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East Central Kansas Experiment Field

Introduction

The research program at the East Central Kansas Experiment Field is designed to enhance the area's agronomic agriculture. Specific objectives are to (1) identify top performing varieties and hybrids of wheat, corn, grain sorghum, and soybean, (2) determine the amount of tillage necessary for optimum crop production, (3) evaluate weed control practices by using chemical, nonchemical, and combination methods, and (4) test fertilizer rates and application methods for crop efficiency and environmental effects.

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.

2008 Weather Information

Precipitation during 2008 totaled 45.5 in., which was 8.68 in. above the 35-year average (Table 1). Most of the extra moisture occurred from increased precipitation during February, June, and September. Precipitation for January, April, and November was below average. The coldest days during 2008 occurred in January, March, and December with 18 days in single digits. The overall coldest temperature was -1.0°F on January 24. There were 22 days during the summer of 2008 on which temperatures exceeded 90.0°F. During the hottest 5-day period, August 1 to 5, temperatures averaged 96.4°F. On the hottest day, August 28, the temperature reached 99.3°F. The last freeze in the spring was April 14 (average, April 18), and the first killing frost in the fall was October 27 (average, October 21). The number of frost-free days was 195 (long-term average, 185).

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

Month	2008	35-year avg.	Month	2008	35-year avg.
	-----------in.-----------			-----------in.-----------	
January	0.82	1.03	July	3.40	3.37
February	3.24	1.32	August	3.85	3.59
March	2.99	2.49	September	7.87	3.83
April	2.74	3.50	October	4.02	3.43
May	5.37	5.23	November	1.44	2.32
June	7.77	5.21	December	1.95	1.45
Annual total				45.46	36.78

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

K. A. Janssen

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

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

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

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

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

Results

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

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

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

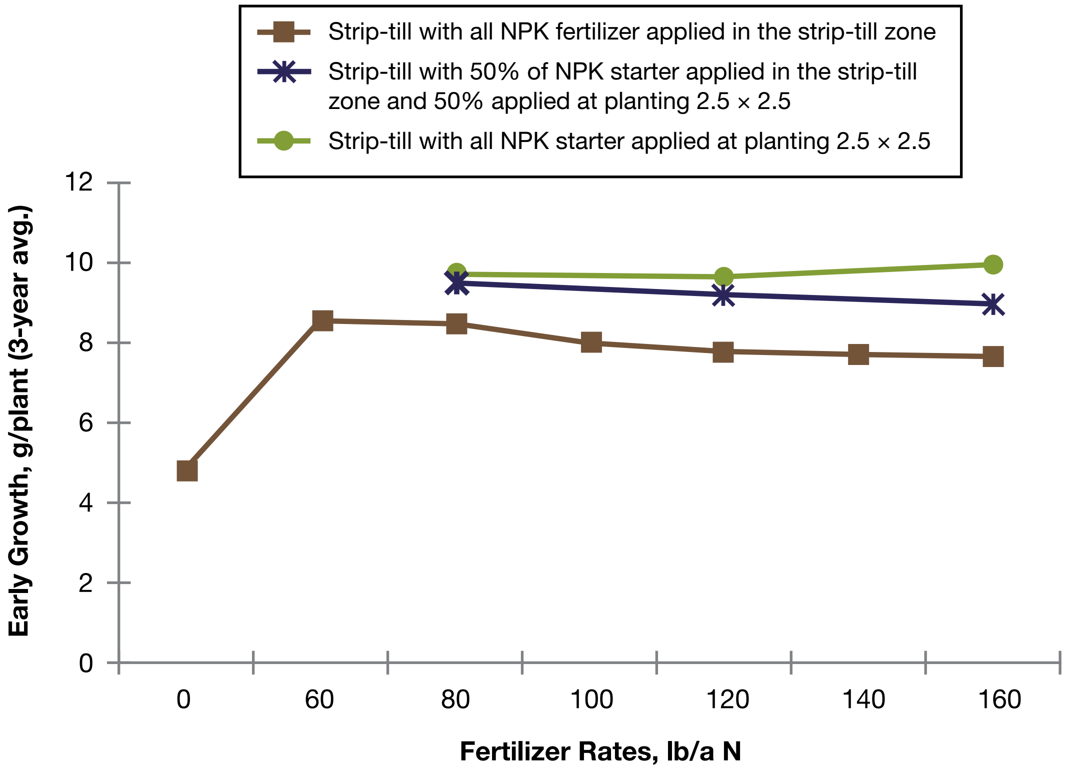

Figure 1. Nitrogen rates and starter NPK fertilizer placement effects on 6-leaf stage growth of strip-till corn.

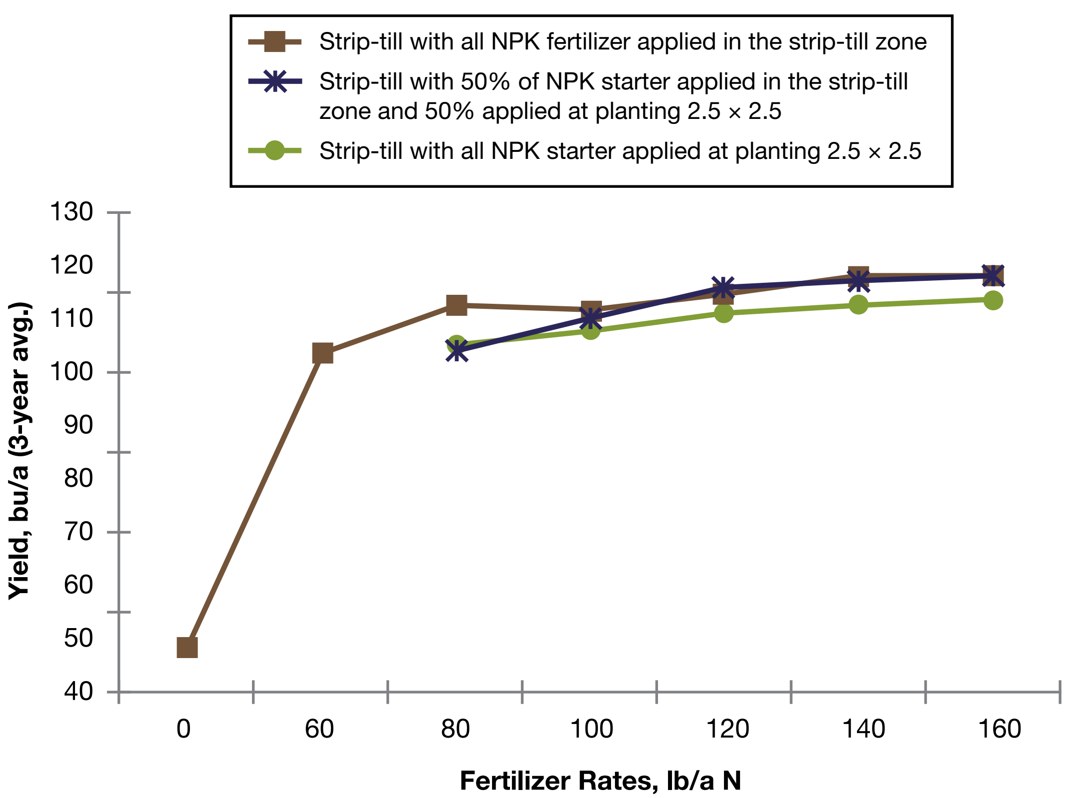

Figure 2. Nitrogen rates and starter NPK fertilizer placement effects on yield of strip-till corn.

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

K. A. Janssen

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

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

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

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

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

Procedures

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

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

Results

Moisture for pollination and grain fill for 2006, 2007, and the May planting date of 2008 was below average. Seasonal moisture was above average for the June planting date in 2008. Overall, few differences in plant stands were observed between strip tillage and no-till in these experiments (data not shown). In 2006, early season grain sorghum growth, days to half bloom, and grain yields were similar for strip-till and no-till planted sorghum (Table 1). In 2007, when two hybrids were planted in June, strip tillage increased early growth slightly and increased grain yields 3 to 6 bu/a, on average, compared with no-till (Table 2). The largest yield differences occurred with Pioneer 84G62, a long-season hybrid. In 2008, early season sorghum growth was again similar for both the May- and June-planted strip-till and no-till systems, but yield for June-planted sorghum was significantly affected (Table 3). Strip-till yield, averaged over all N rates, was 12 bu/a less than no-till yield. Fertilizer N for the 2008 strip-till sorghum was applied April 30 during the strip-till operation, and fertilizer N for the no-till sorghum was applied at planting on June 19. Twelve inches of rain fell between these two dates of application. Thus, we believe that some strip-till fertilizer N was lost and that is what caused most of the yield difference. Overall, application of starter fertilizer at planting for strip-till fertilized sorghum had little effect on early season sorghum growth and yields, except for the June-planted sorghum in 2008. Starter (30-20-10) applied at planting for

the June 2008 sorghum increased strip-till sorghum yield by 10 bu/a compared with all starter applied in the strip-till zone. This single response to starter further confirms that N had been lost from the earlier strip-till fertilizer. For both tillage systems, 60 to 90 lb/a N optimized grain sorghum yields following soybean when moisture was limited. Up to 150 lb/a N was required to maximize yields for sorghum planted in June 2008, when rainfall was greater, yield potential was higher, and N losses were evident. Additional years of testing with more normal rainfall amounts are needed before meaningful N rate recommendations for strip-till and no-till sorghum can be made. Also, more years of research comparing strip-till and no-till systems at early planting dates are needed before recommendations can be made regarding best tillage systems for planting grain sorghum early and at the traditional planting time. These studies will continue in 2009.

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

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

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

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

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

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

Planting Date, Hybrid Maturity, and Plant Population Effects on Strip-Till Corn

L. D. Maddux

Summary
Three planting dates (March 15, April 1, and April 15); three corn hybrids with comparative relative maturity (CRM) of approximately 98, 105, and 113 days; and three plant populations (18,000, 22,000, and 26,000 plants/a) were evaluated from 2006 to 2008 near Ottawa, KS. Over the 3 years, actual planting dates varied considerably from the attempted planting dates because of weather conditions. The March 15 planting date froze out in 2007. All 3 years had a stressful, dry period during July and August. Plant populations were close to desired populations, except in 2008, when cool, wet soil conditions resulted in lower population for the first two planting dates. The earliest planting dates did not always significantly change the date that corn reached half-silk compared with the second planting date. Days to half-silk were often different among years for similar planting dates. From these 3 years of data, it was concluded that the optimum planting date would be from about March 25 to April 15. The corn hybrid with a 105 CRM at a plant population of 22,000 plants/a appeared to be the best choice when averaged over the 3 years.

Introduction
During the past few years, corn acreage in east central Kansas has increased. This study was designed to evaluate the effects of three planting dates, three plant populations, and three corn hybrids of various maturities.

Procedures
Three corn hybrids of different maturities were planted from 2006 to 2008 on a Woodson silt loam at the East Central Kansas Experiment Field. Pioneer brand hybrids (and their approximate CRM) planted in 2006-2007 and 2008, respectively, were: 38H66 and 38H65 (98 day); 35P80 and 35P10 (105 day); and 33B49 and 33B54 (113 day). Seed was planted at 19,800, 24,200, and 28,600 seeds/a to obtain final populations of 18,000, 22,000, and 26,000 plants/a. Planting dates of March 15, April 1, and April 15 were attempted. Actual planting dates in 2006 were close: March 13, March 29, and April 13. In 2007, the first planting was made March 19. Unseasonable warm weather resulted in faster emergence than in 2006, and an extreme cold spell on April 7 and 8 resulted in 100% loss of the corn. The second planting date in 2007 was April 5, and the third planting date was delayed by wet weather until May 16. The first planting date was replanted June 7. In 2008, wet spring weather resulted in planting dates of March 28, April 16, and April 30. Corn was planted following a previous crop of soybean each year. Fertilizer (120-30-30) was applied with a strip-till applicator prior to planting. Recommended herbicides were applied for weed control. Plots were harvested with a JD 3300 plot combine.

Results

Plant populations obtained were close to the desired populations in 2006 and 2007 (Table 1). In 2008, stands were decreased from that desired because of wet soil conditions at the March 28 and April 16 planting dates. Corn planted March 13, 2006, emerged only 3 days before corn planted March 29, and these plants reached 50% silking on approximately the same dates (Table 2). Corn planted on the third planting date reached 50% silking about 8 days later. In 2007, corn planted March 19 emerged quickly and was killed by cold weather. The second planting date (April 5) was the only one close to the proper date. The third planting date was delayed by wet weather until May 16, and the first planting date was replanted on June 7. Hybrids planted on the second planting date in 2007 reached 50% silking, similar to corn planted on the second planting date in 2006 (planted 5 days later and silked 3 to 5 days later). Corn from the third planting date and the replanted first planting date were silking in mid to late July under considerable moisture stress. In 2008, wet weather delayed planting again. The first date of planting was March 28, and the second planting date was April 16, which corresponds to the desired second and third planting dates. The 50% silking date for the March 28 planting date was later than for the March 29, 2006, planting date, probably because the wetter, cooler weather in 2008 resulted in slower corn growth. Corn planted April 16, 2008, silked about the same time as corn planted March 28. As the relative maturity of the corn hybrid increased, length to half-silk usually increased but varied among planting dates and years.

Grain yields (Table 3) were not significantly different ($P<0.05$) in 2006, although corn from the March 29 planting date had the highest yield, and corn from the April 13 date had the lowest yield. In 2007, yields were highest with the April 5 planting date and also higher than in 2006. Yields decreased with delayed planting in 2007; corn planted June 7 yielded less than half as much as corn planted April 5. Yields in 2008 were similar to the April 5, 2007, yields, with no significant differences between the March 28 and April 16 planting dates. However, yields of the 98 and 105 CRM hybrids planted April 30 were slightly higher than those of the 113 CRM hybrid, especially at the 22,000 plants/a population. No significant differences in yields among hybrids or plant populations were observed in 2006. However, populations of 22,000 and 26,000 plants/a tended to yield higher at the early planting date, whereas 18,000 plants/a tended to yield higher at the April 13 planting date. In 2007, PI 35P80 (113 CRM) yielded higher than the other two hybrids, and no consistent response to plant population was observed.

These results indicate that responses to planting date, plant population, and hybrid maturity will vary from year to year. However, it appears from these data that the optimum planting date is from March 25 to April 15. The best choice of hybrid maturity appears to be the 105-day maturity, followed by the 98-day and then the 113-day maturity. The best plant population appears to be 22,000 plants/a, although 26,000 plants/a resulted in a higher yield a couple of times. However, it is doubtful that the extra seed cost would result in a return on investment when averaged over years.

Table 1. Actual plant populations obtained as affected by hybrid maturity, planting population, and planting date, East Central Kansas Experiment Field, Ottawa, 2006-2008

		Plant population								
Hybrid maturity	Desired population	3/13/06	3/28/08	3/29/06	4/05/07	4/13/06	4/16/08	4/30/08	5/16/07	6/07/07
days	---plants/a---									
98	18,000	18,656	13,649	18,804	19,239	19,384	17,933	20,692	18,441	19,167
	22,000	23,232	17,424	23,886	23,014	23,523	20,837	24,757	24,031	23,668
	26,000	26,499	21,345	25,265	25,265	25,628	21,272	27,734	27,516	26,717
105	18,000	17,497	14,738	19,747	17,932	18,223	16,335	18,949	19,021	20,110
	22,000	22,143	13,576	22,143	23,232	23,595	18,804	23,958	23,595	24,539
	26,000	25,192	15,972	25,991	25,991	24,684	24,612	26,427	28,242	28,169
113	18,000	16,916	14,085	19,747	15,827	18,441	17,787	19,675	19,384	19,820
	22,000	21,272	19,239	19,893	19,893	24,539	20,038	24,176	24,539	23,813
	26,000	23,305	21,490	23,886	23,886	25,991	24,031	28,096	19,201	28,314

Wet soil conditions and subsequent rain resulted in poor stands at the first 2008 planting date.

Table 2. Days after June 1 to half-silk of corn as affected by hybrid maturity, plant population, and planting date, East Central Kansas Experiment Field, Ottawa, 2006-2008

		Days to half-silk								
Hybrid maturity	Desired population	3/13/06	3/28/08	3/29/06	4/05/07	4/13/06	4/16/08	4/30/08	5/16/07	6/07/07
days	plants/a	---days---								
98	18,000	19	30	19	21	27	30	35	41	53
	22,000	19	30	20	21	25	30	35	42	54
	26,000	19	30	20	21	25	30	35	42	54
105	18,000	21	28	21	25	27	36	35	44	56
	22,000	21	28	22	25	28	29	35	44	57
	26,000	22	29	22	25	29	29	35	44	56
113	18,000	23	31	23	28	32	32	37	47	61
	22,000	23	33	23	28	32	31	38	47	62
	26,000	24	32	24	28	33	32	38	47	62

Table 3. Corn yield as affected by hybrid maturity, plant population, and planting date, East Central Kansas Experiment Field, Ottawa, 2006-2008

		Yield								
Hybrid maturity	Desired population	3/13/06	3/28/08	3/29/06	4/05/07	4/13/06	4/16/08	4/30/08	5/16/07	6/07/07
days	plants/a	---bu/a[1] at 15.5%---								
98	14,000[2]		91							
	18,000	92	101	103	118	88	108	110	95	64
	22,000	106	118	110	111	89	116	127	101	62
	26,000	107		108	119	91	107	115	92	58
105	14,000[2]		100							
	18,000	95	116[3]	103	130	100	109	120	111	66
	22,000	96		100	128	93	108	124	96	60
	26,000	93		102	146	95	125	120	93	60
113	14,000[2]		108							
	18,000	93	95	88	115	92	114	111	97	53
	22,000	100	106	89	123	89	106	107	98	39
	26,000	103		91	123	93	107	117	101	43

[1] At 15.5% moisture.
[2] Approximate population obtained with the first planting date in 2008.
[3] Actual population was about 16,000.

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.

2008 Weather Information

The frost-free season was 196 days at the Paramore and Rossville Units (average = 173 days). The last spring freeze was April 14 (average = April 21), and the first fall freeze was October 27 (average = October 11) at both fields. There were only 25 and 21 days above 90°F at the Paramore and Rossville Units, respectively. Precipitation was average at the Rossville Unit and 6 in. below normal at the Paramore Unit for the growing season (Table 1). Precipitation was below average from November through April and above normal in June, July, and September. Precipitation in May and August was about normal. Some sudden death syndrome was observed in soybean, but the disease was not as bad as in previous years. Corn yield was excellent, and soybean yield was fair at both fields.

Table 1. Precipitation at the Kansas River Valley Experiment Field

	Rossville Unit		Paramore Unit	
Month	2007-2008	30-year avg.	2007-2008	30-year avg.
	-----------in.-----------		-----------in.-----------	
October	4.24	0.95	4.14	0.95
November	0.10	0.89	0.10	1.04
December	1.83	2.42	0.86	2.46
January	0.22	3.18	0.20	3.08
February	2.23	4.88	1.73	4.45
March	1.73	5.46	1.33	5.54
April	2.54	3.67	1.92	3.59
May	3.78	3.44	2.68	3.89
June	5.60	4.64	3.77	3.81
July	5.15	2.97	3.62	3.06
August	1.97	1.90	1.79	1.93
September	6.52	1.24	5.51	1.43
Total	35.91	35.64	29.44	35.23

Corn Herbicide Performance Test

L. D. Maddux

Summary

Two tests were conducted at the Rossville Unit. Herbicide applications consisting of preemergence (PRE), two-pass (PRE plus early or mid-postemergence [EP or MP]), and EP were compared. Ratings made on July 2 showed that most treatments gave greater than 90% control of large crabgrass (LC), palmer amaranth (PA), and common sunflower (CS). Only one rating was less than 80%. Control of ivyleaf morningglory (IM) was lower, with several treatments having less than 90% control and two treatments having less than 80% control. All treatments resulted in much greater yield than the untreated check, and there was little difference among treatments.

Introduction

Controlling weeds in row crops with chemical weed control and cultivation can reduce weed competition and, in turn, weed yields. Timeliness of application is a major factor in effective weed control. This study compared effectiveness of 15 herbicide treatments including PRE, EP, and PRE plus EP or PRE plus MP for controlling LC, PA, CS, and IM.

Procedures

Two tests were conducted on a Eudora silt loam soil previously cropped to soybean at the Rossville Unit. Test 1 consisted of 10 treatments plus an untreated check, and Test 2 consisted of 22 treatments plus an untreated check. The tests were conducted next to each other on soil with a pH of 6.9 and an organic matter content of 1.1%. Corn hybrid Hoegemeyer 8778, Herculex, LL RR2 was planted May 5 at 29,600 seeds/a in 30-in. rows. Anhydrous ammonia at 150 lb/a nitrogen (N) was applied preplant, and 120 lb/a of 10-34-0 fertilizer was banded at planting. Herbicides were broadcast in 15 gal/a with 8003XR flat fan nozzles at 17 psi. The experimental design was a randomized complete block with three replications. PRE applications were made May 5. EP applications were applied June 3 to 4-leaf corn, 1- to 3-in. LC, 2- to 8-in. PA, 2- to 8-in. CS, and 1- to 2-in. IM. MP treatments were applied June 18 to 8-leaf corn, 1- to 3-in. LC, 2- to 6-in. PA, 2- to 8-in. CS, and 2- to 4-in. IM. Populations of all four weed species were moderate to heavy. However, weed populations were generally fairly light at the time of postemergence treatment in plots that received a PRE treatment. Plots were not cultivated. The reported weed control ratings were made July 2. A total of 0.83 in. of rain was received from May 8 to 10. Plots were irrigated as needed. The test was harvested September 30 with a modified John Deere 3300 plot combine.

Results

Rainfall of 0.83 in. occurred within 5 days following planting. No crop injury from the PRE, EP, or MP treatments was observed (data not reported). In Test 1, excellent control (greater than 90%) of PA and CS was obtained with most treatments (Table 1). Control of LC and IM was generally satisfactory, although a couple of treatments resulted in less than 80% control. In Test 2, most treatments gave greater than 90% control of all four weeds (Table 2). The PRE-only treatments usually had the lowest control of LC, PA, and

IM. Grain yields were excellent, with little difference among treatments. Check plots in Test 1 had so many weeds, especially sunflower, that they were unable to be harvested, and yield of check plots in Test 2 averaged 80 bu/a.

Table 1. Effects of preemergence and postemergence herbicides on weed control and grain yield of corn, Kansas River Valley Experiment Field, Rossville, 2008

Treatment	Rate	Application time[1]	Weed control, July 2[2] LC	PA	CS	IM	Grain yield
			----------------	%	----------------		bu/a
Untreated check	–	–	0	0	0	0	0
Halex GT	3.6 pt/a	EP	100	100	100	98	235
+ AMS + NIS	+ 2.5 lb/a + 0.25% v/v						
Halex GT + AAtrex	3.6 pt/a	EP	100	100	100	100	224
+ AMS + NIS	+ 2.5 lb/a + 0.25% v/v						
Touchdown Total	24 oz/a	EP	87	97	98	88	216
+ AMS	2.5 lb/a						
Touchdown Total	24 oz/a	EP	88	98	100	88	206
+ Impact + AMS	+ 0.5 fl oz/a + 2.5 lb/a						
Touchdown Total	24 oz/a	EP	97	100	100	87	222
+ Laudis + AMS	+ 2.0 fl oz/a + 2.5 lb/a						
SureStart *fb*	1.75 pt/a	PRE	83	93	100	93	225
Durango DMA + AMS	24 fl oz/a + 2.5 lb/a	EP					
SureStart	1.75 pt/a	EP	97	100	100	92	227
+ Durango DMA + AMS	+ 24 fl oz/a + 2.5 lb/a						
Lexar	3.0 qt/a	PRE	100	98	100	85	225
Harness Xtra *fb*	1.5 qt/a	PRE	78	98	83	77	226
Roundup OM + AMS	22 oz/a + 0.5 lb/a	EP					
Guardsman Max	2.0 qt/a	PRE	82	98	88	85	197
LSD (0.05)			13	6	10	14	35

[1] PRE = preemergence (5/05), EP = early postemergence (6/03).
[2] LC = large crabgrass, PA = Palmer amaranth, CS = common sunflower, IM = ivyleaf morningglory.

Table 2. Effects of preemergence and postemergence herbicides on weed control and grain yield of corn, Kansas River Valley Experiment Field, Rossville, 2008

Treatment	Rate	Application time[1]	Weed control, July 2[2] LC	PA	CS	IM	Grain yield
			-----------------	%	-----------------		bu/a
Untreated check	–	–	0	0	0	0	80
Balance Flex + AAtrex 4L *fb*	3.0 oz/a + 1 qt/a	PRE	100	100	100	100	241
Laudis + AAtrex 4L	3.0 oz/a + 1 pt/a	MP					
+ COC + UAN	+ 1% v/v + 1.5 qt/a						
Balance Flex + AAtrex 4L *fb*	3.0 oz/a + 1 qt/a	PRE	100	100	100	100	231
Laudis + AAtrex 4L	3.0 oz/a + 1 pt/a	MP					
+ MSO + UAN	+ 1% v/v + 1.5 qt/a						
Lumax *fb*	1.5 qt/a	PRE	100	100	100	100	249
Lumax + NIS	1.5 qt/a + 0.25% v/v	MP					
Harness Xtra *fb*	2.1 qt/a	PRE	100	100	100	100	259
Laudis + AAtrex 4L	3.0 oz/a + 1 pt/a	MP					
+ COC + UAN	+ 1% v/v + 1.5 qt/a						
Laudis + AAtrex 4L	3.0 oz/a + 1 pt/a	MP	100	100	100	93	245
+ Roundup OM + AMS	+ 22 oz/a + 8.5 lb/100 gal						
Laudis + AAtrex 4L	3.0 oz/a + 1 pt/a	MP	100	97	98	100	236
+ Roundup OM + AMS	+ 11 oz/a + 8.5 lb/100 gal						
Laudis + AAtrex 4L	3.0 oz/a + 1 pt/a	EP	100	100	100	100	244
+ MSO + UAN	+ 1% v/v + 1.5 qt/a						
Balance Flex + AAtrex 4L *fb*	3.0 oz/a + 1 qt/a	PRE	100	100	100	100	240
Capreno + AAtrex 4L	3.0 oz/a + 1 pt/a	MP					
+ COC + UAN	+ 1% v/v + 1.5 qt/a						
Balance Flex + AAtrex 4L *fb*	3.0 oz/a + 1 qt/a	PRE	100	100	100	100	225
+ Capreno	3.0 oz/a	MP					
+ MSO + UAN	+ 1% v/v + 1.5 qt/a						
Capreno + Roundup OM	3.0 oz/a + 22 oz/a	MP	100	100	100	77	239
+ AMS	+ 8.5 lb/100 gal						

continued

Table 2. Effects of preemergence and postemergence herbicides on weed control and grain yield of corn, Kansas River Valley Experiment Field, Rossville, 2008

Treatment	Rate	Application time[1]	Weed control, July 2[2] LC	PA	CS	IM	Grain yield
			----------------	%	----------------		bu/a
Capreno + AAtrex 4L + Roundup OM + AMS	3.0 oz/a + 1.0 qt/a + 22 oz/a + 8.5 lb/100 gal	MP	100	98	97	100	230
Capreno + AAtrex 4L + COC + UAN	3.0 oz/a + 1.0 qt/a + 1% v/v + 1.5 qt/a	EP	100	100	100	100	228
Impact + AAtrex 4L + COC + UAN	0.75 oz/a + 1.0 qt/a + 1% v/v + 1.5 qt/a	EP	100	100	100	100	243
Corvus *fb* Ignite 280 + Laudis + AMS	2.2 oz/a 22 oz/a + 2.0 oz/a + 1.5 lb/a	PRE MP	100	100	100	100	259
Corvus *fb* Roundup OM + Laudis + AMS	2.2 oz/a 22 oz/a + 3.0 oz/a + 1.5 lb/a	PRE MP	100	100	100	98	233
Balance Flex + AAtrex 4L *fb* Ignite 280 + Laudis + AMS	3.0 oz/a + 1 pt/a 22 oz/a + 2.0 oz/a + 1.5 lb/a	PRE MP	100	100	100	100	238
Balance Flex + Harness Xtra	4.0 oz/a + 1.5 qt/a	PRE	92	97	100	85	247
Lexar	3.0 qt/a	PRE	95	95	100	87	236
Corvus + AAtrex 4L	3.3 oz/a + 1.0 qt/a	PRE	97	100	100	97	246
Corvus + AAtrex 4L	4.5 oz/a + 1.0 qt/a	PRE	100	98	100	100	229
Balance Flex + AAtrex 4L	4.0 oz/a + 1.0 qt/a	PRE	85	90	98	85	226
Balance Flex + AAtrex 4L	5.0 oz/a + 1.0 qt/a	PRE	95	98	100	100	252
LSD (0.05)			7	5	2	5	34

[1] PRE = preemergence (5/05), EP = early postemergence (6/03), MP = mid-postemergence (6/18).
[2] LC = large crabgrass, PA = Palmer amaranth, CS = common sunflower, IM = ivyleaf morningglory

Soybean Herbicide Performance Test

L. D. Maddux

Summary
This study was conducted at the Rossville Unit to compare herbicide treatments for soybean. Control of large crabgrass (LC) was good to excellent with all but two treatments. All treatments gave excellent control of palmer amaranth (PA) and common sunflower (CS). Control of ivyleaf morningglory (IM) was 90% or greater for all but two treatments. There were no significant yield differences among treatments, although all yielded higher than the untreated check.

