FIELD DAY 2012

Report of Progress 1070

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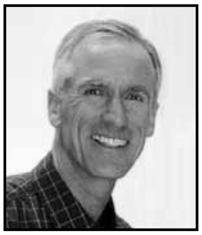
Research and Extension

Kansas State University Agricultural Experiment Station and Cooperative Extension Service

SOUTHWEST RESEARCH-EXTENSION CENTER



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Dr. Gillen was appointed head of the Western Kansas Agricultural Research Centers (Colby, Garden City, Hays, and Tribune) in 2006. His research interests include grazing management systems, grassland ecology, and forage establishment.

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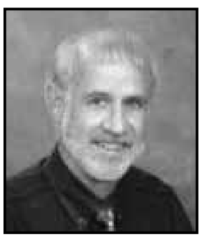

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Weather Information for Garden City

J. Elliott

Precipitation for 2011 totaled 12.12 in. This was 7.12 in. below the 30-year average of 19.24 in. Each month, with the exception of April and December, recorded below-average moisture. The year 2011 was ranked the 15th driest since our records began 103 years ago. The largest precipitation event was 1.20 in. of rain/snow on December 20. Pea-size hail was noted on May 25.

Measureable snowfall occurred in January, February, March, and December 2011. Annual snowfall totaled 17.2 in. The 30-year average is 19.7 in. The largest event was 8.0 in. of wet snow recorded on December 20. Seasonal snowfall (2010–2011) was 9.5 in.

Average daily wind speed was 4.65 mph. The 30-year average is 5.10 mph. Open-pan evaporation from April through October was 89.03 in., which is 18.77 in. above the 30-year mean. Notably, evaporation totaled more than 10 times precipitation for the same 7-month period.

In addition to the dry conditions, the other story of 2011 was the heat. Triple-digit temperatures were observed on 45 days in 2011, with the highest being 109°F on June 30. Ten record-high temperatures were equaled or exceeded in 2011: 81°F on February 17, 91°F on March 5, 93°F on March 10, 102°F on May 30, 107°F on June 27, 109°F on June 30, 108°F on July 21, 106°F on July 28, 105°F on August 19, and 106°F on August 24. Sub-zero temperatures occurred 11 times in 2011, and the lowest temperature, -13°F, was recorded on February 10. Two record-low temperatures were set in 2011, -8°F on January 13 and -13°F on February 10.

The last spring freeze was 32°F on May 16, which is 17 days later than the 30-year average. The first fall freeze was 32°F on October 18, which is 6 days later than normal. This resulted in a 155-day frost-free period, which is 10 days shorter than the 30-year average.

The 2011 climate information for Garden City is summarized in Table 1.

Table 1. Climate data, Southwest Research-Extension Center, Garden City

	Precipitation		Monthly temperatures: 2011 avg.				Monthly temperatures: 2011 extreme		Wind		Evaporation	
Month	2011	avg.	Max	Min	Mean	30-year avg.	Max	Min	2011	30-year avg.	2011	30-year avg.
	--------in.---------		--------------------------------°F---------------------------------						------mph-------		---------in.----------	
January	0.18	0.46	44.3	12.8	28.5	30.4	71	-9	3.09	4.50	--	--
February	0.43	0.55	47.5	12.0	29.7	33.9	81	-13	4.57	5.24	--	--
March	0.66	1.31	57.1	26.9	42.0	42.9	84	10	5.04	6.31	--	--
April	1.79	1.74	70.7	36.9	53.8	52.3	93	26	5.88	6.42	9.74	8.21
May	1.14	2.98	78.4	44.0	61.2	62.8	102	29	5.83	5.76	12.79	10.04
June	1.69	3.12	93.3	59.8	76.6	72.6	109	48	5.72	5.37	16.09	11.96
July	0.54	2.80	101.3	68.5	84.9	77.9	108	65	4.50	4.59	18.17	13.22
August	2.43	2.51	98.1	65.9	82.0	76.3	106	60	3.95	4.11	14.03	11.28
September	0.37	1.42	83.4	49.4	66.4	67.7	105	36	3.83	4.73	10.12	9.22
October	0.44	1.21	72.5	39.8	56.1	54.9	95	25	4.83	4.89	8.09	6.33
November	0.42	0.55	57.1	26.0	41.6	41.6	79	15	4.71	4.80	--	--
December	2.03	0.59	39.9	16.5	28.2	31.4	62	0	3.86	4.45	--	--
Annual	12.12	19.24	70.3	38.2	54.3	53.7	109	-13	4.65	5.10	89.03	70.26

Normal latest spring freeze (32°F): April 29. In 2011: May 16.
Normal earliest fall freeze (32°F): October 12. In 2011: October 18.
Normal frost-free period (>32°F): 165 days. In 2011: 155 days.
30-year averages are for the period 1981–2010. All recordings were taken at 8:00 a.m.

Weather Information for Tribune

D. Bond and D. Nolan

Total yearly precipitation was 22.93 in., which is 5.03 in. above normal. Seven months had above-normal precipitation. July (5.15 in.) was the wettest month. The largest single amount of precipitation was 3.11 in. on June 21. January was the driest month (0.33 in.). Snowfall for the year totaled 33.0 in.; January, February, March, November, and December had 3.7, 7.7, 5.0, 1.6, and 15.0 in., respectively, for a total of 44 days of snow cover. The longest consecutive period of snow cover, 12 days, occurred December 20 through 31.

Record high temperatures were recorded on five days: March 22 (85°F), April 3 (89°F), April 4 (87°F), June 6 (101°F), and June 7 (101°F). Record high temperatures were tied on May 31 (97°F) and October 4 (94°F). No record low temperatures were recorded, but a record low temperature was tied on May 31 (37°F). July was the warmest month with a mean temperature of 80.9°F. The hottest days of the year (103°F) occurred on June 30; July 1 and 20; and August 24. The coldest day of the year (-14°F) was January 11. December was the coldest month with a mean temperature of 28.0°F.

Mean air temperature was above normal for seven months. July had the greatest departure above normal (4.2°F), and February had the greatest departure below normal (-3.5°F). Temperatures were 100°F or higher on 22 days, which is 11 days above normal. Temperatures were 90°F or higher on 79 days, which is 16 days above normal. The latest spring freeze was May 16, which is 10 days later than the normal date, and the earliest fall freeze was October 19, which is 12 day later than the normal date. This produced a frost-free period of 156 days, which is 2 days more than the normal of 154 days.

Open-pan evaporation from April through September totaled 76.50 in., which is 5.10 in. above normal. Wind speed for this period averaged 4.8 mph, which is 0.5 mph less than normal.

A summary of the 2011 climate information for Tribune is presented in Table 1.

Table 1. Climatic data, Southwest Research-Extension Center, Tribune

			Monthly average temperatures (°F)									
	Precipitation (in.)		2011		Normal		2011 extreme		Wind (mph)		Evaporation (in.)	
Month	2011	Normal	Max	Min	Max	Min	Max	Min	2011	Normal	2011	Normal
January	0.33	0.49	44.5	13.3	44.0	16.2	72	-14	---	---	---	---
February	0.69	0.52	46.4	13.7	47.5	19.4	77	-12	---	---	---	---
March	0.88	1.22	57.6	25.9	56.3	26.8	85	11	---	---	---	---
April	1.36	1.45	68.9	36.2	65.7	34.9	89	22	5.7	6.0	9.37	8.27
May	0.80	2.38	76.5	43.8	75.1	46.4	100	28	6.0	5.6	14.21	11.75
June	4.80	2.94	90.3	58.2	85.7	56.6	103	49	5.5	5.2	15.96	14.04
July	5.15	2.85	96.7	65.1	91.8	61.7	103	58	4.4	5.2	16.90	15.58
August	3.40	2.33	93.7	63.5	89.4	60.4	103	58	3.8	4.7	12.01	12.16
September	0.95	1.18	79.8	49.1	81.5	50.6	102	35	3.2	5.0	8.05	9.60
October	2.53	1.49	70.3	38.7	68.9	37.1	94	23	---	---	---	---
November	0.63	0.55	56.2	25.5	54.9	25.7	75	14	---	---	---	---
December	1.41	0.50	39.9	16.0	44.7	17.0	61	-6	---	---	---	---
Annual	22.93	17.90	68.5	37.6	67.1	37.7	103	-14	4.8	5.3	76.50	71.40

Normal latest freeze (32°F) in spring: May 6. In 2011: May 16.
Normal earliest freeze (32°F) in fall: Oct. 7. In 2011: October 19.
Normal frost-free (>32°F) period: 154 days. In 2011: 156 days.
Normal for precipitation and temperature is 30-year average (1981–2010) from the National Weather Service.
Normal for latest freeze, earliest freeze, wind, and evaporation is 30-year average (1981–2010) from Tribune weather data.

Benefits of Long-Term No-till in a Wheat-Sorghum-Fallow Rotation[1]

A. Schlegel, L. Stone[2], and T. Dumler

Summary
Grain yields of wheat and grain sorghum increased with decreased tillage intensity in a wheat-sorghum-fallow (WSF) rotation. Averaged over the past 11 years, no-till (NT) wheat yields were 6 bu/a greater than reduced tillage and 9 bu/a greater than conventional tillage. Grain sorghum yields in 2011 were 35 bu/a greater with long-term NT than short-term NT. Averaged across the past 11 years, sorghum yields with long-term NT have been twice as great as short-term NT (62 vs. 31 bu/a).

Procedures
Research on different tillage intensities in a WSF rotation at the Tribune Unit of the Southwest Research-Extension Center was initiated in 1991. The three tillage intensities in this study are conventional (CT), reduced (RT), and no-till (NT). The CT system was tilled as needed to control weed growth during the fallow period. On average, this resulted in four to five tillage operations per year, usually with a blade plow or field cultivator. The RT system originally used a combination of herbicides (one to two spray operations) and tillage (two to three tillage operations) to control weed growth during the fallow period; however, in 2001, the RT system was changed to using NT from wheat harvest through sorghum planting (short-term NT) and CT from sorghum harvest through wheat planting. The NT system exclusively used herbicides to control weed growth during the fallow period. All tillage systems used herbicides for in-crop weed control.

Results and Discussion
Since 2001, wheat yields have been severely depressed in 6 of 11 years, primarily because of lack of precipitation. Reduced tillage and no-till increased wheat yields (Table 1). On average, wheat yields were 9 bu/a higher for NT (25 bu/a) than CT (16 bu/a). Wheat yields for RT were 3 bu/a greater than CT even though both systems had tillage prior to wheat. NT yields were less than CT or RT in only 1 of the 11 years.

The yield benefit from RT was greater for grain sorghum than wheat. Grain sorghum yields for RT averaged 13 bu/a more than CT, whereas NT averaged 31 bu/a more than RT (Table 2). For sorghum, both RT and NT used herbicides for weed control during fallow, so the difference in yield could be attributed to short-term compared with long-term no-till. In 2011, sorghum yields were 35 bu/a greater with long-term NT than short-term NT. This consistent yield benefit with long-term vs. short-term NT has been observed since the RT system was changed in 2001. Averaged across the past 11 years, sorghum yields with long-term NT have been twice as great as short-term NT (62 vs. 31 bu/a).

[1] This research project was partially supported by the Ogallala Aquifer Initiative.
[2] Kansas State University Department of Agronomy.

Table 1. Wheat response to tillage in a wheat-sorghum-fallow rotation, Tribune, 2001–2011

	Tillage				ANOVA ($P > F$)		
Year	Conventional	Reduced	No-till	LSD (0.05)	Tillage	Year	Tillage × year
	------------- bu/a -------------						
2001	17	40	31	8	0.002		
2002	0	0	0	- - -	- - -		
2003	22	15	30	7	0.007		
2004	1	2	4	2	0.001		
2005	32	32	39	12	0.360		
2006	0	2	16	6	0.001		
2007	26	36	51	15	0.017		
2008	21	19	9	14	0.142		
2009	8	10	22	9	0.018		
2010	29	35	50	8	0.002		
2011	22	20	20	7	0.649		
Mean	16	19	25	2	0.001	0.001	0.001

Table 2. Grain sorghum response to tillage in a wheat-sorghum-fallow rotation, Tribune, 2001–2011

	Tillage				ANOVA ($P > F$)		
Year	Conventional	Reduced	No-till	LSD (0.05)	Tillage	Year	Tillage × year
	------------- bu/a -------------						
2001	6	43	64	7	0.001		
2002	0	0	0	- - -	- - -		
2003	7	7	37	8	0.001		
2004	44	67	118	14	0.001		
2005	28	38	61	35	0.130		
2006	4	3	29	10	0.001		
2007	26	43	62	42	0.196		
2008	16	25	40	20	0.071		
2009	19	5	72	31	0.004		
2010	10	26	84	9	0.001		
2011	37	78	113	10	0.001		
Mean	18	31	62	5	0.001	0.001	0.001

Cover Crops Reduce Wind and Water Erosion

H. Blanco and J. Holman

Summary

We studied the impacts of various cover crops on wind and water erosion under a no-till, wheat-fallow rotation at the Southwest Research-Extension Center in Garden City, KS, after five years of cover crop establishment. Cover crops generally reduced wind and water erosion. Spring lentil cover crop reduced soil's susceptibility to wind erosion, whereas spring pea and winter triticale reduced runoff and loss of sediment and nutrients compared with fallow. Results also indicated that haying of cover crops may not affect wind erosion risks in the short term. Overall, cover crops can conserve soil by reducing wind and water erosion in this semiarid climate.

Introduction

Growing annual forages or cover crops in place of fallow in a wheat-fallow system is a farming practice that may potentially conserve and improve soil resources. Cover crops may particularly help to reduce wind and water erosion in semiarid regions such as the central Great Plains. Winter wheat-fallow rotation is a dominant cropping system in the region. This rotation is, however, highly vulnerable to wind erosion and soil quality degradation during the fallow phase due to reduced residue cover.

Although wind erosion is often a greater concern than water erosion in semiarid regions, water erosion from crop-fallow systems also can be significant. The limited precipitation in the semiarid Great Plains often occurs in the form of intense and localized rainstorms, which can cause large seasonal losses of soil and nutrients in runoff.

Cover crops are attracting attention, but the extent to which cover crops reduce water and wind erosion in semiarid regions is not well understood. Some producers want to grow annual forages in place of fallow rather than a cover crop; however, harvesting forages reduces the amount of residue left on the soil surface and might reduce soil erosion and improve soil quality less than cover crops. Thus, the effects of annual forages and cover crops on soil erosion need to be determined. This study assessed the effects of both annual forages and cover crops on wind and water erosion for a no-till, wheat-fallow rotation.

Procedures

We studied wheat-fallow rotation managed with a number of cover crops and annual forages under no-till for five years at the Southwest Research-Extension Center. Within the fallow phase, treatment plots consisted of chemical fallow, winter crops (hairy vetch, winter lentil, Austrian winter pea, winter triticale, and each winter legume combined with winter triticale), spring crops (spring lentil, spring field pea, spring triticale, and each spring legume combined with spring triticale), winter and spring peas grown for grain, and continuous winter wheat. Each plot was split in two, with half the plot managed under cover crops (non-hayed) and the other half under annual forage (hayed.) The treatments were replicated three times in a randomized complete block design.

