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East Central Kansas Experiment Field

Introduction

The research program at the East Central Kansas Experiment Field is designed to keep area crop producers abreast of technological advances in agronomic agriculture. Specific objectives are to (1) identify top performing varieties and hybrids of wheat, corn, soybean, and grain sorghum; (2) establish the amount of tillage and crop residue cover needed for optimum crop production; (3) evaluate weed and disease control practices using chemical, no chemical, and combination methods; and (4) test fertilizer rates, timing, and application methods for agronomic proficiency and environmental stewardship.

Soil Description

Soils on the field's 160 acres are Woodson. The terrain is upland and level to gently rolling. The surface soil is a dark gray-brown, somewhat poorly drained silt loam to silty clay loam over slowly permeable clay subsoil. The soil is derived from old alluvium. Water intake is slow, averaging less than 0.1 in./hour when saturated. This makes the soil susceptible to water runoff and sheet erosion.

2012 Weather Information

Precipitation during 2012 totaled 21.1 in., which was15.7 in. below the 35-year average (Table 1). Overall, the 2012 growing season was even hotter and drier than 2011. Average rainfall during the months of April through August was 28% of average. During the summer of 2012, 76 days had temperatures exceeding 90.0°F and 26 days had temperatures exceeding 100.0°F. The hottest period was a 9-day stretch of July 17 through 25 that averaged 103.3°F. The overall hottest day was July 29, when the temperature reached 108.5°F. The coldest temperatures occurred in January and February, with only 2 days in single digits. The last freezing temperature in the spring was March 10 (average, April 18), and the first killing frost in the fall was October 7 (average, October 21). There were 211 frost-free days, which is more than the long-term average of 185. The corn crop was hurt severely by the heat, especially just prior to and during pollination, with most fields yielding less than 20 bu/a. Soybeans were able to take advantage of September rains and produce modest yields around 30 bu/a.

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

	2012	35-year avg.		2012	35-year avg.
Month	------------- in. -------------		Month	------------- in. -------------	
January	0.04	1.03	July	1.17	3.37
February	2.24	1.32	August	0.61	3.59
March	4.74	2.49	September	3.36	3.83
April	1.62	3.50	October	1.05	3.43
May	3.75	5.23	November	1.54	2.32
June	0.00	5.21	December	0.97	1.45
			Annual total	21.08	36.78

Evaluation of Wheat Planted on 15-Inch Row Spacing

D.E. Shoup and E.A. Adee

Summary
Producer interest in sowing wheat with a 15-in. row planter instead of traditional 7.5-in. row drill equipment is growing. Wheat yields and weed emergence patterns are unknown with this relatively new concept. The objectives of this study were to evaluate weed emergence, weed competition, and wheat yield effects when sowing wheat with a 15-in. row planter vs. 7.5-in. row drill equipment. Wheat was sowed October 21 and October 12 in 2010 and 2011, respectively, at the Ottawa experiment field. A high seeding rate of 1.2 million seeds/a and low seeding rate of 1 million seeds/a were sowed with the 7.5-in. row drill and the 15-in. row planter. Treatments were replicated 4 times in a herbicide treated and untreated block. Henbit, Carolina foxtail, smallflowered bittercress, and common chickweed emergence was greater in the 15-in. wheat rows than in the 7.5-in. wheat rows. Increased emergence in the 15-in. wheat rows is likely because of less shading by the wheat. In general, seeding rate had little effect on weed emergence. In 2011, wheat sowed with the 15-in. row planter in the herbicide-treated block yielded 16.7 bu/a less than wheat sowed with the 7.5-in. row drill. Wheat sowed with the 15-in. row planter in the untreated herbicide block yielded 11.7 bu/a less than wheat sowed with the 7.5-in. row drill. In 2012, an 18.0 and 18.5 bu/a yield loss in the 15-in. row-planted wheat was observed in the herbicide treated and untreated block, respectively, when compared with 7.5-in. wheat. Yield losses for the wheat in 15-in. rows in both herbicide treatment blocks are attributed to row spacing too wide to maximize yields.

Introduction
In various regions of eastern Kansas, an increasing number of producers are utilizing planters with row units on 15-in. spacings to plant wheat as an alternative to using drills with 7.5- to 10-in. spacings. Potential perceived benefits for using planters to sow wheat are equipment savings, better seed placement, better plant emergence, and a perception that planters can manage the residue more effectively than a drill in no-till conditions. Research evaluating the effect of sowing wheat with 15-in. planters and 7.5-in. drills in no-till conditions was evaluated in eastern Kansas to determine weed emergence patterns and the impact on yield at two seeding rates.

Procedures
Wheat plots were sown on October 21, 2010, and October 12, 2011, at the East Central Kansas Experiment Field near Ottawa, Kansas. Two sowing methods were evaluated: (1) drilled wheat on 7.5-in. row spacing (Great Plains Solid Stand No-Till Drill, Great Plains Manufacturing, Salina, KS); and (2) planted wheat on 15-in. row spacing (Kinze 3000 , Kinze Manufacturing, Williamsburg, IA). Two seeding densities were established for each sowing method: (1) high seeding rate of 1.2 million seeds/a; (2) lower seeding rate of 1 million seeds/a. Plots were 10 ft × 100 ft in an herbicide-treated and untreated block, and treatments were replicated 4 times. The experiment

was a randomized complete block design in a 2 × 2 factorial arrangement with planting density and row spacing as the factors.

Wheat was fertilized with 95 and 125 lb/a N in 2011 and 2012, respectively. PowerFlex (DowAgrosciences, Indianapolis, IN) was applied to the herbicide-treated block in the spring of 2011, and Finesse (DuPont, Wilmington, DE) was applied in 2012. Weed densities were determined on April 7 and March 26 in 2011 and 2012, respectively, at three random 1-ft^2 areas per plot. Weed species present in 2011 in the untreated block primarily consisted of henbit (*Lamium amplexicaule* L.), Carolina foxtail (*Alopecurus carolinianus* Walt.), and smallflowered bittercress (*Cardamine parviflora* L.), and henbit and common chickweed (*Stellaria media*) were observed in 2012. Grain yield, test weight, and moisture were determined on June 27 and June 5 in 2011 and 2012, respectively, and adjusted to 13.5% moisture. Grain yield and weed counts were analyzed using analysis of variance and means were separated using LSD at $P = 0.05$.

Results

Weed Emergence

In 2011, we observed a significant interaction between seeding rate and row spacing. Henbit, Carolina foxtail, and smallflowered bittercress emergence was greater in the 15-in. wheat rows than in the 7.5-in. wheat rows (Table 1). The increase in emergence in the 15-in. wheat rows is likely because of less shading by the wheat. Seeding rate didn't affect weed emergence in the drilled wheat, but significant differences in weed emergence did occur in the planted wheat. Henbit in the 15-in. wheat row at the low seeding rate emerged more than at the high wheat seeding rate at 14.2 vs. 10.1 plants/ft^2, respectively. Smallflowered bittercress emergence was greater in the high seeding rate vs. low seeding rate in 15-in. row wheat at 6.5 vs. 4.2 plants/ft^2, respectively. The row spacing and seeding rate that suppressed the greatest number of weeds from emerging was the 7.5-in. drilled wheat at the low seeding rate. Weed emergence in the 7.5-in. drilled wheat at the low seeding rate suppressed 38, 33, and 1% of the henbit, Carolina foxtail, and smallflowered bittercress, respectively, when compared with the treatment with the highest weed emergence.

In 2012, the predominant weeds were henbit and common chickweed. No interaction was observed between seeding rate and row spacing, so data are presented only for row spacing (Table 2). In general, a similar pattern was seen in 2012, with greater weed emergence with wheat in wider rows. Henbit emergence was roughly 3.5 times higher in wider 15-in. planted rows vs. 7.5-in. rows. Although common chickweed prevalence was less, emergence was also significantly inhibited by wheat shading in the narrow 7.5-in. vs. 15-in. rows.

Wheat Yield

Seeding rate had no significant effect on wheat yield in either 2011 or 2012, so data are averaged across row spacing for herbicide treated and untreated blocks. In 2011, wheat sowed with the 15-in. row planter in the herbicide treated block yielded 16.7 bu/a less than wheat sowed with the 7.5-in. row drill (Table 3). Wheat sowed with the 15-in. row planter in the untreated herbicide block yielded 11.7 bu/a less than wheat sowed with the 7.5-in. row drill. In 2012, an 18.0 and 18.5 bu/a yield loss in the 15-in. row

planted wheat were observed in the herbicide treated and untreated block, respectively, compared with 7.5-in wheat.

Significant yield losses for the wheat in 15-in. rows in both herbicide treatment blocks for both years are attributed to row spacing too wide to maximize yields. This yield penalty is likely too great to offset any perceived benefits from planting wheat with a 15-in. row planter vs. a more conventional no-till drill on narrower row spacings.

Table 1. Weed emergence densities as affected by wheat row spacing and sowing equipment in 2011

			Weed density		
Equipment	Row spacing	Seeding rate	Henbit	Carolina foxtail	Smallflowered bittercress
	in.	seeds/a	-------------------- plants/ft^2 --------------------		
Drill	7.5	1 million	5.3	4.6	0.1
Drill	7.5	1.2 million	7.5	7.5	0.3
Planter	15	1 million	14.2	11.6	4.2
Planter	15	1.2 million	10.1	13.9	6.5
LSD (0.05)			4.0	3.8	2.3

Table 2. Weed emergence densities as affected by wheat row spacing and sowing equipment in 2012

		Weed density	
Equipment	Row spacing	Henbit	Common chickweed
	in.	-------------------- plants/ft^2 --------------------	
Drill	7.5	6.8	0.4
Planter	15	23.9	2.2
LSD (0.05)		4.4	1.4

Table 3. Wheat yields as affected by sowing equipment and row spacing in herbicide treated or untreated blocks in 2011 and 2012

Year	Equipment	Row spacing	Herbicide treatment	Yield
		in.		bu/a
2011	Drill	7.5	Untreated	47.9
	Planter	15	Untreated	36.2
	LSD (0.05)			4.0
	Drill	7.5	Treated	49.3
	Planter	15	Treated	30.6
	LSD (0.05)			4.2
2012	Drill	7.5	Untreated	50.5
	Planter	15	Untreated	32.0
	LSD (0.05)			5.0
	Drill	7.5	Treated	52.7
	Planter	15	Treated	34.7
	LSD (0.05)			4.2

Pigweed Management in No-till Soybeans

D.E. Peterson and E.A. Adee

Summary
This study was conducted at the East Central Kansas Experiment Field near Ottawa to compare herbicide treatments for soybean grown in no-till conditions. Glyphosate-resistant waterhemp previously had been confirmed in the study area. Fourteen herbicide treatments were evaluated for control of waterhemp and their effects on grain yield. All treatments provided excellent early waterhemp control, but sequential treatments generally provided better late-season control than preplant-only treatments. Zidua (BASF, Research Triangle Park, NC) + Verdict (BASF) + Roundup PowerMax (RUPM; Monsanto, St. Louis, MO) followed by RUPM + Outlook (BASF), and Fierce (Valent USA, Walnut Creek, CA) + RUPM followed by RUPM + Warrant (Monsanto) tended to provide the best season-long waterhemp control. Soybean yields were modest due to the hot, dry conditions much of the season. Soybean yields were greatly improved by controlling waterhemp and generally corresponded to the level of waterhemp control.

Introduction
The introduction of Roundup Ready soybean in 1996 provided farmers with a cost-effective technology to achieve good postemergence weed control in soybean. Consequently, Roundup Ready soybean was widely adopted, and glyphosate has been relied on extensively for weed control. Unfortunately, heavy reliance on glyphosate has resulted in the development of glyphosate-resistant weed populations, including common waterhemp. Glyphosate-resistant waterhemp is now present across much of eastern Kansas and has become a serious weed control challenge. The objective of this experiment was to evaluate various herbicide programs for control of glyphosate-resistant waterhemp in Roundup Ready soybean.

Procedures
A field experiment was established on a Woodson silt loam soil with 3.0% organic matter and a pH of 6.2 at the East Central Kansas Experiment Field near Ottawa, KS. Pioneer 94Y70 Roundup Ready soybeans were planted in 30-in. rows at 125,000 seeds/a. Preplant (PP) herbicide treatments were applied on May 9, 2012, into a plot area with 1-in. waterhemp. Postemergence (P) treatments were applied to 3 trifoliate, 8-in. soybean and 1- to 6-in. waterhemp on June 26 at 76°F, 43% relative humidity, and clear skies. All treatments (Table 1) were applied with a CO_2 backpack sprayer delivering 15 gal/a spray volume at 30 psi through TT110015 flat fan spray tips to the center 6.3 ft of 10- by 30-ft plots. The experiment had a randomized complete block design with four replications. Soybean injury and waterhemp control were visually evaluated at regular intervals throughout the growing season. Soybean was harvested on October 29.

Results
Warm early season temperatures and rainfall at the end of April resulted in a flush of seedling waterhemp that had emerged when the preplant treatments were applied on May 9. No precipitation occurred after that until 1.1 in. was received on May 24. That

provided enough soil moisture for soybean establishment and activation of the preplant residual herbicides. The remainder of the growing season was very hot and dry. None of the herbicide treatments caused noticeable crop injury (data not shown). All treatments provided excellent early waterhemp control, but some treatments started to break by mid-June (Table 1). Sequential treatments generally provided better late-season waterhemp control than the preplant-only treatments. Zidua plus Verdict + RUPM followed by RUPM + Outlook, and Fierce + RUPM followed by RUPM + Warrant tended to provide the best season-long waterhemp control. Soybean yields were modest due to the hot, dry conditions much of the season; however, yields differed between treatments. Soybean yields were greatly improved by controlling waterhemp and were highly correlated to the level of waterhemp control.

Table 1. Glyphosate-resistant waterhemp control in no-till Roundup Ready soybean

Treatment[1]	Application rate	Timing[2]	Waterhemp control June 7	June 21	July 3	July 17	Aug. 7	Aug. 20	Soybean yield
	oz/a		%						bu/a
Untreated			0	0	0	0	0	0	4.4
OpTill[3] + Outlook+ RUPM	2+10+22	PP	97	90	83	79	74	70	9.1
OpTill + Outlook+ RUPM	2+18+22	PP	99	94	86	86	81	78	14.2
OpTill + Outlook+ RUPM/ RUPM + Outlook	2+10+22 22+8	PP P	97	89	84	86	84	81	19.0
Verdict[3] + Outlook +RUPM	5+8+22	PP	97	86	80	79	73	71	9.2
Verdict + Outlook + RUPM	5+14+22	PP	99	94	83	81	74	71	13.2
Verdict + Outlook +RUPM/ RUPM + Outlook	5+8+22 22+6	PP P	98	91	86	88	88	85	17.8
Zidua[3] + Sharpen + RUPM	2.5+1+22	PP	100	96	88	86	83	78	16.2
Zidua + Sharpen + RUPM/ RUPM + Outlook	2.5+1+22 22+8	PP P	99	95	89	89	88	88	19.1
Zidua + Verdict + RUPM/ RUPM + Outlook	2.5+5+22 22+8	PP P	100	97	93	94	94	93	19.2
Prefix + RUPM	32+22	PP	98	92	83	79	74	70	11.6
Fierce + RUPM/ RUPM + Warrant	3+22 22+20	PP P	100	95	92	94	94	93	18.7
Authority First + RUPM/ RUPM + Warrant	3+22 22+20	PP P	96	89	88	88	88	86	15.9
Valor SX + RUPM/ RUPM + Warrant	3+22 22+20	PP P	98	93	92	92	91	89	19.3
LSD (P = 0.05)			1.6	4.3	4.9	4.3	5.4	4.6	4.4

[1] RUPM = Roundup PowerMax; always applied with 2% v/v ammonium sulfate; /=sequential application.
[2] PP = preplant; P = postemergence.
[3] Optill, Verdict, and Zidua applied with methylated seed oil 1% v/v.

