yield was greater with knifed application than with dribble application, and broadcast application gave intermediate yields. An interaction between tillage and N treatment significantly affected yield ($P=0.10$). This interaction occurred because yield differences among N placements in conventional and reduced tillage were not significant, but dribble application resulted in lower yield than knifing in no-till.

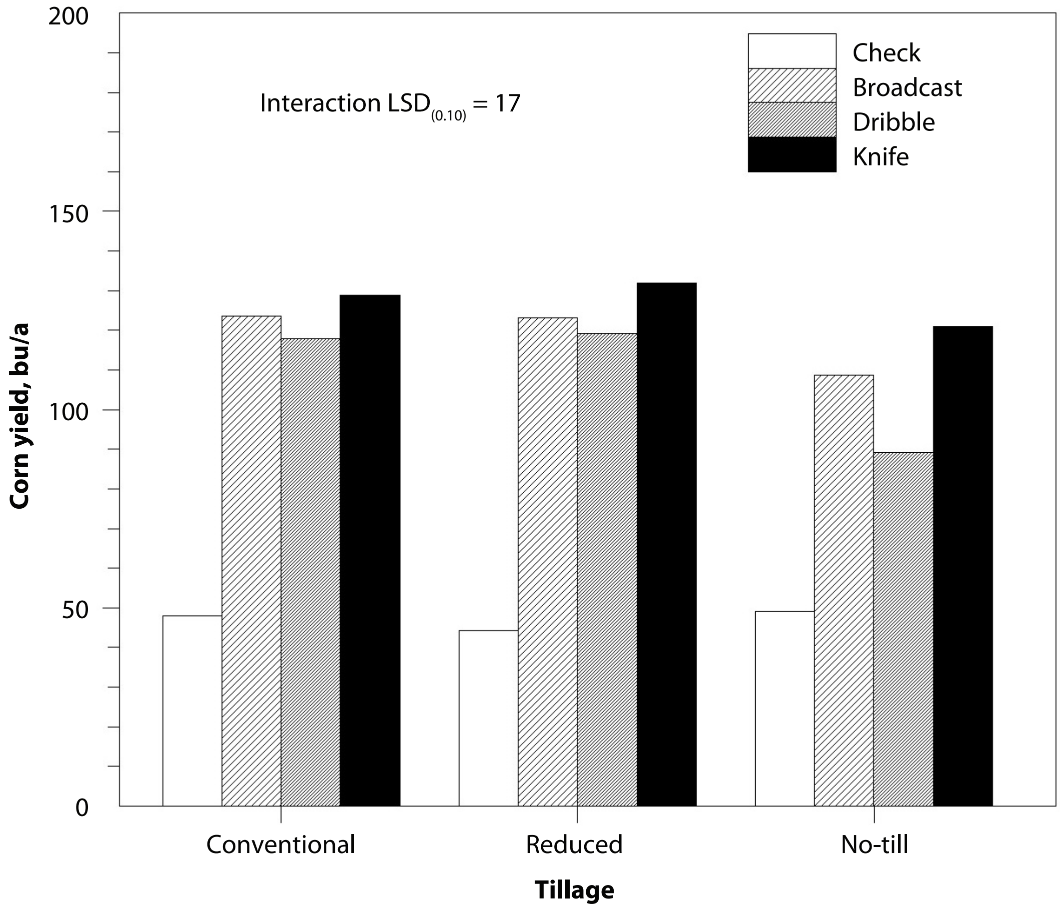

Figure 1. Effect of tillage and nitrogen placement on short-season corn yield in 2009.

Seeding Rates and Fertilizer Placement to Improve Strip-Till and No-Till Corn[1]

D.W. Sweeney and K.W. Kelley

Summary

Weather conditions adversely affected corn stand and yield in 2009. Producers who use strip-till and no-till systems to grow corn in southeastern Kansas should note that these responses are not expected to be typical.