Introduction
Controlling weeds in row crops with chemical weed control and cultivation can reduce weed competition and, in turn, weed yields. Treatments in this study included an untreated check, preemergence (PRE) applications followed by glyphosate alone or with a tank mix partner, a two-pass postemergence treatment, and a treatment of only one application of glyphosate. Weeds evaluated in this test were LC, PA, CS, and IM.

Procedures
This test was conducted on a Eudora silt loam soil previously cropped to corn. Soil at the test site had a pH of 6.9 and an organic matter content of 1.1%. Corn stubble had been disked and chiseled in the fall and field cultivated in the spring. Soybean variety NK S37-F7 was planted May 15 at 139,000 seeds/a in 30-in. rows with 10-34-0 fertilizer banded at 120 lb/a. Herbicides were broadcast at 15 gal/a with 8003XR flat fan nozzles at 17 psi. A randomized complete block design with three replications per treatment was used. PRE applications were made May 16. Mid-postemergence (MP) treatments were applied June 21 to 5-trifoliate soybean, 1- to 3-in. LC, 2- to 6-in. PA, 3- to 10-in. CS, and 2- to 4-in. IM. The late postemergence (LP) treatment was applied July 14 to 7-trifoliate soybean, 1- to 2-in. LC, and 1- to 2-in. IM. No PA or CS were present in the plots at the LP application time. All postemergence applications received 2.5 lb/a ammonium sulfate. Populations of all four weeds were moderate to heavy. Plots were not cultivated. Rainfall of 0.29 in. was received 6 days after PRE applications; an additional 1.82 in. was received within the next 4 days. Plots were irrigated as needed and harvested October 9 with a modified John Deere 3300 plot combine.

Results
Sufficient rainfall to activate the PRE herbicides was received 6 days after application. Significant crop injury was observed from the PRE application of Prefix, Boundary, and Prowl but not from any of the other PRE herbicides (data not shown). Table 1 shows weed control ratings made July 25. Control of CS was excellent for all treatments (100%). Control of PA was also excellent, with all treatments having 90% or greater control ratings. Six of the treatments had greater than 90% LC control, but one, Boundary + Touchdown Total, had only 80% control. Control of IM was 90% or greater with all but two treatments, which had 80 and 88% control. All treatments had higher grain yields than the untreated check; there were no significant differences among treatments. Yields were low for irrigated soybean.

Table 1. Effects of herbicide application on weed control and grain yield of soybean, Kansas River Valley Experiment Field, Rossville, 2008

Treatment[1]	Rate	Application time[2]	Weed control, July 25[3]				Grain yield
			LC	PA	CS	IM	
			----------%----------				bu/a
Untreated check	–	–	0	0	0	0	0
Prefix *fb*	1.5 pt/a	PRE	93	98	100	93	43.3
Touchdown Total	24.0 oz/a	MP					
Prefix *fb*	2.0 pt/a	PRE	97	100	100	97	48.3
Touchdown Total	24.0 oz/a	MP					
Boundary *fb*	1.5 pt/a	PRE	70	100	100	88	46.5
Touchdown Total	24.0 oz/a	MP					
Touchdown Total	24.0 oz/a	MP	80	97	100	80	48.7
Sonic *fb*	3.0 oz/a	PRE	93	97	100	97	48.9
Durango	24.0 oz/a	MP					
Sonic *fb*	4.5 oz/a	PRE	97	97	100	100	44.7
Durango	24.0 oz/a	MP					
FirstRate +	0.3 oz/a +	MP	97	95	100	97	50.3
Durango DMA *fb*	24.0 oz/a						
Durango DMA	24.0 oz/a	LP					
Prowl H2O *fb*	3.0 pt/a	PRE	92	98	100	97	46.3
Extreme	3.0 pt/a	MP					
Prowl H2O *fb*	3.0 pt/a	PRE	87	90	100	93	43.6
Scepter +	2.8 oz/a +	MP					
Touchdown Total	24.0 oz/a						
Prowl H2O *fb*	3.0 pt/a	PRE	97	95	100	97	43.2
Scepter +	3.0 oz/a	MP					
Touchdown Total	24.0 oz/a						
Intro +	48.0 oz/a +	MP	93	100	100	90	45.8
Roundup WeatherMax	22.0 oz/a						
LSD (0.05)			12	9	0	1	11.0

[1] Postemergence treatments had ammonium sulfate added at 2.5 lb/a.
[2] PRE = preemergence (5/16), MP = mid-postemergence (6/21), LP = late postemergence (7/14).
[3] LC = large crabgrass, PA = Palmer amaranth, CS = common sunflower, IM = ivyleaf morningglory.

Effect of Various Foliar Fertilizer Materials on Irrigated Soybean

L. D. Maddux

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

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

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

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

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

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

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

L. D. Maddux

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

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

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

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

Results

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

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

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

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

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

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

L. D. Maddux

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

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

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

Corn hybrids planted were: BoJac 603 (1983), Pioneer 3377 (1985, 1987, 1989), Jacques 7820 (1991, 1993), Mycogen 7250 (1995), DeKalb DKC626 (1997, 1999), Golden Harvest H2547 (2001), Pioneer 33R77 (2003), DeKalb DKC63-81 (2005), and Asgrow RX785 (2007). Soybean varieties planted in even years were: Douglas (1984), Sherman (1986, 1988, 1990, 1992, 1996, 1998), Edison (1994), IA 3010 (2000), Garst 399RR (2002), Stine 3982-4 (2004), Stine 4302-4 (2006), and Midland 9A385 (2008). Corn was planted in mid-April, and soybean was planted in early to mid-May. Herbicides were applied preplant and incorporated each year, and postemer-

gence herbicides were applied as needed. Plots were cultivated, furrowed, and furrow irrigated through 2001 and sprinkler irrigated with a linear move irrigation system from 2002 to 2008. A plot combine was used for harvesting grain yields.

Results

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

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

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

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

continued

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

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

[1] Fertilizer applied to corn in odd years from 1983 to 2007 and to soybean for 11 years prior to 1983 (the first number of two is the rate applied to corn from 1983 to 1995).
[2] P treatments not applied in 1997. Starter fertilizer of 10 gal/a of 10-34-0 was applied to all treatments in 1997 and 1998 (corn and soybean). N and K treatments were applied to corn in 1997.

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

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

continued

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

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

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

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

Harvey County Experiment Field

Introduction
Research at the Harvey County Experiment Field deals with many aspects of dryland crop production on soils of the Central Loess Plains and Central Outwash Plains of central and south central Kansas and is designed to directly benefit agricultural industries in the area. The focus is primarily on wheat, grain sorghum, and soybean, but research is also conducted on alternative crops such as corn, sunflower, and canola. Investigations include variety and hybrid performance tests, chemical weed control, reduced tillage/no-till systems, crop rotations, cover crops, fertilizer use, planting practices, and disease and insect resistance and control.

Soil Description
The Harvey County Experiment Field consists of two tracts. The headquarters tract (North Unit), 75 acres immediately west of Hesston, KS, on Hickory Street, is all Ladysmith silty clay loam with 0 to 1% slope. The South Unit, 4 miles south and 2 miles west of Hesston, is composed of 142 acres of Ladysmith, Smolan, Detroit, and Irwin silty clay loams as well as Geary and Smolan silt loams. All have a 0 to 3% slope. Soils on the two tracts are representative of much of Harvey, Marion, McPherson, Dickinson, and Rice counties as well as adjacent areas. These are deep, moderately well to well-drained, upland soils with high fertility and good water-holding capacity. Water runoff is slow to moderate. Permeability of the Ladysmith, Smolan, Detroit, and Irwin series is slow to very slow, whereas permeability of the Geary series is moderate.

2007-2008 Weather Information
Relatively dry conditions prevailed in September (Table 1). Rains interfered with wheat planting during the first 3 weeks of October. Then conditions turned dry again, with no substantial rainfall until mid-December, when heavy rains changed the fortune of the wheat crop. Average temperatures were slightly above normal in October, near normal in November, and about 3.8°F below normal in December. Winter and spring months had near normal to somewhat below normal precipitation, with the exception of February and June, each of which had precipitation totals exceeding the long-term monthly averages by more than 1 in. at the North Unit.

The coldest temperatures of the winter occurred on and off between mid-December and early February. Single-digit observations were recorded on 12 days. However, periods of mild temperatures also occurred during this time. Mean temperatures actually were slightly above normal in January. All remaining months of the wheat growing season had relatively cool temperatures, with averages typically 2 to 5°F below normal. Wheat survival was good. Wheat heading was later than usual because of delayed planting and cool spring temperatures. There were no symptoms of soilborne/spindle streak mosaic. Leaf rust became the dominant disease.

Warm days in mid-March facilitated early corn planting, but subsequent cool temperatures greatly delayed emergence and seedling development. The last spring freeze occurred 3 days earlier than normal on April 14. All corn plantings emerged after that

date. The timing of soybean and grain sorghum plantings was affected to some extent by rain events. Precipitation was generally near normal or above normal throughout the row crop growing season.

During the summer months, 15 days had temperatures of 95°F or higher, and only 4 days had temperatures of 100 to 104°F. In July, August, and September, average temperatures were 1 to 2.5°F below normal. Maturation of row crops was delayed somewhat by relatively mild conditions with ample rainfall. Summarily, the season was favorable for all row crops.

Corn, soybean, and grain sorghum generally had no insect or disease problems of significance. Sunflower suffered serious damage from head-clipper weevil. The first killing frost of the fall occurred 5 days later than normal on October 26. Late arrival of freezing temperatures in the fall benefited late-planted row crops, most of which matured before the advent of cold temperatures.

Table 1. Monthly precipitation totals, Harvey County Experiment Field, Hesston[1]

Month	North Unit	South Unit	Normal	Month	North Unit	South Unit	Normal
	------------in.-----------				------------in.-----------		
2007				2008			
October	2.74	2.60	2.95	March	2.56	2.33	2.71
November	0.19	0.18	1.68	April	2.79	3.60	2.84
December	3.09	2.90	1.01	May	4.60	5.06	4.83
				June	5.78	4.32	4.72
2008				July	4.58	3.54	3.59
January	0.36	0.23	0.79	August	3.76	5.17	3.88
February	2.20	1.88	1.08	September	4.72	4.92	2.99
12-month total					37.37	36.73	33.07
Departure from 30-year normal at North Unit					4.30	3.66	

[1] One experiment reported herein was conducted at the South Unit: *Effects of Late-Maturing Soybean and Sunn Hemp Summer Cover Crops and Nitrogen Rate in a No-Till Wheat/Grain Sorghum Rotation.* All other experiments in this report were conducted at the North Unit.

No-Till Crop Rotation Effects on Wheat, Corn, Grain Sorghum, Soybean, and Sunflower

M. M. Claassen and D. L. Regehr

Summary
A field experiment consisting of 11 no-till crop rotations was initiated in 2001 in central Kansas on Ladysmith silty clay loam. Cropping systems involving winter wheat (W), corn (C), grain sorghum (GS), double-crop grain sorghum ([GS]), soybean (SB), double-crop soybean ([SB]), and sunflower (SF) are as follows: W-C-SB, W-[SB]-C-SB, W-SB-C, W-GS-SB, W-[SB]-GS-SB, W-[GS]-GS-SB, W-GS-SF, W-[SB]-GS-SF, W-[GS]-GS-SF, GS-C-SB, and GS-GS-GS. Data collection to determine cropping system effects began in 2004. In 2008, highest wheat yields occurred in rotations in which wheat followed soybean and averaged 50.2 bu/a. Wheat following sunflower and corn produced 2.2 and 4.2 bu/a less, respectively, than wheat after soybean. From 2004 to 2008, wheat also performed best after soybean with a top yield of 56.6 bu/a but produced 6.6 and 9.9 bu/a less following corn and sunflower, respectively. Inclusion of [GS] or [SB] in the rotation had no meaningful effect on wheat. Corn averaged 141.3 bu/a without a significant crop rotation effect. Grain sorghum production was greatest in rotations in which it followed wheat, [SB], or full-season soybean, averaging 122.6, 115.1, and 113.4 bu/a, respectively. Grain sorghum yields were lowest following full-season grain sorghum or [GS], averaging 81.8 and 89.3 bu/a, respectively. Double-crop grain sorghum produced 66.8 bu/a without a significant rotation effect. Full-season soybean produced an average yield of 39.5 bu/a without a significant effect of the preceding crop. Double-crop soybean yields ranged from 22.9 to 27.2 bu/a without a meaningful rotation effect. Sunflower yielded 1228 lb/a with no crop rotation effect.

Introduction
The number of acres devoted to no-till crop production in the United States has risen steadily in recent years, most notably since 2002. According to the Conservation Technology Information Center, no-till was used on 62.4 million acres, nearly 23% of the cropland in 2004. At that time, Kansas ranked seventh in the nation with 4.2 million acres of no-till annual crops, representing 21.2% of planted acres. Anecdotal information suggests that no-till annual crop acreages have continued to increase. Soil and water conservation issues; cost of labor, fuel, and fertilizers; changes in government farm programs; development of glyphosate-tolerant crops; and lower glyphosate herbicide cost all contribute to no-till adoption by growers.

Crop rotation reduces pest control costs, enhances yields, and contributes significantly to successful no-till crop production. Selecting appropriate crop rotations provides adequate diversity of crop types to facilitate realization of these benefits and sufficient water-use intensity to take full advantage of available moisture.

In central and south central Kansas, long-term, no-till research on multiple crop rotations is needed to determine profitability and reliability of these systems. This experiment includes 10 three-year rotations. Nine of these involve wheat, corn or grain sorghum, and soybean or sunflower. One rotation consists entirely of row crops. Con-

tinuous grain sorghum serves as a monoculture check treatment. Double-crop soybean and [GS] after wheat are used as intensifying components in five of the rotations. One complete cycle of these rotations was completed in 2003. Official data collection began in 2004.

Procedures

The experiment site was located on a Ladysmith silty clay loam where no-till soybean had been grown in 2000. Lime was applied according to soil test recommendations and incorporated by light tillage in late fall of that year. Detailed soil sampling was done in early April 2001, just before establishment of the cropping systems. Average soil test values at that time included pH of 6.2, 2.7% organic matter, 46 lb/a available phosphorus (P), and 586 lb/a exchangeable potassium.

Eleven crop rotations (see summary) were selected to reflect adaptation across the region. The experiment uses a randomized complete block design with four replications of 31 annual treatments representing each crop in each rotation.

Wheat planting was delayed by wet weather in October 2007. Plots to be planted to wheat were sprayed with Roundup WeatherMax at the end of that month to control late-emerged weeds. Overley wheat was planted into corn, soybean, and sunflower stubble on November 2 in 7.5-in. rows at 90 lb/a with a John Deere 1590 no-till drill with single-disk openers. Wheat was fertilized with 120 lb/a nitrogen (N) and 32 lb/a P_2O_5 as preplant broadcast 46-0-0 and as in-furrow 18-46-0 at planting. No herbicides were used on wheat in any of the cropping systems. Wheat was harvested on June 26, 2008.

Wheat plots to be planted to corn were sprayed with Roundup Original Max in mid-July, late August, and mid-November 2007. Corn planting also was delayed somewhat by wet weather. Near planting time, all corn plots were sprayed with Roundup WeatherMax plus Dual II Magnum. Subsequently, weeds were controlled with a single postemergence application of Roundup PowerMax. A White no-till planter with double-disk openers on 30-in. centers was used to plant corn hybrid Pioneer 35P10 RR with Poncho insecticide at approximately 19,000 seeds/a on Apr. 22, 2008. All corn was fertilized with a blend of 10-34-0 and 28-0-0, providing 30 lb/a N and 30 lb/a P_2O_5, banded 2 in. from the row at planting. Corn after wheat, [SB], and grain sorghum received an additional 95 lb/a N, and corn after full-season soybean received 65 lb/a N as 28-0-0 injected in a band 10 in. on either side of each row on June 4. Corn was harvested on Sept. 19, 2008.

Wheat plots to be planted to grain sorghum were treated the same as corn during the preceding summer and fall. Wheat, soybean, and sorghum plots to be planted to grain sorghum were treated either in late April or mid-May with Roundup WeatherMax plus very low rates of Clarity and 2,4-D_{LVE}. AAtrex 4L plus Dual II Magnum was applied soon after grain sorghum planting to complete residual weed control. Sorghum Partners hybrid KS 585 with Concep III safener and Cruiser insecticide was planted at approximately 42,000 seeds/a in 30-in. rows with 30 lb/a N and 30 lb/a P_2O_5 banded 2 in. from the row on May 20. Sorghum after wheat, grain sorghum, [GS], and [SB] received an additional 60 lb/a of N, and grain sorghum after full-season soybean received 30 lb/a of N as 28-0-0 injected in a band 10 in. on either side of each row in mid-June. Sorghum was harvested on Sept. 26, 2008.

Double-crop grain sorghum plots received an application of Roundup WeatherMax just before planting. Sorghum hybrid Pioneer 87G57 with Concep III safener and Cruiser insecticide was planted on July 3 with the same procedures used for full-season grain sorghum. An additional 30 lb/a N were injected on July 25. Postemergence application of AAtrex 4L plus crop oil concentrate was made with drop nozzles on August 13. Double-crop grain sorghum was harvested on Nov. 8, 2008.

Weed control procedures for wheat and row crop plots to be planted to soybean were similar to those for grain sorghum prior to planting. Asgrow AG3802 RR soybean was planted at 115,000 seeds/a in 30-in. rows on May 19. During the season, two applications of Roundup were required for satisfactory weed control. Soybean was harvested on Nov. 1, 2008, after a long delay from wet weather.

Double-crop soybean had a preplant application of Roundup WeatherMax. Asgrow AG3802 RR soybean was planted as a double crop at 115,000 seeds/a in 30-in. rows on July 3. One additional Roundup application was required in mid-August. Double-crop soybean was harvested on Nov. 4, 2008.

All sunflower plots were sprayed with Roundup WeatherMax plus very low rates of Clarity and 2,4-D_{LVE} on April 22. Roundup plus a 0.66x rate of Dual II Magnum was applied in early June and again about 1 month later but with a 0.33x rate of Dual II Magnum. Triumph s672 sunflower was planted on July 2 at 28,000 seeds/a with 30-30-0 fertilizer banded 2 in. from the row. An additional 40 lb/a N as 28-0-0 were injected in a band 10 in. on either side of each row on July 21. Baythroid XL at 2.8 oz/a was applied on August 18 for control of head-clipper weevils. Sunflower was harvested on Oct. 20, 2008.

Results

Wheat

The month of November was very dry; only 0.19 in. of precipitation were received during the first 4 weeks after planting. Emergence was 50 to 60% complete by mid-November. Nevertheless, wheat stand establishment was excellent in all crop rotations. Wheat heading was later than usual because of delayed planting and cool spring temperatures. No differences in incidence of wheat diseases were observed among rotations. There were no significant differences in wheat maturity among rotations (Table 1). Variation in plant height among rotations was minor, but wheat after soybean tended to be slightly taller than after corn or sunflower. Plant N concentration averaged 2.2% in wheat after soybean, about 10% greater than after the other crops. Highest wheat yields also occurred in rotations in which wheat followed soybean, averaging 50.2 bu/a. The yield advantage was 2.2 and 4.2 bu/a vs. wheat after sunflower and corn, respectively. Five-year averages were highest for wheat after soybean at 56.6 bu/a, with a yield decline of 6.6 and 9.9 bu/a following corn and sunflower, respectively. Double cropping with soybean or grain sorghum in selected rotations did not meaningfully influence wheat yield. Grain test weights were not affected by crop rotation. Grain protein levels ranged from 10.2% for wheat after sunflower to 11.2% for wheat following soybean. Protein content of wheat after corn was not significantly different from that of wheat after soybean. In general, antecedent crop effects were much more significant than overall rotation effects in determining wheat performance.

Corn

Two rain events within 10 days of corn planting brought a total of 0.79 in. Corn emerged about 14 days after planting. Final corn populations averaged 17,685 plants/a (Table 2), with slightly lower stands following wheat or [SB]. Corn reached the half-silking stage 67 to 71 days after planting and about 3 days later following wheat or [SB] in rotation. Leaf N ranged from 2.69 to 2.95% and was greatest for corn after soybean. There was no lodging. Corn yields averaged 141.3 bu/a, test weights averaged 58.5 lb/bu, and number of ears/plant averaged 1.02, all without a significant crop rotation effect.

Grain sorghum

During the first 10 days after full-season grain sorghum planting, rainfall totaled 2.82 in. Emergence occurred 8 days after planting. Final populations ranged from 32,500 to 35,900 plants/a. Lowest full-season grain sorghum plant counts occurred where the preceding crop was wheat or [GS]. On average, full-season grain sorghum reached half-bloom stage at 62 days after planting. Grain sorghum after soybean, however, reached this stage earliest, on average at 60 days after planting. On the other hand, grain sorghum following [GS] was the latest, requiring 65 days. Leaf N levels ranged from 2.31 to 2.91% among rotations, with the highest mean values in grain sorghum after wheat, [SB], or soybean and lowest mean values in grain sorghum following full-season grain sorghum or [GS]. Grain sorghum production ranged from 81.8 to 122.6 bu/a. Yields recorded for grain sorghum were highest following wheat, intermediate following soybean or [SB], and lowest after grain sorghum or [GS]. Notably, grain sorghum after full-season soybean produced a yield similar to grain sorghum following [SB]. Double cropping after wheat in W-GS-SB reduced grain sorghum yields by 10.9 and 29.5 bu/a with [SB] and [GS], respectively. Double cropping after wheat in W-GS-SF reduced grain sorghum yields by 4.0 and 37.2 bu/a with [SB] and [GS], respectively.

In 2008, continuous full-season grain sorghum produced 7.7 bu/a less than after [GS]. Grain test weight ranged from 58.4 to 59.4 lb/bu with minor differences among most rotations. Number of heads/plant ranged from 1.15 to 1.64, following the trend observed for yield. Head counts were highest for grain sorghum following wheat, intermediate following soybean or [SB], and lowest after grain sorghum or [GS]. No lodging was observed.

Rainfall totaled 2.8 in. during the first 10 days after [GS] planting. Emergence occurred in 8 days, and stands averaged 33,200 plants/a. Yields of [GS] averaged 66.8 bu/a, about 63% of the full-season crop. There were no crop rotation effects on yield or any of the other variables measured in [GS].

Soybean

Full-season soybean received 2.82 in. of rainfall within 10 days after planting and emerged in less than a week. Stands were excellent among all rotations (Table 3). Soybean plant heights averaged 33 in. across all rotations but were slightly shorter in rotations involving [SB] or [GS]. Soybean uniformly reached maturity at 135 days after planting. Soybean averaged 40.0 bu/a in rotations involving wheat but yielded 3.6 bu/a less in the GS-C-SB rotation. However, these differences generally were not statistically significant. There was no lodging.

Double-crop soybean also received 2.8 in of rainfall within 10 days after planting, emerging in 8 days with excellent stands. Plant heights averaged 26 in. with no rotation effect. Double-crop soybean reached maturity without treatment effect at 158 days after planting. No lodging occurred. Yields of [SB] ranged from 22.9 to 27.2 bu/a without meaningful differences among rotations.

Sunflower

A total of 2.8 in. of rain fell during the first 10 days after sunflower planting, and emergence occurred 5 days after planting. Populations averaged 23,247 plants/a. Triumph s672 NuSun short-stature sunflower reached half-bloom stage at 53 days on average and had an average height of 38 in. Sunflower was significantly affected by head-clipper weevils, though not as severely as in 2007. Approximately 19% of sunflower heads were lost because of head-clipper weevil activity. Yields averaged 1228 lb/a with 3% lodging. None of these variables were affected by crop rotation.

Table 1. Effects of crop rotation on no-till wheat, Harvey County Experiment Field, Hesston, 2008

Crop	Crop rotation[1]	Yield[2] 2008	Yield[2] 5-year	Test weight	Stand	Heading[3]	Plant height	Plant N[4]	Grain protein
		------bu/a------		lb/bu	%	days	in.	%	%
Wheat	W-C-SB	54.9	56.9	58.3	99	46	34	2.15	11.1
	W-[SB]-C-SB	50.3	57.2	58.1	98	46	33	2.24	11.7
	W-SB-C	46.0	50.0	57.3	97	46	32	1.98	10.8
	W-GS-SB	49.7	57.4	57.4	98	46	33	2.20	10.9
	W-[SB]-GS-SB	49.7	56.7	58.1	99	46	34	2.22	11.0
	W-[GS]-GS-SB	46.4	54.9	57.5	98	46	32	2.18	11.2
	W-GS-SF	49.4	46.6	57.3	99	46	32	1.90	10.2
	W-[SB]-GS-SF	47.0	47.5	58.0	98	46	32	2.11	10.5
	W-[GS]-GS-SF	47.6	46.1	57.9	99	46	32	1.91	9.9
	LSD (0.05)	4.1		NS	NS	NS	1.1	0.13	1.00
	LSD (0.10)	3.4		NS	NS	NS	0.9	0.11	0.83
	Preceding crop main effect means								
	Corn	46.0	50.0	57.3	97	46	32	1.98	10.8
	Soybean	50.2	56.6	57.9	98	46	33	2.20	11.2
	Sunflower	48.0	46.7	57.7	99	46	32	1.97	10.2
	LSD (0.05)[5]	2.8		NS	NS	NS	0.8	0.09	0.56
	LSD (0.10)[5]	2.4		NS	0.7	NS	0.7	0.07	0.46

[1] C = corn, GS = grain sorghum, SB = soybean, SF = sunflower, W = wheat, and [ ] = double crop.
[2] Means of four replications adjusted to 12.5% moisture.
[3] Days after March 31 on which 50% heading occurred.
[4] Whole-plant nitrogen levels at late boot to early heading.
[5] Estimate based on the average number of crop sequences involving the same preceding crop = 3.0.

Table 2. Effects of crop rotation on no-till corn and grain sorghum, Harvey County Experiment Field, Hesston, 2008

Crop	Crop rotation[1]	Yield[2] 2008	Yield[2] 5-year	Test weight	Stand	Maturity[3]	Ears or heads/ plant	Lodging	Leaf N[4]
		-----bu/a-----		lb/bu	1000/a	days		%	%
Corn	W-C-SB	146.3	103.2	58.5	17.0	71	1.05	0	2.95
	W-[SB]-C-SB	139.6	101.6	58.7	16.9	71	1.02	0	2.82
	W-SB-C	144.9	99.7	58.1	18.1	67	1.01	0	2.69
	GS-C-SB	134.7	97.6	58.6	18.7	68	1.00	0	2.78
	LSD 0.05	NS		NS	NS	1.0	NS	NS	0.12
	LSD 0.10	NS		NS	1.3	0.8	NS	NS	0.10
Sorghum	W-GS-SB	122.6	106.1	59.4	32.7	63	1.64	0	2.91
	W-[SB]-GS-SB	111.7	100.0	58.8	33.8	63	1.44	0	2.81
	W-[GS]-GS-SB	93.1	88.3	58.5	33.1	65	1.28	0	2.41
	W-GS-SF	122.6	107.5	58.8	34.0	63	1.57	0	2.87
	W-[SB]-GS-SF	118.6	98.9	58.8	35.0	64	1.40	0	2.80
	W-[GS]-GS-SF	85.4	89.1	58.5	32.5	66	1.27	0	2.50
	GS-C-SB	113.4	103.0	58.6	35.9	60	1.43	0	2.71
	GS-GS-GS	81.8	89.1	58.4	34.8	63	1.15	0	2.31
[Sorghum]	W-[GS]-GS-SB	66.6	72.7	56.2	33.8	56	1.20	0	2.58
	W-[GS]-GS-SF	67.0	74.3	56.8	32.5	56	1.29	0	2.53
	LSD (0.05)	7.5		0.7	NS	1.2	0.11	NS	0.17
	LSD (0.10)	6.3		0.6	1.9	1.0	0.09	NS	0.14
	Preceding crop main effect means								
Sorghum	Wheat	122.6	106.8	59.1	33.3	63	1.60	0	2.89
	[Soybean]	115.1	99.5	58.8	34.4	63	1.42	0	2.81
	Soybean	113.4	103.0	58.5	35.9	60	1.44	0	2.71
	[Sorghum]	89.3	88.7	58.5	32.8	65	1.28	0	2.46
	Sorghum	81.8	89.1	58.5	34.7	63	1.16	0	2.31
	LSD (0.05)[5]	7.2		0.4	NS	0.9	0.09	NS	0.14
	LSD (0.10)[5]	6.0		0.4	1.5	0.7	0.08	NS	0.12

[1] C = corn, GS = grain sorghum, SB = soybean, SF = sunflower, W = wheat, and [ ] = double crop.
[2] Means of four replications adjusted to 15.5% moisture (corn) or 12.5% moisture (grain sorghum).
[3] Maturity expressed as follows: corn - days from planting to 50% silking, and grain sorghum - number of days from planting to half bloom.
[4] Nitrogen level of the ear leaf plus one in corn and of the flag leaf in sorghum.
[5] Estimate based on the average number of crop sequences involving the same preceding crop to full-season grain sorghum = 1.6.