Glyphosate-Resistant Waterhemp Control in Corn, East Central Experiment Field, 2011–2012

C.R. Thompson, E.A. Adee, D. Peterson, J. Kimball, and C. Minihan

Summary
Glyphosate-resistant waterhemp can be controlled effectively with many preemergence- and postemergence-applied herbicides. Preemergence-applied chloroacetamides alone or with atrazine, Anthem (FMC Corp. Ag Products, Philadelphia, PA), Anthem ATZ (FMC), or Cinch ATZ (DuPont, Wilmington, DE) gave excellent waterhemp control. Verdict (BASF, Research Triangle Park, NC) and Corvus (Bayer Crop Science, Research Triangle Park, NC) alone or with atrazine and Prequel all provided good preemergence control of waterhemp. Postemergence-applied treatments containing HPPD-inhibiting herbicides Armezon (BASF), Impact (Amvac Chemical Corp., Los Angeles, CA), Laudis (Bayer), Callisto (Syngenta Crop Protection, Greensboro, NC), or Halex GT (Syngenta) all provided very good control of glyphosate-resistant waterhemp. The addition of Status (BASF) at 5 oz/a to postemergence-applied glyphosate will increase control of waterhemp. The HPPD herbicides will be most effective if applied with atrazine.

Introduction
Glyphosate-resistant waterhemp has continued to increase in eastern Kansas corn/soybean rotations. Continued exclusive use of glyphosate for weed control has contributed to the magnitude of the problem. Fortunately, several preemergence and postemergence herbicides registered in corn effectively control waterhemp, and many of these herbicides effectively control glyphosate-resistant waterhemp. Experiments were conducted to evaluate control of glyphosate-resistant waterhemp with postemergence-applied herbicides in 2011 and preemergence- and postemergence-applied herbicides during 2012 at the East Central Kansas Experiment Field.

Procedures
Experiments were conducted during 2011 and 2012 to evaluate herbicides for control of glyphosate-resistant waterhemp in field corn. DKC 63-87 and Garst 85V88 corn hybrids were planted April 20, 2011, and April 16, 2012, on Reading and Woodson silt loam soils, respectively. Soil organic matter ranged from 2.3 to 2.5 and soil pH from 6.3 to 6.6. Postemergence treatments were applied to 8-collar, 22-in.-tall corn and 3- to 10-in. waterhemp on June 9, 2011. Waterhemp densities were 10 to15 plants/ft^2. In the 2012 experiment, preemergence herbicides were applied on April 18, V2 postemergence treatments were applied to 2-leaf corn and cotyledon waterhemp on May 5, and V6 postemergence treatments were applied to 6-leaf corn and cotyledon to 2-in. waterhemp on May 21. Waterhemp densities were very low, often less than 1 plant/ft^2. All herbicide treatments were applied with a backpack sprayer equipped with Turbo-Tee 11002 nozzles (Teejet Spraying Systems Co., Wheaton, IL) operating at 34 psi and traveling 3 mph delivering 15 gal/a. All evaluations were made visually using a scale of 0 to 100 (0 = no control; 100 = complete control).

Results

Table 1 provides the weed control data for the 2011 experiment. Evaluations were made for both glyphosate-resistant waterhemp and fall panicum approximately 1, 2, and 4 weeks after the herbicide application. Control ratings generally increased over time, with the July 8 rating providing the highest level of control for each treatment. Armezon at 0.5 oz + 1 pint of atrazine + Roundup PowerMax (RPM) did not provide adequate control of waterhemp. Status at 2.5 oz + RPM also did not provide adequate control of waterhemp. The Status label suggests that 5.0 oz of Status should be used when glyphosate-resistant weeds are present. Armezon (same chemistry as Impact herbicide), Callisto, and Laudis are all HPPD-inhibiting herbicides and provide the best control when applied with atrazine. These herbicides applied with atrazine and RPM gave 95 to 97% control of glyphosate-resistant waterhemp. Halex GT, which is a mixture of Callisto, glyphosate, and S-metolachor, controlled glyphosate-resistant waterhemp at 92%. All treatments contained glyphosate, which effectively controls fall Panicum.

Table 2 shows the weed control evaluations for the 2012 experiment. All preemergence-applied herbicides gave excellent control of waterhemp. Verdict alone at 13 fl oz allowed a few waterhemp to escape by the June 16 rating. All postemergence-applied herbicides provided 90% or greater control of waterhemp. Exceptions were Liberty at 86% and RPM at 88%. All treatments provided acceptable control of Venice mallow. The addition of atrazine to Anthem, Verdict, or Corvus increased Venice mallow control with these preemergence treatments. Liberty to V2 corn or RPM or RPM+Status to V6 corn provided less than 90% control of Venice mallow. Hophornbeam copperleaf densities were variable, ranging from $1/yd^2$ to $3–5/ft^2$. All treatments generally gave acceptable control. Only Lexar preemergence and Liberty on V2 corn gave less than 90% control at the June 16 rating. In both cases, it was a result of late-emerging hophornbeam copperleaf.

Acknowledgements

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Table 1. Glyphosate-resistant waterhemp control with postemergence herbicides applied to corn, East Central Experiment Field, 2011

Trt no.	Treatment[1]	Rate	Rate unit/a	Waterhemp[2] June 15	Waterhemp[2] June 22	Waterhemp[2] July 8	Fall Panicum[2] June 15	Fall Panicum[2] June 22	Fall Panicum[2] July 8
				% control					
1	Armezon + RPM	0.75+22	fl oz	50 d	80 b	91 a	95 a	100 a	100 a
	COC + NPAK AMS	1+2.5	% v/v						
2	Armezon + RPM	1+22	fl oz	50 d	71 c	92 a	100 a	100 a	100 a
	NPAK AMS	2.5	% v/v						
3	Armezon + RPM	0.5+22	fl oz	58 c	61 d	76 c	100 a	100 a	100 a
	Atrazine+NPAK AMS	1+2.5	pt + % v/v						
4	Armezon + RPM	0.75+22	fl oz	68 ab	87 ab	96 a	98 a	100 a	100 a
	Atrazine+	1	pt						
	COC+NPAK AMS	1+2.5	% v/v						
5	Laudis + RPM	3+22	fl oz	70 a	90 a	97 a	98 a	100 a	100 a
	Atrazine+	1	pt						
	NIS+NPAK AMS	0.25+2.5	% v/v						
6	Callisto+Atrazine+	3+19.2	fl oz	68 ab	83 ab	95 a	100 a	100 a	100 a
	RPM + NPAK AMS	22 + 2.5	fl oz+% v/v						
7	Status + RPM	2.5+22	oz wt+Fl oz	61 bc	66 cd	83 b	100 a	100 a	100 a
	NIS + NPAK AMS	0.25+2.5	% v/v						
8	Status+Armezon	2.5+0.75	oz wt+Fl oz	66 ab	79 b	95 a	100 a	100 a	100 a
	Roundup Power Max	22	fl oz						
	COC+NPAK AMS	1+2.5	% v/v						
9	Halex GT + Atrazine	3.6 + 1	pt	68 ab	81 ab	92 a	98 a	100 a	100 a
	NIS + NPAK AMS	0.25+2.5	% v/v						
	LSD (P = 0.05)			4.7	6.6	4.9	5.1	0	0

[1] RPM = Roundup PowerMax (glyphosate); Armezon and Impact contain the same active ingredient.

[2] Means followed by same letter do not significantly differ (*P* = 0.05).

Table 2. Control of glyphosate-resistant waterhemp and other weeds in corn, East Central Exp. Field, 2012

Trt no.	Treatment[1]	Rate	Rate unit/a	Appl. time	Waterhemp[2] May 2	Waterhemp[2] June 16	Venice mallow[2] May 2	Venice mallow[2] June 16	HHBCF[1,2] June 16	LCRGR[1,2] June 16
					% control					
1	Anthem	8	fl oz	PRE	100 a	96 a	100 a	89 a-e	93 abc	99 a
2	Anthem	10	fl oz	PRE	100 a	100 a	99 a	86 cde	95 abc	100 a
3	Anthem ATZ	2	PT/A	PRE	100 a	99 a	100 a	94 a-d	95 abc	100 a
4	Anthem ATZ	2.5	PT/A	PRE	99 a	99 a	100 a	95 a-d	94 abc	100 a
5	Anthem /	8	fl oz	PRE	100 a	100 a	99 a	96 abc	100 a	100 a
	Balance Flexx + atra	6 + 8	fl oz	V2						
6	Verdict	13	fl oz	PRE	100 a	91 ab	100 a	86 cde	93 abc	99 a
7	Verdict + atrazine	13+32	fl oz	PRE	100 a	100 a	100 a	90 a-e	91 abc	99 a
8	Corvus	5	fl oz	PRE	100 a	98 a	95 a	90 a-d	94 abc	98 a
9	Corvus + atrazine	5 +32	fl oz	PRE	100 a	99 a	98 a	94 a-d	96 abc	99 a
10	Lexar	2.5	qt	PRE	100 a	99 a	100 a	85 de	89 c	100 a
11	Anthem /	8	fl oz	PRE	100 a	100 a	100 a	99 a	100 ab	100 a
	Cadet + Callisto +	0.75 + 2	fl oz	V6						
	Atrazine + COC	1+1	pt+% v/v	V6						
12	Prequel /	1.66	oz wt	PRE	100 a	100 a	95 a	100 a	100 ab	100 a
	Realm Q + RPM	4	oz wt+fl oz	V6						
	Atrazine+NIS+AMS	1+.25+2	qt+%+lb	V6						
13	Prequel /	1.66	oz wt	PRE	95 a	98 a	95 a	99 a	99 ab	100 a
	Steadfast Q + RPM	1+22	oz wt+fl oz	V6						
	Atrazine + COC+AMS	1+1+2	qt+%+lb	V6						
14	Cinch ATZ /	3	pt	PRE	100 a	99 a	98 a	93 a-d	95 abc	100 a
	Steadfast Q + RPM	1+22	oz wt+fl oz	V6						
	COC + AMS	1+2	%+lb	V6						
15	Anthem + Liberty 280 +	8 + 22	fl oz	V2		94 ab		93 a-d	98 abc	98 a
	NPAK AMS	2.5	% v/v	V2						
16	RPM + NPAK AMS	22+2.5	fl oz+% v/v	V2		86 b		80 e	89 c	98 a
17	Anthem + Liberty 280 +	8 + 22	FL OZ/A	V2		100 a		98 ab	98 ab	100 a
	Atrazine + NPAK AMS	1+2.5	qt + %v/v	V2						
18	Halex GT + atrazine	3.6 + 2	pt	V2		100 a		95 a-d	99 ab	100 a
	NIS + AMS	0.25 + 2.5	% v/v	V2						
19	Laudis + atrazine +	3 + 32	fl oz	V6		100 a		95 a-d	100 a	100 a
	MSO + UAN	1 + 3	% v/v+pt	V6						
20	Callisto + atrazine +	3 + 32	fl oz	V6		99 a		95 a-d	99 ab	95 a
	COC + UAN	1 + 3	% v/v+pt	V6						
21	Impact + atrazine +	0.75 + 32	fl oz	V6		100 a		91 a-d	99 ab	96 a
	MSO + UAN	1 + 3	% v/v+pt	V6						
22	Armezon + atrazine +	0.75 + 32	fl oz	V6		99 a		98 ab	100 a	96 a
	Status +	5	oz wt	V6						
	MSO + UAN	1 + 3	% v/v+pt	V6						

Table 2. Control of glyphosate-resistant waterhemp and other weeds in corn, East Central Exp. Field, 2012

Trt no.	Treatment[1]	Rate	Rate unit/a	Appl. time	Waterhemp[2] May 2	Waterhemp[2] June 16	Venice mallow[2] May 2	Venice mallow[2] June 16	HHBCF[1,2] June 16	LCRGR[1,2] June 16
23	Roundup Power Max	22	fl oz	V6		95 ab		97 abc	96 abc	100 a
	Atrazine + Status	2 + 5	pt + oz wt	V6						
	NIS + NPAK AMS	0.25 + 2.5	% v/v	V6						
24	RPM + Status	22+5	fl oz+ oz wt	V6		95 ab		88 b-e	95 abc	98 a
	NIS + NPAK AMS	0.25 + 2.5	% v/v	V6						
25	RPM + NPAK AMS	22+2.5	fl oz+% v/v	V6		88 b		85 de	90 bc	96 a
	LSD (P = 0.05)				3	6	4	6	5	4

[1] RPM = Roundup PowerMax, atra = atrazine, HHBCL = hophornbeam copperleaf, LCRGR = large crabgrass.
[2] Means followed by the same letter do not significantly differ (*P* = 0.05).

Kansas River Valley Experiment Field

Introduction

The Kansas River Valley Experiment Field was established to study management and effective use of irrigation resources for crop production in the Kansas River Valley. The Paramore Unit consists of 80 acres located 3.5 miles east of Silver Lake on U.S. Highway 24, then 1 mile south of Kiro, and 1.5 miles east on 17th street. The Rossville Unit consists of 80 acres located 1 mile east of Rossville or 4 miles west of Silver Lake on U.S. Highway 24.

Soil Description

Soils on the two fields are predominately in the Eudora series. Small areas of soils in the Sarpy, Kimo, and Wabash series also occur. Except for small areas of Kimo and Wabash soils in low areas, the soils are well drained. Soil texture varies from silt loam to sandy loam, and the soils are subject to wind erosion. Most soils are deep, but texture and surface drainage vary widely.

2012 Weather Information

The frost-free season was 197 days at the Paramore and Rossville units (average = 173 days). The last spring freeze was March 10 (average = April 21), and the first fall freeze was September 23 (average = October 11). There were 79 days above 90°F and 14 days above 100°F. Precipitation was below normal at both fields for the growing season (Table 1). Precipitation was above average for August and October and below normal the other months. For the year, the rainfall deficit for Rossville was 14.1 in., and the deficit was 14.9 in. for Paramore. Irrigation was necessary in late May through August. Estimated corn and soybean yields were 153 and 51 bpa, respectively. Dryland crops and sudden death syndrome in soybeans at Rossville reduced overall yields.