Introduction

Use of conservation tillage systems is promoted because of environmental concerns. In the claypan soils of southeastern Kansas, no-till crops may yield less than crops grown in systems involving some tillage operation, often because of reduced plant emergence. Strip tillage provides a tilled seed-bed zone where early spring soil temperatures might be greater than those in no-till soils. But like no-till, strip tillage leaves residues intact between the rows as a conservation measure. Optimizing seeding rates for different tillage systems should improve corn stands and yields.

Procedures

This experiment was established in spring 2009 at the Mound Valley Unit of the Southeast Agricultural Research Center. Experimental design was a split-plot arrangement of a randomized complete block with three replications. The whole plots were three tillage systems: conventional, strip tillage, and no-till. Conventional tillage consisted of chisel and disk operations in the spring. Strip tillage was done with a Redball strip-till unit in the spring prior to planting. The subplots were a 5 × 2 factorial combination of five seed planting rates (18,000, 22,000, 26,000, 30,000, and 34,000 seeds/a) and two nitrogen-phosphorus (N-P) fertilizer placement methods: surface band (dribble) on 30-in. centers near the row and subsurface band (knife) at a depth of 4 in. The N and P nutrients were supplied as 28% urea-ammonium nitrate and ammonium polyphosphate (10-34-0) applied at 125 lb/a N and 40 lb/a P_2O_5. Wet weather delayed planting until May 21, 2009.

Results

An interaction between tillage and N-P placement affected yield and plant stands. This interaction primarily resulted from reduced stands for the knife application, especially in no-till (Figure 1). After fertilizer application on May 20 and planting on May 21, rainfall was sparse for the next 3 weeks, and soil drying in knifed bands near the seed resulted in reduced emergence. This effect is not expected to be typical, especially if the corn is planted earlier. Even so, the effect on total yield in 2009 was not as dramatic as the effect on stand because corn yield was reduced by knife applications only in no-till (Figure 2). Seeding rate did not interact with tillage system on corn yield as anticipated. Seeding rate produced maximum yields at about 26,000 seeds/a when N-P fertilizer was dribble-applied, but yield increased linearly as seeding rate increased to 34,000 seeds/a

[1] This research was partly funded by the Kansas Corn Commission.

when N-P fertilizer was knifed (Figure 3), a likely artifact of the reduced stands in the knife application treatments.