Table 3. Effects of crop rotation on no-till soybean and sunflower, Harvey County Experiment Field, Hesston, 2008

Crop	Crop rotation[1]	Yield[2] 2008	Yield[2] 5-year	Stand[3]	Plant height	Maturity[4]	Lodging
		----------bu/a---------			in.	days	%
Soybean	W-C-SB	39.4	42.2	100	35	135	0
	W-[SB]-C-SB	40.4	42.3	100	32	135	0
	W-SB-C	40.4	41.5	100	35	135	0
	W-GS-SB	40.6	41.3	100	34	135	0
	W-[SB]-GS-SB	37.2	39.7	100	32	135	0
	W-[GS]-GS-SB	41.8	40.9	100	31	135	0
	GS-C-SB	36.4	40.4	100	33	135	0
[Soybean]	W-[SB]-C-SB	27.2	19.5	100	26	158	0
	W-[SB]-GS-SB	22.9	18.0	100	25	158	0
	W-[SB]-GS-SF	26.1	21.9	100	26	158	0
	LSD (0.05)	4.8		NS	2.3	1.2	NS
	LSD (0.10)	4.0		NS	1.9	1.0	NS
	Preceding crop main effect means						
	Wheat	40.4	41.5	100	35	135	0
	Corn	38.7	41.6	100	33	135	0
	Sorghum	39.9	40.6	100	32	135	0
	LSD (0.05)[5]	NS		NS	NS	NS	NS
	LSD (0.10)[5]	NS		NS	1.7	NS	NS
Sunflower	W-GS-SF	1094	1568	24.5	39	53	3
	W-[SB]-GS-SF	1337	1511	23.1	38	52	3
	W-[GS]-GS-SF	1254	1494	22.1	38	53	2
	LSD (0.05)	NS		NS	NS	NS	NS
	LSD (0.10)	NS		NS	NS	NS	NS

[1] C = corn, GS = grain sorghum, SB = soybean, SF = sunflower, W = wheat, and [ ] = double crop.
[2] Means of four replications adjusted to 13% moisture (soybean) or 10% moisture (sunflower in lb/a).
[3] Stand expressed as a percentage for soybean and as plant population in thousands per acre for sunflower.
[4] Maturity expressed as number of days from planting to 95% mature pod color for soybean and as number of days from planting to half bloom for sunflower.
[5] Estimate based on the average number of crop sequences involving the same preceding crop to full-season soybean = 2.3.

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

M. M. Claassen

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

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

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

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

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

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

Procedures

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

Wheat

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

Grain Sorghum

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

Results

Wheat

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

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

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

Grain Sorghum

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

The 2008 grain sorghum crop emerged 6 days after planting. Final stands averaged 36,800 plants/a without a crop rotation effect (Table 2). During the first 10 days after planting, rainfall from several events totaled 0.61 in. The season was relatively mild and generally favorable for sorghum. Both cover crop and N rate effects on grain sorghum were significant. Soybean and sunn hemp significantly increased sorghum nutrient concentration by 0.12 and 0.19% N, respectively, when averaged over N rate. Most of this effect occurred at rates of 60 lb/a N or less. At 90 lb/a N, sorghum leaf N concentration was comparable in all rotations. Averaged over N rate, grain sorghum heads/plant increased by 8 and 14% in rotations with soybean and sunn hemp, respectively. This positive effect of cover crops was seen throughout the range of fertilizer N. Cover crops

generally did not influence the length of time for grain sorghum to reach the half-bloom stage. However, at 0 lb/a N, half bloom was delayed by several days in the rotations with no cover crop or with soybean.

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

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

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

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

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

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

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

Effects of Planting Date, Hybrid Maturity, and Plant Population in No-Till Corn

M. M. Claassen

Summary
Three Pioneer corn hybrids (38H65, 35P10, and 33B54) representing 99-, 103-, and 114-day maturities were planted in a soybean rotation under no-till conditions on March 14, March 28, and April 16, each with final populations of 14,000, 18,000, and 22,000 plants/a. The growing season was unusually favorable for corn, with generally moderate temperatures and normal or above normal rainfall. All treatment factors significantly affected corn. Planting date had the largest effect on length of time to reach half-silk stage. Corn planted on April 16 reached silking 32 and 18 days faster than corn planted on March 14 and March 28, respectively. March planting dates resulted in identical yields that were 4.7 bu/a less than yields from the April 16 planting, which produced 145 bu/a. Corn hybrid 33B54 produced an average of 145 bu/a, whereas the earlier-maturing 38H66 and 35P10 had 5 and 2%, respectively, lower yields. Maximum yields occurred with the highest plant population (22,000 plants/a). At 18,000 and 14,000 plants/a, yields declined by 5 and 13%, respectively. In 2004, yields were largest with the latest planting date (mid-April), but in 2005 and 2006, highest yields occurred with the earliest planting (mid-March). In 2006, yields were low and not affected by plant population. In 2004 and 2005, maximum yields occurred with the latest maturing hybrid and highest plant population. Because of weather factors, planting dates in 2007 did not conform to the established schedule, making treatment comparisons difficult across years. Nevertheless, a positive yield trend occurred with increasing hybrid maturity and plant population in 2007. Grain test weight was good in 2008, with no planting date effect, minor differences among plant populations, and hybrid differences of 0.5 to 1.2 lb/bu (Table 1). Corn averaged 1.14 ears/plant, tending to be greatest with the latest planting, earliest maturing hybrid, and lowest plant population.

Introduction
In central and south central Kansas, dryland corn often does not perform as well as grain sorghum under existing seasonal weather conditions, which usually involve some degree of drought. Nevertheless, corn is preferred as a rotational crop by some producers because earlier growth termination and harvest facilitate planting of double-crop, no-till wheat in rotations. Genetic gains in corn drought tolerance as well as no-till planting practices that conserve soil moisture have encouraged producer interest in growing corn despite increased risk of crop failure.

Planting date, hybrid maturity, and plant population all have a major effect on dryland corn production. Previous research at this location indicated that highest dryland yields occurred at plant populations of 14,000 or 18,000 plants/a. This experiment was initiated in 2004 to determine whether drought effects on no-till corn can be minimized by early planting dates, use of hybrids ranging in maturity from 97 to 114 days, and populations of 14,000 to 22,000 plants/a. Actual planting dates were Mar. 18, Apr. 2, and Apr. 15, 2004; Mar. 14, Apr. 4, and Apr. 16, 2005; Mar. 16, Mar. 31, and Apr. 14, 2006; and Apr. 23, May 21, and June 5, 2007. Hybrids planted in 2004 and 2005 were Pioneer 38H67, 35P12, and 33B51, which have maturities of 97, 105, and 111 days, respective-

ly. Hybrids planted in 2006 and 2007 were Pioneer 38H66, 35P80, and 33B49, which have maturities of 98, 106, and 112 days, respectively.

Procedures

The experiment was conducted on a Ladysmith silty clay loam site that had been cropped to no-till soybean in 2007. Corn was fertilized with 95 lb/a nitrogen (N) and 37 lb/a P_2O_5 as 18-46-0 banded close to the row before planting and as 28-0-0 injected in a band 10 in. on either side of each row in early June. The experiment design was a split plot with planting date main plots and subplots with factorial combinations of three hybrids and three plant populations in four replications. Pioneer hybrids 38H65, 35P10, and 33B54 representing maturities of 99, 103, and 114 days to black layer, respectively, were no-till planted at approximately 24,200 seeds/a into moist soil on March14, March 28, and April 16. These hybrids with Roundup Ready and corn borer resistance traits represented the same maturities as hybrids without these traits grown in earlier years. Weeds were controlled with an April 2 application of 1.5 qt/a AAtrex 4L plus 1.6 pt/a Dual II Magnum plus 22 oz/a Roundup WeatherMax plus 1 pt/a Superb HC surfactant. Subsequently, Roundup WeatherMax plus 1% ammonium sulfate was applied postemergence to complete season-long weed control. Corn was hand thinned to specified populations of 14,000, 18,000, and 22,000 plants/a. Evaluations included maturity, plant height, lodging, ear number, yield, grain moisture, and test weight (Table 1). Plots were combine harvested on Sept. 19, 2008.

Results

Rainfall totaled 1.02, 0.42, and 1.18 in. during the first 10 days after the respective planting dates. Corn emerged 38, 26, and 13 days after the mid-March, late March, and mid-April planting dates, respectively. Delays in emergence were a reflection of relatively low air temperatures, which averaged 2.5 to 5.3°F below normal in March and April. Across these planting dates, plant populations before hand thinning averaged 89 to 95% of the planting rate. The summer was favorable for corn, with generally cooler-than-normal temperatures and rainfall that was above average during a significant part of the growing season. Length of time to reach half-silk stage increased with early planting and hybrid maturity but, on average, was not meaningfully affected by plant populations. The March 14 and March 28 planting dates delayed silking by 32 and 18 days vs. the April 16 planting. Average hybrid differences in silking date ranged from 0 to 5 days.

Corn yields were significantly affected by planting date, hybrid, and plant population. None of the two-way interactions between these treatment variables affected yields. Corn produced an average of 140, 140, and 145 bu/a when planted on March 14, March 28, and April 16, respectively. In order of increasing maturity, these hybrids produced 138, 142, and 145 bu/a. Populations of 14,000, 18,000, and 22,000 plants/a had average yields of 131, 143 and 150 bu/a.

Test weight averaged 58.1 lb/bu with no significant effect by planting date and a relatively minor plant population effect. Hybrid 35P10 had the highest test weight, 1.2 lb/bu more than 38H65 and 0.7 lb/bu more than 33B54. Number of ears/plant averaged 1.14 but ranged from 1.00 to 1.61 among treatments. The largest number of ears/plant occurred in the April planting with the earliest maturing hybrid at the lowest plant population. Plant heights were affected little by planting date and plant population but increased by 1 to 4 in. with hybrid maturity. Lodging was essentially nonexistent.

Table 1. Dryland corn hybrid response to planting date and plant populations, Harvey County Experiment Field, Hesston, 2008

Planting date[1]	Hybrid[2]	Plant population	Yield 2008[3]	Yield 4-year[4]	Moisture	Bushel weight	Ears/ plant	Days to silk[5]	Plant height	Lodging
		no./a	------bu/a-----		%	lb/bu			in.	%
March 14	38H65	14,000	127	97	14.4	57.6	1.46	100	81	0
		18,000	136	105	14.3	57.4	1.13	100	81	0
		22,000	145	111	14.2	57.6	1.06	100	80	0
	35P10	14,000	130	98	14.8	58.5	1.18	100	81	0
		18,000	139	108	14.7	58.7	1.06	102	83	0
		22,000	158	116	14.5	58.9	1.00	101	81	0
	33B54	14,000	130	103	16.6	57.5	1.18	105	85	0
		18,000	142	113	16.2	57.8	1.00	106	85	0
		22,000	153	120	16.0	58.1	1.00	106	84	0
March 28	38H65	14,000	127	101	14.3	57.8	1.50	86	81	0
		18,000	132	105	14.2	57.8	1.15	86	82	0
		22,000	141	111	14.2	57.5	1.07	87	80	0
	35P10	14,000	131	97	14.7	58.8	1.25	86	82	0
		18,000	144	106	14.5	58.9	1.05	87	82	0
		22,000	153	115	14.4	58.8	1.00	88	82	0
	33B54	14,000	136	106	16.5	57.7	1.14	91	85	0
		18,000	146	111	15.9	58.1	1.00	91	85	0
		22,000	149	113	15.4	58.7	1.00	91	84	0
April 16	38H65	14,000	136	94	14.4	57.6	1.61	68	83	1
		18,000	144	101	14.1	57.2	1.29	68	83	0
		22,000	153	110	14.1	57.4	1.06	68	82	0
	35P10	14,000	126	94	14.7	58.4	1.24	68	83	0
		18,000	148	108	14.6	58.6	1.02	69	83	0
		22,000	148	109	14.5	58.8	1.00	69	82	0
	33B54	14,000	138	100	16.6	57.4	1.16	72	86	1
		18,000	154	110	15.7	58.3	1.03	72	85	0
		22,000	154	116	15.3	58.4	0.99	74	86	0
LSD (0.05) means in same DOP			12.8		0.35	0.41	0.08	10.7	1.5	NS
LSD (0.05) means in different DOP			12.5		0.39	0.51	0.08	0.9	1.5	NS

continued

Table 1. Dryland corn hybrid response to planting date and plant populations, Harvey County Experiment Field, Hesston, 2008

Planting date[1]	Hybrid[2]	Plant population	Yield 2008[3]	Yield 4-year[4]	Moisture	Bushel weight	Ears/ plant	Days to silk[5]	Plant height	Lodging
		no./a	------bu/a------		%	lb/bu			in.	%
Interactions										
DOP*Hybrid[6]			NS	–	NS	NS	0.009	0.004	NS	NS
DOP*Population[7]			NS	–	NS	NS	NS	NS	NS	NS
Hybrid*Population[8]			NS	–	0.0001	0.0001	0.0001	0.001	NS	NS
Main effect means[9]										
Planting date										
March 14			140	108	15.1	58.0	1.12	102	82	0
March 28			140	107	14.9	58.2	1.13	88	82	0
April 16			145	105	14.9	58.0	1.16	70	83	0
LSD (0.05)			3.4		NS	NS	0.02	0.6	0.5	NS
Hybrid										
38H65			138	104	14.2	57.5	1.26	85	81	0
35P10			142	106	14.6	58.7	1.09	85	82	0
33B54			145	110	16.0	58.0	1.06	90	85	0
LSD (0.05)			4.3		0.12	0.14	0.03	0.2	0.5	NS
Plant population										
14,000			131	99	15.2	57.9	1.30	86	83	0
18,000			143	107	14.9	58.1	1.08	87	83	0
22,000			150	114	14.7	58.2	1.02	87	82	0
LSD (0.05)			4.3		0.12	0.14	0.03	0.2	NS	NS

[1] DOP. Actual planting dates were Mar. 18, Apr. 2, and Apr. 15, 2004; Mar. 14, Apr. 4, and Apr. 16, 2005; and Mar. 16, Mar. 31, and Apr. 14, 2006.
[2] Pioneer brand.
[3] Average of four replications adjusted to 56 lb/bu and 15.5% moisture.
[4] Average yields for 2004 through 2008, with 2007 omitted because of atypical planting dates.
[5] Days from planting to 50% silking.
[6] Probability of planting date effect differing with hybrid; NS = not significant.
[7] Probability of planting date effect differing with plant population; NS = not significant.
[8] Probability of hybrid effect differing with plant population; NS = not significant.
[9] Average values from 36 plots.

Herbicides for Cheat Control in Winter Wheat

M. M. Claassen

Summary
Sixteen herbicide treatments were evaluated for crop tolerance and cheat control efficacy in wheat as influenced by time of PowerFlex application vs. standards. Moderate populations of cheat developed. All fall treatments with PowerFlex, Maverick, Olympus, and Olympus Flex completely controlled cheat. Most late winter and spring treatments still provided good to excellent control, but on average, treatments tended to be somewhat less effective as application was delayed. However, late applications of Maverick were inferior. Crop injury from herbicides was minor and inconsequential. Fall and winter treatments significantly improved wheat yield by an average of 11.5 and 6.9 bu/a, respectively, but there was no significant yield increase with spring treatments. Grain test weight was not affected by herbicide treatments.

Introduction
Winter annual bromes such as cheat may develop into significant competition for wheat that is grown without adequate crop rotation. Shallow tillage or no-till can contribute to the problem. Several herbicides are currently available to growers that offer good crop tolerance and selective control of cheat in wheat. These products differ in their efficacy in controlling other weedy grasses as well as in the rotational restrictions for crops that follow. Pyroxsulam, marketed under the brand name PowerFlex, is a new ALS inhibitor without long soil persistence. The label for PowerFlex was released in March 2008, and the product became available for use in Kansas in the fall. Research reported herein was designed to evaluate this product's cheat control efficacy and crop tolerance when applied in the fall, winter, late winter, and spring.

Procedures
Winter wheat was grown on the experiment site in 2007. Soil was a Ladysmith silty clay loam with pH 6.6 and 2.4% organic matter. Reduced tillage practices were used to maintain the site and prepare the seedbed. Cheat seed was broadcast over the area to enhance uniformity of weed populations prior to the last preplant tillage operation. Wheat was fertilized with 91 lb/a nitrogen (N) and 33 lb/a P_2O_5. Variety 2137 was planted at 60 lb/a in 8-in. rows on Oct. 6, 2007. Seedbed condition was very good, but soil moisture was limited at seed depth. All herbicide treatments (Table 1), replicated four times, were broadcast in 20 gal/a of water with TeeJet XR8003 nozzles at 18 psi. Fall, winter, late winter, and spring postemergence treatments were applied on November 9, January 26, March 11, and March 26, respectively. Corresponding wheat stages were one to two tillers and a height of 3 to 4 in. in the fall, tillered with a height of 4 to 5 in. at both winter applications, and tillered with a height of 5 to 6 in. in the spring. On these dates, cheat had two leaves to one tiller and a height of 1 to 2 in. in the fall, 3 to 4 tillers and a height of 2 to 3 in. at both winter applications, and tillered with a height of 2 to 4 in. in the spring. Crop injury and weed control were rated several times during the growing season. Wheat was harvested on June 26, 2008.

Results

Wheat and cheat emergence were enhanced by 0.47 in. of rainfall 2 days after planting. Dry weather prevailed in November. Following fall herbicide applications, the next notable rainfall was limited to 0.18 in. at 15 days after treatment (DAT) plus 0.26 in. at 22 DAT. Heavier rains at 31 and 32 DAT totaled 2.25 in. Wet weather in December resulted in postponement of the intended late fall treatments until January. Rainfall totaled 0.60 in. during the first 11 days following the January (winter) application, 1.02 in. occurred within 7 days after the late winter application, and 1.58 in. were received at 11 to 15 days after the spring treatments.

Crop injury in the form of growth inhibition and/or chlorosis was minor and did not appear to be consequential. Moderate cheat populations developed. Cheat control was complete with all fall treatments. Results were essentially equivalent with all winter treatments, but maximum control was delayed until later in the spring. Average cheat control across treatments remained good to excellent with most late winter and spring treatments but declined significantly with each delay in application timing. PowerFlex, Olympus, and Olympus Flex performed equally well in controlling cheat at each time of application. Maverick also provided excellent cheat control following the first two times of application but was notably inferior to the other herbicides when applied in late winter or spring.

Averaged across all herbicide treatments, wheat yield increases were greatest with fall application and trended lower with later times of application. Average yields improved significantly by 11.5 and 6.9 bu/a with fall and winter treatments, respectively. Yield increases were significant with all fall treatments and, with the exception of PowerFlex, all winter treatments. Among late winter treatments, only Olympus Flex significantly improved wheat yield. Yield increases were not significant with any of the spring treatments. Grain test weight was not affected by herbicide treatments.

Table 1. Cheat control in winter wheat, Harvey County Experiment Field, Hesston, 2008

Herbicide treatment[1]		Product			Timing[2]	Injury 4/1[3]	Cheat control			Yield	Bushel weight[4]
		Form	Rate/a	Unit			4/1	5/6	6/11		
						%	%	%	%	bu/a	lb
1.	PowerFlex	7.5 WG	3.57	oz wt	Fall	0	84	100	100	58	59.4
	NIS		0.5	% v/v							
	AMSU		1.52	lb							
2.	Olympus	70 WG	0.9	oz wt	Fall	0	86	100	100	60	57.4
	NIS		0.5	% v/v							
3.	Olympus Flex	11.25 WG	3.17	oz wt	Fall	0	86	100	100	61	59.1
	NIS		0.5	% v/v							
	AMSU		1.52	lb							
4.	Maverick	75 WG	0.67	oz wt	Fall	1	85	100	100	54	59.3
	NIS		0.5	% v/v							
5.	PowerFlex	7.5 WG	3.57	oz wt	Winter	1	71	94	99	52	59.4
	NIS		0.5	% v/v							
	AMSU		1.52	lb							
6.	Olympus	70 WG	0.9	oz wt	Winter	1	69	96	100	56	59.3
	NIS		0.5	% v/v							
7.	Olympus Flex	11.25 WG	3.17	oz wt	Winter	0	70	92	100	53	59.4
	NIS		0.5	% v/v							
	AMSU		1.52	lb							
8.	Maverick	75 WG	0.67	oz wt	Winter	0	68	91	100	54	59.7
	NIS		0.5	% v/v							
9.	PowerFlex	7.5 WG	3.57	oz wt	L Winter	1	43	80	97	50	59.4
	NIS		0.5	% v/v							
	AMSU		1.52	lb							

continued

Table 1. Cheat control in winter wheat, Harvey County Experiment Field, Hesston, 2008

Herbicide treatment[1]		Product				Injury	Cheat control				Bushel
		Form	Rate/a	Unit	Timing[2]	4/1[3]	4/1	5/6	6/11	Yield	weight[4]
						%	%	%	%	bu/a	lb
10.	Olympus	70 WG	0.9	oz wt	L Winter	1	54	86	100	52	59.8
	NIS		0.5	% v/v							
11.	Olympus Flex	11.25 WG	3.17	oz wt	L Winter	0	49	81	95	53	59.4
	NIS		0.5	% v/v							
	AMSU		1.52	lb							
12.	Maverick	75 WG	0.67	oz wt	L Winter	1	56	73	87	49	59.1
	NIS		0.5	% v/v							
13.	PowerFlex	7.5 WG	3.57	oz wt	Spring	1	0	66	95	49	59.2
	NIS		0.5	% v/v							
	AMSU		1.52	lb							
14.	Olympus	70 WG	0.9	oz wt	Spring	1	0	65	94	48	59.3
	NIS		0.5	% v/v							
15.	Olympus Flex	11.25 WG	3.17	oz wt	Spring	0	1	65	93	51	59.1
	NIS		0.5	% v/v							
	AMSU		1.52	lb							
16.	Maverick	75 WG	0.67	oz wt	Spring	0	1	58	79	48	59.9
	NIS		0.5	% v/v							
17.	Untreated					0	0	0	0	47	58.9
LSD (0.05)						NS	12	6	5	6.0	NS

[1] AMSU = ammonium sulfate. NIS = Agral 90 nonionic surfactant.
[2] Fall = Nov. 9, 2007; Winter = Jan. 26, 2008; Late winter = Mar. 11, 2008; Spring = Mar. 26, 2008.
[3] Visual injury in the form of growth inhibition. Following fall treatments, means ranged from 3 to 5% on December 5.
[4] Apparent grain test weight of combine-harvested wheat.

Irrigation and North Central Kansas Experiment Fields

Introduction

The 1952 Kansas legislature provided a special appropriation to establish the Irrigation Experiment Field to serve expanding irrigation development in north central Kansas. The original 35-acre field was located 9 miles northwest of Concordia. In 1958, the field was relocated to its present site on a 160-acre tract near Scandia in the Kansas-Bostwick Irrigation District. Water is supplied by the Miller Canal and stored in Lovewell Reservoir in Jewell County, KS, and Harlan County Reservoir in Republican City, NE. In 2001, a linear sprinkler system was added on a 32-acre tract 2 miles south of the present Irrigation Field. In 2002, there were 125,000 acres of irrigated cropland in north central Kansas. Current research on the field focuses on managing irrigation water and fertilizer in reduced tillage and crop rotation systems.

The 40-acre North Central Kansas Experiment Field, located 2 miles west of Belleville, was established on its present site in 1942. The field provides information on factors that allow full development and wise use of natural resources in north central Kansas. Current research emphases are fertilizer management for reduced tillage crop production and management systems for dryland corn, sorghum, and soybean production.

Soil Description

The predominant soil type on both fields is a Crete silt loam. The Crete series consists of deep, well-drained soils that have a loamy surface underlain by a clayey subsoil. These soils developed in loess on nearly level to gently undulating uplands. The Crete soils have slow to medium runoff and slow internal drainage and permeability. Natural fertility is high. Available water holding capacity is approximately 0.19 in. of water per inch of soil.

Table 1. Climatic data for the Irrigation and North Central Kansas Experiment Fields

	Rainfall			Temperature		Growth units	
Month	Scandia 2008	Belleville 2008	30-year avg.	Daily mean 2008	Avg. mean	2008	Avg.
	-----------------in.-----------------			----------°F----------			
April	3.4	4.4	2.3	51	52	226	217
May	3.9	5.9	3.7	64	63	398	421
June	4.7	4.6	4.6	74	73	656	679
July	5.0	3.8	3.8	79	78	792	807
August	2.5	3.2	3.8	75	77	763	780
September	4.3	4.3	3.6	66	68	505	538
Total	23.8	26.2	21.8			3340	3442

Potassium Fertilization of Irrigated Corn

W. B. Gordon

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

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

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

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

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

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

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

Procedures

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

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

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

Results

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

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

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

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

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

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

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

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Table 1. Sources of potassium fertilizers

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

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

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

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

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

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

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

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

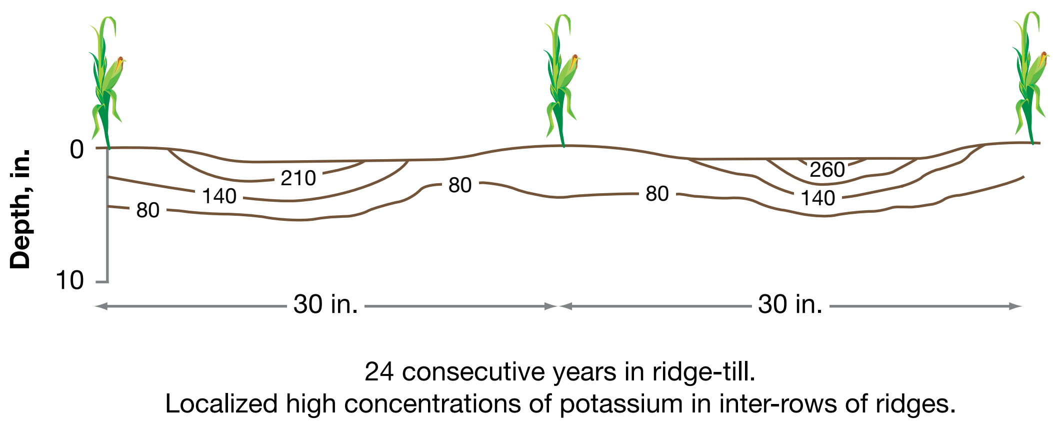

Figure 1. Potassium stratification on a Crete silt loam soil in north central Kansas.

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

W. B. Gordon

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

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

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

Conservation-tillage systems are being used by an increasing number of producers in the central Great Plains. No-till systems have proven effective at maintaining soil quality and reducing soil erosion because of several inherent advantages: reduction of soil erosion losses, increased soil water use efficiency, and improved soil quality. The large amount of surface residue present in reduced-tillage systems can reduce seed zone temperatures, which may inhibit root growth and reduce nutrient uptake. Lower-than-optimum soil

temperature can reduce the rate of root growth (Ching and Barbers, 1979) and P uptake by the root (Carter and Lathwell, 1967). Mackay and Barber (1984) found that when soil temperature was reduced from 70 to 58°F, corn root growth decreased fivefold, and P uptake by corn roots decreased fourfold. Because of these environmental and physical conditions, nutrient deficiencies can take place even on soils that are not low in available nutrients.

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

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

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

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

Procedures

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

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

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

Results

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

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

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

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

Zinc deficiencies can occur in areas where topsoil was removed by erosion, land leveling, or terracing (Gerwing et al., 1982). Zinc deficiencies are frequently reported during

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

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

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

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

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

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

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

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

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

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

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

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

Table adapted from Gordon et al. (1997).

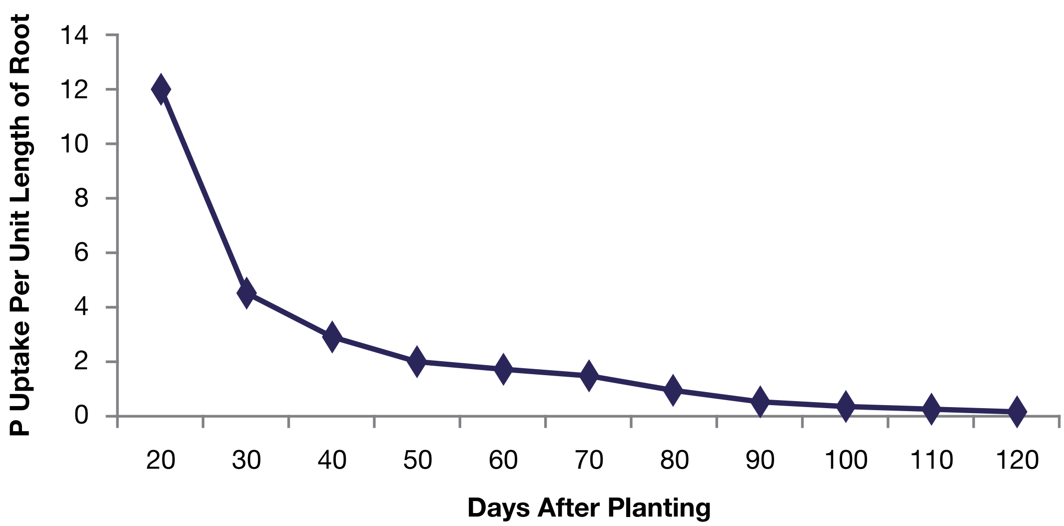

Figure 1. Phosphorus uptake per unit of root length over time.
Figure adapted from Mengel and Barber (1974).