For the study of wind erosion, seven treatments, including fallow (control), winter lentil, spring pea, spring lentil, winter triticale, spring triticale, and continuous winter wheat, were selected from the larger experiment. To study the effects of cover crop haying on wind erosion, winter triticale and spring triticale with half the plot managed under cover crops (non-hayed) and the other half under annual forage (hayed) were selected. For the study of water erosion, five cover crop treatments including fallow (control), winter lentil, spring triticale, spring pea, and winter triticale were selected.

Two soil parameters that directly influence the soil's susceptibility to wind erosion, wind-erodible fraction of the soil and aggregate size expressed as geometric mean diameter of dry aggregates, were used to evaluate wind erosion. About 5 lb of soil sample were collected from the 0- to 2-in. depth from the 10 treatments in August 2011. The soil samples were oven-dried at 56°C for 48 hours and passed through a rotary sieve. Soil aggregates using the rotary sieve method were classified into different aggregate-size fractions as follows: <0.42, 0.42 to 0.84, 0.84 to 2, 2 to 6.35, 6.35 to 14.05, 14.05 to 44.45, and >44.45 mm in diameter. Wind-erodible fraction was computed as the fraction of soil aggregates with diameter <0.84 mm. The different aggregate-size fractions were used to compute the geometric mean diameter of dry aggregates.

Water erosion was measured using a rainfall simulator in August 2011. A solenoid-operated and single-nozzle rainfall simulator was used. Small 3-ft × 6-ft runoff plots were established within the larger cover crop plots. Rainfall was applied for 1 hour to each plot at 3 in./hour, representing a five-year rainfall return period for the study region. Runoff volume was measured and runoff samples were collected for the determination of sediment and nutrient (nitrogen [N] and phosphorus [P]) concentrations.

Results and Discussion

Wind erosion

Replacing fallow with cover crops affected all soil erodibility properties. Cover crops generally reduced the wind-erodible fraction of the soil and increased the size of aggregates compared with fallow. For example, spring lentil reduced the erodible fraction by 73% (Figure 1A) and increased geometric mean diameter of dry aggregates by 65% compared with fallow (Figure 1B). These results indicate that replacing fallow with a crop increased soil macroaggregation. The larger the aggregates, the lower the aggregate breakdown and the lower the soil's susceptibility to wind erosion. Results also suggest that the effects of cover crops on reducing wind erosion depend on cover crop species.

Effects of harvesting an annual forage compared with growing a cover crop on wind erosion were not significant (Figures 1A and 1B). Although haying of winter and spring triticale increased the wind-erodible fraction and reduced aggregate size relative to winter and spring triticale without haying, differences were not statistically significant due to the high variability in data. Based on the trend for increased wind erosion with haying, we suggest that haying of cover crops may significantly increase wind erosion crops in the long term.

Continuous wheat also reduced erodible fraction (Figure 1A) and increased geometric diameter of aggregates (Figure 1B) relative to fallow. Annual straw input and permanent straw cover may be the reasons for the greater ability of continuous wheat to reduce wind erosion.

Water erosion

The five selected cover crop treatments also affected water erosion. Cover crops reduced water erosion, but the effects were significant only at the 0.10 statistical probability level. This result suggests that cover crops may have more beneficial effects on reducing wind erosion than water erosion in this soil with moderate slopes (<3%). Cover crops generally reduced runoff (Figure 2A), sediment loss (Figure 2B), and loss of sediment-associated total P and nitrates (NO_3-N). Winter triticale, spring pea, and spring triticale had large effects and reduced runoff by 350% relative to fallow (Figure 2A). Winter triticale and spring pea reduced sediment loss by 370%, but winter lentil and spring triticale had no effects (Figure 2B). Winter triticale and spring pea reduced losses of total P and NO_3-N by 380% compared with fallow.

Results show that 60% of simulated rain was lost as runoff from plots without cover crops, and only about 13% was lost from plots with winter triticale, spring pea, and spring triticale cover crops. Winter triticale and spring pea cover crops reduced sediment loss by about 0.53 tons/a under a single and simulated rainfall event at 3 in./hour. Winter triticale appeared to be the most effective cover crop treatment for reducing runoff and loss of sediment and nutrients.

Conclusions

Results from this study showed that cover crops reduced wind and water erosion in a no-till, wheat-fallow rotation in this semiarid region. In general, the wind-erodible fraction of the soil was lower and soil aggregates were larger when cover crops were included in the wheat-fallow rotation. Similarly, runoff and sediment loss were reduced with the inclusion of cover crops. Winter triticale and spring pea cover crops were particularly effective for reducing runoff and sediment loss. Our study also showed that continuous wheat was effective to reduce wind erosion risks compared with fallow. Haying of winter and spring triticale appears not to have significant effects on wind erosion in the short term. Long-term (>5 years) monitoring is needed to determine conclusively the effects of cover crop haying on wind erosion and other soil and environmental parameters.

The use of cover crops in semiarid regions has been questioned because cover crops use water and may thus reduce plant-available water for the subsequent crops. Our results suggest that cover crops may contribute to water storage by reducing runoff, which may somewhat reduce the negative effects of cover crops on soil water storage for the subsequent crops. Selection of the most suitable or drought-tolerant species and development of improved management strategies (i.e., early termination) may reduce the adverse effects of cover crops on water storage.

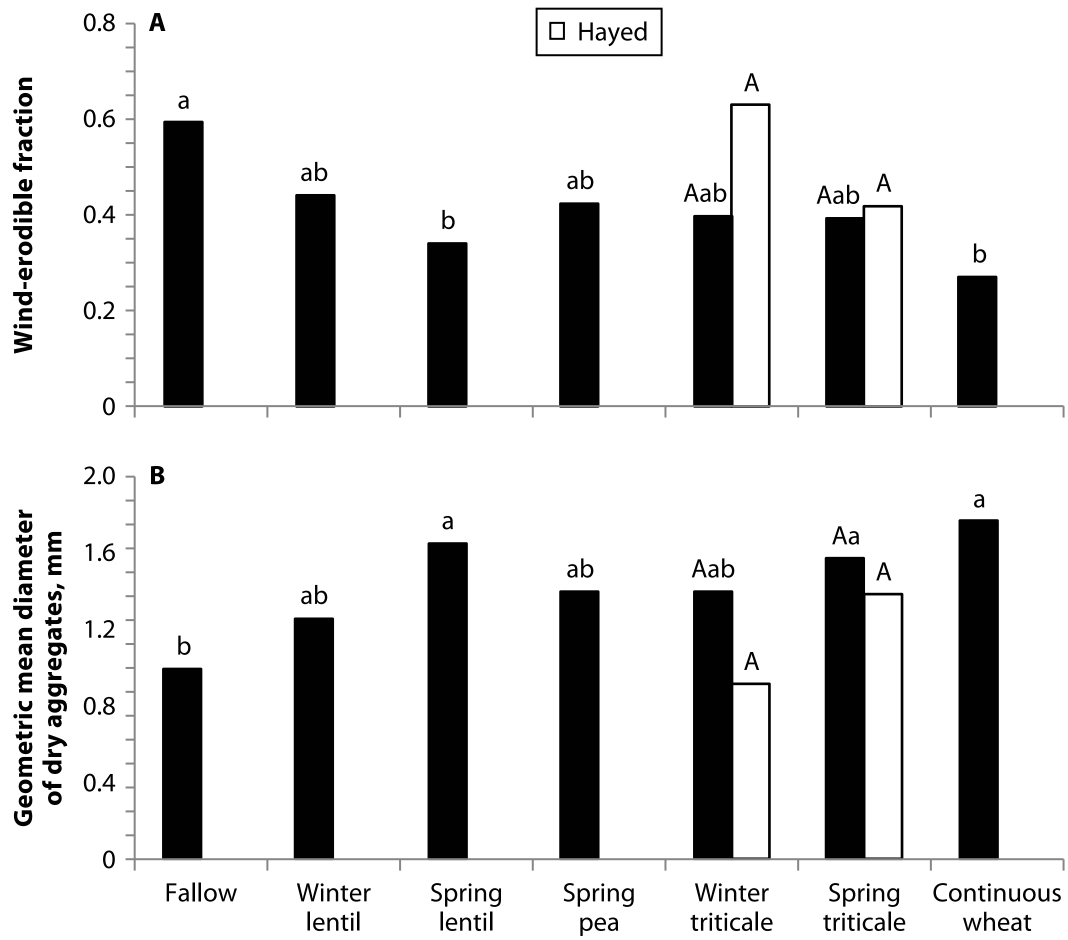

Figure 1. Impact of cover crops on the (A) wind-erodible fraction (<0.84 mm aggregates) of the soil and (B) dry aggregate size expressed as geometric mean diameter of aggregates. Means with the same lowercase letter are not significantly different. Means with the same uppercase letter for hayed (white bars) and non-hayed (black bars) winter and spring triticale are not statistically different at *P* = 0.10.

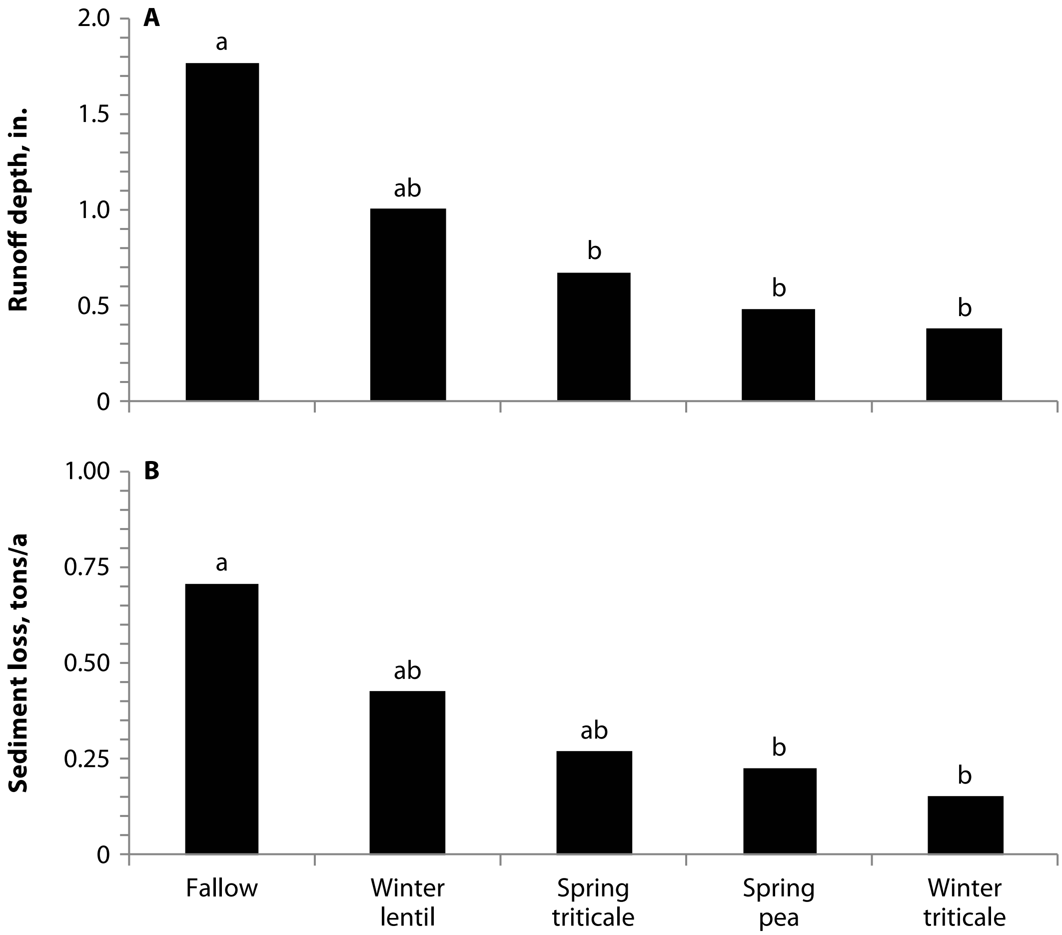

Figure 2. Impact of cover crops on runoff and sediment loss. Means or bars with the same lowercase letter are not statistically different at *P* = 0.10.

Cover Crop Forage Biomass Yield

J. Holman, T. Dumler, T. Roberts, and S. Maxwell

Summary

Producers are interested in growing cover crops or annual forages in place of fallow. A study was initiated in 2007 to evaluate several crops grown in place of fallow in a no-till wheat-fallow system. Crops that produce more biomass may be the best cover crop and forage crop. Cover crops that produce the most biomass may also have the least amount of wind and water soil erosion and the greatest impact on soil carbon (C). Forage crops that produce the most biomass may be the most profitable to grow. Winter triticale produced the most yield, spring triticale and spring pea produced the second most yield, and all other crops yielded less.

Introduction

Interest in growing cover crops and replacing fallow with a cash crop has necessitated research on species that are adapted to southwest Kansas and their forage biomass potential. Fallow stores moisture, which helps stabilize crop yields and reduce the risk of crop failure; however, only 25 to 30% of the precipitation received during the fallow period of a no-till wheat-fallow rotation is stored. The remaining 70 to 85% precipitation is lost primarily to evaporation. Moisture storage in fallow is more efficient earlier in the fallow period when the soil is dry and during the winter months when the evaporation rate is lower. Increasing cropping intensity without reducing winter wheat yield may be possible. Growing a cover crop that produces a lot of biomass may reduce evaporation; in contrast, evaporation may be greater following a cover crop harvested for forage. This study evaluated the forage biomass yield of several winter and spring crops.

Procedures

Fallow replacement crops (cover, annual forage, or short-season grain crops) have been grown during the fallow period of a no-till wheat-fallow cropping system every year since 2007. Crops were either grown as cover, harvested for forage (annual forage crop), or harvested for grain. Both winter and spring crop species were evaluated. Winter species included yellow sweet clover (*Melilotus officinalis* (L.) Lam.), hairy vetch (*Vicia villosa* Roth ssp.), lentil (*Lens culinaris* Medik.), Austrian winter forage pea (*Pisum sativum* L. ssp.), Austrian winter grain pea (*Pisum sativum* L. ssp.), and triticale (×*Triticosecale* Wittm.). Spring species included lentil (*Lens culinaris* Medik.), forage pea (*Pisum sativum* L. ssp.), grain pea (*Pisum sativum* L. ssp.), and triticale (×*Triticosecale* Wittm.). Crops were grown in monoculture and in two-species mixtures of each legume plus triticale. Crops grown for grain were grown in monoculture only. Winter lentil was grown in place of yellow sweet clover beginning in 2009. Crops grown in place of fallow were compared with a wheat-fallow and continuous wheat rotation for a total of 16 treatments (Table 1). The study design was a split-split-plot randomized complete block design with 4 replications; crop phase (wheat-fallow) was the main plot, fallow replacement was the split-plot, and fallow replacement method (forage, grain, or cover) was the split-split-plot. The main plot was 480 ft wide and 120 ft long, the split plot was 30 ft wide and 120 ft long, and the split-split plot was 15 ft wide and 120 ft long.