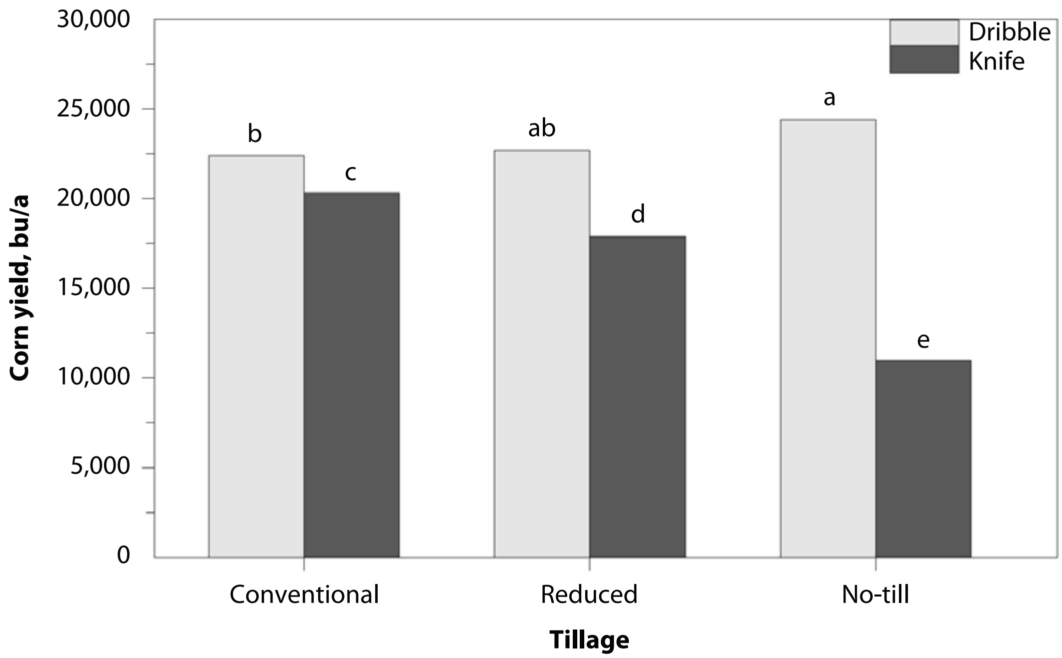

Figure 1. Effect of tillage system and N-P fertilizer placement on short-season corn stand in 2009. Means with the same letter are not significantly different at P<0.05.

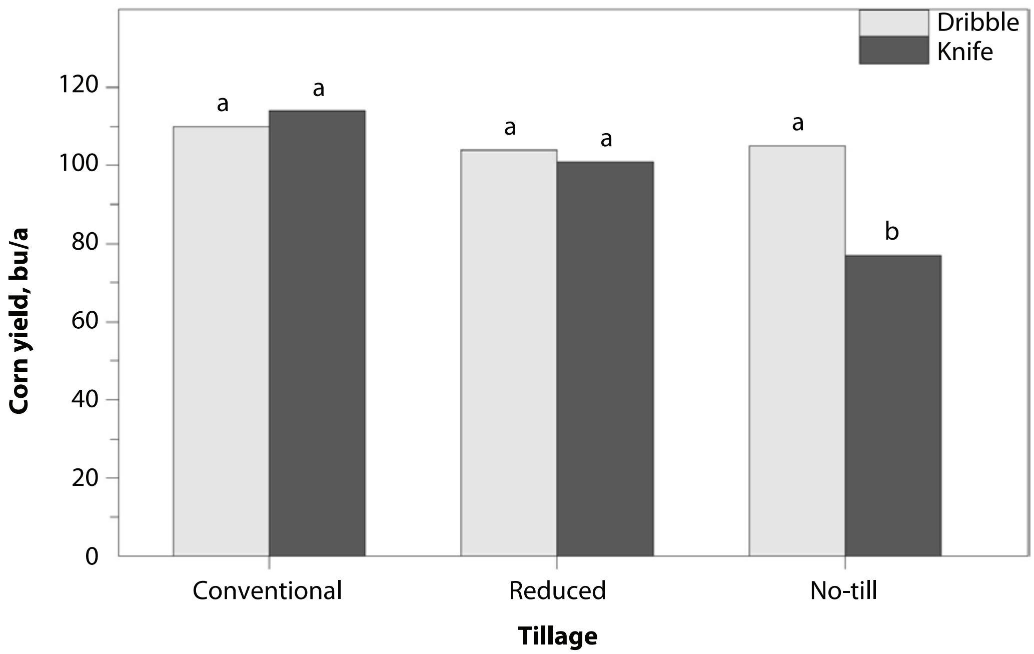

Figure 2. Effect of tillage system and N-P fertilizer placement on short-season corn yield in 2009. Means with the same letter are not significantly different at P<0.05.