Table 1. Precipitation at the Kansas River Valley Experiment Field

	Rossville Unit		Paramore Unit	
Month	2012	30-year avg.	2012	30-year avg.
	--------------- in. ---------------		--------------- in. ---------------	
January	0.13	3.18	0.04	3.08
February	2.49	4.88	2.38	4.45
March	2.81	5.46	2.57	5.54
April	2.03	3.67	2.17	3.59
May	2.66	3.44	1.77	3.89
June	3.87	4.64	2.98	3.81
July	0.75	2.97	0.71	3.06
August	3.11	1.90	4.53	1.93
September	0.87	1.24	0.82	1.43
October	1.07	0.95	0.94	0.95
November	1.57	0.89	1.19	1.04
December	0.22	2.42	0.28	2.46
Total	21.58	35.64	20.38	35.23

Macronutrient Fertility on Irrigated Soybeans in a Corn/Soybean Rotation

E.A. Adee and D. Ruiz Diaz

Summary

Effects of nitrogen (N), phosphorus (P), and potassium (K) fertilization on a corn/soybean cropping sequence were evaluated from 1983 through 2012 (corn planted in odd years). Corn yield was near optimum at 160 lb/a N. P and K fertilization alone did not consistently increase yields. When both P and K were applied with N, yields increased as much as 15 bu/a.

Introduction

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

Procedures

The initial soil test in March 1972 on this silt loam soil was 47 lb/a available P and 312 lb/a exchangeable K in the top 6 in. of the soil profile. Rates of P were 50 and 100 lb/a P_2O_5 (1972–1975) and 30 and 60 lb/a P_2O_5 (1976–2011), except in 1997 and 1998, when a starter of 120 lb/a of 10-34-0 (12 lb/a N + 41 lb/a P_2O_5) was applied to all plots of corn and soybean. Rates of K were 100 lb/a K_2O (1972–1975), 60 lb/a K_2O (1976–1995), and 150 lb/a K_2O (1997–2011). Nitrogen rates included a factorial arrangement of 0, 40, and 160 lb/a of preplant N (with single treatments of 80 and 240 lb/a N). The 40 lb/a N rate was changed to 120 lb/a N in 1997. Treatments of N, P, and K were applied every year to continuous soybean (1972–1982) and every other year (odd years) to corn (1983–1995, 1999–2011).

Soybean varieties planted in even years were: Douglas (1984), Sherman (1986, 1988, 1990, 1992, 1996, 1998), Edison (1994), IA 3010 (2000), Garst 399RR (2002), Stine 3982-4 (2004), Stine 4302-4 (2006), Midland 9A385 (2008), Asgrow 4005 (2010), and Asgrow 3832 (2012). Soybean was planted in early to mid-May. Herbicides were applied preplant each year, and postemergence herbicides were applied as needed. Plots were cultivated, furrowed, and furrow-irrigated through 2001 and sprinkler-irrigated with a linear move irrigation system from 2002 through 2012. A plot combine was used for harvesting grain yields.

Results

Soybean yields are shown in Table 1. Yield response of soybean to N applied to corn is shown in Figure 1. The greatest of the yield increase in soybeans to carryover N was when N was applied near the optimum rate for corn, between 120 and 160 lb/a. Yield actually decreased in soybeans when the N rate was over the optimum for corn, which

could be due to the excess N leaching and/or reduced nodulation in the soybeans early in the season, preventing the soybeans from fulfilling their N requirements later in the season. Corn results were presented in Field Research 2012 (see "Macronutrient Fertility on Irrigated Corn in a Corn/Soybean Rotation," Report of Progress 1066, p. 15–18).

P and K did increase soybean yields significantly (Table 1). We observed a 5.8 bu/a increase in soybean yields due to P applied to corn, and a 1 to 2 bu/a response to K. There were no interactions between nutrients for soybean yield.

These data show that over the long history of this study, there has been a significant carryover benefit from the fertilizer applied to corn to the subsequent soybean crop. To determine the best strategy for fertilizer application requires an economic comparison of the cost and return on investment of the treatments.

To compare which fertilizer program returned the most for the investment, the cost of fertilizer was subtracted from the income generated from corn plus soybeans grown the following year [Profitability = ((corn yield x $6.31) + (soybean yield x $13.71)) – fertilizer cost (N = $0.46/lb, P = $0.72, K = $0.62)](Table 2). Generally, the best return on investment was with 120 to 160 lb/a of N applied, generally in combination with P and possibly K. Although applying N alone did well in this study, the balanced approach to fertility also will help maintain the productivity of the soil over time.

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

Fertilizer[1]			Soybean yield[2]	
N	P_2O_5[3]	K_2O	1984–1994	1998–2012
	N means		---------------- bu/a -------------------	
0			67.36 b	54.3 b
40/120			68.38 b	57.5 a
160			70.34 a	57.6 a
	P means		1984–2012	
	0		58.8 c	
	30		63 b	
	60		64.6 a	
	K means			
		0	67.65 b	55.9 b
		60/150	69.73 a	57.0 a

[1] Fertilizer applied to corn in odd years from 1983 through 2011 and to soybean for 11 years prior to 1983 (the first number of two is the rate applied to corn from 1983 through 1995).
[2] Means followed by the same letter within type of fertilizer are not significantly different at $P < 0.05$.
[3] Phosphorus treatments not applied in 1997. Starter fertilizer of 10 gal/a of 10-34-0 was applied to all treatments in 1997 and 1998 (corn and soybean). N and K treatments were applied to corn in 1997.

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

Fertilizer[1]			Profitability[2,3]	
N	P_2O_5[4]	K_2O	1983–1995	1997–2011
---------- lb/a ----------			---------- $/a ----------	
0	0	0	0.00 h	0.00 gh
0	0	60/150	-15.33 h	-41.36 h
0	30	0	92.51 g	175.77 f
0	30	60/150	21.89 gh	-5.43 gh
0	60	0	32.98 gh	84.12 fg
0	60	60/150	81.99 g	-37.49 h
40/120	0	0	292.11 ef	501.75 abcd
40/120	0	60/150	267.31 ef	409.00 de
40/120	30	0	240.57 f	450.71 abcde
40/120	30	60/150	398.60 cd	521.90 abc
40/120	60	0	290.25 ef	459.33 abcde
40/120	60	60/150	326.91 de	507.76 abcd
160	0	0	553.52 b	483.35 abcd
160	0	60/150	575.62 ab	361.92 e
160	30	0	555.76 b	417.19 cde
160	30	60/150	644.59 a	527.51 ab
160	60	0	556.98 b	554.80 a
160	60	60/150	613.33 ab	538.88 a
80	30	60/150	450.45 c	428.29 bcde
240	30	60/150	593.65 ab	514.29 abcd
LSD (0.05)			81.16	109.93

[1] Fertilizer applied to corn in odd years from 1983 through 2011 and to soybean for 11 years prior to 1983 (the first number of two is the rate applied to corn from 1983 through 1995).

[2] Profitability = ((corn yield x $6.31) + (soybean yield x $13.71)) – fertilizer cost (N = $0.46/lb, P = $0.72, K = $0.62).

[3] Means followed by the same letter within type of fertilizer are not significantly different at $P < 0.05$.

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

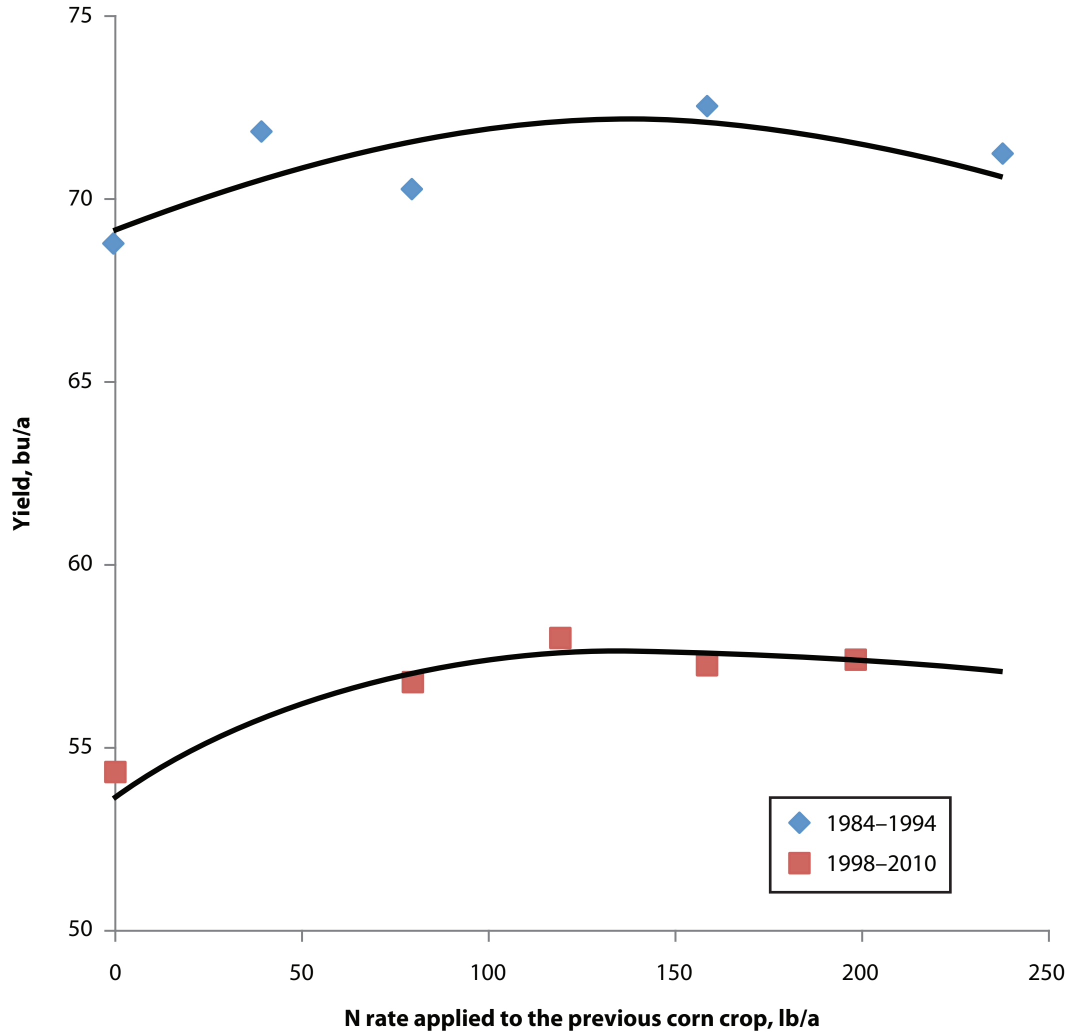

Figure 1. Soybean response to nitrogen (N) rate with 30 lb phosphorus (P) and 60 lb potassium (K) in 1984–1994 and 30 lb P and 150 lb K in 1998–2010 applied to corn the previous year.

Comparison of Drought-Tolerant and Regular Corn Hybrids at Different Populations and Irrigation Levels

E.A. Adee and R. Nelson

Summary
Drought-tolerant and regular corn hybrids were compared with four plant populations at Topeka and three populations at Scandia under three irrigation levels in 2012. At Topeka, both types of hybrids were nearly identical in their yield and linear response to increasing populations when water was not a limiting factor. At Scandia, there was very little yield response to population in the regular hybrids and a decreasing yield trend in the drought-tolerant hybrids as population increased. Averaged across populations, however, the drought-tolerant hybrids out-yielded the regular hybrids at the highest irrigation level. As water became more limiting, the drought-tolerant hybrids sustained yields at higher populations at both sites. When water availability was reduced further, the yields of the drought-tolerant hybrids were as much as 20% greater than regular hybrids at Topeka and Scandia. Furthermore, the drought-tolerant hybrids demonstrated the ability to sustain populations as much as 10,000 plants/a higher than the standard hybrids at both study sites.

Introduction
The recent development of drought-tolerant corn hybrids has created the potential for increased yield stability in semiarid corn production regions; however, research determining how to maximize yield while exploiting the water conservation benefits of these new hybrids is limited. In Kansas, corn is irrigated across a large precipitation gradient, ranging from ~15 in. annually in the far west to ~38 in. in the east. Although the benefits of water-efficient corn hybrids are obvious in semiarid western Kansas, it has yet to be determined how this technology will translate to water savings and economic benefit for irrigated corn producers in central and eastern Kansas. Irrigation management techniques must be studied closely to maximize the potential for improved irrigation use efficiency while maximizing yield and profitability. The addition of plant population to this study will begin the process of creating profitable and efficient production systems for new corn hybrids that will become available in the next several years.

Procedures
Research was conducted at the Kansas River Valley Experiment Field (Topeka) and the Irrigation Experiment Field (Scandia). Research compared Pioneer 1151 HR AquaMax and 1498 HR AquaMax, two drought-tolerant corn hybrids, with similar regular hybrids, Pioneer 1162 HR and 33D49. The hybrids were planted at four populations and subjected to three irrigation treatments. The three irrigation treatments were approximately 50, 75, and 100% of calculated crop evapotranspiration (E/T) as calculated with the KanSched 2 irrigation-scheduling program (http://mobileirrigation lab.com/kansched2); this approach allowed a comparison of how different hybrids responded to a range of irrigation rates. Due to dry conditions at Topeka, 3 in. of water was applied to all plots from the end of May through June (before tasseling). Irrigation

water applied after tasseling was 6.75, 9.34, and 12.00 in. for the low, medium, and high irrigation levels, respectively. Rainfall totaled 7.75 in. from planting to maturity. Due to irrigation equipment malfunction, irrigation treatments at Scandia were initiated on July 16, approximately 30 days later than the average irrigation initialization in the North Central Kansas region for the 2012 growing season. This resulted in an early season deficit water situation that affected the performance of all treatments. Total water applied for the low, medium, and high irrigation levels was 5.00, 7.50, and 10.00 in., respectively. Rainfall at Scandia totaled 11.53 in. from planting to maturity; however, yields of all treatments were slightly below normal due to early season water stress. At Topeka, each hybrid was planted at four different populations (25, 30, 35, and 40,000 plants/a) on April 17. Planting at Scandia was completed on May 22. Due to field space restrictions, each hybrid was planted at only three populations (30, 35, and 40,000 plants/a). The study was designed to improve the understanding of how drought-tolerant hybrids respond to the interaction of plant density and irrigation. The experiment was replicated three times. Stand counts were taken after emergence to ensure accuracy of planting populations. At Topeka, plots were rated for percentage of brown leaves above the ear leaf at dent stage on July 11. Plots were machine-harvested for yield, moisture, and test weight on August 31. At Scandia, soil water was monitored throughout the growing season by neutron attenuation. Plots were machine-harvested for yield, moisture, and test weight on November 1.