Winter crops were planted approximately October 1. Winter cover and forage crops were chemically terminated or forage harvested approximately May 15. Spring crops were planted between the end of February and middle of March. Spring cover and forage crops were chemically terminated or forage harvested approximately June 1. Forage biomass yield for both cover crop and forage crop was determined from a 3-ft by 120-ft area cut 3 in. high using a small-plot Carter forage harvester from within the split-split-plot managed for forage. Winter and spring grain peas and winter wheat were harvested with a small plot combine from a 6.5-ft by 120-ft area at grain maturity, which occured approximately the first week of July.

Volumetric soil moisture content was measured at cover crop termination and winter wheat planting using a Giddings Soil Probe (Giddings Machine Company, Windsor, CO) to a 6-ft soil depth. Grain yield was adjusted to 13.5% moisture content and test weight was measured using a grain analysis computer. Grain samples were analyzed for nitrogen content. Forage samples were weighed wet, then a homogenized subsample was collected, dried at 50°C in a forced-air oven for 96 h, weighed dry for dry matter yield, and sent to a commercial laboratory for crude protein (CP), acid detergent fiber (ADF), and neutral detergent fiber (NDF) determination.

Results and Discussion

Forage yield of crop species varied by year due to differences in winter survival and moisture conditions. Winter species (2,336 lb/a) tended to yield more than spring species (1,493 lb/a), although there were differences between years ($P = 0.003$) (Figure 1). Forage yield data from 2007 was not included in the analysis since previous land area management might have caused variation in yield. Forage yield data from 2008 through 2011 were analyzed. Yellow sweet clover did not produce any harvestable biomass in 2007 or 2008 and was replaced with winter lentil beginning in 2009.

In 2008, yields of winter (2,712 lb/a) and spring crops (2,030 lb/a) did not differ ($P = 0.08$), and all winter crops survived the winter (Figure 2). Winter pea showed some visual sign of winter injury, but all other winter crops survived the winter without injury symptoms. Treatments that included winter triticale yielded the most, and treatments with spring triticale yielded the second most. Spring pea, hairy vetch, winter pea, and spring lentil yielded the least. Yellow sweet clover did not produce any harvestable biomass (data not shown).

In 2009, winter crops (2,708 lb/a) yielded more than spring crops (1,296 lb/a) (Figure 3). Winter stand loss was estimated at 50% for winter pea and 95% for hairy vetch. Winter lentil showed no signs of winter injury. Winter survival of winter pea and hairy vetch was greater when grown in mixture with winter triticale than in monoculture. Treatments with winter triticale yielded the most. Winter pea/triticale (5,220 lb/a) yielded more than hairy vetch/triticale (4,503 lb/a) or winter lentil/triticale (3,703 lb/a), which was likely due to the winter peas adding to the yield of triticale grown alone (4,726 lb/a). Treatments with spring triticale yielded the second most, ranging from 1,266 to 1,815 lb/a, which did not differ from spring peas grown alone (1,467 lb/a). Winter pea, spring lentil, and winter lentil yielded the least. Hairy vetch did not yield any harvestable biomass due to winter-kill.

In 2010, winter crops (3,018 lb/a) yielded more than spring crops (1,548 lb/a) (Figure 4). Winter stand loss was estimated at 60% for winter pea and 70% for hairy vetch. Winter lentil showed no signs of winter injury. Winter survival of winter pea and hairy vetch was greater when grown in mixture with winter triticale than in monoculture. Treatments with winter triticale yielded the most, and there were no differences between that set of treatments. Winter triticale treatments yielded between 4,589 and 5,174 lb/a. Treatments with spring triticale yielded the second most, ranging from 1,689 to 2,435 lb/a. Spring triticale (1,772 lb/a) did not yield any more than spring pea (1,398 lb/a). Winter pea, hairy vetch, winter lentil, and spring lentil yielded the least.

2011 was an abnormal year. The fall of 2011 was extremely dry, and winter treatments had to be reseeded due to very dry soil conditions at planting. Only 6.77 in. of precipitation occurred between October 1, 2010, and July 1, 2011. Of this, only 2.15 in. of precipitation occurred between October 1, 2010, and April 1, 2011. The dry conditions and lack of fall and winter precipitation favored spring crops more than winter crops. Spring crops (968 lb/a) yielded more than winter crops (501 lb/a; Figure 5). The combination of dry soil conditions and winter-kill resulted in no harvestable yield of winter lentil, hairy vetch, and winter pea. Winter survival of winter pea and hairy vetch was greater grown in mixture with winter triticale than in monoculture. Spring triticale (1,407 lb/a), spring pea (1,264 lb/a), spring lentil/triticale (1,091 lb/a), and hairy vetch/triticale (1,011 lb/a) yielded the most. Spring lentil yielded the least amount of harvestable yield (174 lb/a). Spring pea/triticale, winter lentil/triticale, winter triticale, and winter pea/triticale yielded less than spring triticale.

Averaged over years from 2008 through 2011 (2007 excluded because it was the initial year of the study), winter triticale treatments yielded the most and spring triticale treatments yielded the second most. Spring triticale yields were similar to spring pea/triticale and spring pea, but spring pea/triticale yielded more than spring pea, indicating the addition of spring pea to spring triticale tended to increase yield. Winter pea, spring lentil, hairy vetch, and winter lentil yielded the least. Winter triticale averaged 3,675 lb/a, and spring triticale averaged 1,869 lb/a.

Conclusions

Forage yield varied based on growing season conditions, primarily precipitation and winter injury. Winter peas and hairy vetch had significant winter injury and stand loss. Winter lentil survived the winter well but had low yield potential and did not add to the yield potential of winter triticale. Winter legumes had less winter injury when grown in combination with triticale, and occasionally winter pea or hairy vetch increased the yield potential of winter triticale; however, the additional seed cost and risk of winter injury make planting winter pea or hairy vetch with winter triticale unadvisable. Winter triticale survived the winter well every year and yielded the most except in 2011, which had a very dry fall and winter.

Spring triticale treatments and spring peas yielded the second most. Spring peas grown in combination with spring triticale tended to increase the yield of spring triticale, whereas spring lentil grown in combination with spring triticale did not improve yield. Spring triticale averaged slightly more yield (439 lb/a) than spring pea. Spring and winter lentil did not produce enough biomass for forage but may be grown as a cover crop where biomass production is not a primary concern.

Table 1. Crop treatments

		Year produced				
Season	Crop	2007	2008	2009	2010	2011
Winter	Yellow sweet clover	x	x			
	Yellow sweet clover/winter triticale		x			
	Hairy vetch	x	x	x	x	x
	Hairy vetch/winter triticale		x	x	x	x
	Winter lentil			x	x	x
	Winter lentil/winter triticale			x	x	x
	Winter pea	x	x	x	x	x
	Winter pea/winter triticale		x	x	x	x
	Winter triticale	x	x	x	x	x
	Winter pea (grain)		x	x		x
Spring	Spring lentil	x	x	x	x	x
	Spring lentil/spring triticale		x	x	x	x
	Spring pea	x	x	x	x	x
	Spring pea/spring triticale		x	x	x	x
	Spring triticale		x	x	x	x
	Spring pea (grain)				x	x
Other	Chem-fallow	x	x	x	x	x
	Continuous winter wheat	x	x	x	x	x

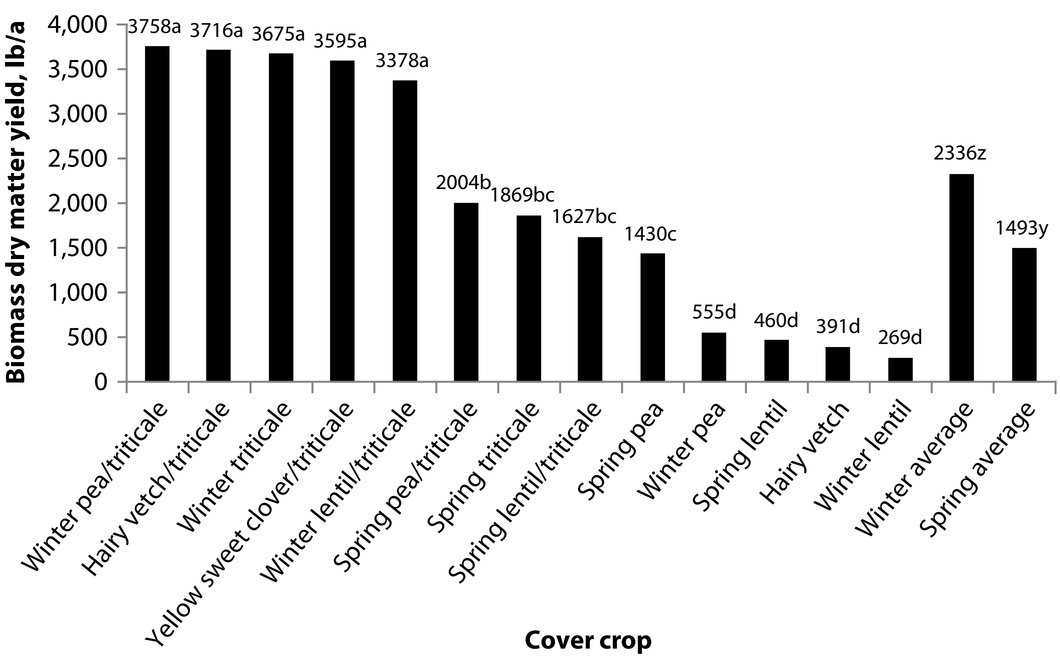

Figure 1. Crop biomass yield, 2008–2011. Means or bars with the same lowercase letter are not statistically different at *P* = 0.05.

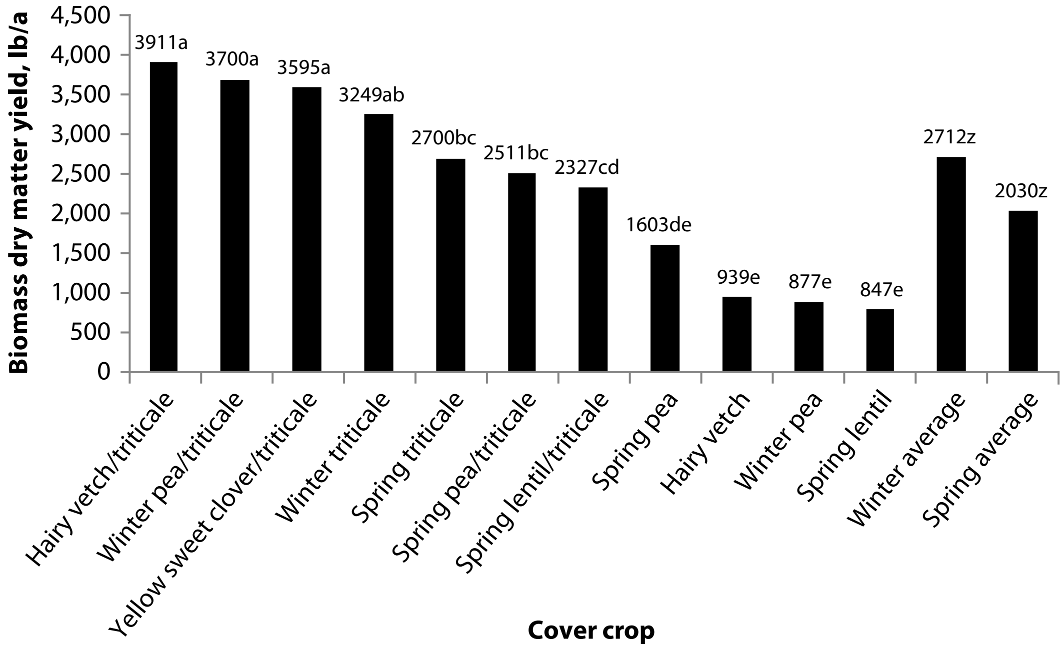

Figure 2. Crop biomass yield, 2008. Means or bars with the same lowercase letter are not statistically different at *P* = 0.05.

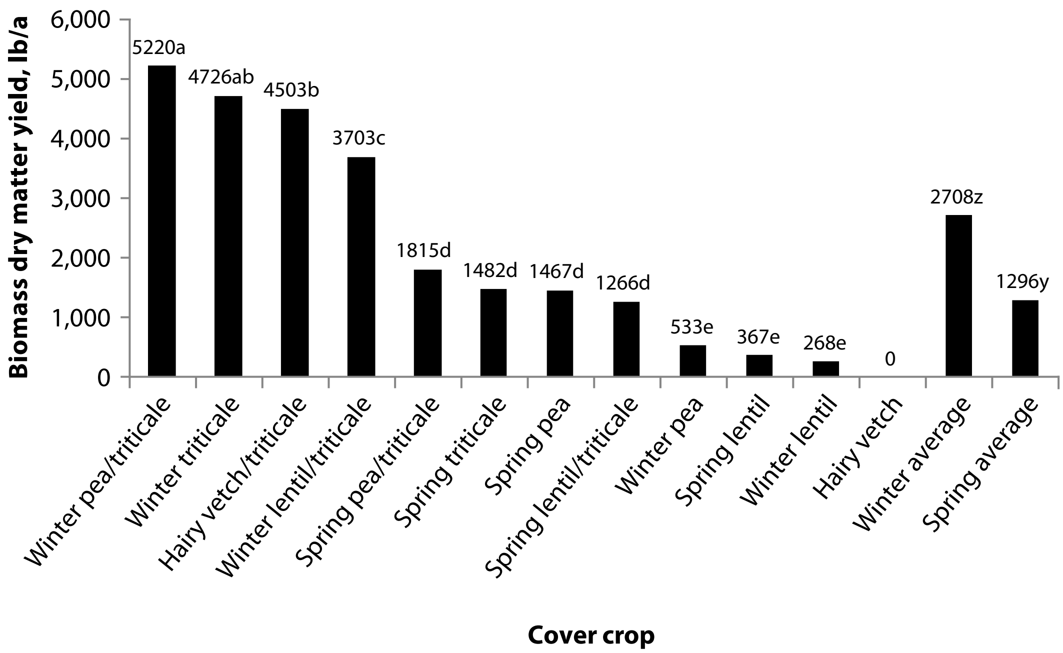

Figure 3. Crop biomass yield, 2009. Means or bars with the same lowercase letter are not statistically different at *P* = 0.05.