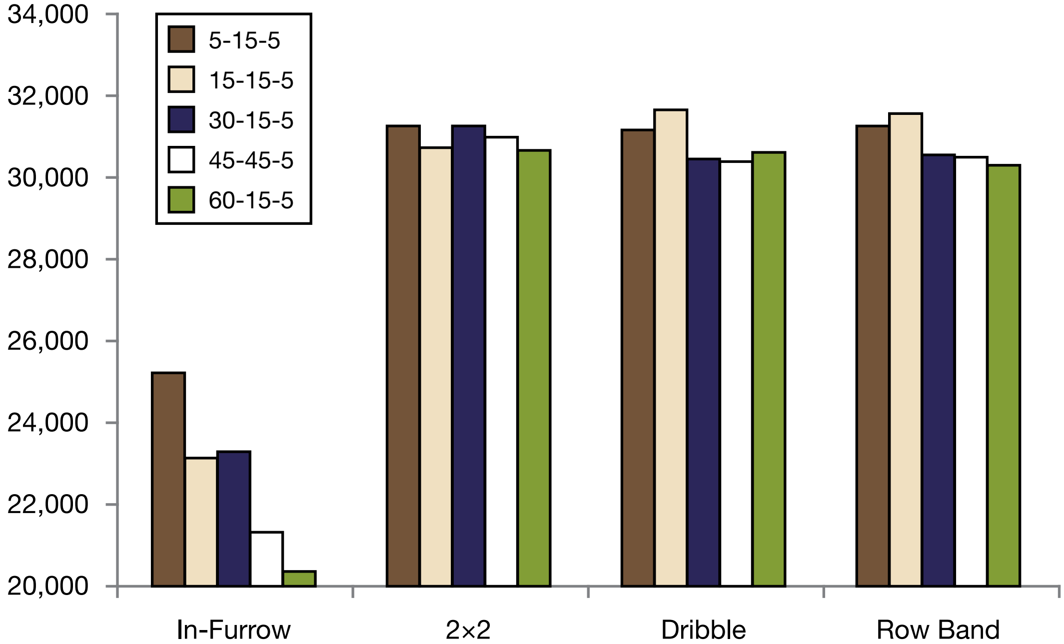

Figure 2. Plant population, 3-year average.

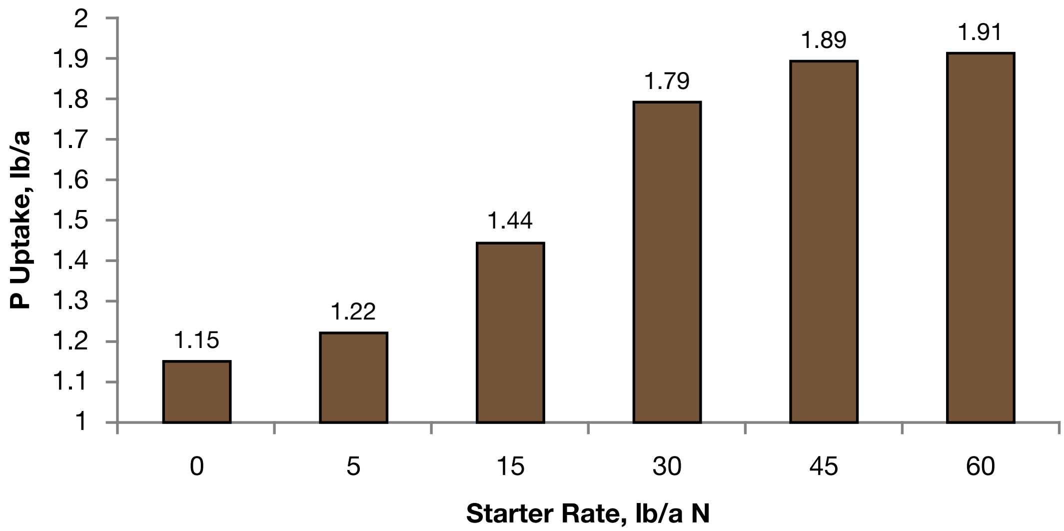

Figure 3. Starter nitrogen rate effects on V6 stage whole plant phosphorus uptake, 3-year average.

Use of Soybean Seed Treatments

W. B. Gordon

Summary
Soil temperatures below 60°F will inhibit soybean growth and promote seed rot and damping off, particularly in wet, cool soils. Crusted soils can cause stress in emerging plants and promote seedling diseases. Insects such as wireworms, seed corn maggots, potato leafhoppers, and bean leaf beetles can be problems in stand establishment and early season growth of soybean. Use of seed-applied fungicides and insecticides may improve stands and increase yield. A 3-year study was conducted at the North Central Kansas Experiment Field to evaluate the effectiveness of a seed-applied fungicide and insecticide on three soybean varieties (NKS 32-G5, NKS 35-F9, and NKS 37-N4). Treatments include a fungicide alone, a fungicide plus insecticide, and a no-seed-treatment check. The fungicide used was Apron Maxx RFC (mefenoxam plus fludioxnil), and the insecticide was Crusier 5FS (thiamethoxam). Averaged over years, use of seed-applied fungicide improved stands of all varieties by more than 17,000 plants/a and improved yield by 5 bu/a. In general, neither stand nor yield were improved with addition of an insecticide, except for one variety in 1 year of the experiment. In 2007, addition of the insecticide increased yield of NKS 32 G5 by more than 10 bu/a compared with the fungicide-only treatment. When planting in April to mid-May, applying fungicides to soybean seed can significantly improve yield. Insect levels can be unpredictable. Insecticides applied to seed can increase yield, but probably not every year.

Introduction
As producers move to earlier planting dates for soybean and use reduced or no-till production systems, seedling diseases and early season insects could become more of a problem. Soil temperatures below 60°F will inhibit soybean growth and promote seed rot and damping off, particularly in wet, cool soils. Crusted soils can cause stress in emerging plants and promote seedling diseases. Soilborne diseases such as *Phytophora*, *Pythium*, *Rhizoctonia*, and *Fusarium* can be problems in cool, wet soils. Seedborne diseases such as *Phomopsis* and *Sclerotina* can also be prevalent. Seed-applied fungicides can be useful in controlling these diseases.

Procedures
From 2004 to 2007, three soybean varieties (NKS 32-G5, NKS 35-F9, and NKS 37-N4) were planted without tillage into corn stubble at the rate of 160,000 seeds/a. Planting dates were May 10, 2005, May 12, 2006, and May 28, 2007. Planting was delayed in 2007 because of wet weather. Seeds of the three soybean varieties were treated with a fungicide (Apron Maxx), a fungicide plus insecticide (Apron Maxx + Cruiser), or left untreated.

Results
Averaged over the 3 years of the experiment, use of a fungicide increased plant population by more than 17,000 plants/a compared with the untreated check (Figure 1).

Averaged over years and varieties, soybean yield was improved by 5 bu/a when the crop was treated with a fungicide (Figure 2). Addition of a seed-applied insecticide improved yield in only 1 year (2007) for one variety (NKS 32-G5) (Figure 3).

When planting in April to mid-May, applying fungicides to soybean seed can significantly improve yield. As planting date moves to June 1 or later, there is less need for seed-applied fungicides. Insect levels can be unpredictable. Insecticides applied to seed can increase yield, but probably not every year.

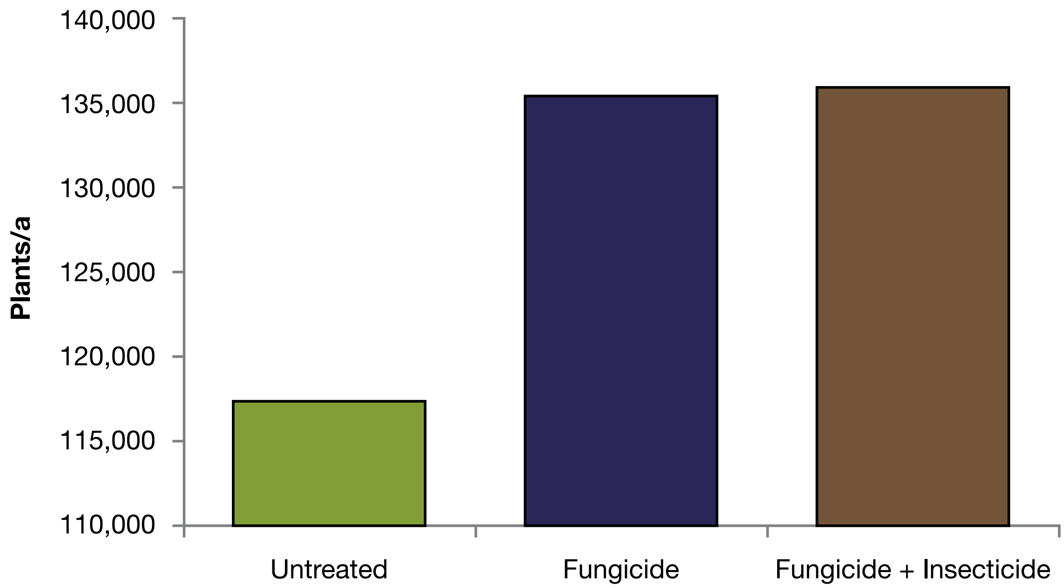

Figure 1. Soybean seed treatment effects on plant population averaged over varieties, 2005-2007.

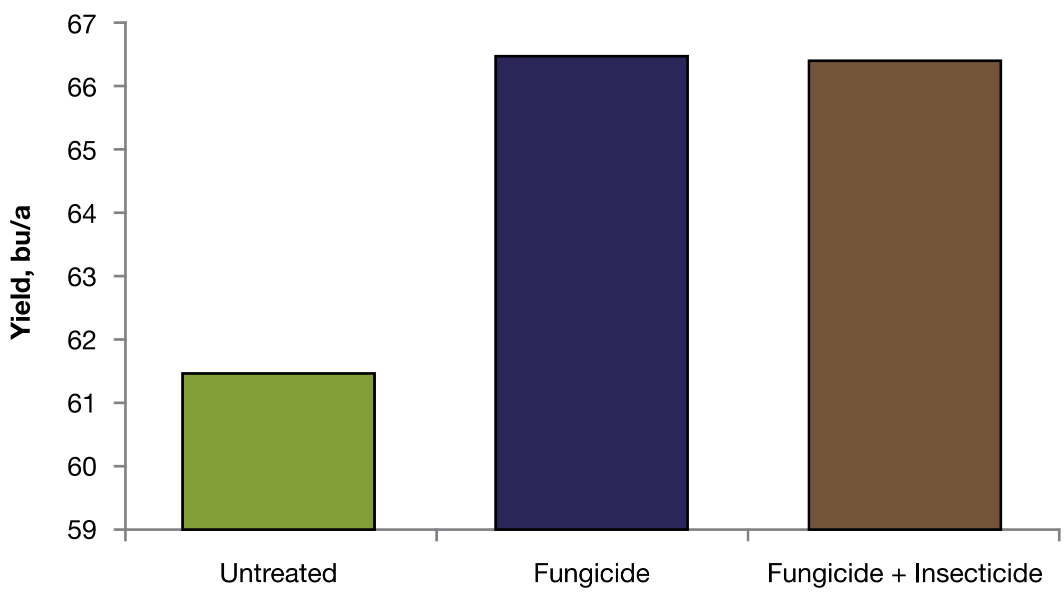

Figure 2. Soybean yield as affected by seed treatment averaged over varieties, 2005-2007.

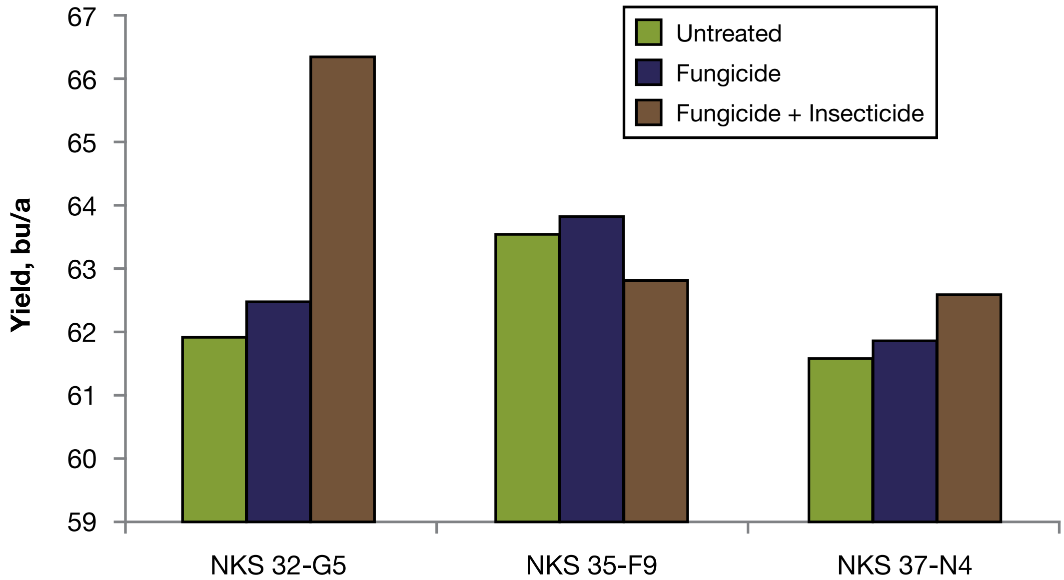

Figure 3. Soybean yield as affected by seed treatment, 2007.

Chloride Fertilization for Wheat and Grain Sorghum

W. B. Gordon

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

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

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

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

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

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

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

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

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

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

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

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

South Central Kansas Experiment Field

Introduction

The South Central Kansas Experiment Field–Hutchinson was established in 1951 on the U.S. Coast Guard Radio Receiving Station located southwest of Hutchinson, KS. The first research data were collected with the harvest of 1952. Prior to this, data for the south central area of Kansas were collected at three locations: Kingman, Wichita/Goddard, and Hutchinson. The current South Central Kansas Experiment Field location is approximately ¾ miles south and east of the old Hutchinson location on the Walter Peirce farm.

Research at the South Central Kansas Experiment Field is designed to help the area's agriculture develop to its full agronomic potential with sound environmental practices. The principal objective is achieved through investigations of fertilizer use, weed and insect control, tillage methods, seeding techniques, cover crops and crop rotations, variety improvement, and selection of hybrids and varieties adapted to the area as well as alternative crops that may be beneficial to the area's agriculture production. Experiments focus on problems related to production of wheat, grain and forage sorghum, oat, alfalfa, corn, soybean, cotton, rapeseed/canola, and sunflower and soil tilth, water, and fertility. Breeder and foundation seed of wheat, oat, and canola varieties and hybrids are produced to improve seed stocks available to farmers. A large portion of the research program at the field is currently dedicated to wheat and canola breeding and germplasm development.

In March 2004, the Kansas State University (KSU) Foundation took possession of approximately 300 acres of land southwest of Partridge, KS. This land was donated to the Foundation by George V. Redd and Mabel E. Bargdill for use in developing and improving plants and crops. The acreage is in two parcels; one is approximately 140 acres, lies south of Highway 61 and west of county road Centennial, and was in CRP until the contract ran out. In December 2007, two wells were drilled on this quarter to provide for future irrigation research. A sprinkler irrigation system has been installed and will allow this parcel of land to be used for irrigated research. The second parcel, a full quarter, is currently used for Foundation wheat and oat production and wheat, canola, grain sorghum, soybean, and cotton fertility combined with various cropping rotations. Both quarters will be worked into the research activities of the South Central Kansas Experiment Field.

Soil Description

A new soil survey was completed for Reno County and has renamed some of the soils on the field. The new survey overlooks some of the soil types present in the older survey, and we believe the following descriptions of soils on the experiment field are more precise. The South Central Kansas Experiment Field has approximately 120 acres classified as nearly level to gently sloping Clark/Ost loams with calcareous subsoils. This soil requires adequate inputs of phosphate and nitrogen fertilizers for maximum crop production. The Clark soils are well drained and have good water-holding capacity. They are more calcareous at the surface and less clayey in the subsurface than the Ost. The Ost soils are shallower than the Clark, having an average surface layer of only 9 in. Both

soils are excellent for wheat and grain sorghum production. Large areas of these soils are found in southwest and southeast Reno County and in western Kingman Counties. The Clark soils are associated with the Ladysmith and Kaski soils common in Harvey County but are less clayey and contain more calcium carbonate. Approximately 30 acres of Ost Natrustolls Complex with associated alkali slick spots occur on the north edge of the field. This soil requires special management and timely tillage because it puddles when wet and forms a hard crust when dry. A 10-acre depression on the south edge of the field is a Tabler-Natrustolls Complex (Tabler slick spot complex). This area is unsuitable for cultivated crop production and was seeded to switchgrass in 1983. Small pockets of the Tabler-Natrustolls are found throughout the experiment field.

The soils on the Redd-Bargdill Foundation land are different from those on the experiment field. The south quarter (CRP) has mostly Shellabarger fine sandy loams with 1 to 3% slopes. There are also some Farnums on this quarter. The new classification has these soils classified as Nalim loam. The north quarter was previously all classified as Tabler clay loam. However, the new survey classifies the soils as Funmar-Taver loams, Funmar loams, and Tever loams.

Weather Information

The U.S. Department of Commerce National Oceanic and Atmospheric Administration National Weather Service rain gage (Hutchinson 10 S.W. 14-3930-8) collected 37.97 in. of precipitation in 2008, which is 7.93 in. above the 30-year (most recent) average of 30.04 in. From 1997 to 2000, precipitation was above average. In 2001, 2003, and 2006, precipitation recorded at the field was below normal. Precipitation for 2002, 2004, 2005, and 2008 was above normal. The 30-year average has been increasing over the past few years. These figures are different from those available through the KSU automated weather station (http://www.ksre.k-state.edu/wdl/) because of the distance between the two rain gages. As with all years, distribution within the year and rainfall intensity determine the usefulness of the precipitation. The late spring and early summer months of April, May, and June are still the months when the field receives most of the yearly precipitation (Table 1). The record amount of precipitation occurred in 1978 with a little more than 47 in. recorded. A frost-free growing season of 195 days (April 14 to October 26, 2008) was recorded. This is 12 days more than the average frost-free season of 183 days (April 19 to October 17).

Table 1. Precipitation at the South Central Kansas Experiment Field, Hutchinson, S.W. 14-3930-8

Month	Rainfall	30-year avg.[1]	Month	Rainfall	30-year avg.
	---------------in.---------------			---------------in.---------------	
2007			2008		
September	0.65	2.59	May	7.41	4.12
October	2.91	2.47	June	6.35	4.43
November	0.11	1.29	July	2.53	3.66
December	4.26	0.97	August	2.29	3.07
2008			September	5.73	2.34
January	0.49	0.74	October	5.10	2.48
February	1.87	1.09	November	1.06	1.23
March	1.69	2.74	December	0.37	1.09
April	3.10	2.49	2008 Total	37.97	30.04

[1] Most recent 30 years.

Crop Performance Tests at the South Central Kansas Experiment Field

W. F. Heer and J. E. Lingenfelser

Summary

Performance tests for winter wheat, grain sorghum, alfalfa, canola, sunflower, oat, spring wheat and summer annual forages were conducted at the South Central Kansas Experiment Field. Off-site tests for irrigated corn, soybean, and grain sorghum were also conducted. Results of these tests can be found in the following publications, which are available through your local K-State Research and Extension office or online at: http://www.ksre.ksu.edu/library/.

For additional information, see the Kansas Crop Performance Test Web site: http://kscroptests.agron.ksu.edu/

2008 Kansas Performance Tests with Winter Wheat Varieties
KAES Report of Progress 999

2008 Kansas Performance Tests with Corn Hybrids
KAES Report of Progress 1000

2008 Kansas Performance Tests with Soybean Varieties
KAES Report of Progress 1003

2008 Kansas Performance Tests with Grain Sorghum Hybrids
KAES Report of Progress 1004

2008 Kansas Performance Tests with Sunflower Hybrids
KAES Report of Progress 1006

2008 National Winter Canola Variety Trial
KAES Report of Progress 1009

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

W. F. Heer

Summary

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

Introduction

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

Procedures

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

Continuous Wheat

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

Wheat After Corn/Grain Sorghum/Fallow

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

Wheat After Soybean

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

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

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

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

Results

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

Continuous Wheat–Canola 2006

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

Wheat After Soybean

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

Wheat After Grain Sorghum/Cover Crop

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

Other Observations

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

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

Soybean and Grain Sorghum in the Rotations

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

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

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

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

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

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

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

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

[3] NT canola did not get established.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

W. F. Heer

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

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

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

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

Results

Winter Wheat

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

Grain Sorghum

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

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

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

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

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

.

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

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

[1] Nitrogen applied after winter pea termination prior to planting grain sorghum.
[2] Early April termination. Actual termination: May 16, 1996, April 21, 1999, April 13, 2002, and April 27, 2005.
[3] Early May termination. Actual termination: June 4, 1996, May 19, 1999, May 25, 2002, and May 18, 2005.

No-Till Management Reduces Soil Compactibility by Increasing Organic Carbon

H. Blanco, L. R. Stone, A. J. Schlegel, D. J. Lyon, M. F. Vigil, M. M. Mikha, P. W. Stahlman, and C. W. Rice

Summary

Compaction can be a problem in some no-till soils, but accumulation of soil organic carbon over time may counteract any excessive compaction. Relationships between soil organic carbon and soil compactibility have not been well documented. Thus, we assessed soil compactibility by using the Proctor test in long-term conventional-tillage, reduced-tillage, and no-till systems managed under the same cropping systems in the central Great Plains and determined the relationships of soil compactibility with soil organic carbon. Experiments were located on four representative soils in Hays and Tribune, KS, Akron, CO, and Sidney, NE. Maximum bulk density, equivalent to maximum compactibility, under conventional tillage was higher than under no-till by 13% at Sidney and by about 6% at the other sites. Soil organic carbon concentration in no-till was higher than in conventional tillage by 82% at Hays and by 76% at Sidney. Maximum bulk density decreased with increased soil organic carbon concentration. This regional study showed that long-term no-till systems can offset some risks of soil compaction by increasing soil organic carbon concentration.

Introduction

Soil compaction is often a major concern in no-till farming. Most no-till soils, however, develop a natural buffering capacity against excessive compaction with time. One of the main reasons for this is the gradual accumulation of soil organic matter in the upper layers of no-till soils. This increase in organic matter makes the soil more elastic, improves soil aggregation, enhances microbial processes, and reduces bulk density of the whole soil. Interaction of soil organic matter accumulated near the surface layers with residue mulch cover under no-till farming may reduce excessive soil compaction, unlike intensive plow tillage, which mixes soil, accelerates soil organic matter oxidation, and reduces soil organic matter concentration, thereby degrading soil structure and increasing the soil's susceptibility to rapid consolidation and compaction.

Influence of soil organic matter on soil compactibility may depend on several variables including amount of soil organic matter, soil texture, antecedent soil water content, management (e.g., tillage and cropping system), and climate. Differences in soil organic matter concentration between no-till and plow tillage in semiarid regions, such as the central Great Plains, are generally small because of reduced biomass production and local climate influence. The importance of soil organic matter in reducing a soil's susceptibility to compaction under different soils and ecoregions has not, however, been widely recognized.

Objectives of this regional study were to assess soil compactibility by using the Proctor test under various long-term no-till systems compared with conventional tillage and reduced tillage in the central Great Plains and determine relationships of soil compactibility with soil organic carbon.

Procedures

This regional study was conducted across four representative soils under ongoing long-term tillage experiments, which have been in place between 19 and 43 years, in the central Great Plains. These experiments were selected because of their long-term management history; they have been managed under the same tillage and cropping systems since inception. The tillage experiments—conventional tillage, reduced tillage, and no-till—were arranged in a randomized complete block design. Crop rotations were winter wheat/grain sorghum/fallow at Hays and Tribune and winter wheat/fallow at Akron and Sidney. Soil samples were obtained from each plot treatment and site for the 0- to 2-in. soil depth for determination of maximum bulk density and soil organic carbon concentration. Maximum bulk density was determined by using the Proctor test, which consisted of preparing soil mixtures at different levels of water content between air-dry and near saturation points and applying a constant compactive force by the Proctor hammer. The test was used on samples moistened successively at six levels of water content. Each soil mixture was compacted in three layers in a standard Proctor mold with 25 blows per layer by using a Proctor drop-hammer falling. Compacted soil was carefully trimmed and weighed, and a subsample was oven dried. Proctor density was computed by dividing the oven-dry weight of the compacted soil by the volume of the Proctor mold. Soil organic carbon concentration was determined by the dry combustion method.

Results

Maximum bulk density differed significantly among tillage systems in all soils (Figure 1A). No-till soils had lower maximum bulk density than conventional-tillage and reduced-tillage soils in most locations. Differences in maximum bulk density between conventional-tillage and no-till soils were relatively smaller at Akron, Hays, and Tribune than at Sidney. Maximum bulk density of conventional-tillage soil was higher than that of no-till soil by about 6% at Akron, Hays, and Tribune and 13% at Sidney (Figure 1A). Maximum bulk density of no-till soil was lower than that of reduced-tillage soil by 3, 4, and 5% at Akron, Hays, and Tribune, respectively. Maximum bulk density of conventional tillage soil was higher than that of reduced-tillage soil at Akron and Sidney.

Soil organic carbon concentration measured for the 0- to 2-in. soil depth was also affected by tillage treatments, except at the Tribune site (Figure 1B). Soil organic carbon concentration in no-till soil was 82% higher than in conventional-tillage soil at Hays and 76% higher than in conventional-tillage soil at Sidney. Soil organic carbon concentration in no-till soil was higher than that in reduced-tillage soil by 48% at Sidney. There were no differences in soil organic carbon concentration between conventional tillage and reduced tillage at any of the four sites, except at Sidney, where soil organic carbon concentration in reduced-tillage soil was 20% higher than that in conventional-tillage soil. Maximum bulk density was negatively correlated with soil organic carbon concentration. Changes in soil organic carbon concentration explained nearly 50% of the changes in

near-surface maximum soil compactibility in soils in the central Great Plains (Figure 2). Across all soils, changes in soil organic carbon concentration between conventional tillage and no-till explained about 64% of the variability in maximum bulk density.

This study showed that no-till soils are less prone to compaction than conventionally tilled soils. In other words, long-term no-till systems can develop a natural defense against shallow compaction by increasing soil organic carbon concentration. Even small or modest increases in soil organic carbon concentration due to no-till appear to offset some risks of compaction over conventional tillage. The study also showed that no-till soils can be trafficked at greater soil water contents with lower susceptibility to compaction. In contrast, plowed soils become more readily compacted at water contents much lower than no-till soils. Reduced tillage can also reduce a soil's susceptibility to compaction, but the benefits are smaller than with no-till farming.

Not all soils will react the same to no-till. The ability of a no-till soil to resist shallow compaction with time will depend on the rate of soil organic carbon accumulation and soil type (e.g., differences in textural class and drainage). In systems with limited return of crop residues, for which there are little or no gains of soil organic carbon, and on clayey and poorly drained soils, no-till may have only a limited effect on the ability of the soil to resist compaction. Benefits of no-till in reducing soil compactibility may also be smaller at deeper soil depths because most of the soil organic carbon is accumulated near the surface layers in no-till soils.

Compared with other methods used to reduce soil compaction, such as deep ripping, no-till and the associated buildup of soil organic carbon have many advantages. An increase in soil organic carbon can reduce susceptibility of a soil to compaction without causing soil disturbance. This has enormous importance at a time when soil compaction and soil deterioration are major concerns. Increasing soil organic carbon is important not only to sustaining crop production, filtering pollutants, improving soil structure and tilth, enhancing microbial processes, and reducing risks of global climate change, but also to reducing the potential for shallow soil compaction.