Results

Topeka

Yield increased 12.5 bu/a for each additional in. of irrigation water applied for the season across all hybrid and population treatments (Table 1a). The percentage of brown or dead leaves at dent was greater in the low irrigation treatment but did not differ between the medium or high irrigation treatments (Table 1a).

The percentage of brown leaves and yield were very similar for three of the hybrids when averaged across all populations and irrigation treatments. The regular 115-day hybrid had a higher number of brown leaves at dent, and the overall yield was lower than with the other hybrids in the study (Table 2a).

The percentage of brown leaves at dent was correlated to the yield and was highly correlated with yield at the low irrigation treatment (Figure 1). Treatments accounted for some effect of the percentage of brown leaves, but variability in soil type influenced how the corn was able to handle the stress of the low irrigation level. Some drought-tolerant treatments had a fairly high number of brown leaves in poorer soil where stress was greater. These data emphasize the importance of healthy corn leaves to yield at dent stage and later.

There was a linear response to plant population in that yield increased for all hybrids as population increased at the high irrigation level (Figure 2a). All hybrids responded similarly, and there was no flattening or decrease in yield at the highest populations as expected.

At the medium irrigation level, the average high yields were similar for the drought-tolerant and regular hybrids, 170 and 175 bu/a, respectively; however, they responded

differently to increasing plant population (Figures 3a and 4a). Yield with the drought-tolerant hybrids plateaued at 30,000 plants but did not drop even at the highest population. The regular hybrids had a pronounced drop in yield as the populations increased over 30,000 plants.

The differences between the drought-tolerant and regular hybrids became more pronounced at the low irrigation level. The top yield with the drought-tolerant hybrids averaged 165 bu/a at close to 35,000 population with the low irrigation treatment, with the yield dropping sharply at 40,000 population (Figure 5a). Conversely, the highest yield with the regular hybrids, 135 bu/a, was the lowest population, 25,000 plants, then progressively decreased as the plant population increased.

Scandia

Yield increased 6 bu/a for each additional in. of irrigation water applied for the season across all hybrid and population treatments (Table 1b).

The yield response to population at the Scandia site was quite different from that observed at Topeka (Figure 2a). For the standard hybrids, there was essentially no significant yield response to plant population at the highest irrigation level. A linear decrease in yield was observed in the drought-tolerant hybrids as population increased (Figure 2b), but the drought-tolerant hybrids out-yielded the regular hybrids at the low and medium populations and nearly matched the yield of the regular hybrids at the highest population level. The different response patterns to plant population at Topeka and Scandia likely can be explained by the early season water deficit that occurred at the Scandia site. The water deficit conditions imposed on all treatments created an environment for the drought-tolerant hybrids to outperform the regular hybrids even at the highest irrigation level.

At the medium irrigation level, average yields of the drought-tolerant hybrids peaked at 35,000 plants, but yield changed very little in one particular hybrid (1151HR) from 35,000 to 40,000 plants, suggesting a yield plateau between the two population levels (Figure 3b). As expected, yield decreased noticeably as population increased in the regular hybrids (Figure 4b). This pattern was similar to that observed at Topeka, with a significant yield decrease in regular hybrids as populations increased past 30,000 plants.

At the low irrigation level, the drought-tolerant hybrids out-yielded the regular hybrids across all population levels by ~20 bu/a. There was a slight decreasing yield trend in the drought-tolerant hybrids as population increased, but as was observed in the medium irrigation level, a single hybrid (1151HR) maintained a fairly consistent yield pattern across all population levels (Figure 5b). Scatter in the regular hybrid data was significant, making it difficult to find a definite yield trend across populations (Figure 6b).

Caution should be used in drawing conclusions from a study conducted at two locations for one year, but some observations can be made that could assist farmers in making decisions.

1) Brown/dead leaves during grain fill result in significant yield loss, which is not surprising.

2) Performance of individual hybrids within the drought-tolerant and regular categories may vary. Some regular hybrids can perform close to the drought-tolerant hybrids even in stressful conditions, and drought-tolerant hybrids have the potential to yield with regular hybrids when water isn't limiting.

3) Populations can be higher than the ~30,000 typically planted in the area, especially if water isn't too limiting. Drought-tolerant hybrids can tolerate higher populations when moisture conditions become stressful.

4) The advantage of the drought-tolerant hybrids became more evident when water stress increased to the point of leaves rolling most days.

Table 1a. Effect of irrigation level on corn yield, Kansas River Valley Experiment Field, Topeka Unit

Irrigation level (evapotranspiration %)	Brown leaf[1,2]	Corn yield, bu/a
Low (50%)	20.6 a	128 c
Medium (75%)	1.6 b	163 b
High (100%)	0 b	193 b

[1] Brown leaf = percentage of brown leaves at ear leaf and above at dent stage.
[2] Means followed by different letters are different at $P = 0.10$.

Table 1b. Effect of irrigation level on corn yield, Irrigation Experiment Field, Scandia

Irrigation level (evapotranspiration %)	Corn yield, bu/a[1]
Low (50%)	145 c
Medium (75%)	159 b
High (100%)	176 b

[1] Means followed by different letters are different at $P = 0.10$.

Table 2a. Effect of drought tolerance and maturity on brown leaves at dent and yield, Kansas River Valley Experiment Field, Topeka Unit

Drought tolerance	Maturity, days	Brown leaf, %[1]	Yield, bu/a[1]
AquaMax	111	4.4 b	162 a
Regular	111	3.4 b	167 a
AquaMax	114	6.4 b	166 a
Regular	115	15.3 a	150 b

[1] Means followed by different letters are different at $P = 0.05$.

Table 2b. Effect of drought tolerance and maturity on corn yield, Irrigation Experiment Field, Scandia

Drought tolerance	Maturity, days	Yield, bu/a[1]
AquaMax	111	166 a
Regular	111	163 a
AquaMax	114	169 a
Regular	115	141 b

[1] Means followed by different letters are different at $P = 0.10$.

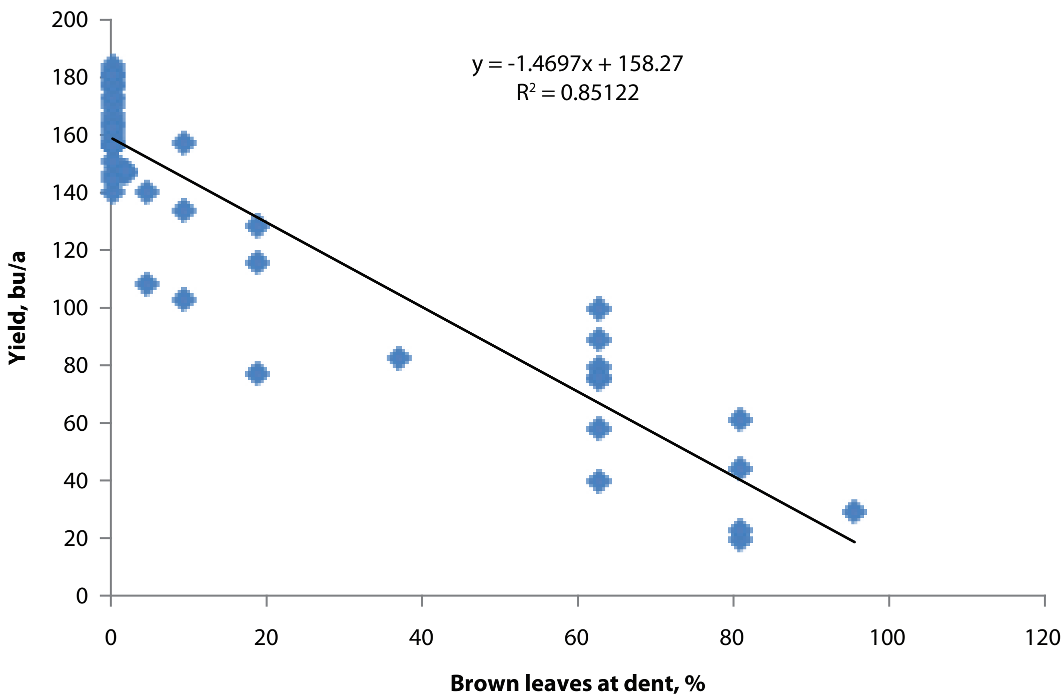

Figure 1. Relationships between brown leaves at dent and yield at low irrigation level.

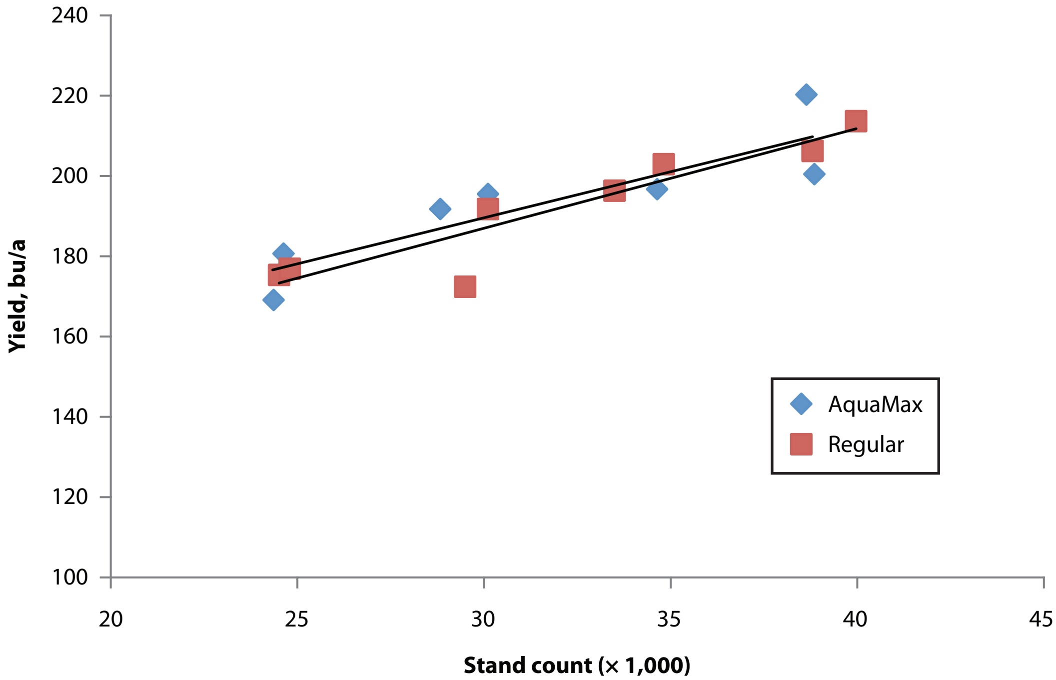

Figure 2a. Yield response to plant population of drought-tolerant and regular hybrids at high irrigation level (12 in.) at Topeka.

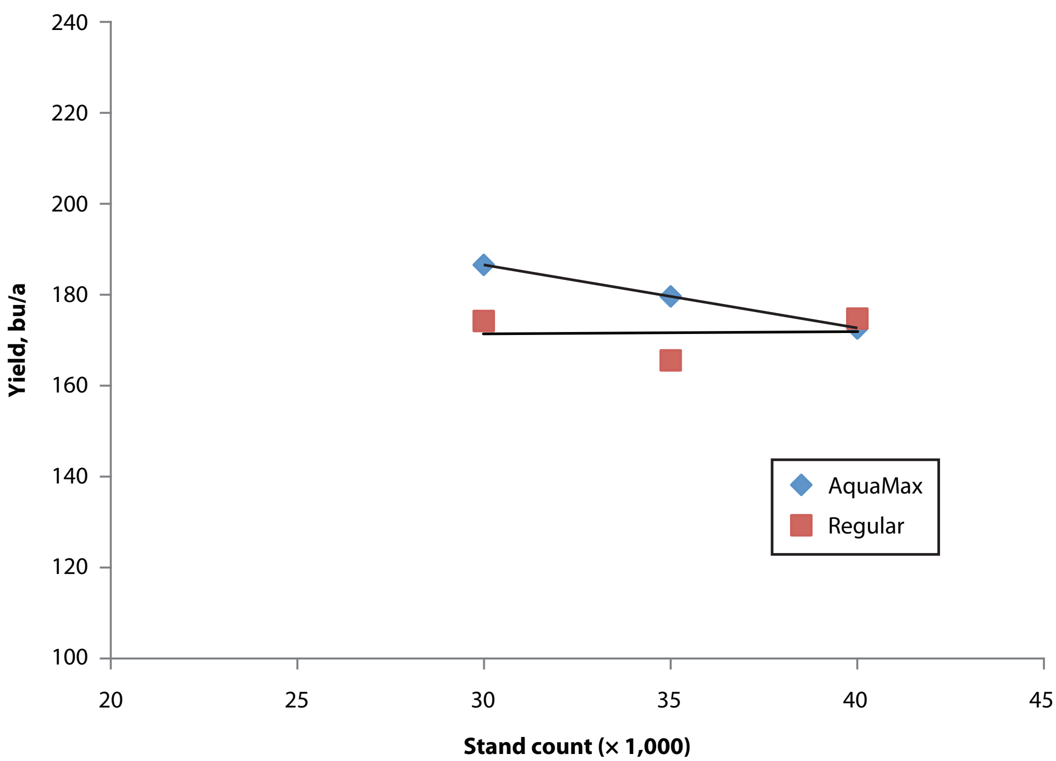

Figure 2b. Yield response to plant population of drought-tolerant and regular hybrids at high irrigation level (10 in.) at Scandia.

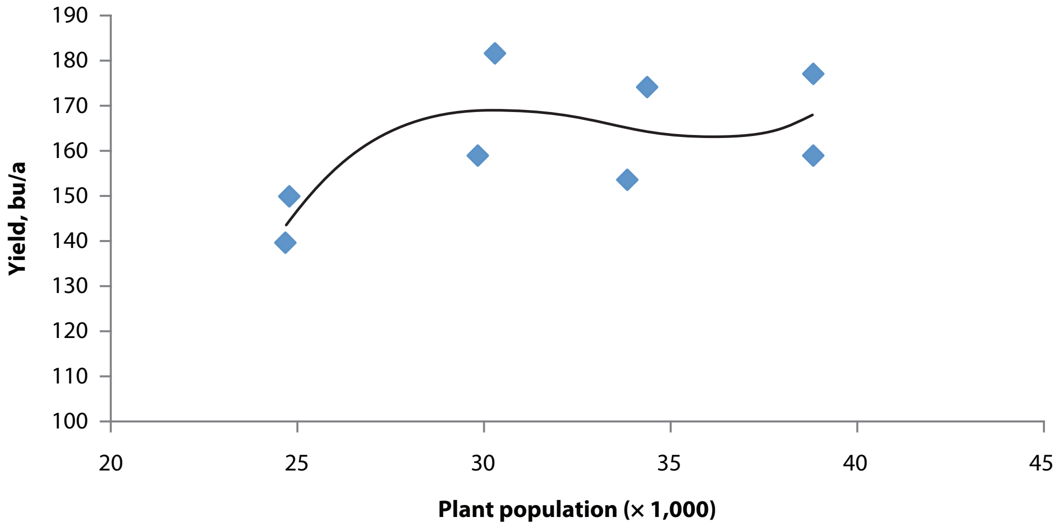

Figure 3a. Yield response to plant population by drought-tolerant hybrids at medium irrigation level (9.3 in.) at Topeka.