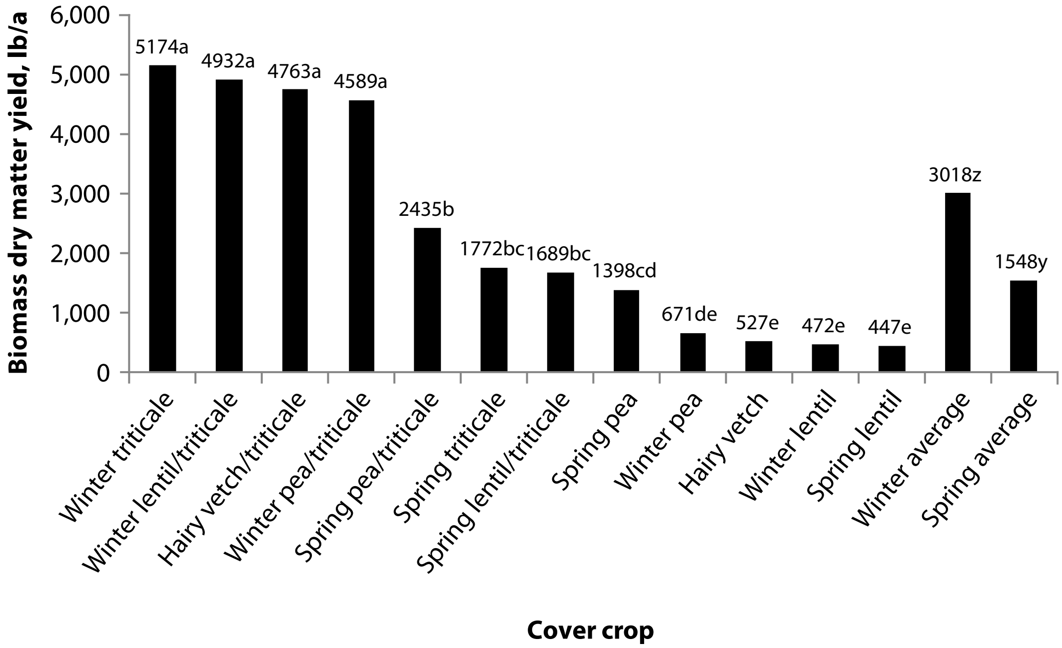

Figure 4. Crop biomass yield, 2010. Means or bars with the same lowercase letter are not statistically different at *P* = 0.05.

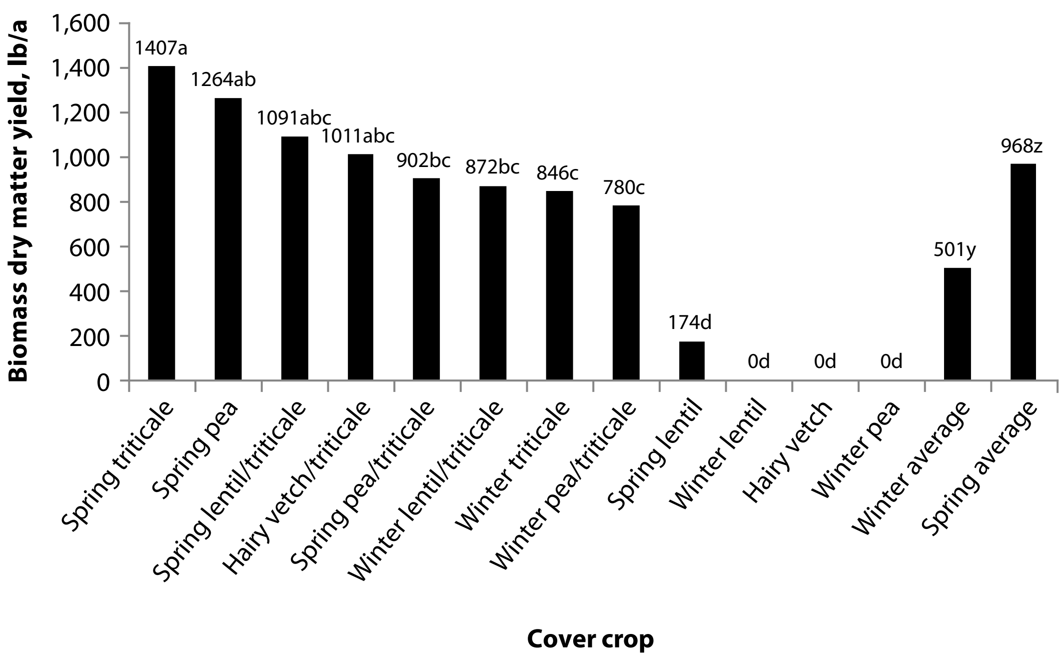

Figure 5. Crop biomass yield, 2011. Means or bars with the same lowercase letter are not statistically different at *P* = 0.05.

Effect of Simulated Hail Damage on Corn Yield

J. Holman, T. Roberts, S. Maxwell, and M. Zarnstorff

Summary
Hail damage is a common occurrence throughout Kansas. This study evaluated the impact of simulated hail damage (stand thinning) on corn at at V5, V8, V11, and V14 growth stages in 2008, 2009, and 2010. The amount that the stand was thinned had a greater impact on corn yield components, yield, and grain quality than the crop stage at thinning. Plants thinned early tended to yield slightly more than plants thinned later. In part, this was because they were able to produce more kernels per ear than plants thinned at V14. Crop yield was reduced at each additional level of thinning. Corn yield was able to partly compensate for thinning by increasing kernel weight, kernels per ear, and ears per plant. Thinning reduced test weight and increased protein content.

Introduction
Hailstorms are a common cause of crop damage in Kansas. Diagnosing and determining the amount of crop injury is important in determining yield loss.

Hail damage always makes corn look bad, and can make for some sleepless nights. Although the physical damage is apparent, the actual effect on yield is not as obvious. Potential corn yield losses from hail gradually increase as the crop matures, up to the silk stage, when peak yield loss occurs. After silking, yield losses from hail damage normally decline again.

From emergence through stem elongation (VE to V5)
Through the five-leaf stage of growth, the growing point of corn is below the soil surface. Hail damage could remove all five leaves but not damage the growing point. A corn plant has 24 to 26 leaves at tasseling; even if the plant loses five of those leaves early on, it will still have the potential to have 19 to 21 leaves at tasseling. Yield will be reduced, but by much less than one might expect from the appearance of the plant.

From stem elongation to tassel (V6 to VT)
The growing point begins extending aboveground by the 6-leaf stage, although it is still protected by several layers of leaves and sheaths. The number of rows that will be in the ear is established by the 12-leaf stage. Stress during V8 to V11 can reduce row number. The number of kernels per row is not determined until about V17, just before tasseling. Hail damage and loss of leaf area during these stages of growth can increase the potential for yield loss. Hail can also cause stalk bruising during these stages of growth, but determining the amount of damage from stalk bruising is difficult until later in the season.

From tassel to maturity (VT to R6)
At VT to R1 (tassel to silk), the corn plant is more vulnerable to hail damage than at any other stage because the tassel and all leaves are exposed. No more leaves will be developed, and the plant cannot replace a damaged tassel. Furthermore, the stalk is exposed, with only one layer of leaf sheath protecting it. Unlike wheat, corn cannot fill

from the stem if leaves are lost at this stage of growth. The six to eight leaves above the ear are the most important, and provide most of the grain fill.

The four-week period surrounding silking is critical to corn, and not only in regard to hail damage. Drought stress, excessive moisture, extreme heat, diseases, and high winds can all stress the plant and reduce yields at this stage of growth. Early in this period, stress can reduce kernel number by limiting potential ear size. Stress right at silking can reduce the number of kernels fertilized, and stress just after silking can cause fertilized kernels to abort.

Procedures

Corn was planted at 36,000 plants/a and thinned to 34,000 plants/a after all corn emerged. Corn was fully irrigated using an overhead pivot. Corn stands were thinned randomly by hand-thinning 0%, 25%, 50%, and 75% at V5, V8, V11, and V14, respectively. Plots were 4 rows wide on 30-in. centers and 30 ft long. Final plant stand, ears per plant, kernels per ear, yield, test weight, 1,000 kernel weight, and protein content were measured from the center 2 rows the full length of the plot. Plots were harvested with a plot combine at grain maturity. Grain yield was adjusted to 15.5% moisture content and test weight was measured using a grain analysis computer. Grain samples were analyzed for nitrogen and converted to protein content. This study was conducted in 2008, 2009, and 2011. For the purposes of this report, results from all years were shown.

Results and Discussion

Yield (bu/a)

Corn yield varied by year ($P \leq 0.01$). Thinning at earlier crop stages tended to yield more than later thinning ($P = 0.08$) (Figure 1). Yield was reduced as the amount of thinning increased ($P \leq 0.01$). Yields averaged 183 bu/a with 0% thinning, 165 bu/a with 25% thinning, 137 bu/a with 50% thinning, and 78 bu/a with 75% thinning.

Kernel weight (g/1,000 kernels)

Kernel weight varied by year ($P \leq 0.01$). Crop stage did not affect kernel weight. Stands thinned 50 and 75% had greater kernel weight (309 g/1,000 kernels) than stands thinned 0 or 25% (295 g/1,000 kernels) ($P \leq 0.01$) (Figure 2).

Kernels per ear

Kernels produced per ear varied by year ($P \leq 0.01$). More kernels were produced per ear when plants were thinned at V5, V8, or V11 (407 kernels/ear) compared with V14 (564 kernels/ear) ($P \leq 0.01$) (Figure 3). No differences were observed in crop stage from V5 to V11. Stands thinned 50 and 75% had more kernels per ear (671 kernels/ear) than stands thinned 25% (566 kernels/ear) or 0% (498 kernels/ear) ($P \leq 0.01$). Stands thinned 25% had more kernels per ear than stands thinned 0%.

Ears per plant

The number of ears produced per plant was not affected by year or crop stage. Stands thinned 75% had more ears per plant (1.11 ears/plant) than the other thinning levels (0.99 ears/plant) ($P \leq 0.01$) (Figure 4).

Test weight (lb/bu)

Test weight varied by year ($P \leq 0.01$). Crop stage did not affect test weight. Stands thinned 50 and 75% had lower test weights (58.9 lb/bu) than stands thinned 0 or 25% (59.4 lb/bu) ($P \leq 0.01$) (Figure 5).

Protein

Protein content of the grain varied by year ($P \leq 0.01$). Crop stage did not affect protein content. Stands thinned 75% had more protein (8.6%) than the other thinning levels (8.1%) ($P \leq 0.01$) (Figure 6).

Conclusions

The amount that the stand was thinned had a greater impact on corn yield components, yield, and grain quality than the crop stage at thinning. Although not significant, plants thinned early tended to yield more than plants thinned later. In part, this was because plants thinned early were able to produce more kernels per ear than plants thinned at V14. Crop yield was reduced at each additional level of thinning, but corn yield was able to partly compensate for thinning by increasing kernel weight, kernels per ear, and ears per plant. Thinning reduced test weight and increased protein content.

This study found slightly different results than research conducted by Dr. Barney Gordon at the North Central Kansas Experiment Field. In that study, yield was affected more by the crop stage thinning that occurred, and thinning affected seed weight; in this study, thinning increased seed weight. In both studies, percentage yield loss was less than the percentage of the stand thinned at every growth stage.

When considering replanting due to poor stands or early season hail damage, keep in mind that planting corn in early June, in much of Kansas, can result in yield losses of up to 50% compared to a typical planting date. Based on the above data, retaining an existing stand even with as much as 50% stand loss would probably be better than replanting in early June. Much depends, of course, on the uniformity of the remaining stand and the weather for the rest of the growing season.

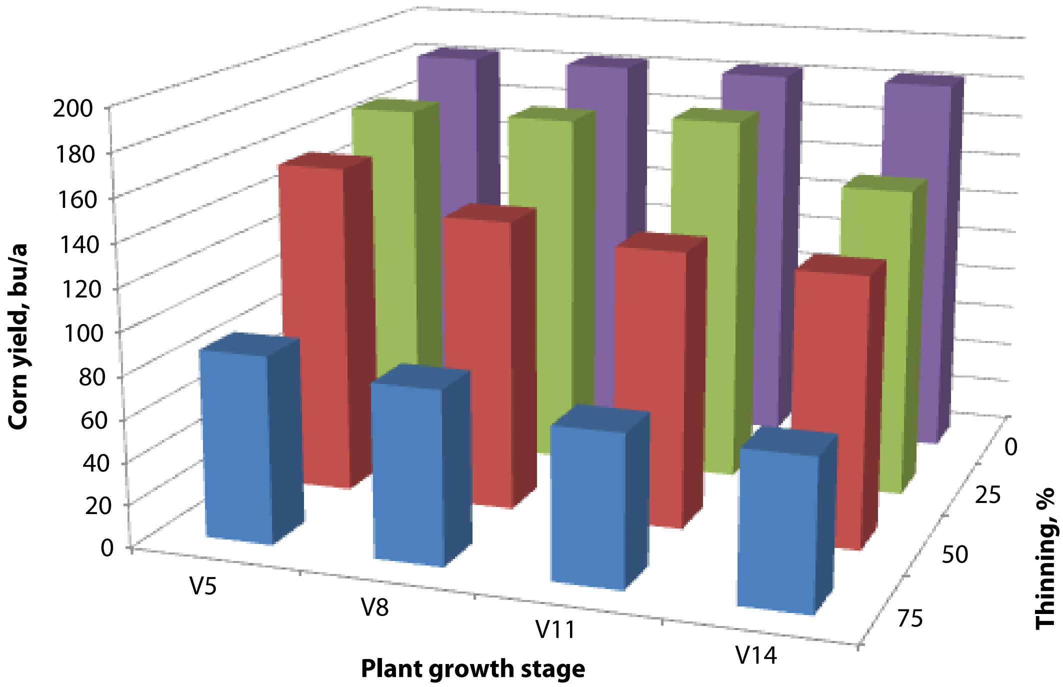

Figure 1. Corn yield response to percentage of stand thinned (0, 25, 50, and 75%) at V5, V8, V11, and V14.

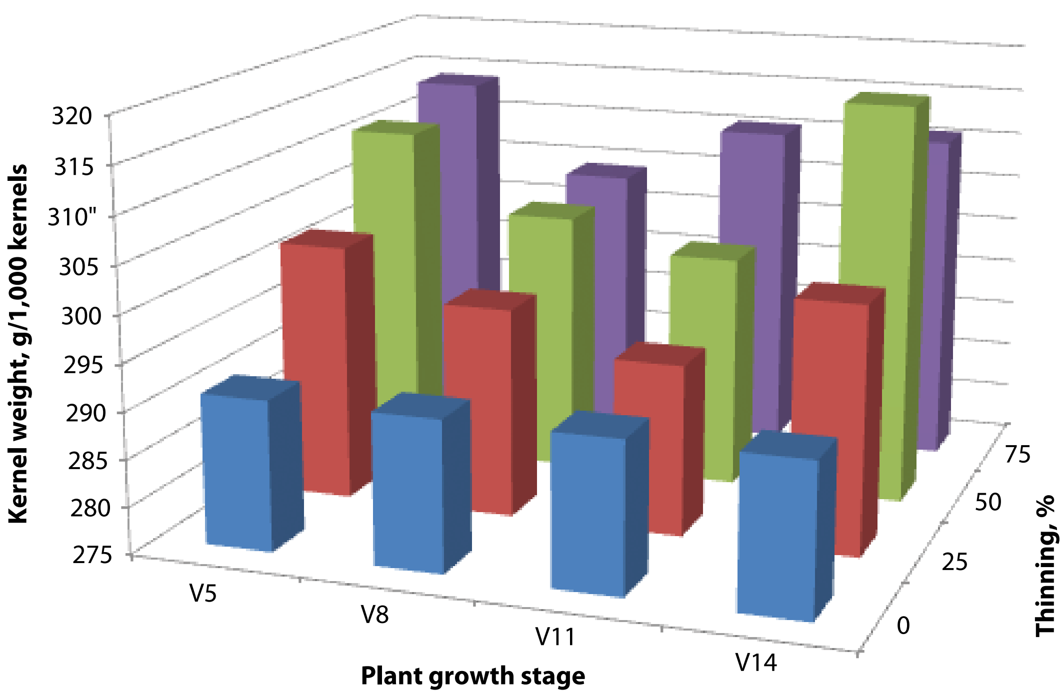

Figure 2. Kernel weight response to percentage of stand thinned (0, 25, 50, and 75%) at V5, V8, V11, and V14.