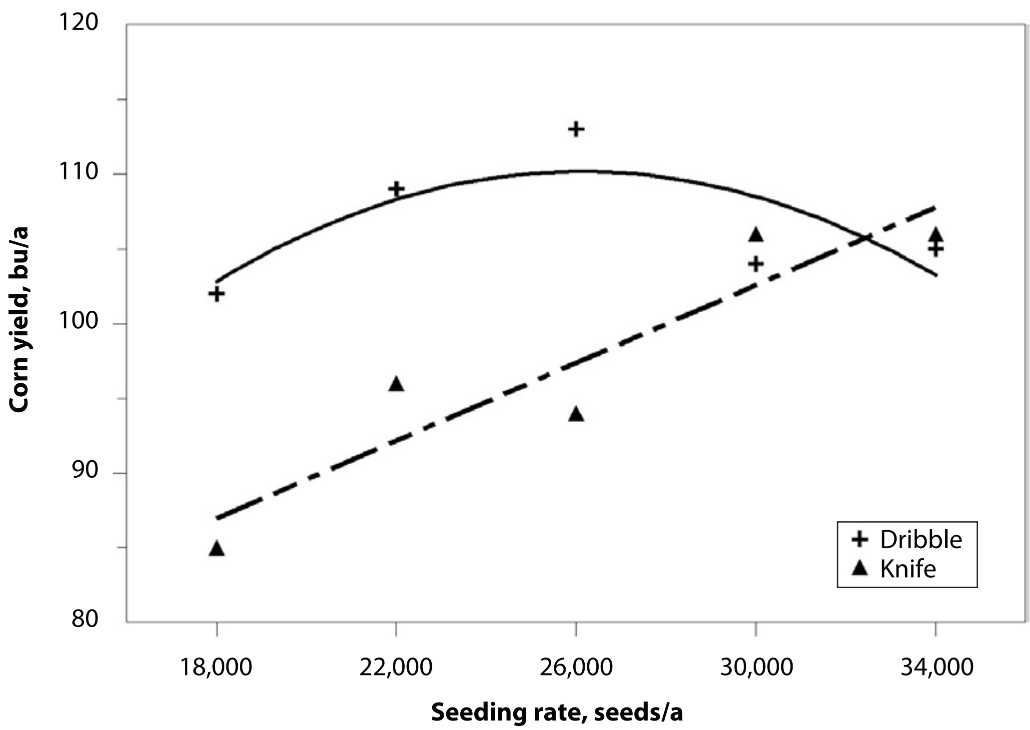

Figure 3. Effect of seeding rate and N-P fertilizer placement on short-season corn yield in 2009.

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

D.W. Sweeney and M.B. Kirkham[1]

Summary
In 2009, wet conditions resulted in poor emergence of and no data from sweet corn planted on the first date in late April. Sweet corn planted in mid-May was little affected by irrigation or nitrogen (N) treatments.

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, lacking information on the effects of irrigation management, N placement, and planting date on performance of sweet corn 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 were two planting dates (targets of late April and mid-May) and four irrigation schemes: (1) no irrigation, (2) 1.5 in. at VT growth stage (tassel), (3) 1.5 in. at R2 growth stage (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 April 24 and May 19, 2009. Wet weather caused poor emergence (<15%) of sweet corn planted on April 24, which this resulted in no data from the first planting date. Corn from the second planting date was harvested on July 30 and August 4, 2009.

Results
In 2009, irrigation had no effect on total ears, total fresh weight, or individual ear weight of sweet corn planted in mid-May (Table 1). Total fresh weight was greater with N application than with no N but was unaffected by N placement. The N treatments had no effect on number of ears or individual ear weight for corn planted in mid-May.

[1] Kansas State University Department of Agronomy.

Table 1. Effect of irrigation scheme and nitrogen placement on sweet corn planted in mid-May, Southeast Agricultural Research Center, 2009

Treatment	Total ears	Total fresh weight	Individual ear weight
	ears/a	ton/a	g/ear
Irrigation scheme			
None	19,500	5.81	270
VT (1.5 in.)	19,800	5.94	272
R2 (1.5 in.)	19,000	5.45	260
VT-R2 (1.5 in. at each)	17,900	5.45	275
LSD (0.10)	NS	NS	NS
N Placement			
None	18,400	5.14	255
Broadcast	19,200	5.77	273
Knife	19,600	6.07	281
LSD (0.05)	NS	0.51	NS
Interaction	NS	NS	NS

NS = Not significant.