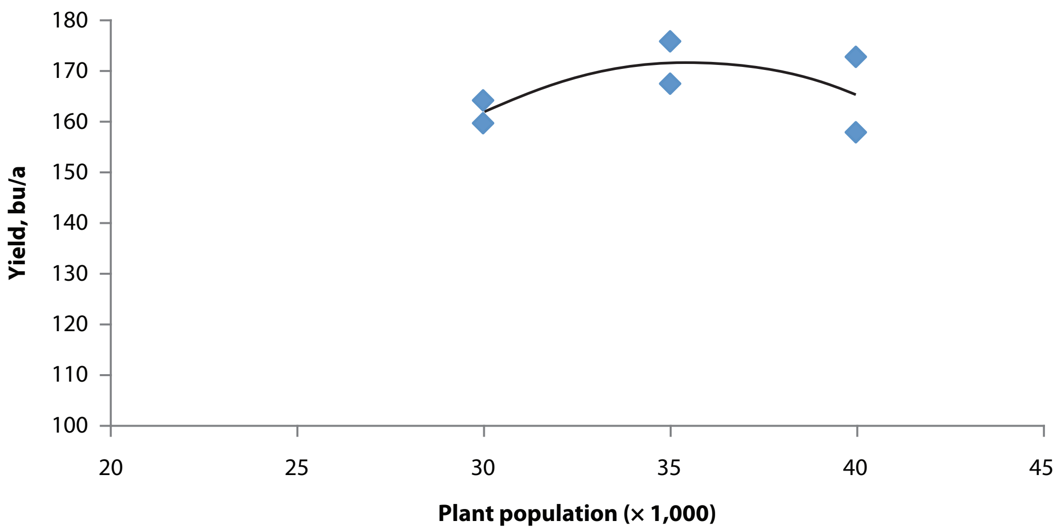

Figure 3b. Yield response to plant population by drought-tolerant hybrids at medium irrigation level (7.5 in.) at Scandia.

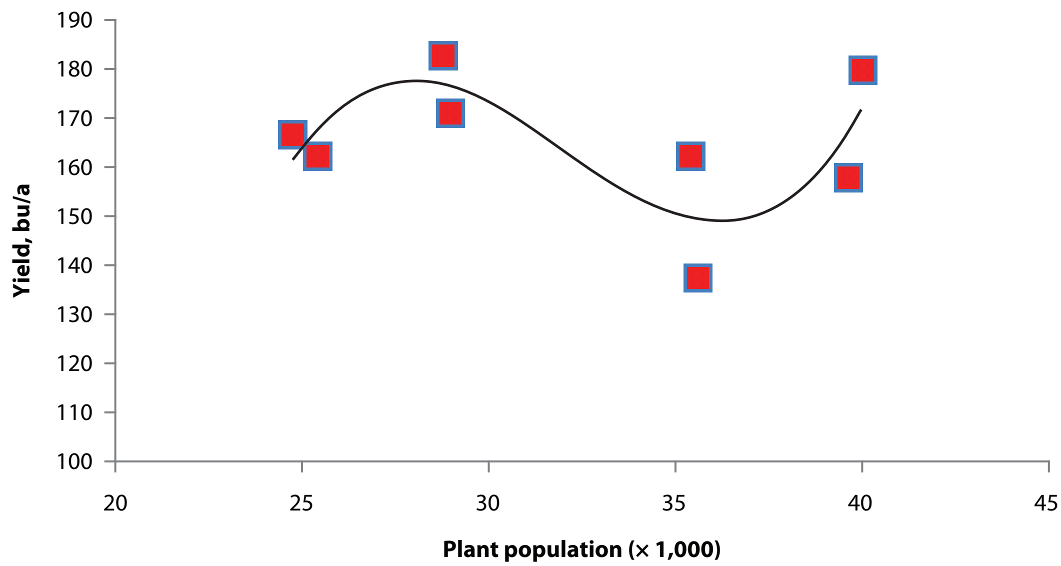

Figure 4a. Yield response to plant population by regular hybrids at medium irrigation level (9.3 in.) at Topeka.

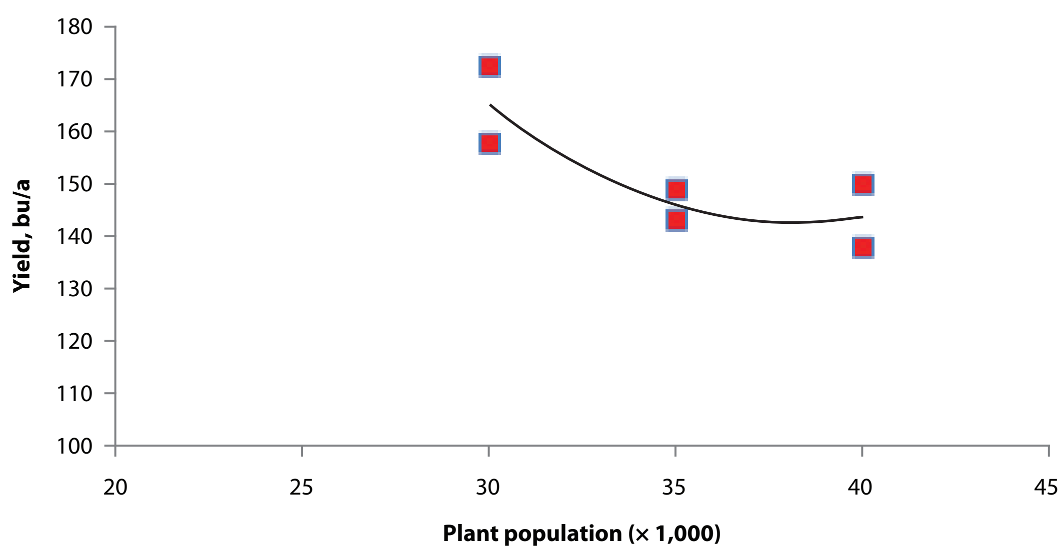

Figure 4b. Yield response to plant population by regular hybrids at medium irrigation level (7.5 in.) at Scandia.

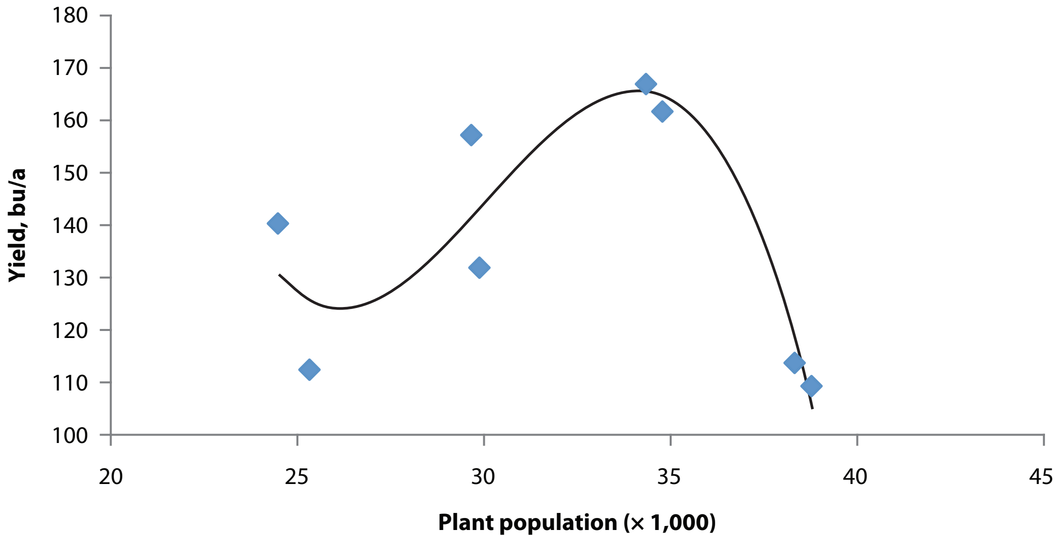

Figure 5a. Yield response to plant population by drought-tolerant hybrids at low irrigation level (6.75 in.) at Topeka.

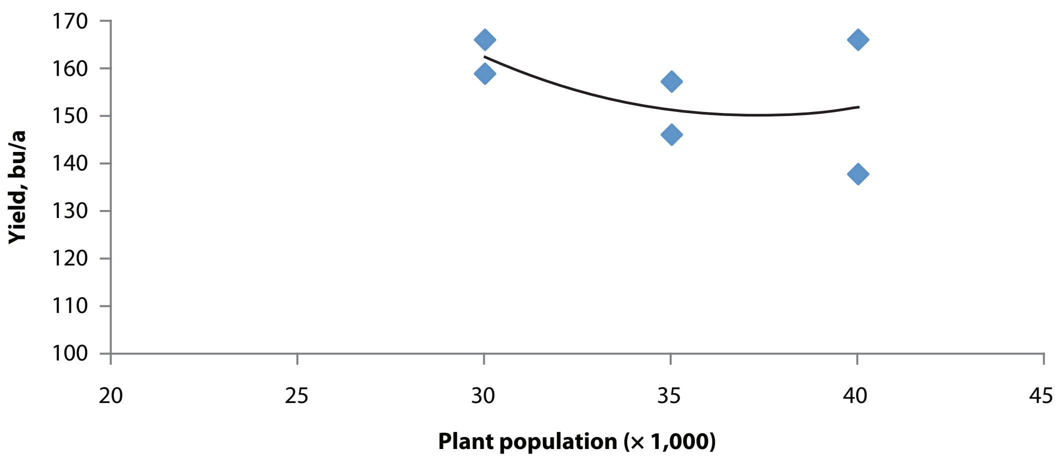

Figure 5b. Yield response to plant population by drought-tolerant hybrids at low irrigation level (5 in.) at Scandia.

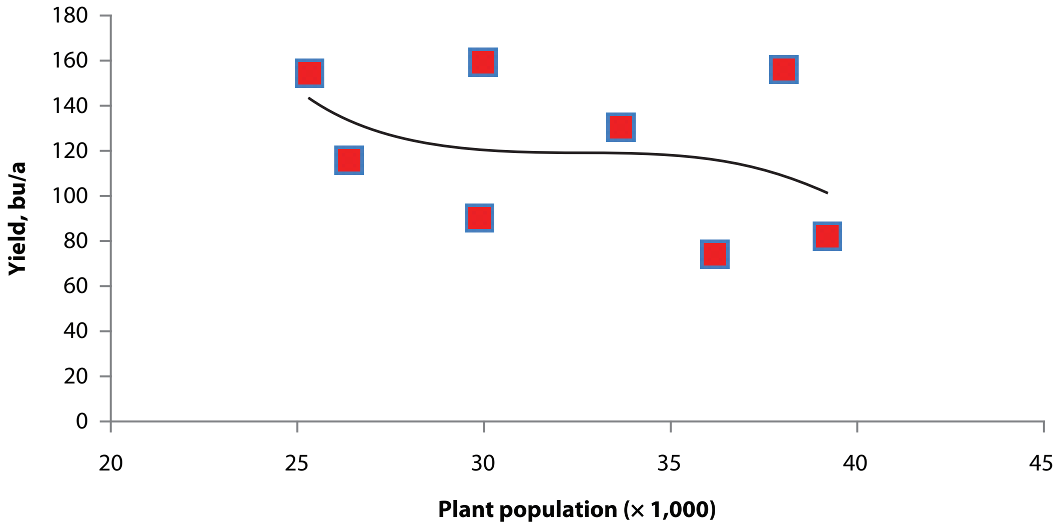

Figure 6a. Yield response to plant population by regular hybrids at low irrigation level (6.75 in.) at Topeka.

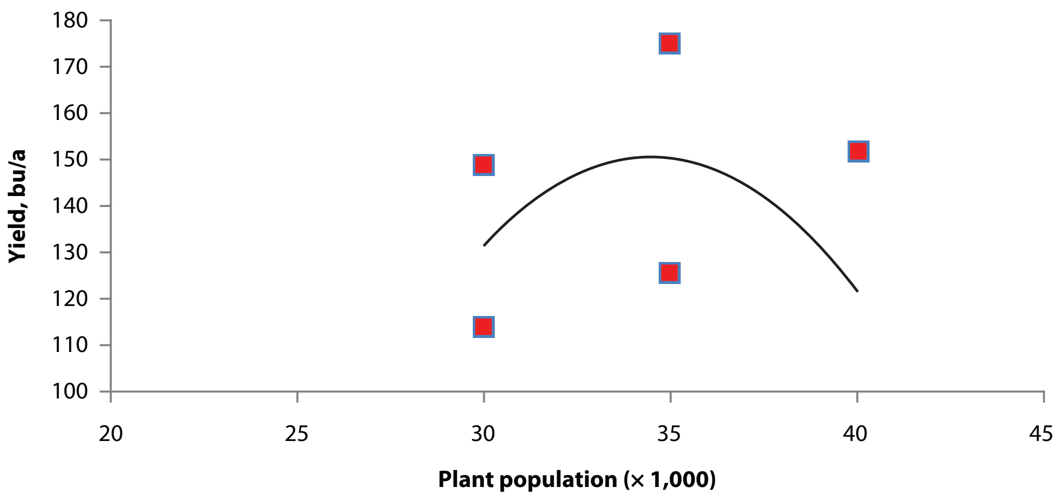

Figure 6b. Yield response to plant population by regular hybrids at low irrigation level (5 in.) at Scandia.

Tillage Study for Corn and Soybeans: Comparing Vertical, Deep, and No-till

E.A. Adee

Introduction

The need for tillage in corn and soybean production in the Kansas River Valley continues to be debated. The soils of the Kansas River Valley are highly variable, with much of the soil sandy to silty loam in texture. These soils tend to be relatively low in organic matter (<2%) and susceptible to wind erosion. Although typically well drained, these soils can develop compaction layers under certain conditions. A tillage study was initiated in the fall of 2011 at the Kansas River Valley Experiment Field near Topeka to compare deep vs. shallow vs. no-till vs. deep tillage in alternate years. Corn and soybean crops will be rotated annually. This is intended to be a long-term study to determine if soil characteristics and yields change in response to a history of each tillage system.