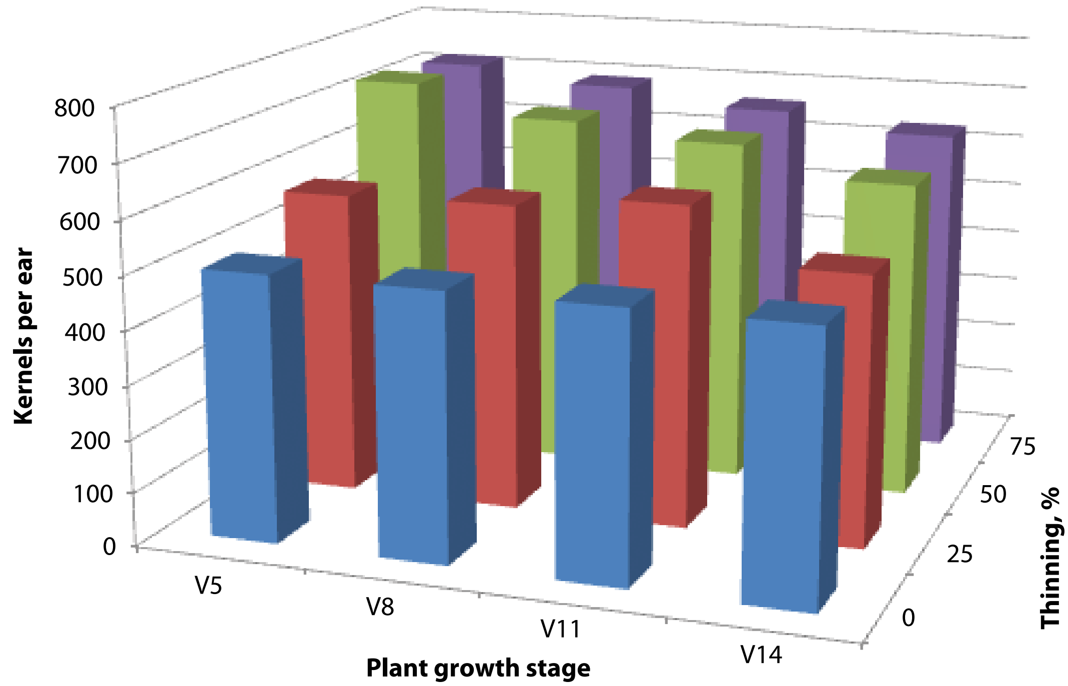

Figure 3. Kernels per ear response to percentage of stand thinned (0, 25, 50, and 75%) at V5, V8, V11, and V14.

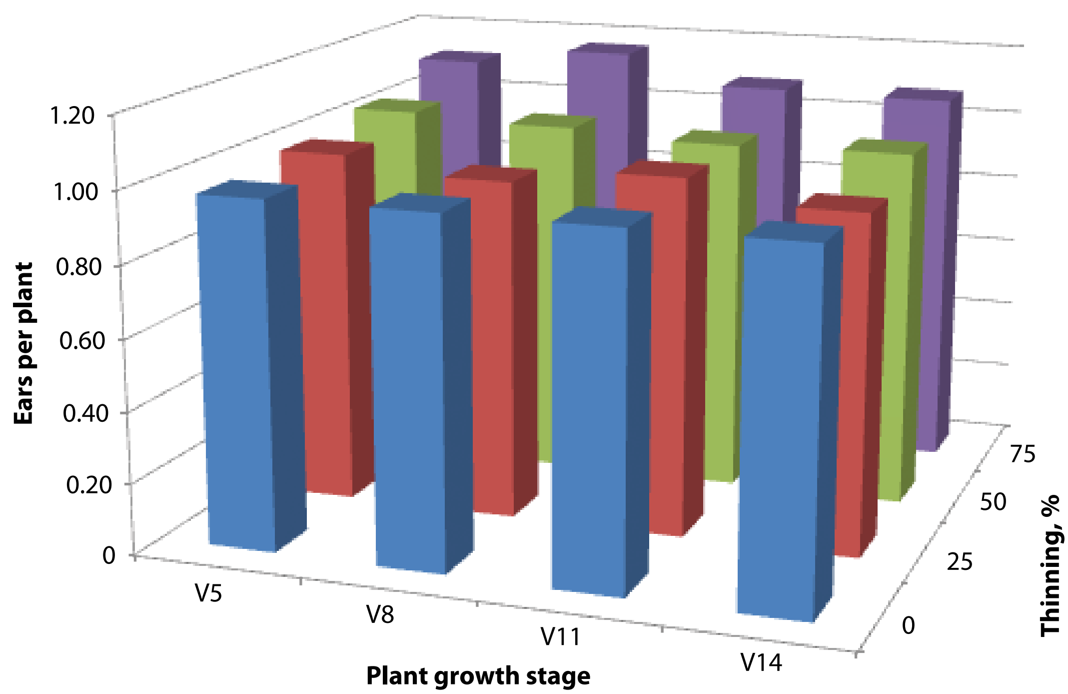

Figure 4. Ears per plant response to percentage of stand thinned (0, 25, 50, and 75%) at V5, V8, V11, and V14.

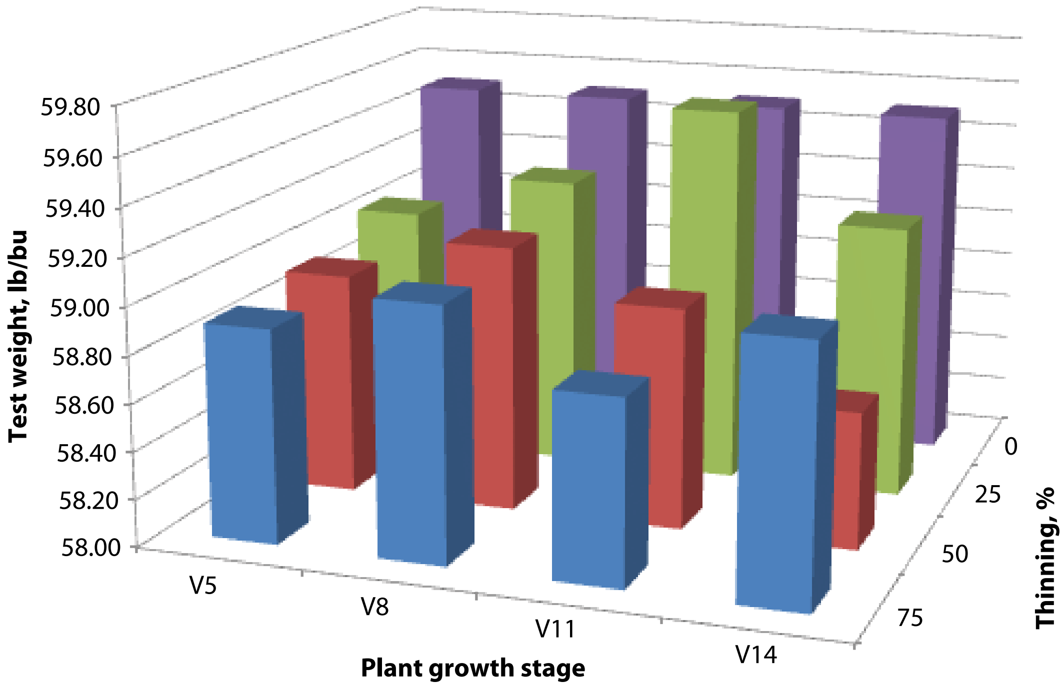

Figure 5. Test weight response to percentage of stand thinned (0, 25, 50, and 75%) at V5, V8, V11, and V14.

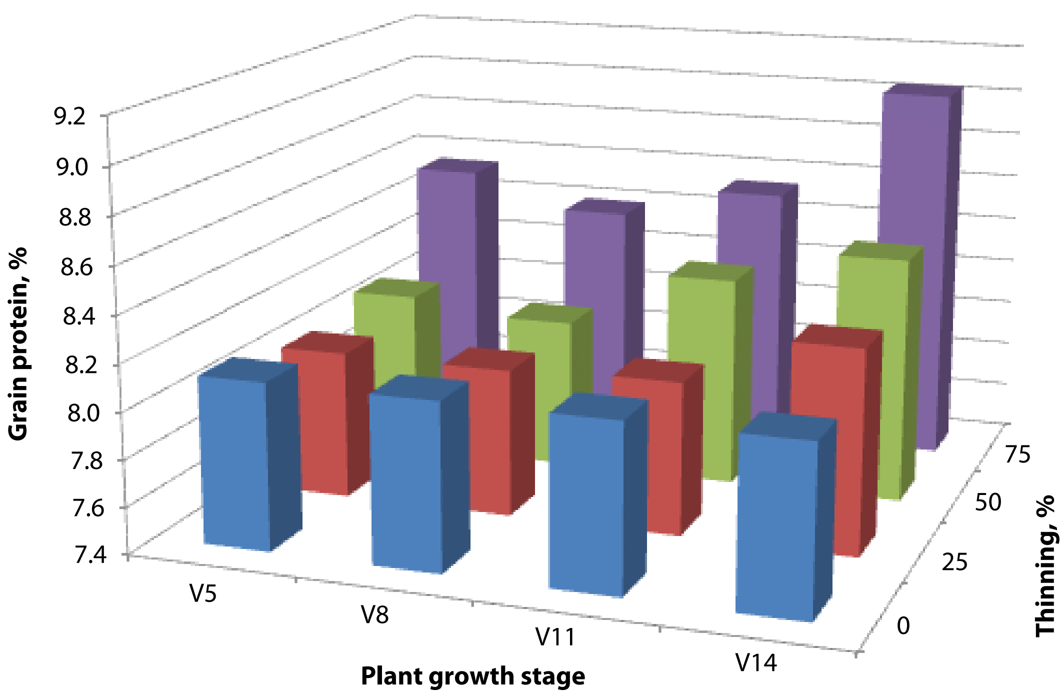

Figure 6. Protein response to percentage of stand thinned (0, 25, 50, and 75%) at V5, V8, V11, and V14.

Fallow Replacement Crop Effects on Wheat Yield

J. Holman, T. Dumler, T. Roberts, and S. Maxwell

Summary
Producers are interested in growing cover crops and reducing fallow. A study was initiated in 2007 to evaluate several crops grown in place of fallow in a no-till wheat-fallow system. Wheat yields following cover crops and annual forages were similar to yields following chemical fallow when the cover crop or annual forage crop was terminated from May 15 through June 1, with the exception of winter triticale. Winter triticale reduced wheat yield about 5 bu/a compared with fallow. Cover crops did not increase wheat yields. Wheat yielded less when grown continuously or after grain peas compared with fallow. The fallow period can be shortened without reducing wheat yield. Grain peas and annual forages provide an economic return, whereas cover crops are an expense to grow.

Introduction
Interest in growing cover crops and replacing fallow with a cash crop has necessitated research on wheat yields following a shortened fallow period. Fallow stores moisture, which helps stabilize crop yields and reduce the risk of crop failure; however, only 25 to 30% of the precipitation received during the fallow period of a no-till, wheat-fallow rotation is stored. The remaining 70 to 85% precipitation is lost primarily to evaporation. Moisture storage in fallow is more efficient earlier in the fallow period when the soil is dry and during the winter months when the evaporation rate is lower. Increasing cropping intensity without reducing winter wheat yield may be possible. This study evaluated the effects of replacing part of the fallow period with a cover, annual forage, or short-season grain crop on the following winter wheat yield.

Procedures
Fallow replacement crops (cover, annual forage, or short-season grain crops) have been grown during the fallow period of a no-till, wheat-fallow cropping system every year since 2007. Crops were grown as cover, harvested for forage (annual forage crop), or harvested for grain. Both winter and spring crop species were evaluated. Winter species included yellow sweet clover (*Melilotus officinalis* (L.) Lam.), hairy vetch (*Vicia villosa* Roth ssp.), lentil (*Lens culinaris* Medik.), Austrian winter forage pea (*Pisum sativum* L. ssp.), Austrian winter grain pea (*Pisum sativum* L. ssp.), and triticale (×*Triticosecale* Wittm.). Spring species included lentil (*Lens culinaris* Medik.), forage pea (*Pisum sativum* L. ssp.), grain pea (*Pisum sativum* L. ssp.), and triticale (×*Triticosecale* Wittm.) Crops were grown in monoculture and in two-species mixtures of each legume plus triticale. Crops grown for grain were grown only in monoculture. Winter lentil was grown in place of yellow sweet clover beginning in 2009. Crops grown in place of fallow were compared with a wheat-fallow and continuous wheat rotation for a total of 16 treatments (Table 1.) The study design was a split-split-plot randomized complete block design with 4 replications; crop phase was the main plot, crop species was the split-plot, and termination method (forage, grain, or cover) was the split-split-plot.

Winter crops were planted approximately October 1. Winter cover and forage crops were terminated or harvested approximately May 15. Spring crops were planted from the end of February through the middle of March. Spring cover and forage crops were terminated or harvested approximately June 1. Winter and spring grain peas were harvested with a small plot combine at grain maturity, which was approximately July 1.

Volumetric soil moisture content was measured at cover crop termination and winter wheat planting using a Giddings Soil Probe (Giddings Machine Company, Windsor, CO) to a 6-ft soil depth. Grain yield was adjusted to 13.5% moisture content, and test weight was measured using a grain analysis computer. Grain samples were analyzed for nitrogen content.

Results and Discussion

Winter wheat yield

In 2008, hail damaged the wheat crop 1 week before harvest; therefore, no statistical separation was made between treatments. Winter wheat yield following a fallow crop ranged from 21 to 26 bu/a, wheat yield following wheat was 13 bu/a, and wheat yield following fallow was 22 bu/a (Figure 1).

In 2009, grain pea and winter clover/triticale yielded 7 and 9 bu/a less than fallow (83 bu/a), and spring pea yielded 7 bu/a more than fallow (Figure 2). Continuous wheat yielded least of all (57 bu/a). All other treatments yielded similar to fallow.

In 2010, winter pea/triticale and winter triticale yielded 5 and 7 bu/a less than fallow (70 bu/a), and spring lentil/triticale and spring pea/triticale yielded 4 and 6 bu/a less than fallow (Figure 3). Continuous wheat yielded least of all (43 bu/a). All other treatments had yields similar to fallow. Wheat following cover crops yielded an average of 2.9 bu/a more than wheat following a hay crop.

In 2011, only 6.77 in. of precipitation occurred between October 1, 2010, and July 1, 2011. This drought resulted in low wheat yields and a greater impact of the preceding crop on wheat yield. Wheat grown following a winter cover or forage crop yielded less than fallow with the exception of winter lentil (22 bu/a), which yielded similar to fallow (23 bu/a) (Figure 4). Wheat yield following all other winter crops was reduced by 4 to 10 bu/a. Wheat yield following spring cover or forage crops was not affected as much as winter crops. Wheat yield following spring lentil, triticale, and lentil/triticale was similar to fallow and wheat following spring pea and pea/triticale was reduced 7 and 3 bu/a, respectively. Wheat following grain pea was reduced 11 bu/a, and wheat following wheat was reduced 16 bu/a compared with fallow.