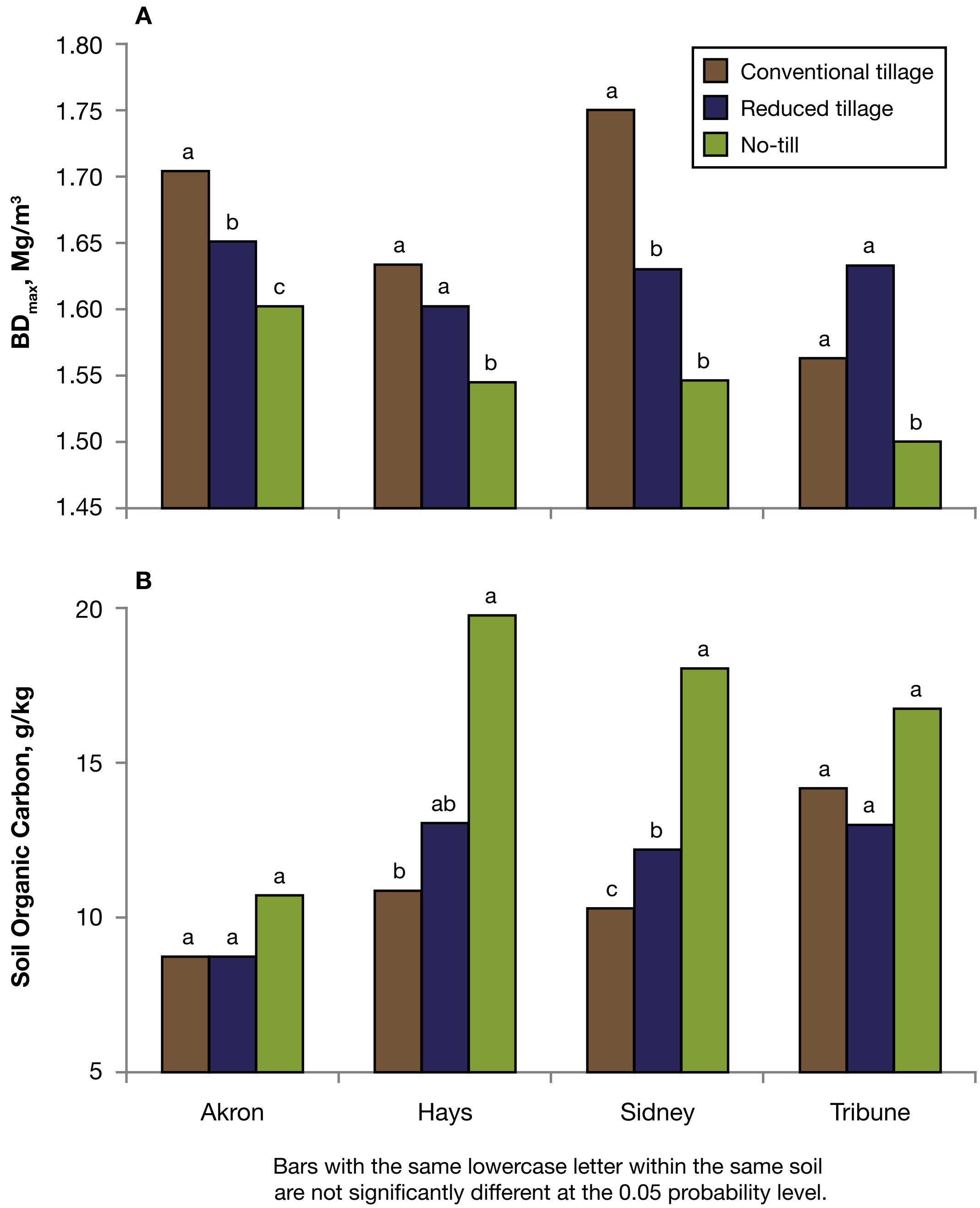

Figure 1. Differences in (A) maximum bulk density (BD_{max}) and (B) soil organic carbon concentration among three tillage systems across four soils (sites) in the central Great Plains.

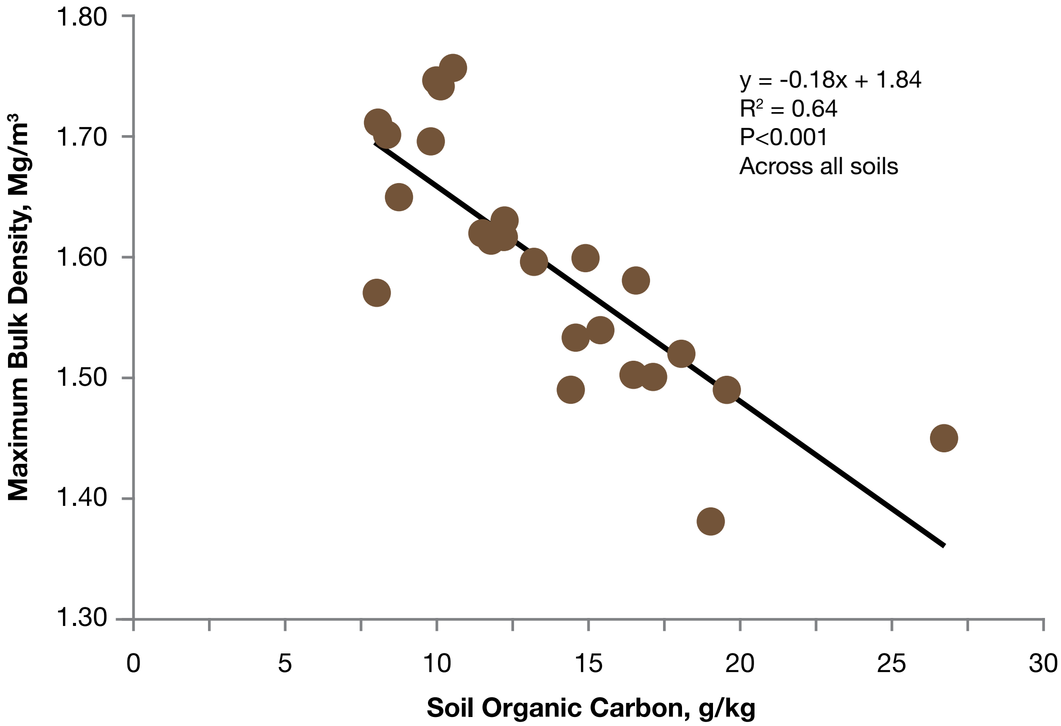

Figure 2. Relationship between maximum bulk density and organic carbon concentration in soils under conventional tillage and no-till in the 2-in. soil depth in the central Great Plains.

No-Till Management Effects on Soil Water and Wind Erodibility Parameters

H. Blanco, M. M. Mikha, J. G. Benjamin, L. R. Stone, A. J. Schlegel, D. J. Lyon, M. F. Vigil, and P. W. Stahlman

Summary

The extent to which no-till management improves water and wind erodibility parameters is not well understood. This study assessed changes in aggregate resistance to raindrops, dry aggregate wettability, and dry aggregate stability as well as their relationships with changes in soil organic carbon concentration in the central Great Plains. Three long-term tillage systems (conventional tillage, reduced tillage, and no-till) were studied at four sites across the central Great Plains: Hays and Tribune, KS, Akron, CO, and Sidney, NE. The kinetic energy of simulated raindrops required to disintegrate 4.75- to 8-mm aggregates from no-till soils was between two and seven times greater than that required for conventionally tilled soils in the 0- to 1-in. depth in all soils. No-till soils delayed water entry into aggregates by four times at Akron and Hays and by seven times at Sidney and Tribune compared with plowed soils. Aggregates from no-till soils were more stable under rain and less wettable than those from plowed soils, particularly at the soil surface. Reduced tillage had lesser beneficial effects than no-till management. Soil organic carbon concentration explained 35% of the variability across soils in aggregate wettability (a measure of how readily aggregates can repel water) and 28% of the variability in resistance to raindrops. Tillage system did not affect dry aggregate size distribution and stability. Aggregates in conventionally tilled soils were either stronger than or equally as strong as those in no-till soils when dry but were less stable when wet. Overall, no-till farming enhanced near-surface aggregate properties affecting water erosion but had small or no effects on dry aggregate stability.

Introduction

Characterization of near-surface soil aggregate structural properties such as aggregate size distribution, stability, and aggregate wettability is crucial to predicting soil erosion potential, structural development, and soil organic carbon dynamics. In fact, knowledge of resistance of near-surface soil aggregates to erosive forces of wind and rain is critical in determining the extent to which a soil will erode. This is especially important in semiarid regions, such as the Great Plains, where low precipitation, high evaporation, and variable and low biomass production in interaction with intensive tillage can alter aggregate properties and accelerate soil's susceptibility to wind and water erosion.

Most producers are aware that no-till can help control water and wind erosion because of increased surface residue. Crop residue helps diminish the impact of raindrops and reduces the erosive power of wind at the soil surface. What if surface crop residue is sparse in a no-till system? No-till and high surface residue levels do not always occur together. Surface residue may be sparse in no-till if crop yields are very low, if low residue producing crops are a part of the rotation, or if crop residue is removed for biofuels or some other use. Will no-till still help control water and wind erosion under those conditions? The answer to this question depends on whether no-till improves near-surface (upper

few inches) soil structural properties. Soil aggregate stability is another factor involved in determining susceptibility of a soil to water and wind erosion. If soil aggregates in the upper layer of the soil are strong and stable, they will be more able to resist breakdown by striking raindrops and withstand the abrasive erosive energy of wind.

Although benefits of conservation tillage for increasing capture and retention of precipitation and intensification of cropping systems are well recognized, effects of these tillage systems on near-surface aggregate structural properties are not well understood. Previous studies have shown that conservation-tillage management may not always increase soil aggregate stability over plowed systems. By leaving crop residues on the soil surface and minimizing soil disturbance, conservation-tillage practices often increase soil organic carbon concentration. In some soils, this increase in soil organic carbon may lead to improved stability of aggregates over plowed systems because materials enriched with soil organic carbon provide organic binding agents to soil, which coalesce microaggregates into stable macroaggregates. Further assessment of tillage effects on near-surface parameters of soil erodibility and their relationships with soil organic carbon across a range of soils is needed.

Objectives of this study were to quantify changes in aggregate properties (e.g., size distribution, stability, resistance to raindrops, and wettability) and study their relationships to soil organic carbon concentration under various long-term tillage systems in the central Great Plains.

Procedures

Four representative long-term (between 19 and 43 years) tillage experiments across the central Great Plains were selected for this study. Field sites were located at Akron, CO, Sidney, NE, and Hays and Tribune, KS. Tillage systems were established in a randomized complete block design at each site. Crop rotations were winter wheat/grain sorghum/fallow at Hays and Tribune and winter wheat/fallow at Akron and Sidney. Soil samples were collected from each treatment plot at each site for the 0- to 4-in. soil depth for determination of aggregate resistance to raindrops, wettability, and dry aggregate stability in late summer 2008.

Aggregate resistance to raindrops was determined by using a raindrop simulator. Wettability of soil aggregates was determined on 4.75- to 8-mm air-dry aggregates by using the water drop penetration time method, which consists of placing a drop of deionized water on top of individual aggregates with a microsyringe and recording time (seconds) required for the drop to completely enter the aggregate. Dry aggregate stability was determined by using a column of sieves with different openings. Soil retained in each sieve was weighed to compute the mean weight diameter of aggregates. Soil organic carbon concentration was determined by the dry combustion method.

Results

Soil Water Erodibility Parameters

No-till farming increased both soil aggregate resistance against raindrops (Figure 1A) and water repellency (Figure 1B) compared with plowed systems, particularly at the soil surface (0- to 1-in. depth). Kinetic energy of raindrops needed for aggregate disintegration in no-till soils was consistently greater than in plowed soils. At Tribune, no-till

management increased kinetic energy for aggregate disintegration at all depth intervals from 0 to 4 in. Kinetic energy for aggregate disintegration between reduced tillage and conventional tillage did not differ in most soils. In the 0- to 1-in. depth, water drop penetration time in no-till soils was four times greater at Akron and Hays and seven times greater at Sidney and Tribune compared with plowed soils (Figure 1B). Water drop penetration time values averaged across soils at Akron and Hays were 2.5 seconds for no-till and 0.6 seconds for conventional tillage, whereas at Sidney and Tribune, water drop penetration time averages were 11 seconds for no-till and 1.5 seconds for plowed soils in the 0- to 1-in. depth.

Soil organic carbon in no-till was greater than in plow tillage in most soils in the surface 0 to 1 in. The greater aggregate resistance to breakdown was partly due to the greater soil organic carbon concentration in no-till soils. Kinetic energy of raindrops for disintegration of aggregates increased positively with the increase in soil organic carbon concentration in all soils (Figure 2). Organic matter is the key to the improvement in aggregate stability found in no-till soils. Soils rich in organic carbon most likely provide organic binding agents, which join microaggregates together into stable macroaggregates. The increase in soil organic carbon concentration with no-till farming also reduces rapid wetting of soil aggregates. Soil organic carbon compounds often coat soil aggregates and impart slight hydrophobic properties, which are critical for aggregate stabilization. The slight reduction in water entry into aggregates reduces both aggregate slaking and the amount of soil which will be eroded. Results suggest that soil organic carbon increase with no-till improved aggregate resistance to raindrops by inducing slight water repellency and by binding soil particles into stable aggregates.

The bottom line is that aggregates from no-till soils were more water-stable, less wettable, and had greater organic carbon concentration than soils under conventional tillage. Aggregates of plowed soils were weaker against water and wetting forces because of frequent soil disturbance, which disrupts aggregate formation and accelerates losses of soil organic matter. It is, however, important to note that no-till soils can also become susceptible to water erosion in the long term if crop residue is continually removed at high levels for expanded uses, such as cellulosic ethanol production. Continued removal of residue can eventually reduce wet aggregate stability and other structural parameters influencing soil water erodibility.

Soil Wind Erodibility Parameters

Results of this regional study also show that under very dry soil conditions, aggregates in no-till soils may be no more stable (or even less stable) than those in plowed soils. The lack of differences of dry aggregate stability contrasted with the large and positive effects of no-till on aggregate wettability and resistance to breakdown under raindrops. The greater soil organic carbon enriched materials in no-till soils may have a more positive effect on stabilizing wet aggregates than dry aggregates because of greater adhesive (e.g., glue-like binding substances) forces of organic materials acting in wet aggregates. This finding suggests that no-till soils, if left without residue cover, can be eroded by wind at equal or even at higher rates than plowed soils.

This points out the crucial need for maintaining surface residue cover to protect soil from wind erosion. Residue cover buffers the erosive forces of wind, reduces evapora-

tion, and minimizes abrupt fluctuations in wetting and drying cycles that weaken soil aggregates. No-till soils with limited aboveground biomass production are more vulnerable to wind erosion compared with plowed soils, for which the transient roughness created by tillage may reduce wind erosion.

Under typical no-till conditions with high levels of residue on the surface, wind erosion rates are expected to be lower in no-till soils. Depending on the amount of residue, no-till soils tend to be wetter than plowed soils because of reduced evaporation, which reduces soil detachment by wind. The greater the water content of surface soils, the lower the wind erosion rates.

This regional study shows that no-till farming has large and positive effects on improving soil structural properties and reducing soil water erodibility, even if surface crop residue levels are sparse. But effects of no-till on aggregate properties influencing wind erosion appear to be limited; adequate surface crop residue levels must be maintained for no-till to reduce wind erosion. The ability of no-till to control water erosion has enormous implications because intense rainstorms can cause large losses of soil in semiarid regions. Increasing soil organic concentration through no-till and other best management practices is crucial for reducing soil erosion while improving soil quality and sustaining crop production.

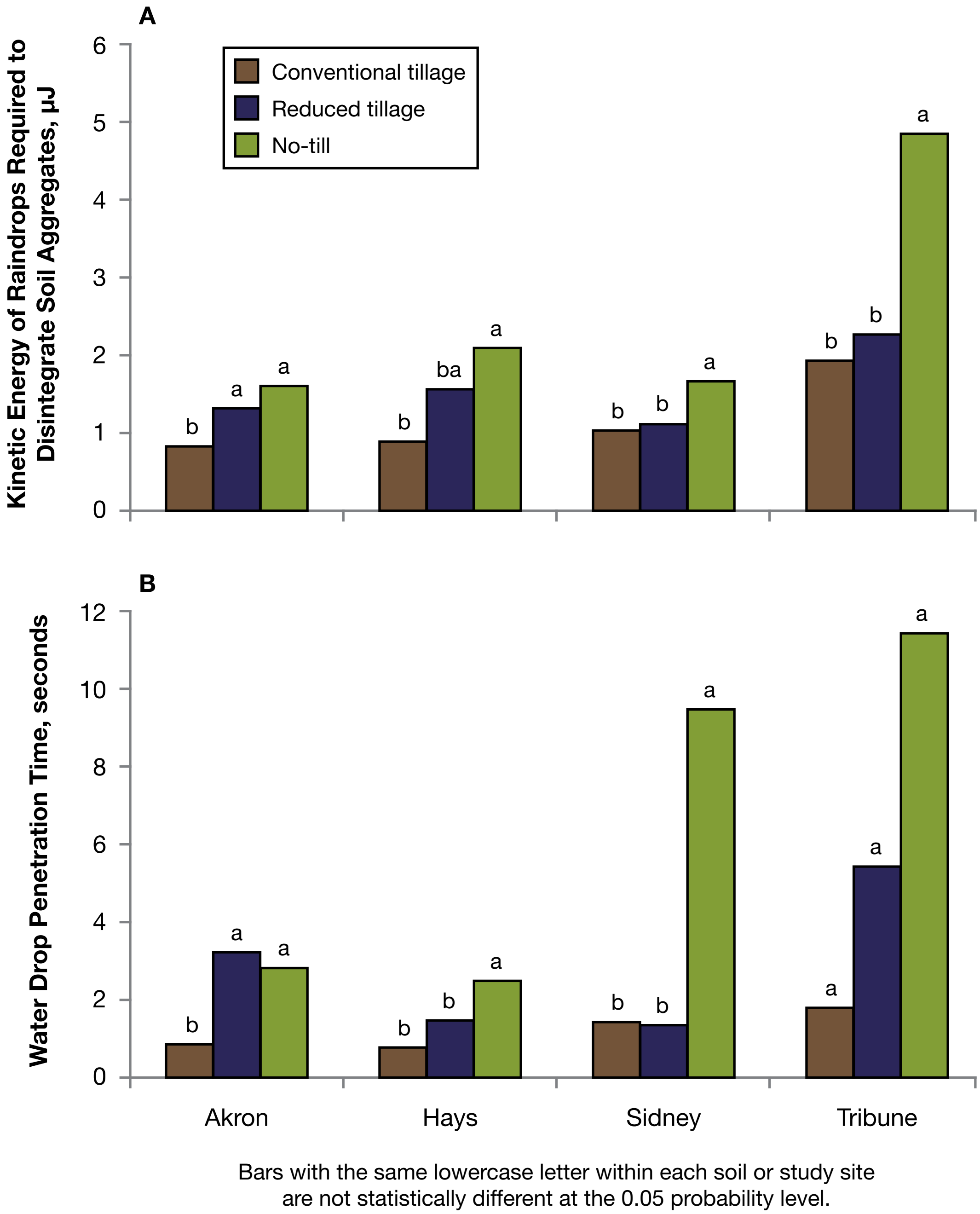

Figure 1. Effect of tillage on two properties of near-surface soil aggregates including (A) resistance to raindrops and (B) water repellency in four soils for the 0- to 1-in. depth in the central Great Plains.

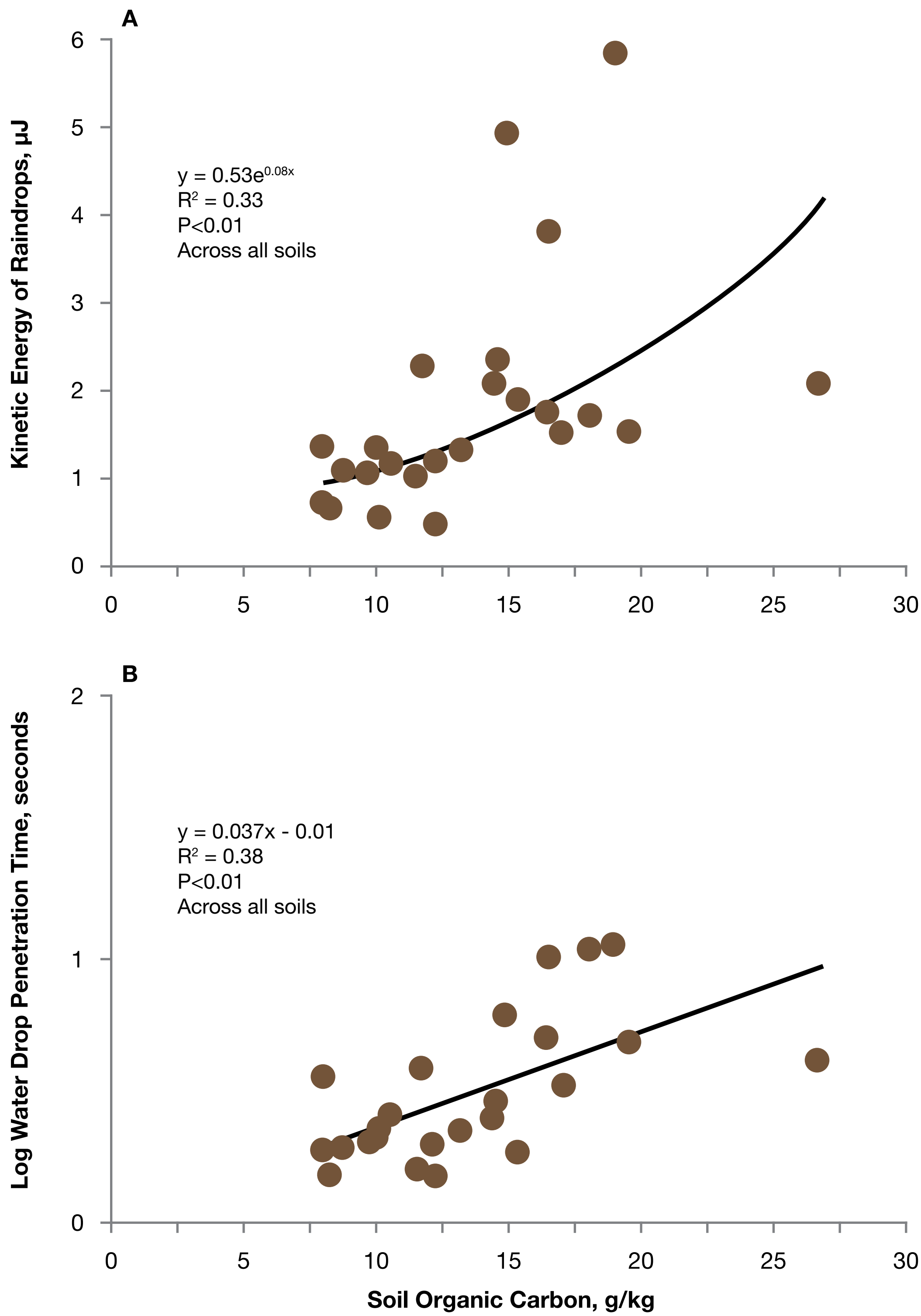

Figure 2. Influence of soil organic carbon concentration on (A) kinetic energy of raindrops required to disintegrate 4.75- to 8-mm air-dry soil aggregates and (B) water repellency across four soils under conventional tillage and no-till in the 0- to 1-in. depth in the central Great Plains.

Excessive Crop Residue Removal as Biofuel Increases Non-Point Source Water Pollution[1]

H. Blanco, R. J. Stephenson, N. O. Nelson, and D. R. Presley

Summary

Excessive removal of crop residue as feedstocks for cellulosic ethanol production and other expanded uses may increase loss of non-point source (NPS) water pollutants such as sediment and nutrients in runoff. The extent of the effects of removal may depend, however, on the amount of removal, soil type, topography, tillage system, cropping system, and climate. This study evaluated the effects of variable rates of residue removal from no-till winter wheat and tilled grain sorghum fields on sediment (soil loss), soil organic carbon (SOC), and nutrient losses in runoff on Harney silt loam soils in western Kansas. Five residue treatments, which consisted of cutting wheat and sorghum stubble after harvest at 0, 25, 50, 75, and 100% of the initial height, were established on 3 × 8-ft plots under two tillage levels for wheat (no-till and freshly tilled) and grain sorghum (spring tilled and freshly tilled). Simulated rain was applied at 4.5 in./hour for 30 minutes. Residue removal had large and significant effects on the transport of NPS pollutants. It increased runoff in tilled plots but not in no-till plots. Residue removal at rates greater than 50% significantly increased soil loss. One of the main findings was that no-till with residue removal at or above 75% lost as much sediment as freshly-tilled plots with ≤ 25% removal. Residue removal at high rates also increased losses of SOC, total nitrogen (N), and total phosphorus (P) associated with sediment. Overall, high levels of wheat and sorghum residue removal induced large losses of NPS pollutants in runoff. Moreover, no-till management can lose all its benefits of controlling soil erosion if residues are excessively removed.

Introduction

Crop residues are valuable natural resources; they protect soil from wind and water erosion, improve soil functions, maintain SOC and nutrient pools, and sustain agronomic production. These resources have been dubbed by many as a "waste" or "trash." Crop residues are a precious commodity and provide numerous ecosystems services. Returning crop residues after harvest is the best and most ecological strategy for conserving soil and water, reducing evaporation, increasing soil water storage, reducing abrupt fluctuations in soil temperature, increasing SOC content, and enhancing nutrient cycling and microbial processes. Crop residues are a buffer against impacting raindrops and traffic. Mulched soils are more resilient and dry more slowly than unmulched soils. At present, there are many competing uses for crop residues including an increased interest in removing crop residues for producing cellulosic ethanol.

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[1] This project was funded by the Kansas Department of Health and the Environment, U.S. EPA Section 319 Grant Program through the Kansas WaterLINK initiative. Thanks are expressed to the students of the Department of Agriculture at Fort Hays State University, Hays, KS, who participated in this research through a service-learning project, and to community partners Harold Kraus and Lance Russell for allowing us to use their farm for this project.

Harvesting residues may, however, have negative consequences for soil and water resources and agronomic production, especially in the long term. One potential effect of widespread residue removal is water pollution. Residue removal will leave the soil partially or completely bare, which can increase the soil's susceptibility to erosion. Loss of sediment and nutrients in runoff from agricultural lands is a main cause of NPS water pollution. Reducing NPS water pollution is a major local, regional, and national environmental concern. Research documenting the potential negative effects that large-scale residue harvesting may have on water quality is limited.

Should residues be removed or left on the soil surface? Should only a portion of those residues be removed? How much residue can be removed from a no-till field without negatively affecting soil and water resources? How much residue is really needed to protect soil from erosion, maintain soil organic matter content levels, and sustain crop production? Answers to these questions depend on site-specific characteristics such as soil type, topography, cropping system, tillage management, and climate. Therefore, the amount of residue that may be harvestable must be determined on the basis of site-specific characteristics.

Crop residue production is highly variable, particularly in semiarid regions such as the Great Plains. On some soils, there is not sufficient residue to protect soil from water and wind erosion and maintain adequate levels of soil organic matter. Even in soils with abundant residue, continued residue removal may adversely affect crop production, soil-water relations, water quality, SOC sequestration, and overall health of the ecosystem in the long term. We designed an experiment to specifically evaluate the extent to which a single rainstorm of high intensity but short duration can cause losses of NPS pollutants from wheat and sorghum fields following residue harvest. Objectives of this study were to determine the on-farm effects of wheat and sorghum residue removal on loss of sediment, SOC, and nutrients associated with sediment under simulated rainfall in two representative soils in western Kansas.

Procedures

The on-farm project was conducted in a no-till wheat and a plow-till grain sorghum field near Hays, KS, in the fall of 2008. The no-till field was managed under continuous wheat in the past 2 years, and the tilled field was under a wheat/sorghum rotation. Soil at both sites is a Harney silt loam (fine, smectitic, mesic Typic Argiustolls) with a 6% slope for wheat and 3% slope for sorghum. The sorghum field was tilled in spring about 6 months before this study.

A randomized complete block design experiment with five wheat and sorghum residue removal treatments was established on 3 × 8-ft plots. Plots were oriented parallel to the dominant slope and bordered with metal sheets inserted to a soil depth of about 4 in. Treatments were established by cutting stubble remaining after harvest at 0, 25, 50, 75, and 100% of the initial height. The average height of the standing stubble was 12 in. for wheat and 23 in. for sorghum.

Two different soil surface conditions were created within each field. The first set of plots was established under existing tillage conditions (no-till for wheat and spring tilled for sorghum). To evaluate how a freshly tilled wheat or sorghum field would respond to an

intense rainstorm, a second set of plots within each field was established by tilling the soil immediately after imposing the five residue treatments. The no-till plots in wheat and spring-tilled plots in sorghum were established on the existing no-till and tilled fields, and no additional tillage operations were performed except cutting stubble at the five height levels.

Simulated rainfall was applied to the plots at 4.5 in./hour for 30 minutes, which represented a rainstorm with a return period of 25 years for western Kansas. A portable rainfall simulator with a single nozzle positioned 9 ft above the soil surface and in the center of two adjacent plots was used to apply rain to the two plots simultaneously. Time to runoff initiation was monitored, and amount of runoff and concentrations of sediment, SOC, and nutrients (i.e., total N and total P) in runoff were determined.

Results

Runoff started much sooner when residue was removed in all tillage and cropping systems. Residue removal increased runoff losses in all treatments except no-till wheat (Figure 1A and 1B). Differences in runoff loss among the five residue treatments for no-till wheat were highly variable and not significant, but runoff water from low residue removal plots had much lower sediment and nutrient concentration.

Residue removal increased sediment loss regardless of tillage and cropping systems (Figure 2A and 2B). Compared with plots without removal, complete wheat residue removal increased sediment loss by twofold in tilled plots and by eightfold in no-till plots. For the same crop, the amount of sediment lost from no-till plots when residue was removed at ≥ 75% did not differ from that in tilled plots with 0 and 25% of removal. Removal of wheat residue at rates of 25% did not increase sediment loss, but removal at rates at or above 50% had large effects on increasing sediment loss. Under sorghum, sediment loss increased almost twofold with residue removal at 50% and by fourfold under complete removal compared with plots without removal. Results also showed that residue removal has greater adverse effects on sloping soils. Losses in sediment are larger from sloping (Figure 2A) than from nearly level (Figure 2B) soils.