Procedures

A tillage study was laid out in the fall of 2011 in a field that had been planted with soybean. The tillage treatments were (1) no-till, (2) deep tillage in the fall and shallow tillage in the spring every year, (3) shallow tillage in the fall following both crops, and (4) deep tillage followed by a shallow tillage in the spring only after soybean, and shallow tilled in the fall after corn. The fall of 2010, prior to the soybean crop, the entire field was subsoiled with a John Deere V-ripper. After soybean harvest, 30-ft × 100-ft individual plots were tilled with a Great Plains TurboMax vertical tillage tool at 3 in. deep or a John Deere V-ripper at 14 in. deep. Spring tillage was with a field cultivator. In this setup year, only the first 3 treatments could be compared. Each tillage treatment had 4 replications. Dry fertilizer (11-50-0 and 0-0-60 nitrogen-phosphorus-potassium, or NPK) was applied at 200 lb/a for each product to the entire field prior to fall tillage. Nitrogen (150 lb) was applied in March prior to corn planting. Corn hybrid Pioneer 1395 was planted at 30,600 seeds/a on April 12. Soybean variety Pioneer 93Y92 was planted at 155,000 seeds/a on May 14. Soybeans were planted after soybeans in this setup year. Irrigation to meet evapotranspiration (ET) rates were started May 26 and concluded August 1 for corn and August 23 for soybean. Two yields were taken from each plot from the middle 2 rows of planter passes. Corn was harvested August 31, and soybean was harvested October 5.

Results

Yields of corn or soybeans did not differ due to tillage in this setup year of the study (Table 1). The yields were respectable considering the extreme heat and drought experienced this growing season. We anticipate that it will take several years for any characteristics of a given tillage system to build up to the point of influencing yields.

Table 1. Effects of tillage treatments on corn and soybean yields in 2012 at Kansas River Valley Experiment Field

Tillage treatment	Corn yield	Soybean yield
	---------------------- bu/a	----------------------
No-till	196	57.2
Fall subsoil/spring field cultivate	202	58.1
Fall vertical till	198	58.1
LSD 0.05	NS	NS

Evaluation of Soybean Inoculant Products and Techniques to Address Soybean Nodulation Problems in Kansas

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Summary
Soybean acreage has been expanding in Kansas, and soybeans are increasingly being planted in fields where the crop has not been grown previously. Nodulation issues have been encountered on several these "new" soybean fields. The purpose of this study was to aid in understanding and to improve the consistency of soybean nodulation and production, especially on new soybean ground. The research objective was to evaluate soybean nodulation performance on fields with varying soybean history with different inoculants and seed treatments. The study was split into two parts. One part was focused on different inoculant products along with double rates and product combinations that are often recommended for land not previously planted to soybeans. The second focused on single-rate inoculant products applied with different combinations of fungicide, insecticide, and nematicide seed treatments.

In the first study, the Novozymes inoculant products generally provided superior nodulation performance over the other company products in the study. The combination of dry and liquid inoculant products provided a significant increase in root nodule number at 3 of 5 sites in 2012. We observed no consistent response to higher rates or inoculant combinations over single rates in 2011. Although there were early season nodulation differences between treatments in new soybean ground, these did not carry through to harvest yield differences in the majority of research sites. Hot and dry summer conditions likely reduced yields, making detection of treatment differences difficult. In the second study, none of the seed treatments had negative effects on nodulation performance. There were significant differences in yield between treatments at one location in 2011, but differences were small, and the raw seed yielded as well or better than all treatment/inoculant combinations. At the other sites in both years, yield was not significantly influenced by seed treatment and inoculant combinations.

Introduction
The recent increase in soybean acreage in Kansas has brought along, in some cases, issues and concerns in achieving effective nodulation on ground that had never previously grown soybeans. Fields that do not attain good nodulation likely will not receive adequate nitrogen for growth and therefore will display a lack of vigor, yellowing, and low yields. Inoculant product suppliers often recommend double rates or combining products when planting into new soybean ground in an attempt to avoid nodulation issues.

Seed-applied inoculants are in direct contact with seed treatments. Soybean seed treatments provide protection against various seedling pests and diseases. Potential interactions of seed treatment formulations with seed-applied *Bradyrhizobium japonicum* bacterial inoculants are of interest. Survival of seed-applied bacterial inoculants is

critical in situations where no *B. japonicum* is present in the soil to achieve adequate nodulation and nitrogen fixation.

This study was designed to evaluate the nodulation performance of soybean in a range of environments across Kansas. The experiment analyzes inoculant products and their relationship with seed treatments to help make better recommendations to producers faced with potential nodulation issues.

Procedures

The inoculant product study consisted of 9 and 10 treatments in 2011 and 2012, respectively. Inoculant companies represented in this study included Novozymes (Franklinton, NC), Becker Underwood (Ames, IA), Advanced Biological Marketing (Van Wert, OH), and TerraMax (Bloomington, MN). Raw seed was inoculated according to company recommended protocols. Inoculated seed was stored in a cooler at 3°C before planting. All seed was planted within a week of inoculation. Equipment was sanitized using ethyl alcohol between inoculant products. Eleven field experiments were conducted at 8 locations in 2011 and 2012. The experiment was designed as a randomized complete block with 4 replications. Individual plots were 4 rows × 30 ft long with 30-in. row spacing. Two nitrogen fertilizer treatments of 60 and 120 lb/a were included on non-inoculated plots. Fertilizer application took place during the V4 growth stage by hand-broadcasting urea.

Evaluation consisted of plant stand counts at the VC to V1 growth stage, characterization of nodulation and plant dry mass at V4, grain yield, and grain quality parameters. Nodulation was evaluated by digging 10 plants per plot from the outer rows near the V4 stage. Roots were washed and nodule count, dry mass, and visual rating were taken. Visual ratings were set on a scale from 0 to 5 (0 = no nodules on the roots; 5 = several large nodules located along the main taproot). The plant tops and roots were dried and weighed for dry mass. Ground plant samples were submitted for nitrogen content. Grain quality parameters measured included test weight, seed nitrogen content, and seed size.

The second study was set up with seed treatments and inoculant products arranged in a factorial structure. Seed treatments included ApronMaxx RFC (Syngenta, Stanton, MN); ApronMaxx RFC, Cruiser (Syngenta); ApronMaxx RFC, Cruiser, Avicta (Syngenta); and ApronMaxx RFC, Poncho/VOTiVO (Bayer CropScience, Research Triangle Park, NC). Inoculant products applied in conjunction with these seed treatments included ExcalibreSA (Advanced Biological Marketing); Vault HP (Becker Underwood); Optimize (Novozymes), and Maximize (Terramax, Bloomington, MN). Seven field experiments were set up in a randomized complete block design with 4 replications at 5 locations in 2011 and 2012. Evaluation was the same as in the first study; however, nodulation was analyzed only on the Optimize inoculated plots due to plant processing limitations.

Experimental locations included the following.

- Belleville: no soybean history for ~16 years
- Manhattan: recent soybean rotation
- Ottawa: recent soybean rotation

- Osage: previously grass, out of soybean production for a minimum of 30 years
- Phillipsburg C: no known soybean history
- Phillipsburg S: no known soybean history
- Scandia: recent soybean rotation
- White City: previously in brome for ~40 years

All treatments were compared within each location, because variation in environmental factors across locations was considerable. Data were analyzed using PROC MIXED in SAS 9.2 (SAS Institute Inc., Cary, NC; $\alpha = 0.05$)

Results

Plant populations averaged 80,000 to 90,000 plants/a. Low stands at all locations were likely due to dry weather conditions. In 2012, seed treatments improved plant populations over untreated seed (Table 12).

The number of nodules per plant was heavily influenced by location and environment. Nodule number was reduced at new soybean ground locations compared with ground in recent rotation, but all inoculated plots achieved some nodulation activity at these sites regardless of inoculant product or rate.

Inoculant treatments did not increase nodule numbers at locations that had soybeans recently in the crop rotation (Tables 1 and 7). Untreated plots nodulated as well as inoculated plots; however, on new soybean ground or ground out of soybeans for many years, Novozymes products generally outperformed the other inoculant products in the study (Tables 1 and 7). In 2011, single rates of inoculant products proved just as effective as double rates or combinations of products (Table 1). In 2012, the combination of Cell Tech Granular with Optimize either ranked highest in nodule counts or was in the top treatment group at all sites (Table 7), indicating a benefit to production combination in 2012. TerraMax and Advanced Biological Marketing products consistently ranked in the lowest groupings at all sites where there were inoculant treatment differences (Tables 1 and 7). Plant nitrogen content and dry mass were unaffected by treatments at the V4 stage in either study (data not shown).

Yield differed significantly between inoculant treatments only at the Belleville location in 2011 (Table 2); however, separation between treatments was minimal. The granular and liquid Novozymes product combination yielded significantly more than single rate Optimize, Vault HP, and the Rhizo-Stick and Vault HP combination, but the untreated check was not significantly different from any of the inoculated treatments. We observed no significant yield differences between treatments in either study in 2012 (Tables 8 and 14), which is likely due to poor summer growing conditions and low yields. Application of nitrogen as SuperU urea at rates of 60 lb N/acre and 120 lb N/acre to uninoculated plots at the V4 growth stage did not significantly influence yields in 2011 (Table 2).

Grain quality parameters did not respond to inoculation treatments except for seed nitrogen content at Belleville in 2011 (Table 3). Grain quality parameter measurements varied in the inoculant product study at the two Phillipsburg experimental locations in 2012 (Tables 9, 10, and 11). The Vault HP ranked highest in test weight at Phillipsburg

1, which was not significantly different from the Rhizo-Stick double rate, but the Vault double rate ranked lowest in test weight at this site. In Phillipsburg S, the smallest seed size and lowest nitrogen content was associated with the Maximize product (Tables 10 and 11).

In the seed treatment/inoculant interaction aspect of the study, seed treatments did not impede nodule counts, numbers, or ratings on seed inoculated with the Optimize product (count data, Tables 4 and 13). Nodulation performance improved where the ApronMaxx RFC Cruiser seed treatment was applied at the Phillipsburg location in 2012 (Table 13). There was a variation in plant dry mass at Belleville in 2011, but it was not significantly different from the check (Table 5). Belleville was the only location with significant yield differences in 2011 (Table 6); however, there was no consistent pattern between seed treatment and yield. There were no treatment differences in grain quality parameters in 2011 and inconsistent variation at two locations in 2012 (Tables 15, 16, and 17).

Conclusions

Inoculant products vary in nodulation performance, but product combinations may result in improved performance on ground not previously planted to soybeans. Inoculating seed planted into ground that has been planted to soybeans in the last few years is unnecessary in that it did not improve nodulation or yield. Seed treatment formulations did not significantly affect soybean nodulation or yield. These results imply that fungicide, insecticide, or nematicide seed treatments are not associated with problems that have been observed on new soybean ground with no naturalized *Bradyrhizobium japonicum* population.

Table 1. Average nodule count (nodules/plant) in inoculant product study, 2011[1]

	Location[2]			
Treatment	Belleville	Manhattan	Osage	White City
ABM-Excalibre	2.6 f	12.8 a	3.7 e	0.9 bcd
ABM-ExcalibreSA	2.6 f	14.2 a	8.3 bcd	0.1 d
Vault HP	10.7 cd	12.9 a	12.2 a	1.9 bc
BU-Rhizo-Stick 2X	13.9 bc	16.5 a	6.7 cd	2.3 b
BU-Rhizo-Stick+BU Vault HP	8.2 de	14.4 a	10.0 ab	0.7 cd
NZ-Optimize	15.6 ab	12.1 a	9.7 ab	6.1 a
NZ-Optimize 2X	18.0 a	15.1 a	8.6 bc	6.7 a
Soil Implant+ + Optimize	17.5 ab	16.7 a	10.1 ab	6.8 a
Untreated check	5.8 ef	15.0 a	5.8 de	0.0 d

[1] Analysis tests for plant nitrogen content nodule quality and quantity were performed by removing 10 randomly selected plants from each plot to obtain a representative sample.
[2]Analysis of variance conducted using PROC MIXED in SAS (SAS Institute Inc., Cary, NC). Treatment means within a column followed by the same letter are not different ($\alpha = 0.05$).

Table 2. Yield (bu/acre) in inoculant product study, 2011

	Location[1,2]			
Treatment	Belleville	Manhattan	Osage	Scandia
ABM-Excalibre	55.9 abc	42.7 a	34.4 a	64.6 a
ABM-ExcalibreSA	58.2 abc	40.6 a	36.6 a	63.2 a
Vault HP	48.7 c	40.1 a	33.7 a	64.5 a
Rhizo-Stick + Vault HP	49.2 c	39.8 a	32.4 a	64.8 a
Rhizo-Stick 2X	61.2 ab	41.8 a	36.0 a	58.6 a
NZ-Optimize	53.3 bc	46.2 a	35.4 a	60.7 a
NZ-Optimize 2X	54.6 abc	43.8 a	34.1 a	58.2 a
Soil Implant+ +Optimize	63.5 a	38.9 a	34.0 a	56.8 a
Untreated (60 lb N/a)	54.0 abc	37.4 a	31.2 a	61.3 a
Untreated (120 lb N/a)	49.3 c	37.4 a	31.8 a	59.7 a
Untreated check	54.0 abc	37.4 a	31.2 a	61.3 a

[1] Analysis of variance conducted using PROC MIXED in SAS (SAS Institute Inc., Cary, NC).
[2] Treatment means within a column followed by the same letter do not differ ($\alpha = 0.05$).

Table 3. Seed nitrogen content (%) in inoculant product study, 2011

	Location[1,2]			
Treatment	Belleville	Manhattan	Osage	Scandia
ABM-Excalibre	5.4 abcd	5.5 a	5.8 a	5.5 a
ABM-ExcalibreSA	5.5 abc	5.5 a	5.8 a	5.6 a
Vault HP	5.4 abcd	5.5 a	5.8 a	5.6 a
BU-Rhizo-Stick 2X	5.5 abc	5.6 a	5.8 a	5.6 a
BU-Rhizo-Stick+BU Vault HP	5.4 bcd	5.5 a	5.7 a	5.6 a
NZ-Optimize	5.4 bcd	5.5 a	5.8 a	5.6 a
NZ-Optimize 2X	5.4 bcd	5.5 a	5.8 a	5.6 a
Soil Implant+ +Optimize	5.5 abc	5.6 a	5.8 a	5.6 a
Untreated (60 lb N/a)	5.4 bcd	5.4 d	5.8 a	5.5 a
Untreated (120 lb N/a)	5.4 cd	5.4 cd	6.0 a	5.6 a
Untreated check	5.5 abc	5.5 a	5.7 a	5.6 a

[1] Analysis of variance conducted using PROC MIXED in SAS (SAS Institute Inc., Cary, NC).
[2] Treatment means within a column followed by the same letter are not different ($\alpha = 0.05$).

Table 4. Average nodule count (nodules/plant) in seed treatments and inoculant interaction study, 2011[1]

		Location[2,3]		
Seed treatment	Inoculant	Belleville	Manhattan	White City
ApronMaxx RFC	NZ-Optimize	14.4 a	11.6 a	51.3 a
ApronMaxx RFC, Cruiser	NZ-Optimize	18.6 a	13.7 a	43.3 a
ApronMaxx RFC, Cruiser, Avicta	NZ-Optimize	11.0 a	13.4 a	45.0 a
ApronMaxx RFC, Poncho/Votivo	NZ-Optimize	15.5 a	12.8 a	45.3 a
None	NZ-Optimize	13.4 a	13.0 a	45.5 a

[1] Analysis tests for plant nitrogen content nodule quality and quantity were performed by removing 10 randomly selected plants from each plot to obtain a representative sample.
[2] Analysis of variance conducted using PROC MIXED in SAS (SAS Institute Inc., Cary, NC).
[3] Treatment means within a column followed by the same letter are not different ($\alpha = 0.05$).