Wheat harvested in 2012 will be the final wheat yield collected from a wheat-fallow rotation. Future research will evaluate replacing fallow in a wheat-grain sorghum-fallow rotation.

Averaged over years from 2009 through 2011 (2008 excluded due to hail damage), there was no difference whether the previous crop was grown as forage or cover ($P = 0.09$). Winter crops with triticale yielded 4 to 7 bu/a less than fallow, winter legume monocultures yielded similar to fallow, and all spring crops yielded similar to fallow (Figure 5). Grain peas yielded 7 bu/a less, and continuous wheat yielded 23 bu/a less than fallow.

Cover vs. annual forage

Across years (2009–2011), whether the previous crop was left as cover or harvested for forage did not affect wheat yield. In 2010, wheat following cover crops yielded an average of 2.9 bu/a more than wheat following a hay crop. This result indicates that the previous crop can be harvested for forage without negatively affecting wheat yield compared with growing a cover crop.

Conclusions

This study found the cropping system can be intensified by replacing part of the fallow period with annual forages or cover crops without reducing the following wheat yield. Winter triticale, continuous wheat, and grain peas reduced wheat yield, but all other treatments yielded similar to fallow. The reduced wheat yield following these treatments was likely due to less available soil moisture at wheat planting. Cover crops did not improve wheat yield. Forages provide an economic return, but cover crops are an expense to grow. A detailed economic analysis is needed; preliminary analysis suggests annual forages and grain peas increase returns whereas continuous winter wheat and cover crops reduce returns.

Table 1. Crop treatments

		Year produced				
Season	Crop	2007	2008	2009	2010	2011
Winter	Yellow sweet clover	x	x			
	Yellow sweet clover/winter triticale		x			
	Hairy vetch	x	x	x	x	x
	Hairy vetch/winter triticale		x	x	x	x
	Winter lentil			x	x	x
	Winter lentil/winter triticale			x	x	x
	Winter pea	x	x	x	x	x
	Winter pea/winter triticale		x	x	x	x
	Winter triticale	x	x	x	x	x
	Winter pea (grain)		x	x		x
Spring	Spring lentil	x	x	x	x	x
	Spring lentil/spring triticale		x	x	x	x
	Spring pea	x	x	x	x	x
	Spring pea/spring triticale		x	x	x	x
	Spring triticale		x	x	x	x
	Spring pea (grain)				x	x
Other	Chem-fallow	x	x	x	x	x
	Continuous winter wheat	x	x	x	x	x

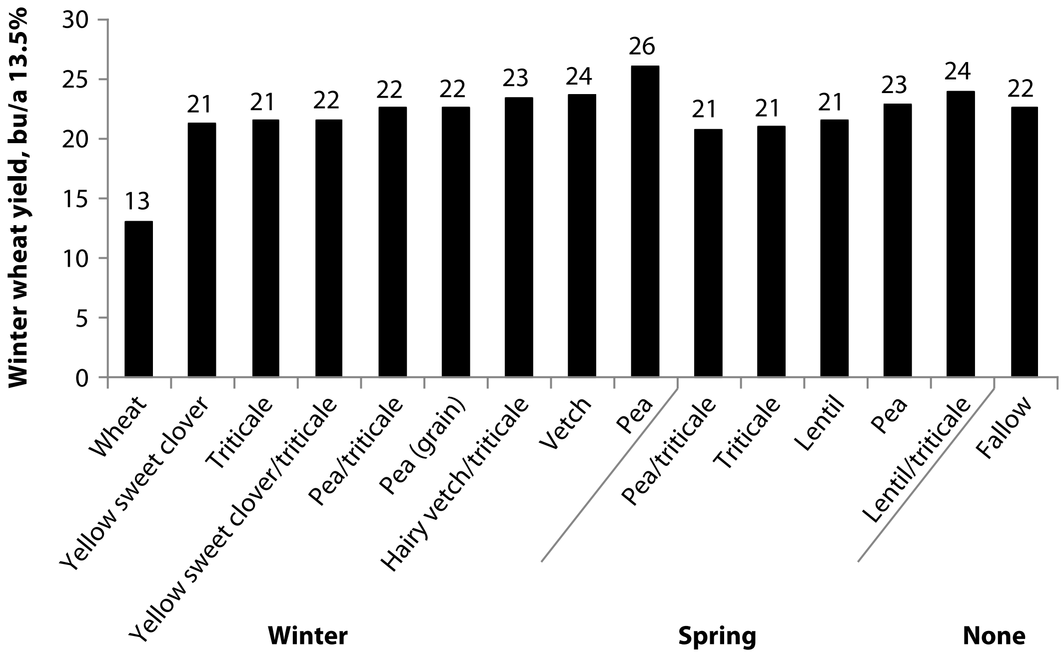

Figure 1. 2008 winter wheat yield following 2007 cover crops. No mean separation performed.

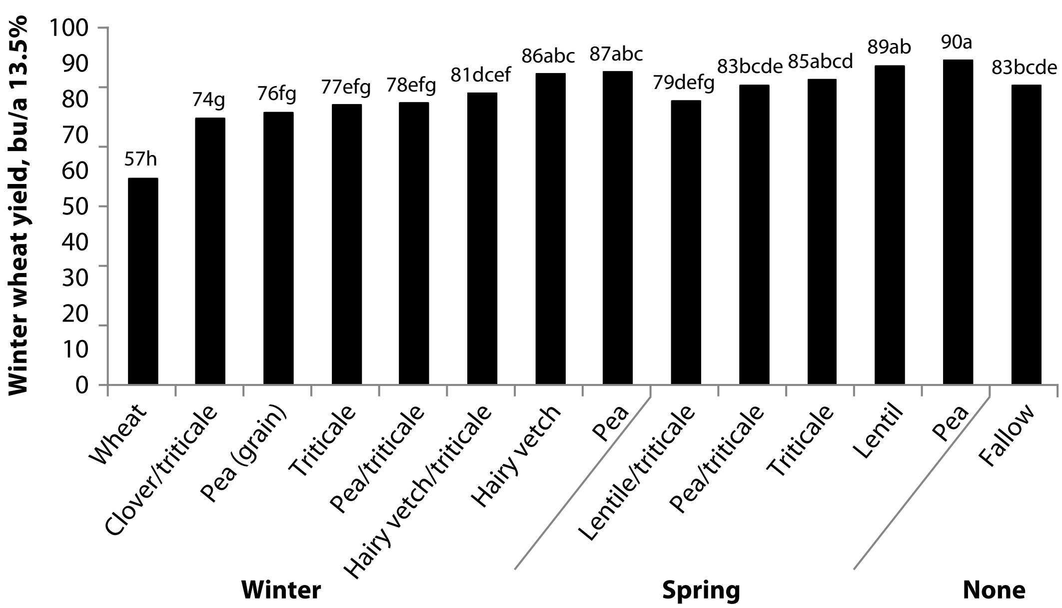

Figure 2. 2009 winter wheat yield following 2008 cover crops. Means or bars with the same lowercase letter are not statistically different at *P* = 0.05.

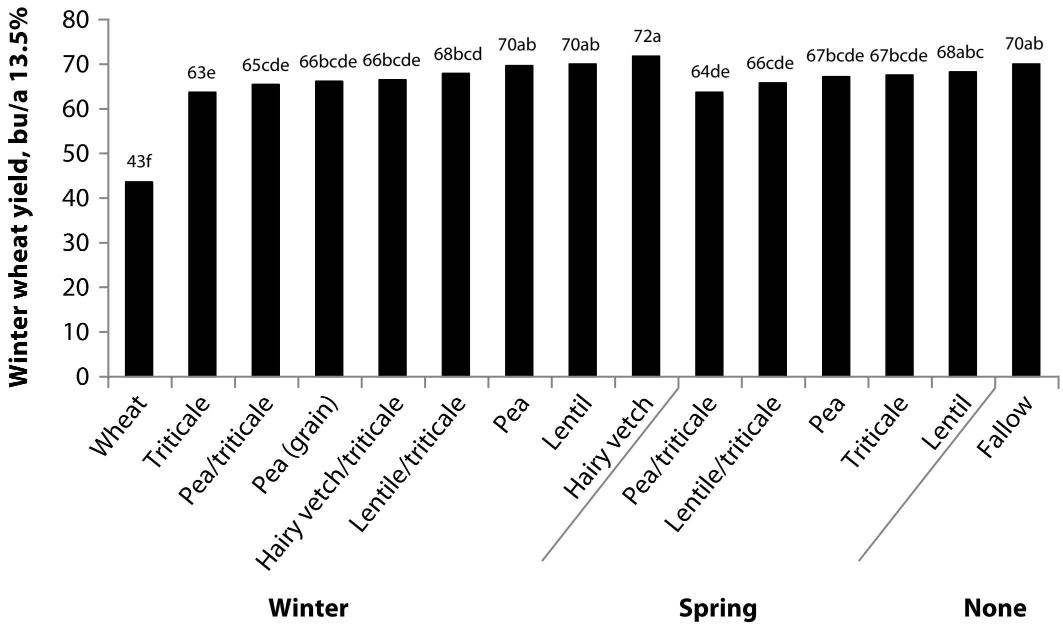

Figure 3. 2010 winter wheat yield following 2009 cover crops. Means or bars with the same lowercase letter are not statistically different at $P = 0.05$.

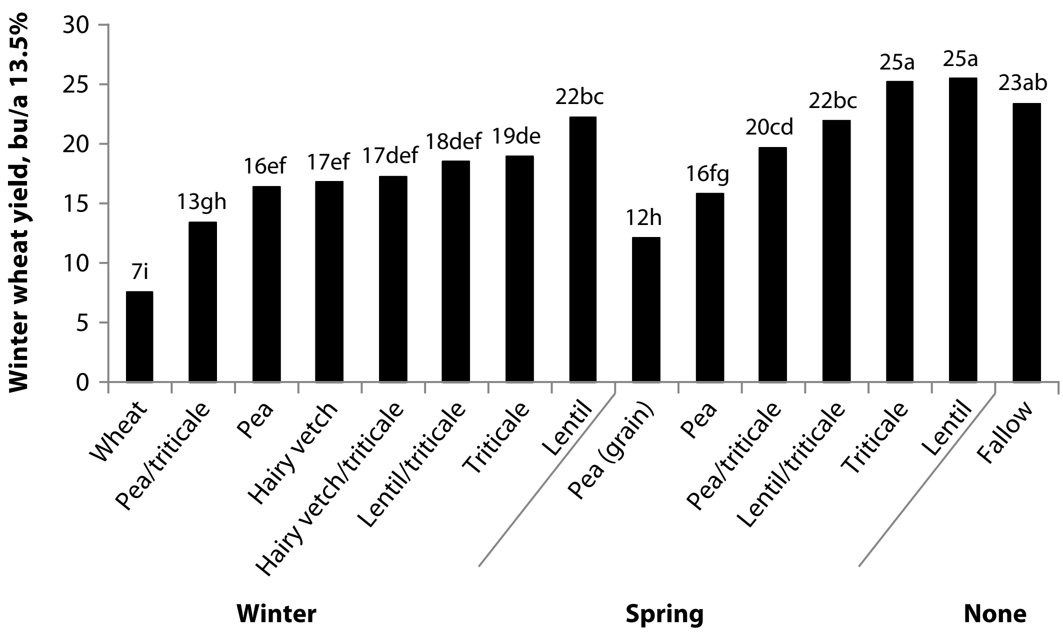

Figure 4. 2011 winter wheat yield following 2010 cover crops. Means or bars with the same lowercase letter are not statistically different at $P = 0.05$.

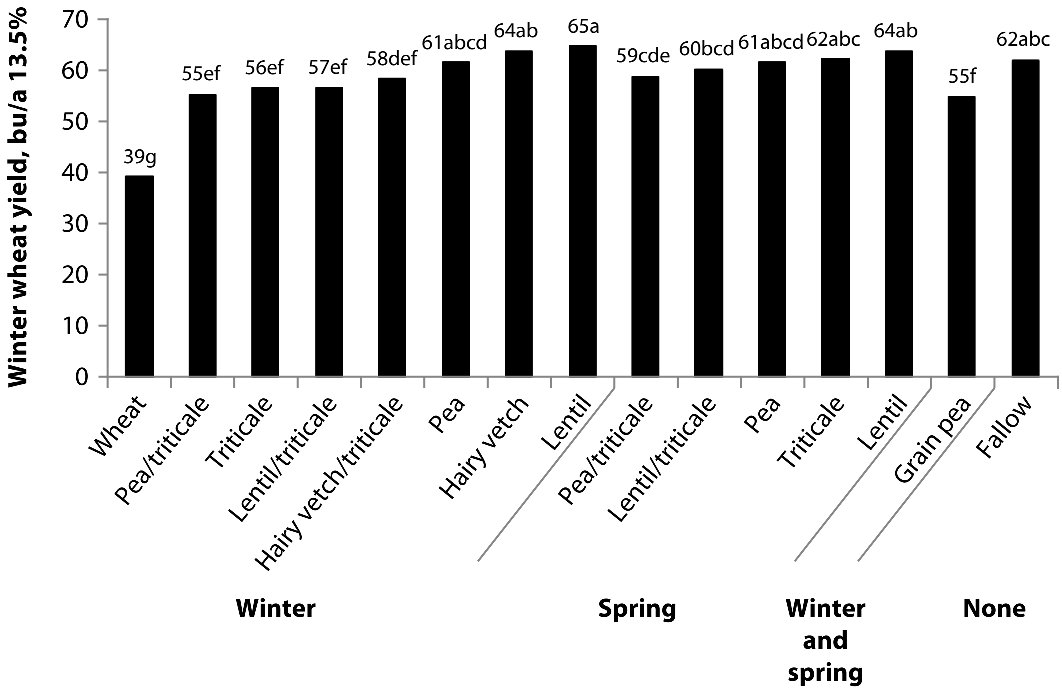

Figure 5. 2009–2011 winter wheat yield following cover crops. Means or bars with the same lowercase letter are not statistically different at *P* = 0.05.

Four-Year Rotations with Wheat and Grain Sorghum

A. Schlegel, T. Dumler, J. Holman, and C. Thompson

Summary

Research on four-year crop rotations with wheat and grain sorghum was initiated at the Southwest Research-Extension Center near Tribune, KS, in 1996. Rotations were wheat-wheat-sorghum-fallow (WWSF), wheat-sorghum-sorghum-fallow (WSSF), and continuous wheat (WW). Soil water at wheat planting following sorghum averaged about 9 in., which is about 3 in. more than the second wheat crop in a WWSF rotation. Soil water at sorghum planting was approximately 1.5 in. less for the second sorghum crop, compared with sorghum following wheat. Grain yield of recrop wheat averaged about 80% of the yield of wheat following sorghum. Grain yield of continuous wheat averaged about 65% of the yield of wheat grown in a four-year rotation following sorghum. Wheat yields were similar following one or two sorghum crops. Similarly, average sorghum yields were the same following one or two wheat crops. Yield of the second sorghum crop in a WSSF rotation averaged 65% of the yield of the first sorghum crop.