Residue removal also increased loss of SOC, total N, and total P associated with sediment (Figure 3A and 3B). Removal of more than 75% of residues increased SOC loss in sorghum and no-till wheat. Removal of residue at high rates (≥ 75%) increased losses of SOC by as much as 0.17 ton/a in freshly tilled wheat. Loss of SOC has large implications because it reduces the buffering capacity of soil to absorb and filter NPS pollutants. Loss of SOC, total N, and total P were positively correlated with sediment loss. The greater the sediment loss, the greater the SOC, total N, and total P loss. Residue removal increased losses of NO_3-N, NH_4-N, and PO_4-P in sorghum. As with sediment, nutrient losses from no-till wheat with high levels (≥ 75%) of removal did not significantly differ from losses from tilled plots with low residue removal.

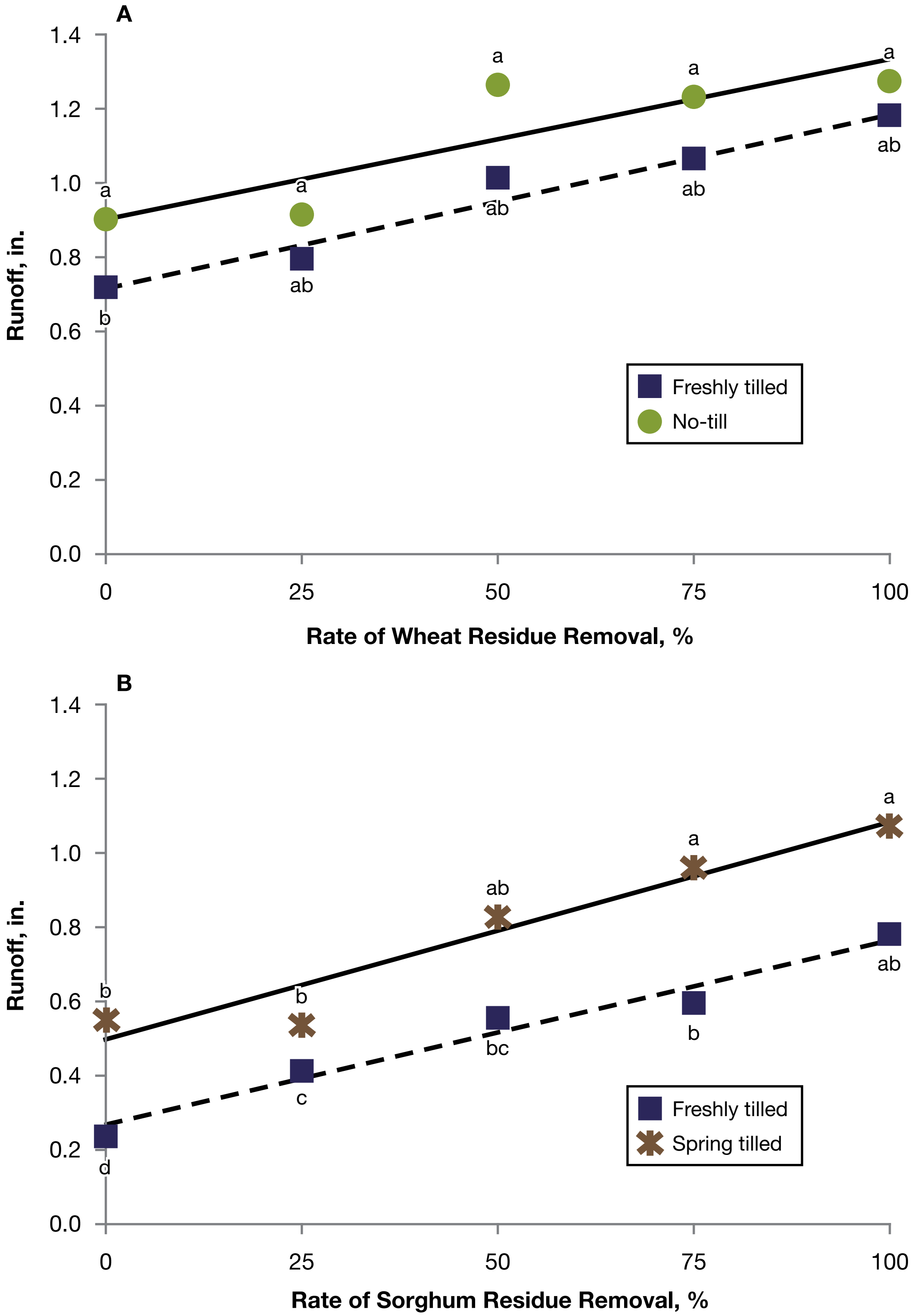
Results showed that wheat and sorghum residue removal has large and immediate effects on increasing loss of NPS pollutants in runoff. Residue removal left the soil surface unprotected from raindrop impacts, which most likely caused rapid soil detachment and surface sealing, thereby reducing rain water infiltration. The freshly tilled soils delayed runoff start more than untilled soils, but as soon as runoff started, runoff rates from

freshly tilled plots were equal to or greater than those from untilled plots because of rapid soil consolidation and surface sealing under the intense rainstorm.

The single rainstorm with an intensity of 4.5 in./hour for 30 minutes increased sediment loss by nearly 4 ton/a in no-till and tilled plots when residues were completely removed from the wheat field. Under tilled wheat plots without removal, sediment loss surpassed the tolerable annual soil loss (*T*) value when residue was removed at rates as low as 50%. Losses of sediment under the single rainstorm were as high as 7 ton/a from the freshly tilled wheat plots when all residues were removed.

Under the same level of residue removal, more sediment was lost from tilled than from no-till wheat plots, which indicates that residue removal combined with intensive tillage can exacerbate losses of soil and nutrients to unsustainable levels. Most importantly, high rates (≥ 75%) of residue from no-till soils can eliminate all the benefits of controlling soil erosion and increasing SOC pools attributed to no-till. No-till technology may not reduce soil erosion compared with tillage if crop residues are excessively removed.

Overall, results from this study show that crop residues are vital for controlling soil erosion. Their excessive removal has immediate effects on increasing off-site transport of NPS pollutants. These results suggest residues can be removed for expanded uses only if the removal is proven not to have adverse consequences for water quality, SOC sequestration, and overall soil productivity.



Means with the same lowercase letter within the same tillage level are not significantly different at the 0.05 probability level.

Figure 1. Residue removal effects on runoff loss for (A) wheat and (B) sorghum in two soils (Harney silt loam) in western Kansas.

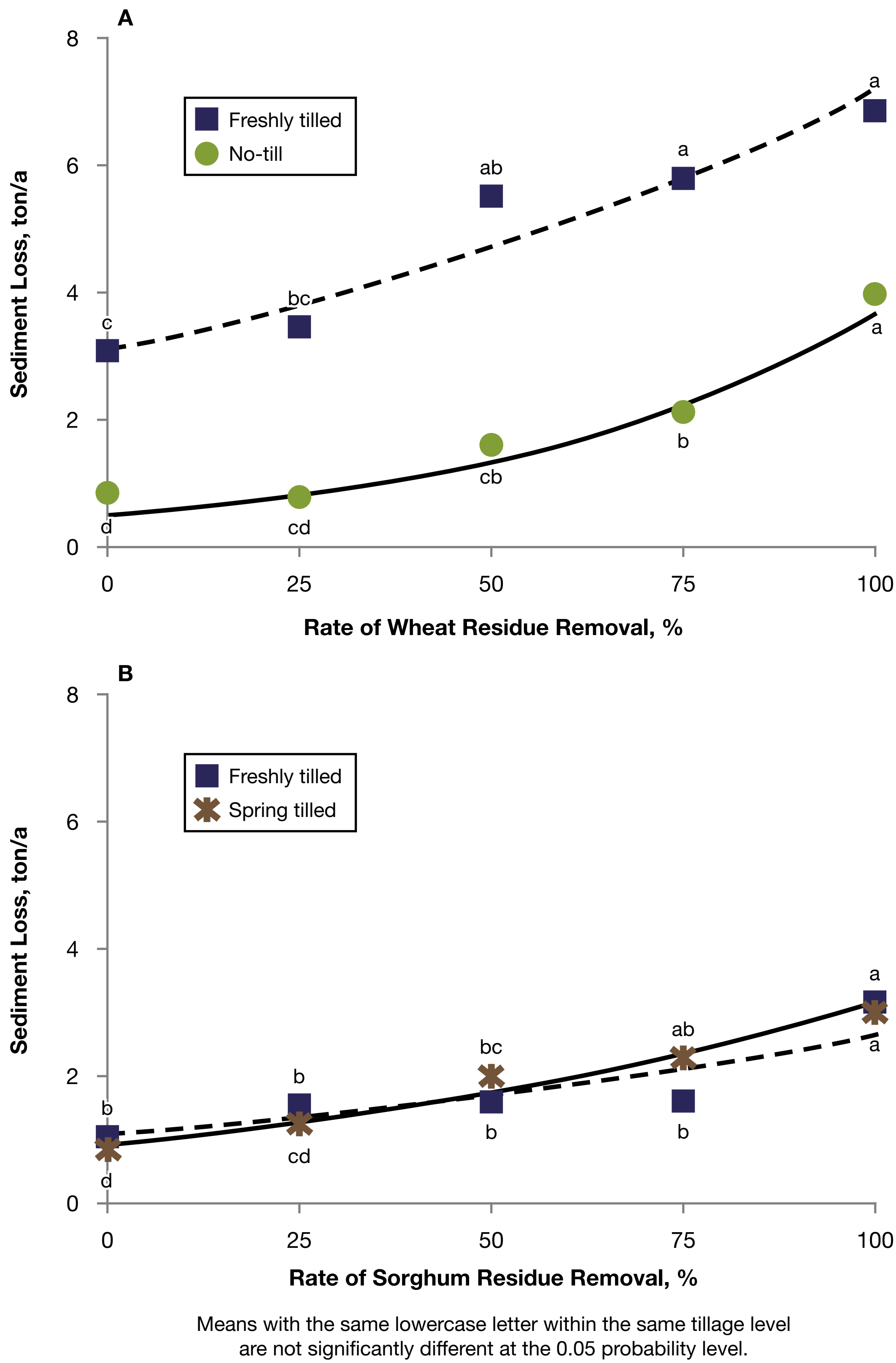


Figure 2. Residue removal effects on sediment loss for (A) wheat and (B) sorghum in two soils (Harney silt loam) in western Kansas.

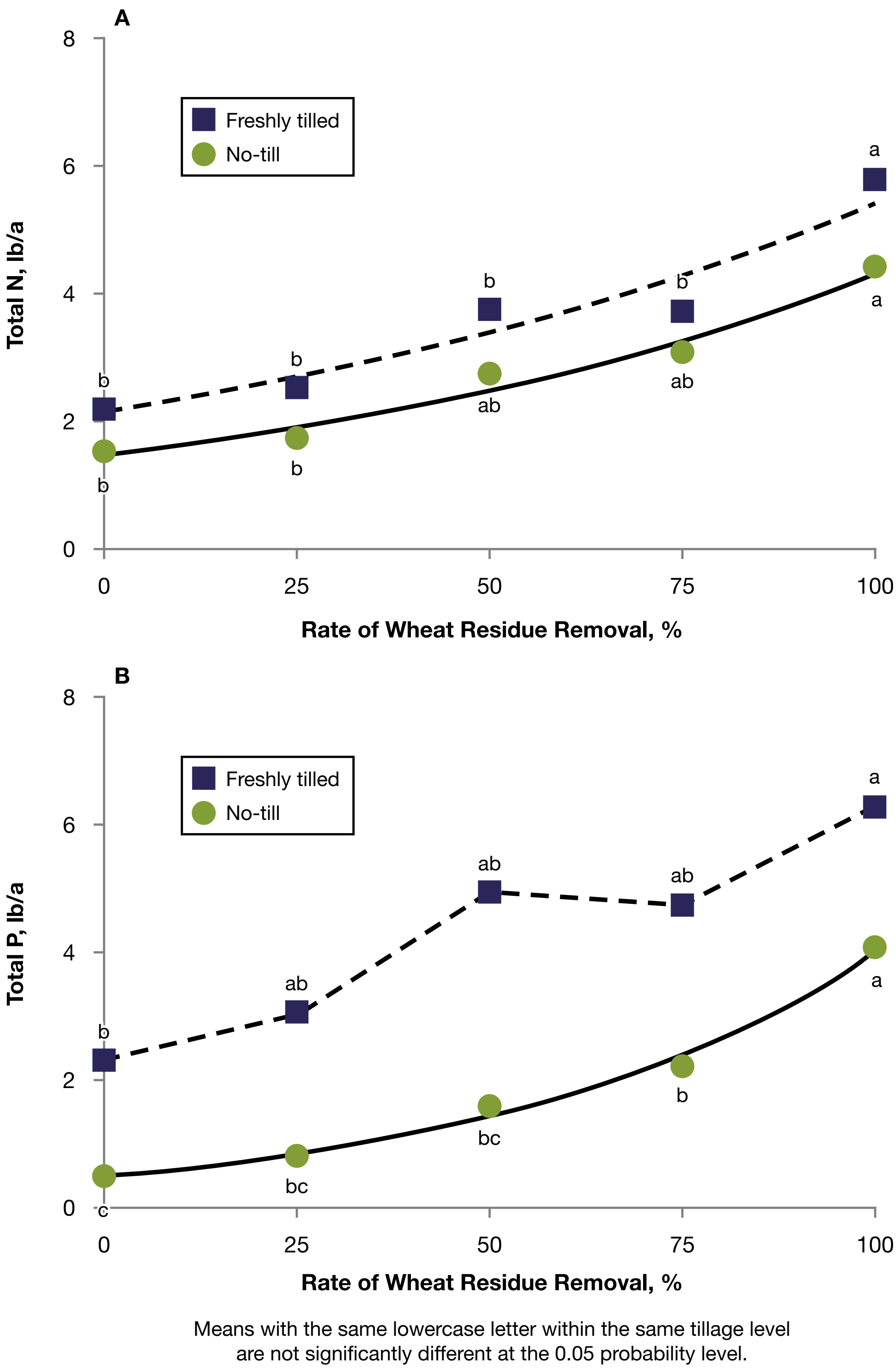


Figure 3. Residue removal effects on loss of (A) total N and (B) total P under two tillage systems for wheat in a Harney silt loam in western Kansas.

Effect of Tillage Practices and Deficit Irrigation on Corn[1]

F. R. Lamm, R. M. Aiken, and A. A. Abou Kheira

Summary

Corn production was compared from 2004 to 2007 for three plant populations (26,800, 30,100 or 33,300 plants/a) under conventional-tillage, strip-tillage, and no-till systems with irrigation capacities limited to 1 in. every 4, 6 or 8 days. Corn yield increased approximately 10% (23 bu/a) from the lowest to highest irrigation capacity in these 4 years of varying precipitation and crop evapotranspiration. Strip tillage and no-till had approximately 8.1 and 6.4% (18 and 14 bu/a), respectively, greater grain yields than conventional tillage. Results suggest strip tillage obtains residue benefits of no-till (i.e., reducing evaporation losses) without the yield penalty that sometimes occurs with high residue. The small increases in total seasonal water use (< 0.5 in.) for strip tillage and no-till compared with conventional tillage can probably be explained by the greater grain yields for these tillage systems.

Introduction

Declining water supplies and reduced well capacities are forcing irrigators to look for ways to conserve and get the best use from their water. Residue management techniques such as no-till or conservation tillage have proven to be very effective tools for dryland water conservation in the Great Plains. However, adoption of these techniques is lagging for continuous irrigated corn. Some of the major reasons given for this lack of adoption are difficulty handling the increased level of residue from irrigated production cooler and wetter seedbeds in the early spring that may lead to poor or slower development of the crop, and, ultimately, a corn grain yield penalty compared with conventional-tillage systems. Under very high production systems, even a reduction of a few percentage points in corn yield can have a significant economic effect. Strip tillage might be a good compromise between conventional tillage and no-till, possibly achieving most water conservation and soil quality management benefits of no-till while providing a method of handling increased residue and increased early growth similar to that used in conventional tillage. Strip tillage can retain surface residues, thus suppressing soil evaporation, and also provide subsurface tillage to help alleviate effects of restrictive soil layers on root growth and function. A study was initiated in 2004 to examine the effect of three tillage systems for corn production under three different irrigation capacities. Plant population was an additional factor examined because corn grain yield increases in recent years have been closely related to increased plant populations.

Procedures

The study was conducted under a center-pivot sprinkler at the Kansas State University Northwest Research-Extension Center at Colby, KS, from 2004 to 2007. Corn was also grown on the field site in 2003 to establish residue levels for the three tillage treatments.

[1] The authors acknowledge the financial support for this project provided by the Kansas Corn Commission and Monsanto.

The deep Keith silt loam soil can supply about 17.5 in. of available soil water for an 8-ft soil profile. The climate is semiarid with a summer precipitation pattern and annual rainfall of approximately 19 in. Average precipitation during the 120-day corn growing season is approximately 12 in.

A corn hybrid of approximately 110-day relative maturity (Dekalb DCK60-19 in 2004 and DCK60-18 in 2005 through 2007) was planted in circular rows on May 8, 2004, Apr. 27, 2005, Apr. 20, 2006, and May 8, 2007. Three target seeding rates (26,000, 30,000 and 34,000 seeds/a) were superimposed onto each tillage treatment. Irrigation was scheduled with a weather-based water budget but was limited to the three treatment capacities of 1 in. every 4, 6, or 8 days. This translates into typical seasonal irrigation amounts of 16 to 20, 12 to 15 and 8 to 10 in., respectively.

Planting was in the same row location each year for the conventional-tillage treatment to the extent that good farming practices allowed. The strip-tillage and no-till treatments were planted between corn rows from the previous year. Fertilizer nitrogen (N) for all three treatments was applied at a rate of 200 lb/a in split applications with approximately 85 lb/a applied in the fall or spring application, approximately 30 lb/a applied in the starter application at planting, and approximately 85 lb/a applied in a fertigation event near corn lay-by. Phosphorus was applied with the starter fertilizer at planting at the rate of 45 lb/a P_2O_5. Urea ammonium nitrate (UAN 32-0-0) and ammonium superphosphate (10-34-0) were used as fertilizer sources in the study. Fertilizer was incorporated in the fall concurrently with the conventional-tillage operation and applied with a mole knife during the strip-tillage treatment. For the no-till treatment, N was broadcast prior to planting.

A post-plant, preemergence herbicide program of Bicep II Magnum and Roundup Ultra was applied. Roundup was also applied postemergence prior to lay-by for all treatments but was particularly beneficial for the strip-tillage and no-till treatments. Insecticides were applied as required during the growing season.

Weekly to biweekly soil water measurements were made in 1-ft increments to an 8-ft. depth with a neutron probe. All measured data were taken near the center of each plot. Similarly, corn yield was measured in each of the 81 subplots at the end of the season. In addition, yield components (aboveground biomass, plants/a ears/plant, kernels/ear and kernel weight) were determined to help explain the treatment differences. Water use and water use efficiency were calculated for each subplot by using soil water, precipitation, applied irrigation, and crop yield data. Surface crop residue and surface residue cover was sampled in April 2007 prior to planting.

Results

Summer seasonal precipitation was approximately 2 in. below normal in 2004, near normal in 2005, nearly 3 in. below normal in 2006, and approximately 2.5 in. below normal in 2007 at 9.99, 11.95, 8.99, and 9.37 in., respectively, for the 120-day period from May 15 through September 11 (long-term average, 11.79 in.). Irrigation requirements were lowest in 2004, with the 1-in./4-day treatment receiving 12 in., the 1-in./6-day treatment receiving 11 in., and the 1-in./8-day treatment receiving 9 in. Irrigation amounts in 2005 were 15, 13, and 10 in. for the three respective treatments.

Irrigation amounts were highest in 2006 at 15.5, 13.5, and 11.50 in. for the three respective treatments. Irrigation amounts in 2007 were 12.5, 11.5, and 10.5 in. for the three respective treatments, just slightly greater than the low irrigation values of 2004. Although seasonal precipitation was considerably lower in 2007 than in 2004, there was very little difference in irrigation requirements. This was because evapotranspiration was considerably lower than normal in 2007 because of light winds and moderate temperatures during much of the summer.

Corn yield was relatively high for all 4 years and ranged from 161 to 279 bu/a (Tables 1 through 4). Greater irrigation capacity generally increased grain yield, particularly in 2005 and 2006. Strip tillage and no-till had greater grain yields at the lowest irrigation capacity in 2004 and at all irrigation capacities in 2005 and 2006. In 2007, all tillage treatment yields were very high, but strip tillage had slightly greater yields at the lowest and highest irrigation capacity. Strip tillage tended to have the highest grain yields for all tillage systems, and the effect of tillage treatment was greatest at the lowest irrigation capacity in the 4 years of the study. Crop residue and residue cover were similar for no-till (20,000 lb/a and 99%) and strip tillage (14,300 lb/a and 92%) but much less for conventional tillage (5,200 lb/a and 79%). These results suggest strip tillage obtains the residue benefits of no-till (i.e., reducing evaporation losses) without the yield penalty that is sometimes associated with greater residue levels in irrigated no-till management.

Greater plant population had a significant effect on increasing corn grain yields (Tables 1 through 4) about 16 to 17 bu/a, on average, for the lowest and highest irrigation capacities, respectively. Greater plant population gives greater profitability in good production years. Assuming a seed cost of $1.92/1000 seeds and corn harvest price of $4/bu, this 16 to 17 bu/a yield advantage would increase net returns approximately $52 to $56/a for the increase in plant population of approximately 6,500 seeds/a. Increasing the plant population by 6500 plants/a reduced kernels/ear by 45 and reduced kernel weight by 2.0 g/100 kernels, on average (Tables 1 through 4). However, this was compensated by the increase in population increasing the overall number of kernels/a by 9.2% (data not shown).

Number of kernels/ear was reduced in 2004 and 2006 compared with 2005 and 2007 (Tables 1 through 4). The potential number of kernels/ear was set at about the ninth leaf stage (approximately 2.5 to 3.5 ft tall), and the actual number of kernels/ear was finalized by approximately 2 weeks after pollination. Greater early season precipitation in 2005 than in 2004 and 2006 may have established a greater potential for kernels/a, and later in the 2005 season, greater irrigation capacity or better residue management may have allowed more kernels to escape abortion. Number of kernels/ear was even greater in 2007 than in 2005. Winds and temperatures were very moderate for much of 2007, and the resulting reduced evapotranspiration probably allowed greater potential kernel set.

Number of kernels/ear was generally greater for the strip-tillage and no-till treatments than for conventional tillage, particularly in 2005 and 2006. This response was probably a result of better management of soil water reserves with strip tillage and no-till. Final kernel weight was affected by plant growing conditions during the grain filling stage (last 60 days prior to physiological maturity) and by plant population and kernels/ear.

Under deficit irrigation capacity, the crop will deplete soil water reserves during the latter portion of the cropping season, so it is not surprising that kernel weight increased with greater irrigation capacity (Tables 1 through 4). The changing patterns in grain yield, kernels/ear, and kernel weight that occur among years and as affected by irrigation capacity and tillage system may indicate that factors in addition to differences in plant water status or evaporative losses affect corn production. For example, there might be physical or biological reasons such as differences in rooting, aerial or soil microclimate, and nutrient status or uptake.

Total seasonal water use in this study was calculated as the sum of irrigation, precipitation, and the change in available soil water over the course of the season. As a result, seasonal water use can include non-beneficial water losses such as soil evaporation, deep percolation, and runoff. Intuitively, one might anticipate that good residue management with strip tillage and no-till would result in reduced water use compared with conventional tillage because of reduced non-beneficial water losses. In this study, however, strip tillage and no-till generally had greater water use (Tables 1 through 4). The small increases in total seasonal water use (< 0.5 in.) for strip tillage and no-till compared with conventional tillage can probably be explained by the greater grain yields for these tillage systems (approximately 16 bu/a) as well as earlier canopy senescence under conventional tillage.

Corn grain yields were high all 4 years (2004 to 2007) with varying seasonal precipitation and crop evapotranspiration. Strip tillage and no-till generally performed better than conventional tillage. Increasing the plant population from 26,800 to 33,300 plants/a was beneficial at all three irrigation capacities.

Table 1. Selected corn yield component and total seasonal water use data for 2004 from an irrigation capacity and tillage study, Northwest Research-Extension Center, Colby

Irrigation capacity	Tillage system	Target plant population	Grain yield	Plant population	Kernels/ ear	Kernel weight	Water use
		plants/a	bu/a	plants/a		g/100	in.
1 in./4 days	Conventional	26,000	229	27,878	550	37.1	23.0
(12 in.)		30,000	235	29,330	557	36.2	22.6
		34,000	234	32,234	529	34.6	22.0
	Strip	26,000	245	27,588	537	38.9	23.5
		30,000	232	30,492	519	37.0	24.4
		34,000	237	33,106	514	35.5	24.3
	No-till	26,000	218	25,846	548	37.7	22.0
		30,000	226	29,330	539	36.8	23.6
		34,000	251	33,686	553	33.8	23.2
1 in./6 days	Conventional	26,000	226	25,265	557	39.0	23.0
(11 in.)		30,000	222	29,621	522	34.9	23.6
		34,000	243	32,525	522	36.0	23.9
	Strip	26,000	235	27,298	558	36.9	23.3
		30,000	224	28,750	556	35.0	24.4
		34,000	237	33,396	487	35.6	24.4
	No-till	26,000	225	26,426	537	37.8	24.5
		30,000	222	29,040	556	34.6	25.0
		34,000	229	32,234	545	32.8	23.4
1 in./8 days	Conventional	26,000	198	24,684	509	37.5	22.1
(9 in.)		30,000	211	29,330	531	34.5	22.4
		34,000	216	31,654	494	34.9	22.0
	Strip	26,000	227	25,846	644	34.2	23.8
		30,000	229	29,911	518	35.6	21.8
		34,000	234	32,815	507	35.1	23.2
	No-till	26,000	220	27,007	541	36.6	22.5
		30,000	225	29,621	528	34.5	23.2
		34,000	220	32,815	506	32.2	22.6

Table 2. Selected corn yield component and total seasonal water use data for 2005 from an irrigation capacity and tillage study, Northwest Research-Extension Center, Colby

Irrigation capacity	Tillage system	Target plant population	Grain yield	Plant population	Kernels/ear	Kernel weight	Water use
		plants/a	bu/a	plants/a		g/100	in.
1 in./4 days	Conventional	26,000	218	23813	644	37.9	28.3
(15 in.)		30,000	238	27588	594	37.3	28.6
		34,000	260	30202	579	37.1	27.3
	Strip	26,000	238	24394	620	39.6	28.3
		30,000	251	27878	590	38.3	26.6
		34,000	253	31073	567	36.8	29.1
	No-till	26,000	228	24974	628	38.3	28.1
		30,000	254	26717	660	37.4	27.7
		34,000	262	31363	606	35.8	28.5
1 in./6 days	Conventional	26,000	203	24684	546	37.7	26.4
(13 in.)		30,000	221	27588	544	37.5	25.8
		34,000	208	31073	472	36.2	25.3
	Strip	26,000	226	24394	604	38.9	26.7
		30,000	207	28169	487	38.4	27.1
		34,000	248	31944	560	36.0	26.2
	No-till	26,000	205	24684	565	38.2	26.7
		30,000	224	29040	547	36.6	27.2
		34,000	234	31654	512	37.1	25.7
1 in./8 days	Conventional	26,000	187	24394	523	37.5	22.8
(10 in.)		30,000	218	27298	536	37.5	22.5
		34,000	208	31654	452	37.3	24.8
	Strip	26,000	212	23813	648	34.9	23.8
		30,000	216	27588	579	35.8	24.1
		34,000	240	31363	537	36.1	24.5
	No-till	26,000	208	24103	608	37.4	24.6
		30,000	211	27588	537	36.2	22.9
		34,000	216	31073	502	36.4	24.7

Table 3. Selected corn yield component and total seasonal water use data for 2006 from an irrigation capacity and tillage study, Northwest Research-Extension Center, Colby

Irrigation capacity	Tillage system	Target plant population	Grain yield	Plant population	Kernels/ ear	Kernel weight	Water use
		plants/a	bu/a	plants/a		g/100	in.
1 in./4 days	Conventional	26,000	239	29330	542	38.1	27.1
(15.5 in.)		30,000	213	31073	476	36.4	26.6
		34,000	212	35138	434	36.1	26.9
	Strip	26,000	232	29330	514	39.1	27.7
		30,000	236	31363	483	38.2	27.4
		34,000	260	33106	522	38.6	27.5
	No-till	26,000	211	28459	497	37.9	26.3
		30,000	263	31363	535	40.3	27.5
		34,000	248	34558	516	35.7	27.0
1 in./6 days	Conventional	26,000	161	29040	422	34.1	24.8
(13.5 in.)		30,000	208	31944	446	37.1	24.6
		34,000	169	33977	374	35.0	25.0
	Strip	26,000	207	29040	492	36.6	26.1
		30,000	215	31363	484	36.7	25.9
		34,000	216	34267	476	34.7	26.5
	No-till	26,000	230	29330	541	36.8	25.9
		30,000	218	30202	516	35.9	25.6
		34,000	223	32815	484	36.7	25.5
1 in./8 days	Conventional	26,000	172	28169	417	37.8	23.5
(11.5 in.)		30,000	191	31654	411	37.7	22.0
		34,000	191	33977	385	37.2	22.6
	Strip	26,000	214	29330	565	32.7	24.6
		30,000	220	31944	510	34.4	24.6
		34,000	230	34558	479	35.7	24.3
	No-till	26,000	204	28750	501	36.9	24.4
		30,000	220	31363	497	35.8	24.6
		34,000	216	33977	458	35.6	24.9

Table 4. Selected corn yield component and total seasonal water use data for 2007 from an irrigation capacity and tillage study, Northwest Research-Extension Center, Colby

Irrigation capacity	Tillage system	Target plant population	Grain yield	Plant population	Kernels/ ear	Kernel weight	Water use
		plants/a	bu/a	plants/a		g/100	in.
1 in./4 days	Conventional	26,000	245	27878	629	34.5	24.7
(12.5 in.)		30,000	274	32234	652	32.8	26.0
		34,000	256	34848	611	31.9	24.4
	Strip	26,000	254	28169	684	33.5	24.6
		30,000	270	31073	671	33.0	25.7
		34,000	279	36010	603	32.9	24.6
	No-till	26,000	246	26717	680	33.0	22.6
		30,000	265	31654	660	32.8	24.4
		34,000	254	34848	651	28.7	23.9
1 in./6 days	Conventional	26,000	244	27878	673	33.2	24.7
(11.5 in.)		30,000	242	32815	603	31.3	24.5
		34,000	235	34848	612	28.2	24.0
	Strip	26,000	244	26426	678	33.5	24.0
		30,000	242	32234	620	30.7	24.6
		34,000	251	35429	658	27.7	24.2
	No-till	26,000	230	27588	635	33.3	24.7
		30,000	256	31944	655	30.5	22.9
		34,000	247	36010	605	29.6	24.6
1 in./8 days	Conventional	26,000	220	27878	606	32.4	24.1
(10.5 in.)		30,000	248	32815	628	31.0	23.9
		34,000	249	34267	634	29.3	24.4
	Strip	26,000	242	27588	683	32.5	23.7
		30,000	255	31073	637	32.5	23.0
		34,000	267	36010	619	30.5	23.2
	No-till	26,000	225	27588	661	31.3	23.9
		30,000	248	32234	631	30.4	24.0
		34,000	235	34848	587	29.2	23.3

Forecasting Corn Yields in Western Kansas[1]

P. Coyne, R. M. Aiken, F. R. Lamm, and S. Maas

Summary
Predicting in-season land productivity can guide irrigation management decisions designed to optimize water utilization in the Ogallala Aquifer region. YieldTracker is a mathematical model that simulates growth and yield of corn by using weather and leaf area index (LAI) as inputs; LAI can be derived by remote sensing. We tested this model by using 3 years of corn yield data from Colby, KS. Results indicated that YieldTracker has potential as a decision aide for managing irrigated corn but is not designed to simulate yields of water-stressed corn.