Table 5. Plant dry mass (g) in seed treatments and inoculant interaction study, 2011[1]

		Location[2,3]		
Seed treatment	Inoculant	Belleville	Manhattan	White City
ApronMaxx RFC	NZ-Optimize	41.8 b	22.5 a	19.3 a
ApronMaxx RFC Cruiser	NZ-Optimize	54.4 a	21.4 a	23.1 a
ApronMaxx RFC Cruiser Avicta	NZ-Optimize	50.0 ab	22.5 a	23.3 a
ApronMaxx RFC Poncho/Votivo	NZ-Optimize	47.0 ab	21.6 a	19.9 a
None	NZ-Optimize	46.5 ab	23.1 a	19.7 a

[1]Analysis tests for plant nitrogen content nodule quality and quantity were performed by removing 10 randomly selected plants from each plot to obtain a representative sample.
[2]Analysis of variance conducted using PROC MIXED in SAS (SAS Institute Inc., Cary, NC).
[3] Treatment means within a column followed by the same letter are not different ($\alpha = 0.05$).

Table 6. Yield (bu/a) in seed treatments and inoculant interaction study, 2011

		Location[1,2]		
Seed treatment	Inoculant	Belleville	Manhattan	Scandia
ApronMaxx RFC	ABM-ExcalibreSA	46.7 bcde	47.8 a	64.5 a
ApronMaxx RFC, Cruiser	ABM-ExcalibreSA	49.7 abcde	48.2 a	60.5 a
ApronMaxx RFC, Cruiser, Avicta	ABM-ExcalibreSA	53.9 ab	48.9 a	65.1 a
ApronMaxx RFC, Poncho/Votivo	ABM-ExcalibreSA	45.0 de	50.1 a	61.6 a
None	ABM-ExcalibreSA	48.8 abcde	45.2 a	63.2 a
ApronMaxx RFC	BU-Vault HP	54.2 a	45.1 a	---
ApronMaxx RFC, Cruiser	BU-Vault HP	51.8 abcd	48.4 a	---
Apron Maxx RFC, Cruiser, Avicta	BU-Vault HP	42.9 e	48.3 a	---
ApronMaxx RFC, Poncho/Votivo	BU-Vault HP	48.5 abcde	45.5 a	---
None	BU-Vault HP	48.8 abcde	47.2 a	58.6 a
ApronMaxx RFC	NZ-Optimize	53.0 abc	49.9 a	63.2 a
ApronMaxx RFC, Cruiser	NZ-Optimize	48.5 abcde	46.2 a	60.9 a
ApronMaxx RFC, Cruiser, Avicta	NZ-Optimize	55.7 a	45.9 a	57.1 a
ApronMaxx RFC, Poncho/Votivo	NZ-Optimize	49.4 abcde	48.6 a	67.3 a
None	NZ-Optimize	46.4 cde	45.0 a	63.2 a

[1]Analysis of variance conducted using PROC MIXED in SAS (SAS Institute Inc., Cary, NC).
[2] Treatment means within a column followed by the same letter are not different ($\alpha = 0.05$).

Table 7. Average nodule count (nodules/plant) in inoculant product study, 2012[1]

	Location[2,3]				
Inoculant	Belleville	Manhattan	Osage	Phillipsburg 1	Phillipsburg 2
BU-Vault HP	9.62 de	12.60 a	5.62 a	1.43 bcde	5.23 bc
BU-Rhizo Stick 2X	13.13 cd	12.55 a	6.78 a	1.85 bcde	6.10 b
BU-Rhizo Stick+VaultHP	13.75 cd	14.08 a	7.60 a	1.64 bcde	6.83 b
BU-Vault HP 2X	13.93 bcd	11.78 a	6.00 a	2.15 bcd	6.05 bc
NZ-Cell Tech Granular+Optimize	23.29 a	16.30 a	8.33 a	8.52 a	14.25 a
NZ-Optimize	15.48 bc	13.60 a	7.55 a	3.28 b	7.90 b
NZ-Optimize 2X	18.83 ab	14.78 a	8.08 a	2.83 bc	8.58 b
TM-Maximize	6.23 e	13.98 a	9.63 a	0.38 de	0.70 d
TM-Maximize 2X	9.95 de	20.55 a	6.48 a	0.88 cde	2.08 cd
Untreated check	7.68 e	13.85 a	7.30 a	0.03 e	0.03 d

[1]Analysis tests for plant nitrogen content nodule quality and quantity were performed by removing 10 randomly selected plants from each plot to obtain a representative sample.
[2]Analysis of variance conducted using PROC MIXED in SAS (SAS Institute Inc., Cary, NC).
[3] Treatment means within a column followed by the same letter are not different ($\alpha = 0.05$).

Table 8. Yield (bu/a) in inoculant product study, 2012

	Location[1,2]				
Inoculant	Belleville	Manhattan	Osage	Phillipsburg 1	Phillipsburg 2
BU-Vault HP	26.67 a	64.82 a	64.82 a	15.44 a	20.15 a
BU-Rhizo Stick 2X	24.36 a	59.28 a	59.28 a	23.94 a	23.68 a
BU-Rhizo Stick+VaultHP	25.92 a	62.77 a	62.77 a	21.52 a	23.82 a
BU-Vault HP 2X	24.64 a	63.11 a	63.11 a	25.05 a	18.74 a
NZ-Cell Tech Granular + Optimize	28.48 a	61.16 a	61.16 a	28.10 a	23.11 a
NZ-Optimize	26.85 a	62.35 a	62.35 a	24.99 a	25.18 a
NZ-Optimize 2X	25.49 a	63.67 a	63.67 a	18.48 a	26.62 a
TM-Maximize	28.41 a	61.78 a	61.78 a	21.84 a	16.34 a
TM-Maximize 2X	28.67 a	55.09 a	55.09 a	17.27 a	20.89 a
Untreated check	25.29 a	---	---	---	---

[1] Analysis of variance conducted using PROC MIXED in SAS (SAS Institute Inc., Cary, NC).
[2] Treatment means within a column followed by the same letter are not different ($\alpha = 0.05$).

Table 9. Test weight (lb/bu) in inoculant product study, 2012

	Location[1,2]				
Inoculant	Belleville	Manhattan	Osage	Phillipsburg 1	Phillipsburg 2
BU-Vault HP	58.73 a	59.48 a	60.00 a	59.55 a	58.95 a
BU-Rhizo Stick 2X	58.95 a	58.75 a	60.25 a	58.83 abc	59.00 a
BU-Rhizo Stick+VaultHP	59.05 a	58.13 a	60.40 a	58.65 bcd	58.78 a
BU-Vault HP 2X	58.38 a	58.70 a	59.98 a	58.00 d	46.88 a
NZ-Cell Tech Granular + Optimize	58.88 a	58.80 a	60.00 a	58.50 bcd	46.60 a
NZ-Optimize	58.70 a	59.03 a	60.10 a	58.20 cd	58.83 a
NZ-Optimize 2X	58.98 a	58.70 a	59.90 a	59.25 ab	58.85 a
TM-Maximize	58.70 a	58.25 a	59.90 a	58.30 cd	58.73 a
TM-Maximize 2X	58.45 a	58.60 a	60.25 a	58.50 bcd	58.40 a
Untreated check	58.58 a	---	---	---	---

[1]Analysis of variance conducted using PROC MIXED in SAS (SAS Institute Inc., Cary, NC).
[2] Treatment means within a column followed by the same letter are not different ($\alpha = 0.05$).

Table 10. Weight of 300 seeds (g) in inoculant product study, 2012

	Location[1,2]				
Inoculant	Belleville	Manhattan	Osage	Phillipsburg 1	Phillipsburg 2
BU-Vault HP	37.33 a	41.10 a	43.71 a	28.78 a	27.33 cd
BU-Rhizo Stick 2X	36.33 a	40.23 a	45.14 a	29.52 a	29.56 ab
BU-Rhizo Stick+VaultHP	36.75 a	39.36 a	44.12 a	22.75 a	29.77 a
BU-Vault HP 2X	37.85 a	39.03 a	46.29 a	30.14 a	28.70 abc
NZ-Cell Tech Granular + Optimize	37.80 a	38.90 a	43.68 a	28.59 a	28.55 abc
NZ-Optimize	37.20 a	39.47 a	45.75 a	28.05 a	29.57 ab
NZ-Optimize 2X	36.33 a	39.06 a	45.39 a	27.87 a	28.02 bcd
TM-Maximize	36.78 a	39.28 a	44.24 a	29.15 a	26.44 d
TM-Maximize 2X	35.95 a	40.74 a	44.41 a	29.04 a	28.00 bcd
Untreated check	36.81 a	---	---	---	---

[1] Analysis of variance conducted using PROC MIXED in SAS (SAS Institute Inc., Cary, NC).
[2] Treatment means within a column followed by the same letter are not different ($\alpha = 0.05$).

Table 11. Seed nitrogen content (%) in inoculant product study, 2012

	Location[1,2]				
Inoculant	Belleville	Manhattan	Osage	Phillipsburg 1	Phillipsburg 2
BU-Vault HP	5.48 a	5.42 a	5.90 a	4.94 a	5.21 bc
BU-Rhizo Stick 2X	5.46 a	5.31 a	5.90 a	5.02 a	5.29 ab
BU-Rhizo Stick+VaultHP	5.49 a	5.47 a	5.95 a	5.04 a	5.36 ab
BU-Vault HP 2X	5.86 a	5.42 a	5.90 a	5.04 a	5.21 bc
NZ-Cell Tech Granular + Optimize	5.47 a	5.53 a	5.84 a	5.08 a	5.44 ab
NZ-Optimize	5.51 a	5.42 a	5.98 a	5.07 a	5.50 a
NZ-Optimize 2X	5.50 a	5.52 a	5.86 a	4.90 a	5.25 abc
TM-Maximize	5.47 a	5.54 a	5.92 a	5.00 a	4.78 d
TM-Maximize 2X	5.48 a	5.36 a	5.92 a	5.02 a	5.02 cd
Untreated check	5.42 a	---	---	---	---

[1] Analysis of variance conducted using PROC MIXED in SAS (SAS Institute Inc., Cary, NC).
[2] Treatment means within a column followed by the same letter are not different ($\alpha = 0.05$).

Table 12. Plant population (plants/a) in seed treatments and inoculant interaction study, 2012

		Location[1,2]		
Seed treatment	Inoculant	Belleville	Manhattan	Phillipsburg
None	BU-Vault HP	---	90,169 abc	65,993 cde
ApronMaxx RFC	BU-Vault HP	---	100,406 ab	82,546 ab
ApronMaxx RFC Cruiser	BU-Vault HP	---	96,180 ab	80,736 abc
ApronMaxx RFC Cruiser Avicta	BU-Vault HP	---	97,574 ab	88,467 a
ApronMaxx RFC Poncho/Votivo	BU-Vault HP	---	97,792 ab	80,368 abcd
None	NZ-Optimize	---	80,586 cd	67,954 bcde
ApronMaxx RFC	NZ-Optimize	---	98,446 ab	79,933 abcd
ApronMaxx RFC Cruiser	NZ-Optimize	---	93,436 abc	74,270 abcde
ApronMaxx RFC Cruiser Avicta	NZ-Optimize	---	101,495 a	82,111 ab
ApronMaxx RFC Poncho/Votivo	NZ-Optimize	---	97,574 ab	83,417 ab
None	TM-Maximize	---	86,249 bcd	65,122 de
ApronMaxx RFC	TM-Maximize	---	99,970 ab	74,270 abcde
ApronMaxx RFC Cruiser	TM-Maximize	---	101,495 a	78,190 abcd
ApronMaxx RFC Cruiser Avicta	TM-Maximize	---	103,455 a	82,546 ab
ApronMaxx RFC Poncho/Votivo	TM-Maximize	---	97,139 ab	73,834 abcde
None	None	---	72,092 d	60,984 e

[1] Analysis of variance conducted using PROC MIXED in SAS (SAS Institute Inc., Cary, NC).
[2] Treatment means within a column followed by the same letter are not different ($\alpha = 0.05$).

Table 13. Average nodule count (nodules/plant) in seed treatments and inoculant interaction study, 2012[1]

		Location[2,3]		
Seed treatment	Inoculant	Belleville	Manhattan	Phillipsburg
None	NZ-Optimize	10.30 a	13.23 a	2.88 b
ApronMaxx RFC	NZ-Optimize	15.24 a	10.80 a	2.35 b
ApronMaxx RFC Cruiser	NZ-Optimize	15.67 a	17.63 a	4.58 a
ApronMaxx RFC Cruiser Avicta	NZ-Optimize	12.82 a	16.73 a	1.85 b
ApronMaxx RFC Poncho/Votivo	NZ-Optimize	10.93 a	15.20 a	2.29 b
None	None	15.17 a	12.15 a	0.10 c

[1] Analysis tests for plant nitrogen content nodule quality and quantity were performed by removing 10 randomly selected plants from each plot to obtain a representative sample.
[2] Analysis of variance conducted using PROC MIXED in SAS (SAS Institute Inc., Cary, NC).
[3] Treatment means within a column followed by the same letter are not different ($\alpha = 0.05$).

Table 14. Yield (bu/a) in seed treatments and inoculant interaction study, 2012

		Location[1,2]		
Seed treatment	Inoculant	Belleville	Manhattan	Phillipsburg
ApronMaxx RFC	BU-Vault HP	25.75 a	58.19 a	25.71 a
ApronMaxx RFC Cruiser	BU-Vault HP	23.49 a	53.67 a	29.55 a
ApronMaxx RFC Cruiser Avicta	BU-Vault HP	23.81 a	57.89 a	28.52 a
ApronMaxx RFC Poncho/Votivo	BU-Vault HP	24.33 a	52.99 a	26.62 a
None	BU-Vault HP	25.14 a	49.64 a	23.73 a
ApronMaxx RFC	TM-Maximize	25.21 a	56.76 a	22.46 a
ApronMaxx RFC Cruiser	TM-Maximize	23.53 a	55.34 a	24.55 a
ApronMaxx RFC Cruiser Avicta	TM-Maximize	24.27 a	57.77 a	24.66 a
ApronMaxx RFC Poncho/Votivo	TM-Maximize	24.08 a	53.57 a	28.05 a
None	TM-Maximize	27.70 a	51.64 a	23.60 a
ApronMaxx RFC	NZ-Optimize	23.43 a	53.30 a	20.36 a
ApronMaxx RFC Cruiser	NZ-Optimize	26.59 a	62.30 a	20.76 a
ApronMaxx RFC Cruiser Avicta	NZ-Optimize	27.76 a	56.81 a	30.41 a
ApronMaxx RFC Poncho/Votivo	NZ-Optimize	26.75 a	56.94 a	20.40 a
None	NZ-Optimize	26.75 a	52.80 a	24.27 a
None	None	25.29 a	---	---

[1] Analysis of variance conducted using PROC MIXED in SAS (SAS Institute Inc., Cary, NC).
[2] Treatment means within a column followed by the same letter are not different ($\alpha = 0.05$).