Introduction

In recent years, cropping intensity has increased in dryland systems in western Kansas. The traditional wheat-fallow system is being replaced by wheat-summer crop-fallow rotations. With concurrent increases in no-till, is more intensive cropping feasible? Objectives of this research were to quantify soil water storage, crop water use, and crop productivity of four-year and continuous cropping systems.

Procedures

Research on four-year crop rotations with wheat and grain sorghum was initiated at the Tribune Unit of the Southwest Research-Extension Center in 1996. Rotations were WWSF, WSSF, and WW. No-till was used for all rotations. Available water was measured in the soil profile (0 to 8 ft) at planting and harvest of each crop. The center of each plot was machine harvested after physiological maturity, and yields were adjusted to 12.5% moisture.

Results and Discussion

Soil water

The amount of available water in the soil profile (0 to 6 ft) at wheat planting varied greatly from year to year (Figure 1). Soil water was similar following fallow after either one or two sorghum crops, and averaged about 9 in. across the 15-year study period. Water at planting of the second wheat crop in a WWSF rotation generally was less than that at planting of the first wheat crop, except in 1997 and 2003. Soil water for the second wheat crop averaged more than 3 in. (or about 40%) less than that for the first wheat crop in the rotation. Continuous wheat averaged about 0.7 in. less water at planting than the second wheat crop in a WWSF rotation.

Similar to wheat, the amount of available water in the soil profile at sorghum planting varied greatly from year to year (Figure 2.) Soil water was similar following fallow after either one or two wheat crops and averaged about 8.25 in. over 16 years. Water at planting of the second sorghum crop in a WSSF rotation was generally less than that at planting of the first sorghum crop. Averaged across the entire study period, the first sorghum crop had about 1.5 in. more available water at planting than the second crop.

Grain yields

In 2011, wheat yields were below average because of a dry fall and winter (Table 1). Averaged across 15 years, recrop wheat (the second wheat crop in a WWSF rotation) yielded about 80% of the yield of first-year wheat in WWSF. Before 2003, recrop wheat yielded about 70% of the yield of first-year wheat. In 2003 and 2009, however, recrop wheat yields were much greater than the yield in all other rotations. For 2003 recrop wheat, this is possibly a result of failure of the first-year wheat in 2002, which resulted in a period from 2000 sorghum harvest to 2003 wheat planting without a harvested crop; however, this was not the case for the 2009 recrop wheat. Generally, little difference has occurred in wheat yields following one or two sorghum crops. In most years, continuous wheat yields have been similar to recrop wheat yields, but in several years (2003, 2007, and 2009), recrop wheat yields were considerably greater than continuous wheat yields.

Sorghum yields in 2011 were greater than average for sorghum following wheat, but average for sorghum following sorghum (Table 2). Sorghum yields were similar following one or two wheat crops, which is consistent with the long-term average. The second sorghum crop typically averages about 65% of the yield of the first sorghum crop, but in 2010, recrop sorghum yields were less than 50% of the yield of the first sorghum crop.

Table 1. Wheat response to rotation, Tribune, 1997–2011

	Wheat yield															
Rotation[1]	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Mean
	bu/a															
Wssf	57	70	74	46	22	0	29	6	45	28	75	40	37	63	25	41
Wwsf	55	64	80	35	29	0	27	6	40	26	61	40	39	60	22	39
wWsf	48	63	41	18	27	0	66	1	41	7	63	5	50	29	25	32
WW	43	60	43	18	34	0	30	1	44	2	41	6	24	23	17	26
LSD (0.05)	8	12	14	10	14	—	14	2	10	8	14	5	15	9	8	2

[1] W, wheat; S, sorghum; F, fallow; capital letters denote current year's crop.

Table 2. Grain sorghum response to rotation, Tribune, 1996–2011

	Grain sorghum yield																
Rotation[1]	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Mean
	bu/a																
wSsf	58	88	117	99	63	68	0	60	91	81	55	101	50	89	98	119	77
wsSf	35	45	100	74	23	66	0	41	79	69	13	86	30	44	52	47	50
wwSf	54	80	109	90	67	73	0	76	82	85	71	101	57	103	105	105	79
LSD (0.05)	24	13	12	11	16	18	—	18	17	20	15	9	12	53	24	34	4

[1] W, wheat; S, sorghum; F, fallow; capital letters denote current year's crop.

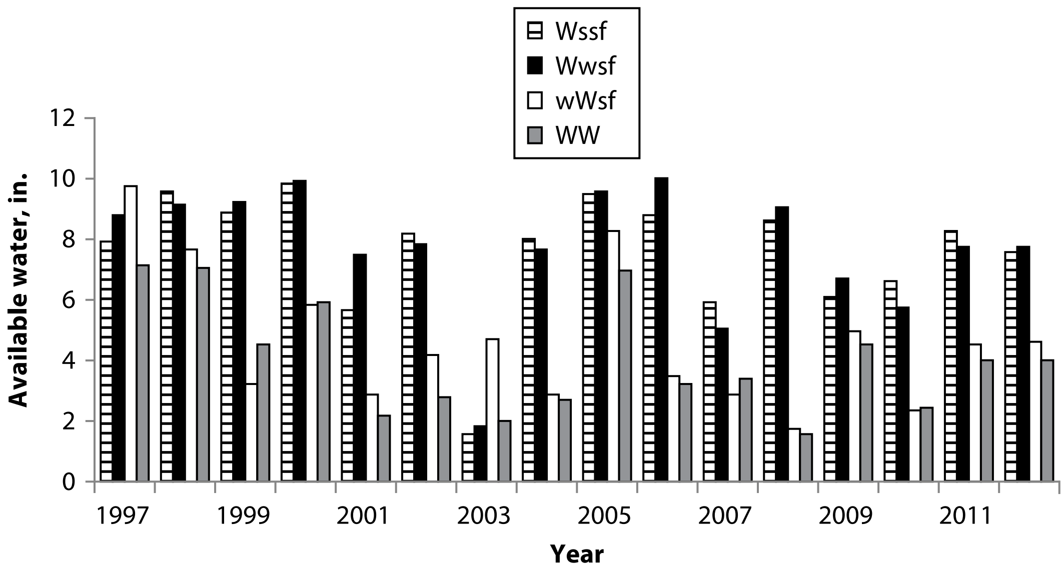

Figure 1. Available soil water at planting of wheat in several rotations, Tribune, 1997–2011.
Capital letter denotes current crop in rotation (W, wheat; S, sorghum; F, fallow). The last set of bars (Mean) is the average across years.

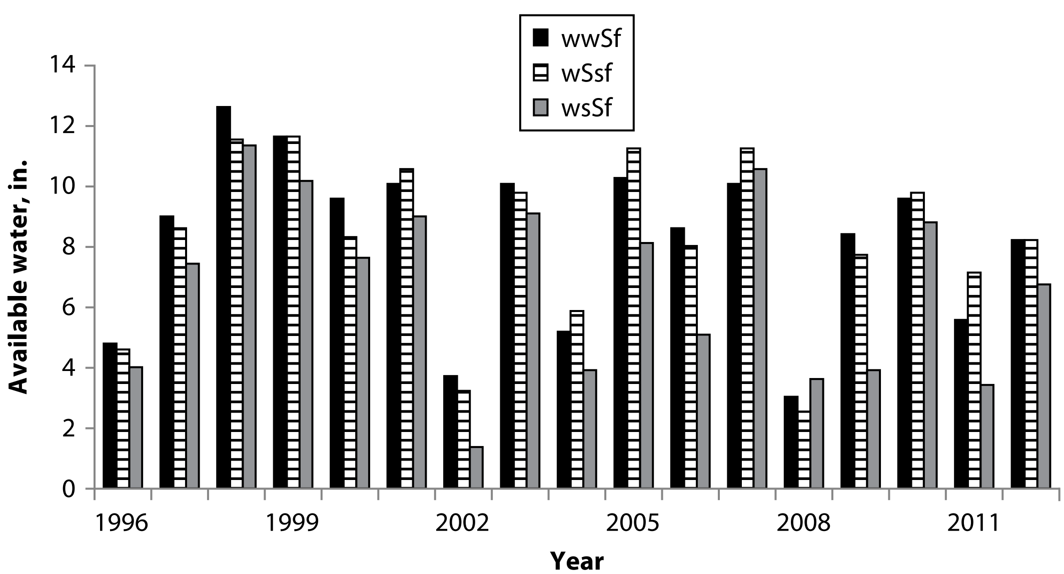

Figure 2. Available soil water at planting of sorghum in several rotations, Tribune, 1996–2011.
Capital letter denotes current crop in rotation (W, wheat; S, sorghum; F, fallow). The last set of bars (Mean) is the average across years.

Nitrogen and Phosphorus Fertilization of Irrigated Corn

A. Schlegel

Summary
Long-term research shows that phosphorus (P) and nitrogen (N) fertilizer must be applied to optimize production of irrigated corn in western Kansas. In 2011, N applied alone increased yields 87 bu/a, whereas P applied alone increased yields 13–19 bu/a. N and P applied together increased yields up to 139 bu/a. This is similar to the past 10 years, where N and P fertilization increased corn yields up to 130 bu/a. Application of 120 lb/a N (with P) was sufficient to produce about 95% of maximum yield in 2011, which was similar to the 10-year average. Application of 80 instead of 40 lb P_2O_5/a increased average yields of only 2 bu/a in 2011. Soil organic matter was increased by N and P fertilization. Soil pH was decreased by increased N rates and not affected by P fertilization. Application of 40 lb P_2O_5/a was not sufficient to maintain soil test P levels.

Introduction
This study was initiated in 1961 to determine responses of continuous corn and grain sorghum grown under flood irrigation to N, P, and potassium (K) fertilization. The study is conducted on a Ulysses silt loam soil with an inherently high K content. No yield benefit to corn from K fertilization was observed in 30 years, and soil K levels remained high, so the K treatment was discontinued in 1992 and replaced with a higher P rate.

Procedures
This field study is conducted at the Tribune Unit of the Southwest Research-Extension Center. Fertilizer treatments initiated in 1961 are N rates of 0, 40, 80, 120, 160, and 200 lb/a without P and K; with 40 lb/a P_2O_5 and zero K; and with 40 lb/a P_2O_5 and 40 lb/a K_2O. The treatments were changed in 1992, when the K variable was replaced by a higher rate of P (80 lb/a P_2O_5). All fertilizers were broadcast by hand in the spring and incorporated before planting. The soil is a Ulysses silt loam. The corn hybrids [Pioneer 33R93 (2002), DeKalb C60-12 (2003), Pioneer 34N45 (2004 and 2005), Pioneer 34N50 (2006), Pioneer 33B54 (2007), Pioneer 34B99 (2008), DeKalb 61-69 (2009), Pioneer 1173H (2010), and Pioneer 1151XR (2011)] were planted at about 30,000 to 32,000 seeds/a in late April or early May. Hail damaged the 2002, 2005, and 2010 crops. The corn is irrigated to minimize water stress; sprinkler irrigation has been used since 2001. The center two rows of each plot are machine harvested after physiological maturity. Grain yields are adjusted to 15.5% moisture. Soil samples (0–6 in.) were taken following harvest in 2010. Soil test P was determined by two methods; Bray-1 because the historical analyses used this method, and Olsen because of the high pH in some treatments.

Results
Corn yields in 2011 were much greater than the 10-year average (Table 1). Nitrogen alone increased yields 87 bu/a, whereas P alone increased yields less than 20 bu/a;

however, N and P applied together increased corn yields up to 139 bu/a. Only 120 lb/a N with P was required to obtain 95% of maximum yield, which is similar to the 10-year average. Corn yields in 2011 (averaged across all N rates) were only 2 bu/a greater with 80 than with 40 lb/a P_2O_5, which is slightly less than the 10-year average of 5 bu/a.

Soil organic matter was increased by N and P fertilization of corn from 2.1% in the non-fertilized control to a maximum of 2.5% with 200 lb/a of N with P (Table 2). Soil test P averaged across N rates was higher with 40 lb/a P_2O_5 than without P (15 vs. 8 ppm Bray-1 P), but still slightly less than at the start of the study (17 ppm Bray-1 P in 1961). Application of 80 lb/a P_2O_5 since 1992 to corn resulted in a buildup of soil test P to 26 ppm by 2010. Soil test P, based on the Olsen test, showed similar trends to that using the Bray-1 P test. Long-term N applications decreased soil pH whereas P fertilization had no effect on soil pH.

Table 1. Effect of nitrogen and phosphorus fertilization on irrigated corn, Tribune, KS, 2002–2011

N	P_2O_5	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Mean
----------- lb/a -----------		------------------------------ bu/a ------------------------------										
0	0	39	79	67	49	42	49	36	85	20	92	56
0	40	43	95	97	60	68	50	57	110	21	111	71
0	80	44	93	98	51	72	51	52	106	28	105	70
40	0	47	107	92	63	56	77	62	108	23	114	75
40	40	69	147	154	101	129	112	105	148	67	195	123
40	80	76	150	148	100	123	116	104	159	61	194	123
80	0	53	122	118	75	79	107	78	123	34	136	92
80	40	81	188	209	141	162	163	129	179	85	212	155
80	80	84	186	205	147	171	167	139	181	90	220	159
120	0	50	122	103	66	68	106	65	117	28	119	84
120	40	78	194	228	162	176	194	136	202	90	222	168
120	80	85	200	234	170	202	213	151	215	105	225	180
160	0	50	127	136	83	84	132	84	139	49	157	104
160	40	80	190	231	170	180	220	150	210	95	229	176
160	80	85	197	240	172	200	227	146	223	95	226	181
200	0	67	141	162	109	115	159	99	155	65	179	125
200	40	79	197	234	169	181	224	152	207	97	218	176
200	80	95	201	239	191	204	232	157	236	104	231	189

continued

Table 1. Effect of nitrogen and phosphorus fertilization on irrigated corn, Tribune, KS, 2002–2011

N	P_2O_5	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Mean
----------- lb/a -----------		---------- bu/a ----------										
ANOVA ($P > F$)												
Nitrogen		0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Linear		0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Quadratic		0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Phosphorus		0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Linear		0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Quadratic		0.007	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
N × P		0.133	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Means												
Nitrogen, lb/a												
0		42	89	87	53	61	50	48	100	23	103	66
40		64	135	132	88	103	102	91	138	50	167	107
80		73	165	178	121	137	146	115	161	70	189	135
120		71	172	188	133	149	171	118	178	74	189	144
160		71	172	203	142	155	193	127	191	80	204	154
200		80	180	212	156	167	205	136	199	89	209	163
LSD (0.05)		8	9	11	10	15	11	9	12	9	13	8
P_2O_5, lb/a												
0		51	116	113	74	74	105	71	121	36	133	89
40		72	168	192	134	149	160	122	176	76	198	145
80		78	171	194	139	162	168	125	187	81	200	150
LSD (0.05)		6	6	8	7	11	8	6	9	7	9	6

Table 2. Selected soil properties (0–6 in.) after long-term (50 years) applications of nitrogen and phosphorus fertilizers to irrigated corn, Tribune, KS, 2010

N	P_2O_5	Soil OM	Bray 1 P	Olsen P	Soil pH
----------- lb/acre -----------		%	------------ ppm ------------		
0	0	2.1	7	4	7.8
	40	2.1	23	14	7.8
	80†	2.1	25	15	7.7
40	0	2.1	8	5	7.8
	40	2.4	15	9	7.7
	80	2.3	27	16	7.6
80	0	2.2	7	4	7.6
	40	2.3	10	6	7.6
	80	2.4	23	14	7.6
120	0	2.2	8	5	7.7
	40	2.4	12	7	7.6
	80	2.5	23	13	7.5
160	0	2.3	8	5	7.4
	40	2.4	14	7	7.2
	80	2.4	23	13	7.4
200	0	2.4	8	4	6.9
	40	2.5	15	8	7.2
	80	2.5	34	17	7.1

continued

Table 2. Selected soil properties (0–6 in.) after long-term (50 years) applications of nitrogen and phosphorus fertilizers to irrigated corn, Tribune, KS, 2010

N	P_2O_5	Soil OM	Bray 1 P	Olsen P	Soil pH
----------- lb/acre -----------		%	------------ ppm ------------		
ANOVA ($P > F$)					
Nitrogen		0.001	0.017	0.008	0.001
Linear		0.001	0.868	0.071	0.001
Quadratic		0.279	0.001	0.001	0.007
P_2O_5		0.001	0.001	0.001	0.786
Linear		0.001	0.001	0.001	0.591
Quadratic		0.078	0.136	0.070	0.664
N × P		0.338	0.044	0.035	0.485
Means					
Nitrogen					
0		2.1	19	11	7.8
40		2.3	17	10	7.7
80		2.3	13	8	7.6
120		2.3	14	8	7.6
160		2.4	15	8	7.3
200		2.5	19	10	7.1
LSD (0.05)		0.1	4	2	0.2
P_2O_5					
0		2.2	8	4	7.5
40		2.3	15	8	7.5
80		2.4	26	15	7.5
LSD (0.05)		0.1	3	1	0.1

† The 80 lb/a rate of P2O5 was applied starting in 1992; prior to then it was 40 lb/a.