Introduction
Knowledge of in-season land productivity can guide management needed to optimize water utilization. Maas (1992) demonstrated the utility of combining remotely sensed surrogates for crop canopy development and crop growth models in the release of GRAMI, a mathematical model that uses weather and plant canopy observations to simulate growth and yield of graminoid crops. YieldTracker, a mathematical crop growth model of the form described by Maas (1993), uses remotely sensed data for within-season calibration of crop growth simulations. YieldTracker evolved from GRAMI to serve as the core model of a project designed to provide farmers with in-season predictions of crop yield in individual fields over the Internet (Maas et al., 2003). These predictions are intended to support real-time management decisions such as irrigation water applications. YieldTracker uses regional weather observations and satellite remote sensing to develop probabilistic predictions of crop yield during the growing season. Estimates of plant canopy LAI used for model calibration are commonly derived from vegetation indices, such as the normalized difference vegetation index (NDVI), extracted from Landsat TM imagery acquired during the growing season. Satellite images can quantify crop canopy formation and yield potential of individual fields in large, multicounty regions. Dynamic quantification of land productivity can support analysis of risks associated with water use as well as demonstrate the value of information analysis. Much of western Kansas overlies the Ogallala Aquifer, which is being mined by pumping. Extending the life of this resource through prudent use seems paramount to sustaining local and state economies. Therefore, our research objectives were to evaluate the accuracy of corn yield forecasts from the YieldTracker model for western Kansas conditions over a range of soil water conditions.

Procedures
YieldTracker Code
An early version of YieldTracker—coded in DOS FORTRAN and parameterized for corn growing in the High Plains of Texas—was ported to Visual Basic for Applications (VBA) to run under Microsoft Access. The crop growth and partitioning algorithms and the

[1] This research was supported in part by the Ogallala Aquifer Program, a consortium between the USDA-Agricultural Research Service, Kansas State University, Texas AgriLife Research, Texas AgriLife Extension Service, Texas Tech University, and West Texas A&M University.

numerical solution were as described for GRAMI by Maas (1992). A graphical user interface was added to provide flexibility for managing input datasets, manipulating run conditions, and exploring parameter sensitivity. A graphics module coded in MatLab (The Mathworks, Inc., Natick, MA) was also developed to visually display select model input and output datasets.

Model Validation Dataset

Corn (*Zea mays* L.) production data from a subsurface drip irrigation study at the Kansas State University Northwest Research-Extension Center at Colby, KS, were obtained for the years 2002 to 2004. End-of-season grain yield and in-season development of LAI data were available from four replications of three treatments—no in-season irrigation (rain-fed), 0.15 in./day (limited irrigation), and 0.30 in./day (full irrigation)—to serve as validation datasets. Irrigation was scheduled by a weather-based water budget but was limited to the irrigation system capacities of 0.15 and 0.30 in./day. Target plant population was 36,000 plants/a.

Local weather data (average daily temperature, global shortwave irradiance) were used as model-driving variables. Annual precipitation was 14.25, 14.53, and 20.20 in. for 2002, 2003, and 2004, respectively; the 30-year mean is 20.16 in. The years 2002 and 2003 were considered to represent severe drought (both hot and dry), whereas 2004 conditions were near normal. Precipitation during the cropping season was 10.59, 9.13, and 12.24 in. for 2002, 2003, and 2004, respectively; the normal is 12.01 in. Calculated evapotranspiration for the 120-day period of May 15 through September 11 was above the long-term normal (22.99 in.) in 2002 and 2003 (27.68 and 25.97 in., respectively) and near normal in 2004 (22.56 in.). Hot and dry conditions during 2003 were associated with increased spider mite pressure, which was not fully controlled by two insecticide applications.

Simulation Runs and Statistical Analysis

Individual model simulation runs were conducted for each of the 36 year-treatment-replication combinations. Simulated yields were compared to observed values.

Results

Analysis for observed minus YieldTracker-simulated yields plus the model goodness of fit for seasonal development of LAI indicated a significant year by treatment interaction. Therefore, only the year by treatment means are discussed herein (Table 1). Yields from the rain-fed treatment were consistently overpredicted, whereas yields from the irrigated treatments were consistently underpredicted across years. Yields from the rain-fed treatment were significantly lower than those from the irrigated treatments in all 3 years. In addition, yields within the rain-fed treatment were different in all 3 years. Precipitation in 2002 and 2003 was 88 and 76%, respectively, of the long-term mean. This was reflected in yields, which were significantly higher in the full irrigation treatment than in the limited irrigation treatment. In 2004, precipitation matched the long-term mean and full irrigation had no yield advantage compared with limited irrigation. Accurate in-season prediction of yields could possibly eliminate late-season irrigations in situations similar to 2004, thereby saving water and reducing input costs.

Overall, simulated yields under limited and full irrigation were slightly underpredicted, whereas simulated yields for the rain-fed condition were generally severely overpredicted (Figure 1). Individual data points plus standard deviation error bars show that scatter or variability within treatments, especially rain-fed, was attenuated by the model compared with observed yields.

The appeal of YieldTracker is its unique numerical solution that requires the user to input, in addition to temperature and radiation data, only one or more green LAI observations. Such LAI values can be obtained by destructive sampling or remote sensing. Effects of water stress must be accounted for by changes in LAI. Earl and Davis (2003) have published conclusive evidence that drought stress reduces yield of corn and other grain crops by reducing radiation-use efficiency (RUE), harvest index (HI), and canopy absorption of incident light in that order. To make this model maximally useful for water management decisions in western Kansas, the algorithm needs to account for these effects.

Because of the utility of YieldTracker (related to its simplicity and minimal driving variable data requirement), modification to improve its performance seems worthwhile. Remote sensing offers potential for straightforward, wide-area quantification of the seasonal course of crop canopy development. Earl and Davis (2003) demonstrated the effects of water deficits on RUE, HI, and light absorption under field conditions. Detecting water deficit conditions and quantifying effects on canopy function could improve YieldTracker performance under water-limiting conditions.

YieldTracker lacks sufficient mechanistic complexity to account for water stress effects on photosynthesis and carbon partitioning. Sinclair (1991) reported a simple analytical model of radiation capture and use efficiency for a crop canopy. The model requires LAI, daily weighted mean radiation angle, shadow projection coefficient, radiation intensity, leaf quantum efficiency and biomass conversion efficiency. Radiation capture by sun and shade fractions of the canopy drives simulation of total carbon assimilation by using a non-rectangular hyperbola to quantify light-limiting effects on photosynthesis. Biomass accumulation assumes constant conversion efficiency, considering respiration effects. This simplified model uses a mechanistic conception of radiation capture and biomass accumulation to calculate use efficiency. As such, it is suitable to quantify effects of incomplete canopy and variable radiation levels on biomass accumulation under water and nutrient sufficiency.

Like YieldTracker, this Sinclair model does not consider water deficit effects. However, its incorporation of additional physiological detail may make it a better starting point for adding water stress effects—to achieve the objective of an in-season irrigation management tool—without greatly increasing the data input requirement compared with YieldTracker.

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Table 1. All pairwise year by treatment mean comparisons of YieldTracker yield simulations and leaf area index goodness-of-fit

Specific interaction			
Year	Treatment	Observed-simulated	Goodness-of-fit
		bu/a	%
2002	Rain-fed	-98.6e	85.5d
2002	Limited irrigation	9.4c	88.3bcd
2002	Full irrigation	41.2a	87.9cd
2003	Rain-fed	-155.0f	93.4a
2003	Limited irrigation	13.1bc	93.1a
2003	Full irrigation	42.7a	93.9a
2004	Rain-fed	-44.7d	87.0cd
2004	Limited irrigation	41.9a	92.0ab
2004	Full irrigation	30.6ab	90.8abc
Standard error			
Critical value			
t-value for $\alpha = 0.05$; df = 18		2.101	Error term: Block*Y*Trt

Within columns, means followed by a different letter are significantly different at (P=0.05).

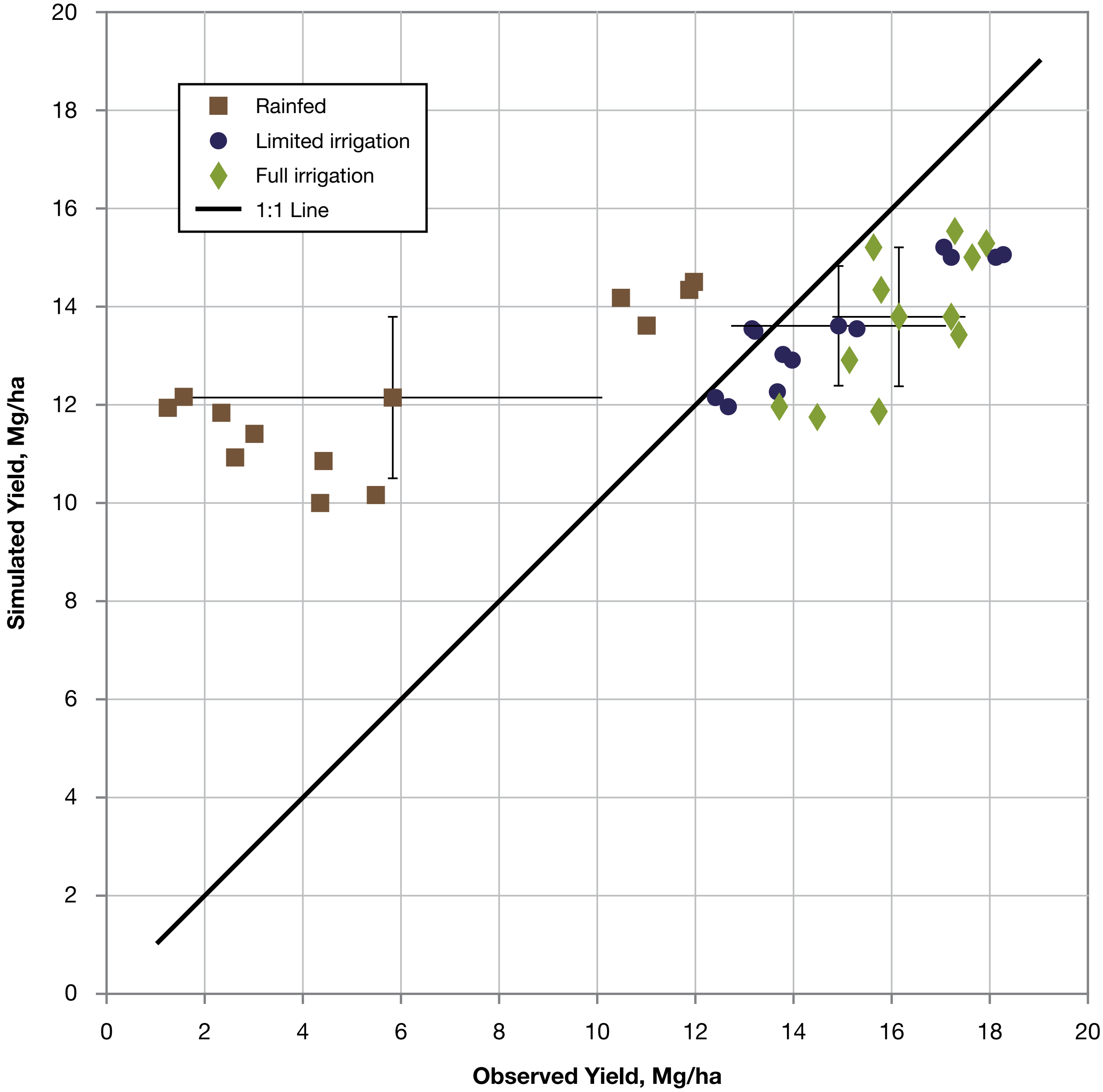

Figure 1. YieldTracker simulated mean yields across years, treatments, and replications vs. observed mean yields. Error bars are observed means ± standard deviation.

Forecasting Wheat and Sorghum Yields with the Kansas Water Budget[1]

R. M. Aiken, L. R. Stone, and A. J. Schlegel

Summary
Weighting factors (which quantify yield effects of water deficits) of the Kansas Water Budget (KWB) were evaluated with respect to wheat and grain sorghum productivity. Simple and accurate models of crop water use and productivity with sparse input requirements can support simulation of hydrologic, yield formation, and soil conservation processes at regional scales. An inverse solution for weighting factors minimized predictive error from the KWB for water deficit effects on wheat and grain sorghum yields observed over 40 site-years at two western Kansas locations. Knowledge of weather and soil effects on crop water use and productivity can enhance decision support for soil, residue, and crop management as well as inform strategic planning for regions subject to reduced aquifer withdrawal.

Introduction
Crop grain yields can be estimated or forecast by using weather data and computer models of crop water use and productivity, such as the KWB (Khan, 1996). Often, rainfall is not sufficient to meet the water required by a wheat or grain sorghum crop, which reduces yield potential. Because the yield effect of limited water changes with crop development, the KWB uses weighting factors for four separate crop development stages to calculate yield effects. Yields of winter wheat and grain sorghum observed over 40 site-years at two western Kansas locations were used to evaluate yield estimates of KWB and to determine whether modified weighting factors would improve KWB yield estimates.

Procedures
The KWB model simulated soil water with the water budget method by using a Jensen-Haise calculation of potential evapotranspiration (ETp) from daily ambient temperature extremes and solar radiation; a crop coefficient function and a water deficit function for actual evapotranspiration (ETa); daily precipitation and effective irrigation; a constant runoff fraction and a Wilcox equation for soil water drainage. Grain yield (Y) was calculated as a linear proportion (k) of effective evapotranspiration (ETe), modified by a yield threshold (YT):

$$Y = k(ET_e - YT)$$

[1] This research was supported in part by the Ogallala Aquifer Program, a consortium between the USDA-Agricultural Research Service, Kansas State University, Texas AgriLife Research, Texas AgriLife Extension Service, Texas Tech University, and West Texas A&M University.

Effective evapotranspiration was calculated from ETp, Eta, and a set of weighting factors (WF, Table 1) corresponding to portions of the growing season with differential yield sensitivity to water deficits (indicated by the subscripted i):

$$ET_e = ET_p \cdot \sum\left(WF_i \cdot \frac{ET_{ai}}{ET_{pi}}\right), \sum WF_i = 1$$

Crop (winter wheat or grain sorghum) productivity and soil water depletion were observed in three long-term, rain-fed crop sequence studies conducted at Tribune and Colby, KS, and a limited-irrigation study at Colby. Soil water status at planting and harvest was determined by neutron thermalization; grain yields were determined by hand harvest (Colby) or machine harvest (Tribune). Khan (1996) reported soil hydraulic properties required by the Wilcox drainage function. Initial soil water conditions were adjusted to match field observations. The crop coefficient function was scaled, linearly, to relative maximum leaf area index (rLAImax), assuming this occurred at anthesis and that canopy light absorption approached a maximum at LAI = 3. Canopy formation observed at Colby was regressed on vegetative ETa simulated by KWB and used to estimate rLAImax at Tribune. Daily ETp, ETa, plant-available water, and total soil water were calculated according to the KWB algorithm (Khan, 1996). The inverse solution for WFi involved adjusting the four values for WFi to minimize predictive error—root mean squared error (RMSE) and mean bias error (MBE) of yield values calculated by KWB.

Results

Soil profile water status was calculated by KWB with little bias (MBE, Table 2 and Figure 1) but similar precision (RMSE) to interannual variation for the wheat crop; model precision increased substantially for the grain sorghum crop, which included limited irrigation studies at Colby. Optimized weighting factors (Table 1) improved precision and bias components of predictive accuracy for wheat yield but not grain sorghum yield.

References

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Table 1. Weighting factors used in the Kansas Water Budget to calculate effective crop water use on the basis of relative sensitivity of grain yield formation for the respective developmental stage

	Wheat		Grain sorghum	
Weighting factor	Default	Optimized	Default	Optimized
Vegetative	0.49	0.30	0.44	0.55
Flowering	0.31	0.35	0.39	0.30
Formation	0.19	0.35	0.14	0.15
Ripening	0.01	0.00	0.03	0.00

Table 2. Predictive accuracy of the Kansas Water Balance model for soil profile water and grain yield

		Stored soil water (in.) observed at harvest			Grain yield (bu/a)				
						Default		Optimized	
Crop	N	Mean (SD)	RMSE	MBE	Mean (SD)	RMSE	MBE	RMSE	MBE
Wheat	43	14.8 (2.0)	2.5	-0.2	34.0 (22.0)	31.6	-23.6	18.8	-.06
Grain Sorghum	42	15.7 (3.9)	2.0	-0.1	74 (45.0)	26.2	-1.3	27.0	-0.2

Weighting factors representing water deficit effects on yield formation were set to default values or optimized to minimize predictive error.
RMSE = root mean squared error, MBE = mean bias error.

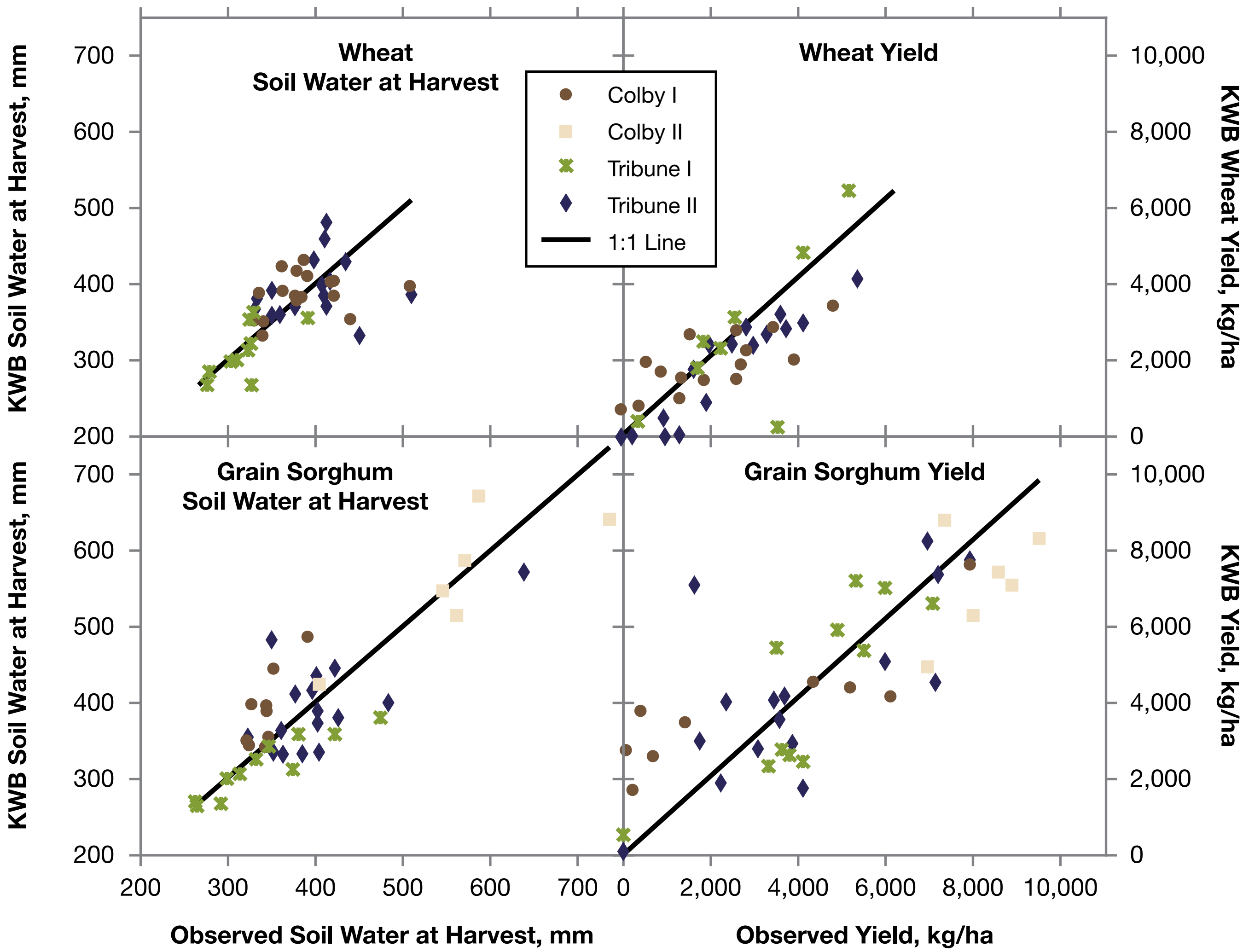

Figure 1. Predicted and observed soil water at harvest and grain yield are depicted for wheat (upper quadrants) and grain sorghum (lower quadrants) as simulated by the Kansas Water Budget.
Optimized weighting factors representing differential effects of soil water deficits were applied to the yield function, with exception of Tribune I wheat, for which default values were applied.

Ten Crop Sequences, Transition to No-Till

R. M. Aiken and D. O'Brien

Summary
Grain productivity and water use of 10 crop sequences, all including winter wheat, were compared for the period 2002 to 2007, which included a 3-year drought. Corn or grain sorghum feed grains were included in nine of the crop sequences; six of the sequences were cropped continuously by including an oilseed crop (spring canola, soybean, or sunflower). Principle trends in the study indicated that land and productivity varied with rainfall among years, wheat productivity benefited from summer fallow, grain sorghum productivity exceeded corn when limited by water, and continuous cropping increased the fraction of precipitation used by crop but reduced overall land productivity. Economic analysis revealed that net returns were similar for wheat/grain sorghum/fallow ($35/a) and wheat/fallow ($31/a); wheat/corn/fallow also gave positive net returns ($14/a), but economic returns were negative for other crop sequences. Net returns were significantly greater in 2005, 2006, and 2007 relative to previous drought years.

Introduction
Available water frequently limits productivity in semiarid cropping systems. The wheat/fallow system accumulates water over a 2-year period, producing a single wheat crop. Tillage provides weed control but often leaves soil exposed to evaporative and erosive forces. Frequently, more precipitation is lost to evaporation than used by a growing wheat crop. More intensive crop sequences use feed grains (corn, grain sorghum) and oilseeds (spring canola, soybean, sunflower) to reduce evaporative losses in fallow periods and increase crop access to precipitation. The objective of this study was to compare water use, grain yield, and biomass productivity for 10 cropping sequences.

Procedures
Crop management was intended to minimize evaporative loss of water, maximize grain productivity, and maximize soil water recharge. Full-season, adapted feed grain cultivars were planted at conventional periods; short-season oilseed cultivars were planted early in continuous cropping sequences to permit wheat planting following harvest. Cultural practices (Table 1) were modified at the beginning of each 3-year cycle to reflect technology advances.

Cropping sequences (Table 2) included 3-year cycles of wheat, feed grain (corn or grain sorghum), and oilseed (sunflower, soybean, canola) or fallow as well as wheat/fallow (2-year cycle) and wheat/corn/sunflower/fallow (4-year cycle). Each phase of a sequence was present each year in triplicate sets of plots. Thus, cropping sequences represent 1:2, 2:3, 3:4, and 3:3 (crop harvest:years in cycle) cropping intensities.

Crop water use was calculated from cumulative precipitation and change in soil profile water content from emergence to flowering to harvest (physiological maturity) crop stages. Yield components (stand, mid-vegetative, and harvest; flowering units; seed weight) and aboveground biomass were hand sampled at maturity. Grain yield was also measured by machine harvest with a plot combine (platform or corn header). For con-

ditions with poor stands, yield potential was estimated from hand-harvested samples. Yields were adjusted to standard moisture content. Annualized crop water use, grain yield, or biomass, computed as the average among all phases (including fallow) of a given sequence, provided a uniform basis for comparing water use and land productivity among crop sequences.

An economic analysis of the relative profitability of the cropping systems was performed. Crop input cost estimates were developed from Table 2 by using recent crop budget guides from K-State Research and Extension, the University of Nebraska-Lincoln, and other sources when needed. Per-unit cost estimates of seed, fertilizer, herbicides, and insecticides were used. Current estimates of current field operation costs were taken from Kansas Agricultural Statistics. Field operation costs used in this analysis included those for plant/seeding; application of fertilizer, herbicides, and insecticides; tillage; and harvesting and hauling of grain. Grain prices for the 2002-2003 through 2007-2008 marketing years for wheat were gathered from USDA sources. Decisions of whether to include harvest costs in net returns for a particular year were made in the following manner: If revenue from crop (yield × grain price) was greater than or equal to total harvesting and hauling cost of the grain, costs were included. Returns over total harvesting cost were then applied toward covering the rest of the crop production costs. Conversely, if crop revenue was less than total harvesting costs, crop enterprise financial losses were minimized by assuming the crop was not harvested.

Results

The study was established in 2000; crops were planted into uniform wheat stubble. Thus, the 2002 harvest was the first year reflecting crop sequence effects for 3-year cycles. Two complete cycles of the 3-year sequences are represented by results from 2002 to 2007. Crop water use, grain yields, and biomass productivity are presented (Table 2) for each phase of the crop sequences, averaged over years. Annualized values represent the sum of each phase divided by number of years in the crop sequence. Some trends observed during these drought years include:

- Land productivity varied with rainfall among years.
- Wheat productivity benefited from summer fallow.
- Grain sorghum productivity exceeded corn productivity when limited by water.
- Continuous cropping increased the fraction of precipitation used by the crop.
- Stand establishment, timing, and amount of water limited oilseed productivity.

Annualized grain yield (averaged over a given sequence) was closely related to aboveground biomass produced by that crop sequence (Figure 1). Annualized productivity, averaged over all growing seasons, indicated that land productivity was greatest for the wheat/grain sorghum/fallow sequence. Land productivity for the wheat/corn/fallow sequence exceeded that of continuous cropping with grain sorghum and either spring canola or soybean.

Economic analysis revealed that net returns (Table 3) were similar for wheat/grain sorghum/fallow ($35/a) and wheat/fallow ($31/a). Wheat/corn/fallow also gave positive net returns ($14/a), but economic returns were negative for other crop sequences. Considering the drought conditions, the threshold for economic harvest was always met for wheat after fallow (Table 4) but was met only in 70% of the cases for wheat after oil-

seed (continuous cropping). The economic threshold for harvest was met for feed grains in 56 (corn) to 72% (grain sorghum) of cases but was met for oilseeds in only 17 to 19% of cases for the oilseed crop (when cropped continuously). Net returns were significantly greater in 2005, 2006, and 2007 relative to previous drought years (Figure 2).