Table 15. Test weight (lb/bu) in seed treatments and inoculant interaction study, 2012

		Location		
Seed treatment	Inoculant	Belleville	Manhattan	Phillipsburg
ApronMaxx RFC	BU-Vault HP	58.93 a	58.70 bcd	59.58 a
ApronMaxx RFC Cruiser	BU-Vault HP	58.30 a	58.25 d	58.33 a
ApronMaxx RFC Cruiser Avicta	BU-Vault HP	58.48 a	59.10 abcd	58.23 a
ApronMaxx RFC Poncho/Votivo	BU-Vault HP	58.68 a	58.70 bcd	58.28 a
None	BU-Vault HP	58.80 a	58.48 cd	58.40 a
ApronMaxx RFC	TM-Maximize	58.33 a	59.08 abcd	58.35 a
ApronMaxx RFC Cruiser	TM-Maximize	58.35 a	59.73 a	57.83 a
ApronMaxx RFC Cruiser Avicta	TM-Maximize	58.35 a	59.10 abcd	58.28 a
ApronMaxx RFC Poncho/Votivo	TM-Maximize	58.68 a	59.15 abc	58.58 a
None	TM-Maximize	58.73 a	58.28 d	58.28 a
ApronMaxx RFC	NZ-Optimize	58.68 a	59.15 abc	58.40 a
ApronMaxx RFC Cruiser	NZ-Optimize	58.73 a	59.35 ab	58.35 a
ApronMaxx RFC Cruiser Avicta	NZ-Optimize	58.63 a	59.20 abc	57.93 a
ApronMaxx RFC Poncho/Votivo	NZ-Optimize	58.70 a	58.88 abcd	58.08 a
None	NZ-Optimize	58.90 a	58.85 bcd	58.38 a
None	None	58.58 a	---	---

[1] Analysis of variance conducted using PROC MIXED in SAS (SAS Institute Inc., Cary, NC).
Treatment means within a column followed by the same letter are not different ($\alpha = 0.05$).

Table 16. Seed nitrogen content (%) in seed treatments and inoculant interaction study, 2012

		Location[1,2]		
Seed treatment	Inoculant	Belleville	Manhattan	Phillipsburg
ApronMaxx RFC	BU-Vault HP	5.47 a	5.51 a	5.20 ab
ApronMaxx RFC Cruiser	BU-Vault HP	5.48 a	5.52 a	5.13 bc
ApronMaxx RFC Cruiser Avicta	BU-Vault HP	5.40 a	5.54 a	5.24 ab
ApronMaxx RFC Poncho/Votivo	BU-Vault HP	5.48 a	5.52 a	5.03 c
None	BU-Vault HP	5.46 a	5.47 a	5.15 b
ApronMaxx RFC	TM-Maximize	5.46 a	5.45 a	5.20 ab
ApronMaxx RFC Cruiser	TM-Maximize	5.55 a	5.54 a	5.15 bc
ApronMaxx RFC Cruiser Avicta	TM-Maximize	5.40 a	5.49 a	5.30 a
ApronMaxx RFC Poncho/Votivo	TM-Maximize	5.47 a	5.50 a	5.23 ab
None	TM-Maximize	5.45 a	5.44 a	5.20 ab
ApronMaxx RFC	NZ-Optimize	5.50 a	5.51 a	5.19 ab
ApronMaxx RFC Cruiser	NZ-Optimize	5.46 a	5.45 a	5.14 bc
ApronMaxx RFC Cruiser Avicta	NZ-Optimize	5.41 a	5.48 a	5.13 bc
ApronMaxx RFC Poncho/Votivo	NZ-Optimize	5.43 a	5.48 a	5.22 ab
None	NZ-Optimize	5.49 a	5.52 a	5.19 ab
None	None	5.42 a	---	----

[1] Analysis of variance conducted using PROC MIXED in SAS (SAS Institute Inc., Cary, NC).
[2] Treatment means within a column followed by the same letter are not different ($\alpha = 0.05$).

Table 17. Weight of 300 seeds (g) in seed treatments and inoculant interaction study, 2012

		Location[1,2]		
Seed treatment	Inoculant	Belleville	Manhattan	Phillipsburg
ApronMaxx RFC	BU-Vault HP	36.43 a	41.38 a	28.21 cd
ApronMaxx RFC Cruiser	BU-Vault HP	35.93 a	38.92 a	30.64 a
ApronMaxx RFC Cruiser Avicta	BU-Vault HP	37.58 a	39.82 a	29.75 abcd
ApronMaxx RFC Poncho/Votivo	BU-Vault HP	36.65 a	41.83 a	28.55 abcd
None	BU-Vault HP	35.08 a	40.86 a	29.03 abcd
ApronMaxx RFC	TM-Maximize	37.88 a	41.85 a	28.61 abcd
ApronMaxx RFC Cruiser	TM-Maximize	36.10 a	39.87 a	29.55 abcd
ApronMaxx RFC Cruiser Avicta	TM-Maximize	36.20 a	39.41 a	28.44 cd
ApronMaxx RFC Poncho/Votivo	TM-Maximize	35.90 a	41.08 a	30.57 ab
None	TM-Maximize	36.38 a	41.87 a	29.44 abcd
ApronMaxx RFC	NZ-Optimize	36.68 a	39.24 a	28.69 abcd
ApronMaxx RFC Cruiser	NZ-Optimize	36.98 a	40.62 a	28.12 d
ApronMaxx RFC Cruiser Avicta	NZ-Optimize	38.65 a	39.37 a	30.25 abc
ApronMaxx RFC Poncho/Votivo	NZ-Optimize	36.48 a	42.17 a	28.47 bcd
None	NZ-Optimize	36.50 a	39.46 a	28.86 abcd
None	None	36.81 a	---	---

[1] Analysis of variance conducted using PROC MIXED in SAS (SAS Institute Inc., Cary, NC).
[2] Treatment means within a column followed by the same letter are not different ($\alpha = 0.05$).

Improving the Performance of Winter Wheat Planted Without Tillage after Grain Sorghum

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Summary
No-till management systems have increased in acres throughout Kansas in the past two decades. No-till has improved soil water conservation while helping reduce soil erosion. The increased amount of available soil water associated with no-till has allowed growers to intensify and diversify their crop rotations, resulting in more acres of winter wheat planted following summer row crops. Grain sorghum and winter wheat are two common crops in Kansas and are adapted to similar growing environments. Previous rotation research has revealed that wheat often performs worse following grain sorghum compared with other summer row crops. The objective of this study was to evaluate various residue and harvest management strategies in no-till systems to improve winter wheat yields following grain sorghum. Three management factors were: glyphosate (preharvest application, postharvest application, and no application), residue (residue removal, residue chopped, and residue left standing), and nitrogen (additional 30 lb/a applied to residue and no additional nitrogen applied). The study was conducted at three locations in Kansas that have environments conducive for planting winter wheat following a summer row crop. No interactions were observed among the treatments and locations, so results were combined over the three locations. Preharvest glyphosate application, leaving sorghum residue in place, and additional nitrogen application tended to result in improved values for most yield components of winter wheat at various stages of development. Wheat yields increased by 5 bu/a with preharvest application of glyphosate to the preceding sorghum crop and decreased by 3 to 4 bu/a with residue chopping or removal. Application of additional nitrogen to the stubble did not improve wheat yields.

Introduction
Grain sorghum and winter wheat are two major crops produced in Kansas. Previous research has revealed that wheat yields following grain sorghum often are reduced compared with wheat yields following other summer row crops grown in Kansas. Sorghum and wheat are grown in semi-arid regions where no-till has become popular due its ability to conserve soil moisture. Determining effective management strategies for grain sorghum to improve yields of the subsequent wheat crop in no-till is essential for improving cropping system productivity in the Great Plains region.

The objective of this study was to identify combinations of grain sorghum harvest and residue management techniques that are effective for improving success of wheat planted after sorghum in no-till systems.

Procedures
This is the first year of a 2-year study. Experiments were conducted at three Kansas State University Research Stations: Belleville, Manhattan, and Ottawa. Plots were 300 ft^2 except at the Manhattan location, where plots were 500 ft^2. The experiment was

arranged in a randomized complete block design with four replications and a 3-way factorial treatment structure. Three management factors evaluated were: glyphosate (preharvest application, postharvest application, and no application), residue (residue removal, residue chopped, and residue left standing), and nitrogen (additional 30 lb/a applied to residue and no additional nitrogen applied).

Grain sorghum hybrids were selected that are suitable to the areas of interest. A medium-early season hybrid, DKS 36-06, was planted at the Manhattan and Ottawa sites, and an early season hybrid, DKS 28-05, was used at Belleville. Preharvest applications of glyphosate to the sorghum crop were performed when grain moisture was 18 to 22%. Glyphosate applied to the sorghum residue postharvest was completed within 1 to 3 days following harvest. Residue and nitrogen treatments were applied approximately 7 days after the postharvest glyphosate treatment. Nitrogen was applied to the sorghum residue as urea-ammonium nitrate (UAN; 28-0-0).

Wheat was planted within the dates recommended by Kansas State University. Yield components observed throughout the growing season were population, fall and spring tiller numbers, head numbers, and spikelets per head. Grain was harvested from the middle 5 ft of each plot using a specialized plot combine.

Results

Grain sorghum yield and moisture are shown in Figure 1. Preharvest applications of glyphosate to the sorghum crop did not significantly affect sorghum yields. Grain moisture was less following the glyphosate treatment, but the observed differences would not affect harvest management decisions.

Treatments did influence winter wheat development (Table 1). Population, fall tiller numbers, and final head counts were greater following preharvest glyphosate compared with treatments that had no glyphosate applied. Leaving residue on the soil surface improved population numbers but had no influence on fall tiller numbers. Spring tiller development was less where residue was removed, but there was no difference in total head number following residue treatments. Applying additional nitrogen to the sorghum residue did not affect wheat population or fall tiller numbers. Nitrogen treatments did improve later stages of wheat development, increasing both spring tiller and head numbers. Spikelet numbers were not influenced by any of the evaluated treatments.

Winter wheat yields were influenced by both glyphosate and residue treatments (Figure 2). Glyphosate applied to the sorghum crop preharvest improved yield of the following wheat crop by 5 bu/a. Wheat yields were decreased following either chopping or removal of residue. Additional nitrogen beyond that currently recommended for wheat following sorghum had minimal influence on wheat yield.

Table 1. Winter wheat yield components

Treatments		Yield components[1]				
		Population (plants/m)	Fall tillers (tillers/m)	Spring tillers (tillers/m)	Heads (heads/m)	Spikelets (spikelets/head)
Glyphosate	Preharvest	45 a	89 a	220 a	110 a	14 a
	Postharvest	44 ab	87 a	211 b	106 ab	13 a
	Untreated	42 b	81 b	213 ab	102 b	13 a
Residue	Chopped	45 a	86 a	218 a	106 a	13 a
	Removed	42 b	86 a	208 b	103 a	13 a
	Untreated	44 a	85 a	219 a	107 a	14 a
Nitrogen	Applied	44 a	87 a	219 a	108 a	13 a
	Untreated	44 a	85 a	211 b	103 b	13 a

[1] Column means within treatments followed by the same letter are not significantly different (α = 0.05).

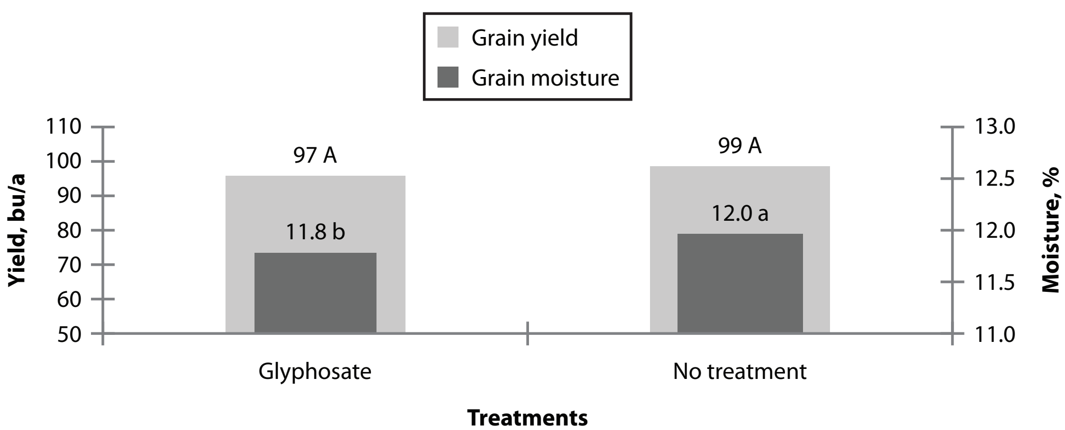

Figure 1. Grain sorghum yields and moisture following glyphosate treatment. Treatment means followed by the same letter are not significantly different (α = 0.05; capital letters indicate grain yield differences, lowercase letters indicate grain moisture differences).

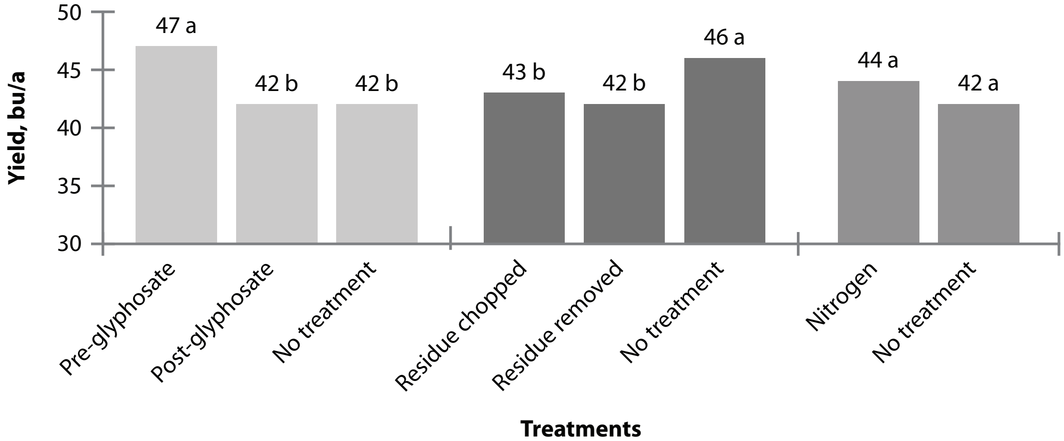

Figure 2. Winter wheat yields following sorghum treatments.
Within residue treatments, means followed by the same letter are not significantly different ($\alpha = 0.05$).

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