Long-Term Nitrogen and Phosphorus Fertilization of Irrigated Grain Sorghum[1]

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 2010, N applied alone increased yields about 25 bu/a, whereas N and P applied together increased yields up to 35 bu/a despite considerable hail damage in late July. Averaged across the past 10 years, N and P fertilization increased sorghum yields up to 60 bu/a. Application of 40 lb/a N (with P) was sufficient to produce about 85% of maximum yield in 2010, which was slightly less than the 10-year average. 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 2008–2010) 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 2010 were reduced because of hail in late July (Table 1). Nitrogen alone increased yields about 25 bu/a while P alone had no affect on yields. However, N and P applied together increased yields up to 35 bu/a. Averaged across the past 10 years, N and P applied together increased yields up to 60 bu/a. In 2010, 40 lb/a N (with P) produced about 85% of maximum yields, which is slightly less than the 10-year average. Sorghum yields were not affected by K fertilization, which has been the case throughout the study period.

[1] This project was partially supported by the International Plant Nutrition Institute.

Table 1. Effect of nitrogen, phosphorus, and potassium fertilizers on irrigated grain sorghum yields, Tribune, KS, 2001-2010

Fertilizer			Grain sorghum yield										
N	P_2O_5	K_2O	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Mean
---------------- lb/a ----------------			---------------- bu/a ----------------										
0	0	0	76	73	80	57	58	84	80	66	64	51	69
0	40	0	81	81	93	73	53	102	97	60	70	51	77
0	40	40	83	82	93	74	54	95	94	65	76	55	78
40	0	0	92	82	92	60	63	102	123	92	84	66	87
40	40	0	124	120	140	112	84	133	146	111	118	77	118
40	40	40	119	121	140	117	84	130	145	105	109	73	116
80	0	0	110	97	108	73	76	111	138	114	115	73	103
80	40	0	138	127	139	103	81	132	159	128	136	86	125
80	40	40	134	131	149	123	92	142	166	126	108	84	127
120	0	0	98	86	97	66	77	101	138	106	113	70	96
120	40	0	134	132	135	106	95	136	164	131	130	88	126
120	40	40	135	127	132	115	98	139	165	136	136	90	128
160	0	0	118	116	122	86	77	123	146	105	108	74	109
160	40	0	141	137	146	120	106	145	170	138	128	92	133
160	40	40	136	133	135	113	91	128	167	133	140	88	128
200	0	0	132	113	131	100	86	134	154	120	110	78	117
200	40	0	139	136	132	115	108	143	168	137	139	84	131
200	40	40	142	143	145	123	101	143	170	135	129	87	133

continued

Table 1. Effect of nitrogen, phosphorus, and potassium fertilizers on irrigated grain sorghum yields, Tribune, KS, 2001-2010

Fertilizer			Grain sorghum yield										
N	P_2O_5	K_2O	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Mean
ANOVA (P>F)													
Nitrogen			0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Linear			0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Quadratic			0.001	0.001	0.001	0.018	0.005	0.004	0.001	0.001	0.001	0.001	0.001
P-K			0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Zero P vs. P			0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
P vs. P-K			0.619	0.920	0.694	0.121	0.803	0.578	0.992	0.745	0.324	0.892	0.968
N × P-K			0.058	0.030	0.008	0.022	0.195	0.210	0.965	0.005	0.053	0.229	0.007
Means													
Nitrogen, lb/a													
0			80	79	88	68	55	93	91	64	70	52	75
40			112	108	124	96	77	121	138	103	104	72	107
80			127	119	132	100	83	128	155	123	120	81	118
120			122	115	121	96	90	125	156	124	126	82	117
160			132	129	134	107	92	132	161	125	125	83	123
200			138	131	136	113	98	140	164	131	126	84	127
LSD (0.05)			8	9	10	11	10	11	9	7	11	5	5
P_2O_5-K_2O, lb/a													
0			104	94	105	74	73	109	130	101	99	68	97
40-0			126	122	131	105	88	132	151	117	120	80	118
40-40			125	123	132	111	87	130	151	117	116	79	118
LSD (0.05)			6	6	7	7	7	7	6	5	7	4	4

Long-Term Nitrogen and Phosphorus Fertilization of Irrigated Corn[1]