Table 1. Typical crop cultural practices for crop sequence study, 2002-2007

Crop	Cultivar	Seeding	Fertilizer	Pesticide/Weed control
			lb/a	
Wheat	Jagger	90 lb/a	70 N 30 P	Starane 0.5 pt/a
Corn	CA 6920 Bt, Ottilie 5170RR, DKC50-20 RR2/YGCB	18,500 seeds/a	70 N 30 P	Roundup UM 24 oz/a
Grain sorghum	CA 737, DK-44	40,000 seeds/a	70 N 30 P	Roundup UM 24 oz/a[1] Starane 8 oz/a or Clarity 8 oz/a[2]
Canola	Hyola 401, Hyola 357RR	11 lb/a	70 N 30 P	Treflan 1.5 pt/a Gaucho seed treatment Capture 2EC 2.5 oz/a Roundup Ultra 16 oz/a[1]
Soybean	IA 1008, Macon, KS4704RR	175,000 seeds/a	70 N 30 P	Raptor 4 oz/a Roundup Ultra 16 oz/a
Sunflower	SF 187, Myc 8N429CL	18,000 seeds/a	70 N 30 P	Lorsban 15 2 lb/a Roundup RT 24 oz/a Beyond 4 oz/a Spartan 3 oz/a
Fallow, no-till	–	–	–	4X Roundup Ultra 16 oz/a[3]
Fallow, reduced till	–	–	–	4X undercut with sweep plow

[1] When weeds were present prior to planting.
[2] Broadleaf control, as needed.
[3] Ammonium sulfate was added (17 lb/100 gal first application, 10 lb/100 gal later applications) to Roundup Ultra fallow applications but not in tank mixes.

Table 2. Crop sequence effects on water use, biomass, and grain yields, 2002-2007

Rotation[1]	Wheat phase	Feed grain phase	Oilseed phase	Annualized[2]
	Crop water use			
	---in.---			
WW-C-Can	9.02	13.53	8.16	10.67
WW-C-Soy	8.84	12.80	12.99	11.52
WW-C-Sun	8.17	12.54	10.78	10.72
WW-C-Fal	12.85	13.74	0.00	8.77
WW-GS-Can	8.75	14.89	8.21	11.05
WW-GS-Soy	8.08	13.80	13.43	11.8
WW-GS-Sun	8.04	12.97	10.42	10.74
WW-GS-Fal	10.88	14.83	0.00	8.49
WW-Fal	10.98	0.00	0.00	5.49
WW-C-Sun-Fal	10.81	14.11	11.86	9.38
	Biomass yield			
	---lb/a---			
WW-C-Can	4137	4190	1550	3259
WW-C-Soy	3484	3846	1518	2920
WW-C-Sun	3060	4026	1763	2920
WW-C-Fal	6883	5428	0	4062
WW-GS-Can	3937	7130	1189	4044
WW-GS-Soy	3271	6879	1527	3854
WW-GS-Sun	3401	5787	1640	3573
WW-GS-Fal	6814	8100	0	4922
WW-Fal	6302	0	0	3151
WW-C-Sun-Fal	6306	5596	2565	3617

continued

Table 2. Crop sequence effects on water use, biomass, and grain yields, 2002-2007

Rotation[1]	Wheat phase		Feed grain phase		Oilseed phase		Annualized[2]
	Grain yield						
	lb/a	bu/a	lb/a	bu/a	bu/a	lb/a	lb/a
WW-C-Can	1096	18.3	1390	24.8		395	951
WW-C-Soy	984	16.4	1362	24.3	10.8	649	988
WW-C-Sun	697	11.6	1393	24.9		350	805
WW-C-Fal	2243	37.4	1997	35.7		0	1400
WW-GS-Can	968	16.1	2824	50.4		249	1333
WW-GS-Soy	851	14.2	2569	45.9	10.7	643	1341
WW-GS-Sun	761	12.7	1892	33.8		293	972
WW-GS-Fal	2240	37.3	3296	58.9		0	1827
WW-Fal	2435	40.6	0			0	1217
WW-GS[3]-Sun-Fal	1916	31.9	1845	32.9		671	1108

[1] WW = winter wheat (13% moisture basis, 60 lb/bu), C = corn (15.5% moisture basis, 56 lb/bu), Can = canola (10% moisture basis, cwt), Soy = soybean (13% moisture basis, 60 lb/bu), Sun = sunflower (10% moisture basis, cwt), Fal = fallow, GS = grain sorghum (12.5% moisture basis, 56 lb/bu).
[2] Annualized is the sum of the phases for a crop sequence divided by number of years in the crop sequence.
[3] Feed grain was corn in 2002.

Table 3. Average annual net returns for crop phase and annualized crop sequence for dryland crop sequences at Colby, KS, 2002-2007

	Average annual net returns[1]				
Crop sequence[2]	Wheat	Feed grain	Oilseed	Fallow	Annualized
	$/a				
W-F	88			(26)	31
W-C-F	72	17		(47)	14
W-GS-F	79	74		(47)	35
W-GS-Sun-F	57	7	(64)		(12)
W-C-OS	(5)	(11)	(79)		(32)
W-GS-OS	(8)	40	(80)		(16)

[1] Values in parentheses indicate negative net returns.
[2] W = winter wheat, F = fallow, C = corn, GS = grain sorghum, Sun = sunflower, OS = oilseed (average of canola, soybean, and sunflower response).

Table 4. Percentage of years when economic value of grain yields matched or exceeded harvest costs for crop phases of crop sequences at Colby, KS, 2002-2007

	Economic harvest		
Crop sequence[1]	Wheat	Feed grain	Oilseed
		%	
W-F	100		
W-C-F	100	56	
W-GS-F	100	72	
W-GS-Sun-F	100	61	28
W-C-OS	69	52	19
W-GS-OS	70	61	17

[1] W = winter wheat, F = fallow, C = corn, GS = grain sorghum, Sun = sunflower, OS = oilseed (average of canola, soybean, and sunflower response).

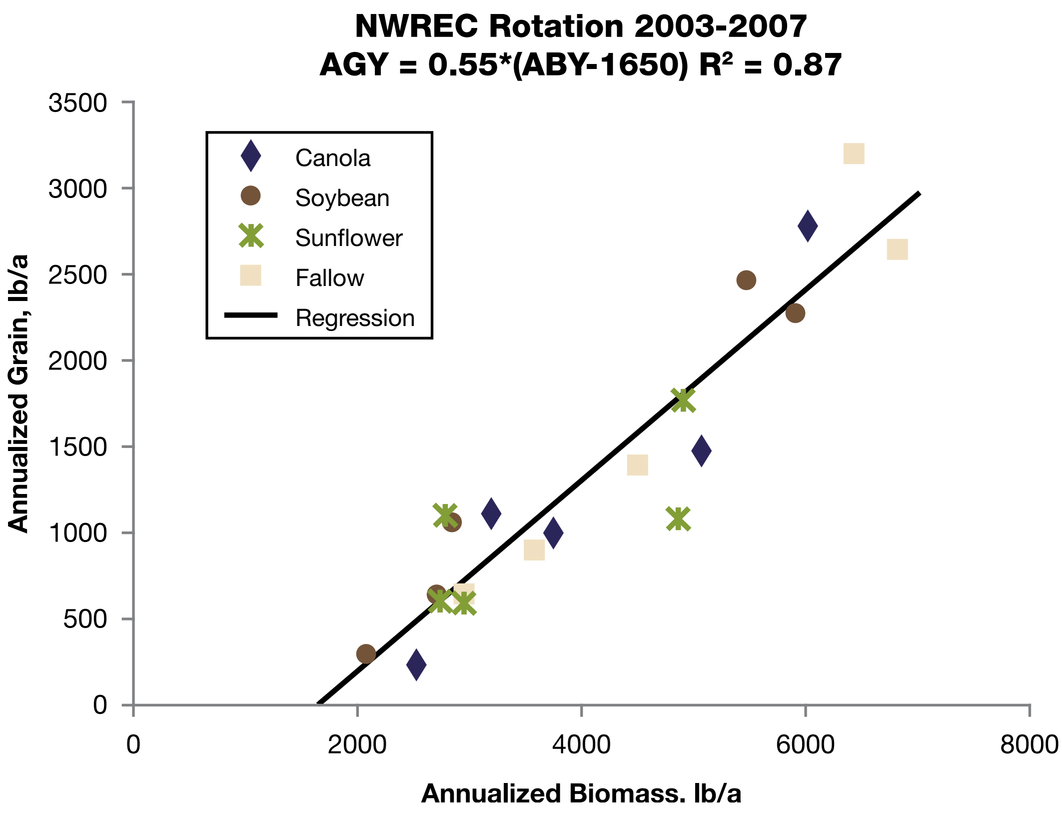

Figure 1. Annualized grain yield (average of crop phases within crop sequence) in relation to annualized aboveground biomass produced by that crop sequence.

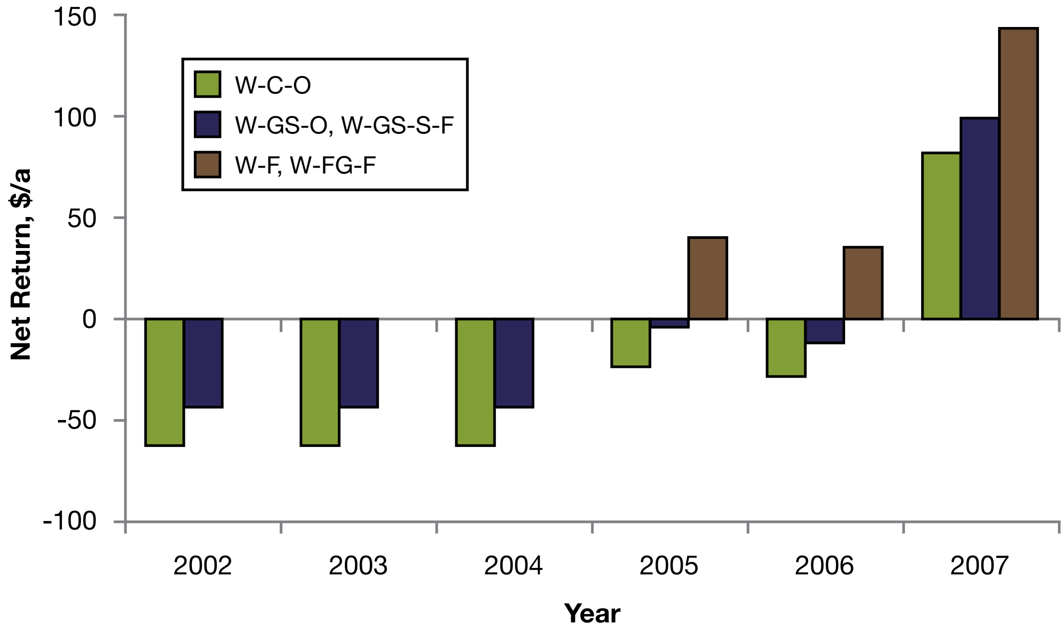

Figure 2. Net economic returns to crop sequences at Colby, KS, 2002-2007; Model of crop sequence and year effects.
W = winter wheat, C = corn, O = oilseed (average of canola, soybean, and sunflower response), GS = grain sorghum, S = sunflower, F = fallow, FG = feed grain.

Sunflower Response to KIH-485

B. L. Olson, C. R. Thompson, P. W. Stahlman, and D. E. Peterson

Summary

Farmers have limited herbicide options for controlling weeds in sunflower. The objective of this research was to evaluate various rates of KIH-485 (pyroxasulfone) with addition of herbicide tank mixes for weed control and sunflower tolerance across multiple sites in Kansas. KIH-485 has potential to be an important herbicide addition for weed control in sunflower by providing a high level of control of weeds such as Palmer amaranth, redroot pigweed, large crabgrass, and kochia. Also, potential for sunflower injury should be minimal across the wide range of soil types in Kansas as long as the KIH-485 rate is adjusted appropriately for the environment.

Introduction

KIH-485 is an experimental seedling-growth inhibiting herbicide developed by Kumiai America that has potential to control weeds in sunflower. Weed control in sunflower remains problematic, and farmers have limited herbicide options. In recent years, Spartan (sulfentrazone), an improved formulation of Prowl H_2O (pendimethalin), and the advent of Clearfield sunflowers have been valuable tools for controlling weeds in sunflower. Even with these additions, weed control gaps still exist. KIH-485 appears to provide control of small-seeded grasses similar to that achieved with Dual Magnum (s-metolachlor) and Prowl H_2O but with potential for better broadleaf weed control. Adding another herbicide to this market segment will benefit farmers by improving options and increasing market competition.

However, little is known about how this new experimental herbicide will interact with various soil types and environments when combined with Spartan. Therefore, the objective of this research was to evaluate various rates of KIH-485 with addition of Spartan for weed control and potential sunflower injury across multiple sites in Kansas.

Procedures

A multisite study was initiated in the spring of 2008 to evaluate several rates of KIH-485 applied alone or in a tank mix with Spartan. Experiments were conducted at the Northwest Research-Extension Center at Colby, KS, the Agricultural Research Center at Hays, KS, the Southwest Research-Extension Center–Tribune Unit at Tribune, KS, and the Ashland Bottoms Research Unit at Manhattan, KS. Sunflower hybrids, planting rates and dates, soil types, soil pH, organic matter, and application information are listed in Table 1. Fertilizer was applied at each site in accordance with soil test levels and yield goal, and insecticides were used at each site as needed to control pest outbreaks. Weed seed was overseeded at all sites to enhance native populations. A standardized protocol was used depending on the soil at each site (Table 2). All treatments were applied to small plots ranging from 6.7 to 10 ft wide and 22 to 25 ft long. Visual levels of weed control at each site were taken 4 weeks after treatment (WAT) on a scale of 0 = no control to 100 = weed mortality. Grain weight was recorded along with test weight and moisture content. Yield was calculated, and data were statistically analyzed. All sites were set up as

a randomized complete block with three or four replications. There was no site by treatment interaction for sunflower injury or crop yield.

Results

Sunflower injury across all sites was almost nonexistent (Table 2), even at the projected 2X application rate of KIH-485. Sunflower response to KIH-485 and Spartan was similar regardless whether the herbicides were applied separately or in a tank mix. Injury potential from KIH-485 appears to be minimal, as long as herbicide rates are adjusted properly for soil type.

Puncturevine and kochia ratings were taken at Hays and Tribune, respectively, at 4 WAT (Table 2.) No herbicide combination at the expected KIH-485 use rates controlled puncturevine more than 63%, and control at the 2X rate of KIH-485 was only 80%. Addition of Spartan to KIH-485 did not improve puncturevine control compared with KIH-485 applied alone.

Kochia control was more than 94% for all herbicide treatments, with the exception of the low rate of KIH-485. The two higher rates of KIH-485 alone provided 94 and 96% kochia control, and Spartan without KIH-485 controlled kochia 100%. Therefore, it was not possible to determine whether combinations of KIH-485 and Spartan are likely to improve residual kochia control more than applying either herbicide alone. No weed control ratings were taken at Colby because of poor emergence of overseeded kochia.

Large crabgrass was rated at Manhattan and Hays at 4 WAT. However, there was a site by treatment interaction, so results are reported for each site. Palmer amaranth was evaluated at Manhattan, and redroot pigweed was rated at Tribune (Table 3).

For large crabgrass, the benefit of adding KIH-485 to Spartan was observed at both Manhattan and Hays. Thirty percent more large crabgrass control was observed at Manhattan, whereas 10 to 15% more was reported at Hays.

Both pigweed species, Palmer amaranth and redroot pigweed, were controlled at a high level. The combination of KIH-485 with Spartan had weed control ratings of 100% at both sites for all treatment combinations.

In conclusion, KIH-485 has potential to be an important herbicide addition for weed control in sunflower by providing a high level of control of weeds such as Palmer amaranth, redroot pigweed, large crabgrass, and kochia. Also, potential for sunflower injury should be minimal across the wide range of soil types in Kansas as long as the KIH-485 rate is adjusted appropriately for the environment.

Table 1. Planting and application information for 2008

	Colby	Hays	Tribune	Manhattan
Sunflower hybrid	Triumph 645	Mycogen 8N386CL	Pioneer 63N82	Pioneer 63N82
Planting date	June 16	June 4	May 27	June 1
Planting rate, seeds/a	17,600	20,000	17,000	22,000
Application date	June 20	June 5	May 27	June 10
Application, gal/a	15	13.1	20	15
Nozzle type	Turbo TeeJet 11002	Turbo TeeJet 110015	Turbo TeeJet 11003	Turbo TeeJet 11003
Soil type	Keith silt loam	Harney silt loam	Ulysses silt loam	Reading silt loam
Soil pH	6.5	6.5	7.9	5.8
Organic matter, %	2.7	2.0	2.5	3.2

Table 2. Sunflower injury, weed control, and yield 4 weeks after treatment

	Treatment	Tribune rate	Colby, Hays, Manhattan rate	Rate unit	Sunflower injury	Yield[1]	Puncturevine Hays	Kochia Tribune
					%	lb/a	---%---	
1.	KIH-485	2.1	2.8	oz/a	0	1889	63	81
2.	KIH-485	2.8	3.5	oz/a	0	1927	50	96
3.	KIH-485	4.2	5.6	oz/a	1	1905	80	94
4.	Spartan	3	3	fl oz/a	0	2017	63	100
5.	Spartan	4	4	fl oz/a	0	1881	35	100
6.	KIH-485	2.1	2.8	oz/a	0	1950	60	100
	Spartan	3	3	fl oz/a				
7.	KIH-485	2.8	3.5	oz/a	0	1879	50	100
	Spartan	3	3	fl oz/a				
8.	KIH-485	4.2	5.6	oz/a	0	2062	63	100
	Spartan	3	3	fl oz/a				
9.	KIH-485	2.1	2.8	oz/a	0	1958	48	99
	Spartan	4	4	fl oz/a				
10.	KIH-485	2.8	3.5	oz/a	1	1886	58	100
	Spartan	4	4	fl oz/a				
11.	KIH-485	4.2	5.6	oz/a	0	2103	38	100
	Spartan	4	4	fl oz/a				
12.	Untreated				0	1695	0	0
	LSD (0.05)				NS	NS	39	8

[1] No yield was taken at Tribune.

Table 3. Weed control 4 weeks after treatment at individual sites

	Treatments	Tribune rate	Colby, Hays, Manhattan rate	Rate unit	Large crabgrass Manhattan	Large crabgrass Hays	Palmer amaranth Manhattan	Redroot pigweed Tribune
					-----------------	----------------- %	-----------------	-----------------
1.	KIH-485	2.1	2.8	oz/a	95	58	97	79
2.	KIH-485	2.8	3.5	oz/a	100	55	97	87
3.	KIH-485	4.2	5.6	oz/a	100	67	100	96
4.	Spartan	3	3	fl oz/a	57	23	87	99
5.	Spartan	4	4	fl oz/a	67	55	92	98
6.	KIH-485	2.1	2.8	oz/a	100	50	100	100
	Spartan	3	3	fl oz/a				
7.	KIH-485	2.8	3.5	oz/a	100	58	100	100
	Spartan	3	3	fl oz/a				
8.	KIH-485	4.2	5.6	oz/a	100	53	100	100
	Spartan	3	3	fl oz/a				
9.	KIH-485	2.1	2.8	oz/a	100	65	100	100
	Spartan	4	4	fl oz/a				
10.	KIH-485	2.8	3.5	oz/a	100	65	100	100
	Spartan	4	4	fl oz/a				
11.	KIH-485	4.2	5.6	oz/a	100	65	100	100
	Spartan	4	4	fl oz/a				
12.	Untreated				0	0	0	0
	LSD (0.05)				11	22	9	6

Effect of Herbicides, Strip Tillage, and Crop Stature on Kochia Interference in Sunflower

B. L. Olson, P. W. Stahlman, and P. W. Geier

Summary
Short-stature sunflower and strip-tillage production have potential to improve sunflower competitiveness with broadleaf weeds. To evaluate the effect of these "new" introductions, a multiyear study was initiated to determine whether short-stature sunflower and strip tillage improve or decrease competitiveness of sunflower in various levels of kochia control compared with conventional-height sunflower and sunflower grown in no-till. Weather conditions and nonuniform population levels of kochia across sites hindered collection of consistent data. There was no tillage by crop stature by kochia control interaction at any site. Strip tillage did not increase sunflower competitiveness. Short-stature and conventional-height sunflower yield potential was similar when these plants competed with a tall, aggressively growing weed such as kochia.

Introduction
Short-stature sunflower and strip-tillage production have been introduced into sunflower production in recent years. Short-stature sunflowers have a shortened internode and grow approximately ½ to ⅔ the typical height of a conventional sunflower. Strip tillage is a process in which 8 to 10 in. of soil are tilled prior to planting and the rest of the ground is kept as no-till. Fertilizer is placed below the soil surface of this tillage zone during the tillage process, and sunflower seed is then planted into this tilled zone.

Both introductions have potential to improve sunflower competitiveness with broadleaf weeds of significance, including kochia and Palmer amaranth. A multiyear study was initiated to evaluate whether short-stature sunflower and strip tillage improve or decrease competitiveness of sunflower exposed to various levels of kochia control compared with conventional-height sunflower and sunflower grown in no-till.

Procedures
In the spring of 2005, a two-site study was initiated at the Northwest Research-Extension Center at Colby, KS, and the Agricultural Research Center at Hays, KS. Fertilizer was applied in the spring as a band on the surface in the no-till plots or subsurface injected in the strip-tillage plots. The previous crop on all sites was wheat. Amounts and rates of fertilizer applied during the strip-tillage/no-till band operations and planting date for each site are reported in Table 1. Amounts of additional nitrogen and phosphorus required to meet nutrient needs of the sunflower crop were determined from soil tests and applied at each site. Weather conditions hindered timely fertilizer application for the strip-tillage treatments at Hays and Colby in 2007 and at Hays in 2008. Triumph 675 was the short-stature sunflower and Triumph 645 was the conventional-height sunflower used at all sites. Planting rate was between 17,600 and 19,000 seeds/a at all sites. Kochia was broadcast overseeded at all sites. Plot width was 20 × 40 ft at Colby and 10 × 22 ft at Hays. Preemergence herbicide treatments were applied to simulate different levels of kochia control: (1) High – sulfentrazone, pendimethalin, glyphosate at 0.75 lb ai/a,

(2) Moderate – pendimethalin and glyphosate at 0.75 lb ai/a, and (3) No control – glyphosate at 0.75 lb ai/a. Sulfentrazone and pendimethalin were applied at 0.125 and 1.43 lb ai/a, respectively, at Colby and 0.094 and 1.25 lb ai/a, respectively, at Hays. Visual levels of kochia control and other prevalent weeds were taken 4 weeks after treatment on a scale of 0 = no control to 100 = weed mortality. Grain weight was recorded along with test weight and moisture content. Yield was calculated, and data were statistically analyzed. The study was set up as a randomized complete block with four replications with tillage (no-till and strip tillage), sunflower stature (short and tall), and herbicide (high, moderate, and no control) as factors at Colby. At Hays, the study was a split block with sunflower stature as the main factor.

Results

Weather conditions and nonuniform population levels of kochia across sites hindered collection of consistent data. High levels of kochia were present at Colby in 2005 and 2006. Low levels were present at Hays in 2005, and no kochia emerged at Colby in 2008. The Hays site was lost in 2006 because of poor growing conditions.

There was no tillage by crop stature by kochia control interaction at any site. Initially, crop stature appeared as though it was going to affect sunflower yield. Kochia quickly overtook the short-stature sunflower in plots where no residual herbicide was present (glyphosate only). Conventional-height sunflower bloomed but soon succumbed to the dry conditions prevalent in plots where kochia was not controlled. In the end, both short-stature and conventional-height sunflower yields were significantly diminished by kochia competition. Table 2 shows yields for each kochia control level across both sunflower statures, with the exception of the Colby site in 2008. Table 3 reports the actual level of kochia control observed in the field for each herbicide treatment.

Tillage system affected sunflower yield, but there were no interactions with crop stature or kochia control. For combined yields of the Colby sites in 2005 and 2006, no difference was observed between strip-till and no-till sunflower. No difference was observed for Colby 2008. At Hays in 2005, no-till sunflower yielded more than strip-till sunflower. The poor performance of strip-till sunflower at Hays can be attributed to the less-than-optimal conditions in which the strip-tillage treatment was applied. The ground was very moist during the strip-tillage operation. Conditions then dried, causing stand establishment and side-wall compaction issues for sunflower planted in strip-tillage plots. These results are shown in Table 4.

In conclusion, this research has been challenging because of variable kochia populations and weather conditions. However, results indicate the short-stature sunflower is no more at risk to yield loss than tall-stature sunflower when competing against a tall, aggressively growing weed such as kochia. Ultimately, both types of sunflower succumbed to competition from kochia.

Table 1. Fertilizer timing, rates of urea ammonium nitrate, and planting date for each site

	Fertilizer date	Fertilizer rate	Planting date
Colby 2005	May 6	45-0-0	June 6
Hays 2005	May 24	40-0-0	June 2
Colby 2006	April 6	90-0-0	June 3
Hays 2006	April 20	90-0-0	June 5
Colby 2008	April 7	30-0-0	June 7

Table 2. Sunflower yield for each level of kochia control across both sunflower statures

	Yield	
Kochia control	Colby 2005 and 2006	Hays 2005
	------------------lb/a------------------	
High	1978	1440
Moderate	1205	1341
Low	685	931
LSD (0.05)	320	220

Table 3. Actual kochia control 4 weeks after treatment across both sunflower statures

	Control	
Kochia control	Colby 2005 and 2006	Hays 2005
	------------------%------------------	
High	98	100
Moderate	57	98
Low	0	97
LSD (0.05)	4.1	NS

Table 4. Tillage effect on sunflower yield

	Yield		
Tillage	Colby 2005 and 2006	Hays 2005	Colby 2008
	------------------lb/a------------------		
No-till	1336	1449	439
Strip tillage	1243	1047	520
LSD (0.05)	NS	180	NS

Wheat Response to Foliar Applications of Copper and Zinc

B. L. Olson

Summary
Recently, questions have arisen as to whether copper and zinc deficiencies are depressing wheat yields in Kansas. A 2-year study was initiated in 2007 to help answer these questions. On-farm wheat production fields where chosen randomly, and soil test levels were taken for copper and zinc. Treatments consisted of 1 lb/a of copper or zinc applied prior to wheat jointing in the spring and an untreated check. No differences in wheat yield were observed when comparing the copper and zinc treatment with the untreated check. Therefore, wheat fields having copper and zinc soil test levels of 0.2 to 1.3 ppm will likely not benefit from supplemental applications of these nutrients applied during jointing.

Introduction
In recent years, there has been speculation that a large number of wheat acres are suffering from copper and zinc deficiencies. Copper deficiency can cause wheat leaves to die back at the tip and curl. Environmental factors that could cause a lack of available copper include high organic matter, poorly drained mineral soils, or high soil pH and phosphorus levels.

Brown lesions on leaves are a symptom of zinc deficiency. Highly calcareous soils with high pH, soils with high phosphorus levels, or coarse-textured soils with low organic matter are just a few of the environments in which zinc can be deficient.

The objective of this research was to evaluate the effect of foliar applications of copper and zinc prior to wheat jointing on various production fields.

Procedures
In the spring of 2007, four wheat production fields in northwestern Kansas were soil sampled for copper and zinc. In 2008, three fields were sampled. A field study was established at each site consisting of a randomized complete block design with four replications. Plot size was 10 × 25 ft. Soil test levels for copper and zinc along with the wheat variety planted at each site are shown in Table 1. Treatments were: (1) 1 lb/a copper, (2) 1 lb/a zinc, and (3) untreated check. The liquid formulation for the copper product was 7.5% copper in 10.5 lb/gal; the zinc formulation was 9% zinc in 11 lb/gal. Treatments were applied prior to wheat jointing on Mar. 22, 2007, and Mar. 26, 2008, to all sites. Appropriate weed control measures were used at each site. Each site was mechanically harvested with a small plot combine. Grain weight was recorded along with test weight and moisture content. Yield was calculated, and data were statistically analyzed.

Results
Results were combined across sites for each year. No differences were observed between applying the copper or zinc treatment and the untreated check (Table 2). Soil test levels

for each micronutrient were not high or exceedingly low, with the exception of Site 1 for zinc in 2008 (Table 1). These soils should be considered representative of northwestern Kansas. Therefore, wheat fields having copper and zinc soil test levels of 0.2 to 1.3 ppm will likely not benefit from supplemental applications of these nutrients applied just prior to wheat jointing.

Table 1. Wheat variety and copper and zinc levels at each site

Year	Site	Variety	Copper	Zinc
2007			---------ppm-----------	
	Site 1	Danby	1	1.3
	Site 2	Jagalene	1	1
	Site 3	Wesley	1	0.7
	Site 4	Jagalene	0.7	0.8
2008				
	Site 1	Jagalene	0.6	0.2
	Site 2	Ike	1	1.2
	Site 3	TAM 111	1.2	0.6

Table 2. Wheat response to copper and zinc

	Yield	
	2007	2008
	------------------bu/a-------------------	
Copper	65	40
Zinc	63	42
Untreated	63	42
LSD (0.05)	NS	NS

FIELD RESEARCH 2009

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