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 2010, hail severely damaged the corn in late July, but N applied alone still increased yields about 45 bu/a, and P applied alone increased yields about 8 bu/a. Nitrogen and P applied together increased yields up to 80 bu/a. Averaged across the past 10 years, N and P fertilization increased 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 2010, which was similar to the 10-year average. Application of 80 instead of 40 lb P_2O_5/a increased yields 5 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 inherently high K content. No yield benefit to corn from K fertilization was observed in 30 years, and soil K levels remained high, so 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 were 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), DeKalb 61-69 (2009), and Pioneer 1173H (2010), were planted at about 30,000 to 32,000 seeds/a in late April or early May. Hail damaged the 2002, 2005, and 2010 crops. The corn is irrigated to minimize water stress. Sprinkler irrigation has been used since 2001. The center two rows of each plot are machine harvested after physiological maturity. Grain yields are adjusted to 15.5% moisture.

Results
Corn yields in 2010 were much lower than the 10-year average because of considerable hail damage in late July (Table 1). Nitrogen alone increased yields 45 bu/a, whereas P alone increased yields less than 10 bu/a. However, N and P applied together increased corn yields up to 80 bu/a. Only 120 lb/a N with P was required to obtain greater than 90% of maximum yield, which is similar to the 10-year average. Corn yields in 2010 (averaged across all N rates) were 5 bu/a greater with 80 than with 40 lb/a P_2O_5, which is similar to the 10-year average.

[1] This project was partially supported by the International Plant Nutrition Institute.

Table 1. Effect of nitrogen and phosphorus fertilization on irrigated corn, Tribune, KS, 2001-2010

N	P_2O_5	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Mean
------------ lb/a ------------		---------- bu/a ----------										
0	0	54	39	79	67	49	42	49	36	85	20	52
0	40	43	43	95	97	60	68	50	57	110	21	64
0	80	48	44	93	98	51	72	51	52	106	28	64
40	0	71	47	107	92	63	56	77	62	108	23	71
40	40	127	69	147	154	101	129	112	105	148	67	116
40	80	129	76	150	148	100	123	116	104	159	61	117
80	0	75	53	122	118	75	79	107	78	123	34	86
80	40	169	81	188	209	141	162	163	129	179	85	151
80	80	182	84	186	205	147	171	167	139	181	90	155
120	0	56	50	122	103	66	68	106	65	117	28	78
120	40	177	78	194	228	162	176	194	136	202	90	164
120	80	191	85	200	234	170	202	213	151	215	105	177
160	0	76	50	127	136	83	84	132	84	139	49	96
160	40	186	80	190	231	170	180	220	150	210	95	171
160	80	188	85	197	240	172	200	227	146	223	95	177
200	0	130	67	141	162	109	115	159	99	155	65	120
200	40	177	79	197	234	169	181	224	152	207	97	172
200	80	194	95	201	239	191	204	232	157	236	104	185

continued

continued

Table 1. Effect of nitrogen and phosphorus fertilization on irrigated corn, Tribune, KS, 2001-2010

N	P_2O_5	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Mean
ANOVA (P>F)												
Nitrogen		0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Linear		0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Quadratic		0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Phosphorus		0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Linear		0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Quadratic		0.001	0.007	0.001	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	0.001
Means												
Nitrogen, lb/a												
0		48	42	89	87	53	61	50	48	100	23	60
40		109	64	135	132	88	103	102	91	138	50	101
80		142	73	165	178	121	137	146	115	161	70	131
120		142	71	172	188	133	149	171	118	178	74	139
160		150	71	172	203	142	155	193	127	191	80	148
200		167	80	180	212	156	167	205	136	199	89	159
LSD (0.05)		15	8	9	11	10	15	11	9	12	9	8
P_2O_5, lb/a												
0		77	51	116	113	74	74	105	71	121	36	84
40		147	72	168	192	134	149	160	122	176	76	140
80		155	78	171	194	139	162	168	125	187	81	146
LSD (0.05)		10	6	6	8	7	11	8	6	9	7	5

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