Nitrogen and Phosphorus Fertilization of Irrigated Grain Sorghum

A. Schlegel

Summary
Long-term research shows that phosphorus (P) and nitrogen (N) fertilizer must be applied to optimize production of irrigated grain sorghum in western Kansas. In 2011, N applied alone increased yields about 50 bu/a, whereas N and P applied together increased yields up to 75 bu/a. Averaged across the past 10 years, N and P fertilization increased sorghum yields more than 60 bu/a. Application of 40 lb/a N (with P) was sufficient to produce about 80% of maximum yield in 2011, which was slightly less than the 10-year average. Application of potassium (K) has had no effect on sorghum yield throughout the study period. Soil organic matter was increased by N and P fertilization. Soil pH was decreased by increased N rates and not affected by P fertilization. Application of 40 lb P_2O_5/a was sufficient to maintain soil test P levels.

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

Procedures
This field study is conducted at the Tribune Unit of the Southwest Research-Extension Center. Fertilizer treatments initiated in 1961 are N rates of 0, 40, 80, 120, 160, and 200 lb/a N without P and K; with 40 lb/a P_2O_5 and zero K; and with 40 lb/a P_2O_5 and 40 lb/a K_2O. All fertilizers are broadcast by hand in the spring and incorporated before planting. Sorghum (Pioneer 8500/8505 from 1998–2007 and Pioneer 85G46 in 2008–2011) is planted in late May or early June. Irrigation is used to minimize water stress. Furrow irrigation was used through 2000, and sprinkler irrigation has been used since 2001. The center two rows of each plot are machine harvested after physiological maturity. Grain yields are adjusted to 12.5% moisture. Soil samples (0–6 in.) were taken following harvest in 2010. Soil test P was determined by two methods: Bray-1, because the historical analyses used this method, and Olsen, because of the high pH in some treatments.

Results
Grain sorghum yields in 2011 were greater than the 10-year average yields (Table 1). Nitrogen alone increased yields about 50 bu/a, and P alone increased yields less than 10 bu/a; however, N and P applied together increased yields up to 75 bu/a. Averaged across the past 10 years, N and P applied together increased yields more than 60 bu/a. In 2011, 40 lb/a N (with P) produced about 80% of maximum yields, which is slightly less than the 10-year average. Sorghum yields were not affected by K fertilization, which has been the case throughout the study period.

Soil organic matter was increased by N and P fertilization of grain sorghum from 2.1% in the unfertilized control up to 2.6% with N and P fertilization (Table 2). Soil test P was increased by P fertilization from an initial value of ~17 ppm up to >30 ppm. Without P fertilization, soil test P was reduced with N rates of 120 lb N/a or less, but at higher N rates, soil test P actually increased from 25 to 28 ppm. This increase in soil test P without P additions is surprising. We also noticed this trend with the Olsen test. Soil pH was reduced by N fertilization from 7.8 in the unfertilized control to 6.6 with 200 lb N/a, whereas P applications had no effect on soil pH.

Table 1. Effect of nitrogen, phosphorus, and potassium fertilizers on irrigated grain sorghum yields, Tribune, KS, 2002–2011

Fertilizer			Grain sorghum yield										
N	P_2O_5	K_2O	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Mean
---- lb/a ----			---- bu/a ----										
0	0	0	73	80	57	58	84	80	66	64	51	75	69
0	40	0	81	93	73	53	102	97	60	70	51	83	77
0	40	40	82	93	74	54	95	94	65	76	55	88	78
40	0	0	82	92	60	63	102	123	92	84	66	106	88
40	40	0	120	140	112	84	133	146	111	118	77	121	118
40	40	40	121	140	117	84	130	145	105	109	73	125	116
80	0	0	97	108	73	76	111	138	114	115	73	117	103
80	40	0	127	139	103	81	132	159	128	136	86	140	125
80	40	40	131	149	123	92	142	166	126	108	84	138	127
120	0	0	86	97	66	77	101	138	106	113	70	116	98
120	40	0	132	135	106	95	136	164	131	130	88	145	127
120	40	40	127	132	115	98	139	165	136	136	90	147	130
160	0	0	116	122	86	77	123	146	105	108	74	124	109
160	40	0	137	146	120	106	145	170	138	128	92	152	135
160	40	40	133	135	113	91	128	167	133	140	88	151	129
200	0	0	113	131	100	86	134	154	120	110	78	128	117
200	40	0	136	132	115	108	143	168	137	139	84	141	131
200	40	40	143	145	123	101	143	170	135	129	87	152	134

continued

Table 1. Effect of nitrogen, phosphorus, and potassium fertilizers on irrigated grain sorghum yields, Tribune, KS, 2002–2011

Fertilizer			Grain sorghum yield										
N	P_2O_5	K_2O	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Mean
-------------- lb/a --------------			bu/a										
ANOVA ($P > F$)													
Nitrogen			0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Linear			0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Quadratic			0.001	0.001	0.018	0.005	0.004	0.001	0.001	0.001	0.001	0.001	0.001
P-K			0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Zero P vs. P			0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
P vs. P-K			0.920	0.694	0.121	0.803	0.578	0.992	0.745	0.324	0.892	0.278	0.839
N × P-K			0.030	0.008	0.022	0.195	0.210	0.965	0.005	0.053	0.229	0.542	0.013
Means													
Nitrogen, lb/a													
0			79	88	68	55	93	91	64	70	52	82	75
40			108	124	96	77	121	138	103	104	72	117	107
80			119	132	100	83	128	155	123	120	81	132	119
120			115	121	96	90	125	156	124	126	82	136	118
160			129	134	107	92	132	161	125	125	83	142	124
200			131	136	113	98	140	164	131	126	84	141	127
LSD (0.05)			9	10	11	10	11	9	7	11	5	8	5
P_2O_5-K_2O, lb/a													
0			94	105	74	73	109	130	101	99	68	111	97
40-0			122	131	105	88	132	151	117	120	80	130	119
40-40			123	132	111	87	130	151	117	116	79	133	119
LSD (0.05)			6	7	7	7	7	6	5	7	4	6	4

Table 2. Selected soil properties (0–6 in.) after long-term (50 years) applications of N and P fertilizers to irrigated grain sorghum, Tribune, KS, 2010

N	P_2O_5	OM	Bray 1 P	Olsen P	pH
---- lb/a ----		%	---- ppm ----		
0	0	2.1	11	6	7.8
	40	2.3	36	21	7.7
40	0	2.2	13	7	7.7
	40	2.4	43	23	7.5
80	0	2.3	14	7	7.1
	40	2.4	35	19	7.4
120	0	2.4	9	5	7.2
	40	2.5	19	10	7.2
160	0	2.5	28	14	7.1
	40	2.6	37	21	6.6
200	0	2.6	25	12	6.6
	40	2.6	35	17	6.5
ANOVA ($P > F$)					
Nitrogen		0.001	0.109	0.113	0.001
Linear		0.001	0.361	0.658	0.001
Quadratic		0.821	0.219	0.226	0.435
Phosphorus		0.001	0.001	0.001	0.128
N × P		0.485	0.444	0.392	0.035
Means					
Nitrogen					
0 lb/a		2.2	24	13	7.8
40		2.3	28	15	7.6
80		2.4	24	13	7.2
120		2.4	14	7	7.2
160		2.5	32	17	6.9
200		2.6	30	15	6.6
LSD (0.05)		0.1	13	7	0.2
P_2O_5					
0 lb/a		2.3	16	8	7.2
40		2.5	34	18	7.2
LSD (0.05)		0.1	8	4	0.1

Phosphorus Fertilization of Irrigated Corn

Alan Schlegel

Summary
Phosphorus increased yields more than 60 bu/a in 2011, which was similar to the long-term average. Application of 80 lb/a P_2O_5 produced maximum yield in 2011, and 97% of maximum yield was obtained with 40 lb/a P_2O_5. Across the eight years of the study, 40 lb/a P_2O_5 produced 93% of maximum yield. Soil test P was maintained by a P fertilizer rate of 40 lb/a P_2O_5 and increased with higher P rates.

Introduction
This study was initiated in 2004 to determine responses of continuous corn grown under sprinkler irrigation to phosphorus (P) fertilization. This study complements a long-term nitrogen (N) and P study by having a wider range of P rates. The study is conducted on a Ulysses silt loam soil with an inherently high potassium (K) content.

Procedures
This field study is conducted at the Tribune Unit of the Southwest Research-Extension Center. Fertilizer treatments are 0, 20, 40, 80, and 120 lb/a of P_2O_5. All P fertilizers were broadcast by hand in the spring and incorporated before planting. Treatments were applied to the same plots each year. Nitrogen was uniformly applied to all plots at 200 lb N/a. The corn hybrids [Pioneer 34N45 (2004 and 2005), Pioneer 34N50 (2006), Pioneer 33B54 (2007), Pioneer 34B99 (2008), DeKalb 61-69 (2009), Pioneer 1173H (2010), and Pioneer 1151XR (2011)] were planted at about 30,000 to 32,000 seeds/a in late April or early May. Hail damaged the 2005, 2008, and 2010 crops. The corn is irrigated to minimize water stress. The center two rows of each plot are machine harvested after physiological maturity. Grain yields are adjusted to 15.5% moisture. Soil samples (0–6 in.) were taken following harvest in most years and analyzed for Mehlich-3 P.

Results
Corn yields in 2011 were much greater than the long-term average (Table 1). Phosphorus increased yields more than 60 bu/a, which was similar to the long-term average. Application of 80 lb/a P_2O_5 produced maximum yield in 2011, and 97% of maximum yield was obtained with 40 lb/a P_2O_5. Across the eight years of the study, 40 lb/a P_2O_5 produced 93% of maximum yield.

Soil test P was maintained by a P fertilizer rate of 40 lb/a P_2O_5 and increased with higher P rates (Table 2). Without P fertilization, soil test P declined from 15 ppm in 2005 to 10 ppm in 2011.

Table 1. Grain yield of irrigated corn as affected by phosphorus (P) rate, Tribune, KS, 2004–2011

P_2O_5 rate	2004	2005[†]	2006	2007	2008	2009	2010	2011	Average
lb/a					bu/a				
0	180	118	122	150	98	161	29	184	130
20	191	145	163	200	140	189	49	206	160
40	206	154	187	211	136	211	57	239	175
80	222	163	204	240	144	226	62	246	188
120	222	170	208	235	137	221	64	246	188
LSD (0.05)	15	14	12	20	17	19	12	23	6
ANOVA ($P > F$)									
Year									0.001
P rate	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Year × P rate									0.001

[†] Hail on August 19, 2005; August 14, 2008; and July 23, 2010.

Table 2. Soil test phosphorus (P) (Mehlich-3) in the surface soil (0–6 in.) following annual P applications to irrigated corn, Tribune, KS, 2005–2011

P_2O_5 rate	2005	2006	2008	2010	2011
lb/a			ppm		
0	15	12	13	11	10
20	14	15	16	15	11
40	15	15	19	21	16
80	21	22	28	39	34
120	25	37	55	76	52
LSD (0.05)	6	5	6	22	6
ANOVA ($P > F$)					
P rate	0.007	0.001	0.001	0.001	0.001

Phosphorus Fertilization of Irrigated Grain Sorghum

Alan Schlegel

Summary
Phosphorus (P) increased sorghum yields more than 30 bu/a in 2011, which was greater than the long-term average. Application of 80 lb/a P_2O_5 produced maximum yield in 2011, and 90% of maximum yield was obtained with 40 lb/a P_2O_5. Across the eight years of the study, 20 lb/a P_2O_5 produced ~95% of maximum yield. Soil test P remained relatively constant even without the application of P fertilizer and was considerably increased with P rates of 40 lb/a P_2O_5 or greater.

Introduction
This study was initiated in 2004 to determine responses of continuous grain sorghum grown under sprinkler irrigation to P fertilization. This study complements a long-term nitrogen (N) and P study by having a wider range of P rates. The study is conducted on a Ulysses silt loam soil with an inherently high potassium (K) content.

Procedures
This field study is conducted at the Tribune Unit of the Southwest Research-Extension Center. Fertilizer treatments are 0, 20, 40, 80, and 120 lb/a of P_2O_5. All P fertilizers were broadcast by hand in the spring and incorporated before planting. Treatments were applied to the same plots each year. Nitrogen was uniformly applied to all plots at 200 lb N/a. Sorghum (Pioneer 8500/8505 from 2004–2007 and Pioneer 85G46 in 2008–2011) is planted in late May or early June. Hail damaged the 2005, 2008, and 2010 crops. The grain sorghum is irrigated to minimize water stress. The center two rows of each plot are machine-harvested after physiological maturity. Grain yields are adjusted to 12.5% moisture. Soil samples (0–6 in.) were taken following harvest in most years and analyzed for Mehlich-3 P.

Results
Grain sorghum yields in 2011 were greater than the long-term average (Table 1). Phosphorus increased yields more than 30 bu/a, which was greater than the long-term average. Application of 80 lb/a P_2O_5 produced maximum yield in 2011, and 90% of maximum yield was obtained with 40 lb/a P_2O_5. Across the eight years of the study, 20 lb/a P_2O_5 produced ~95% of maximum yield.

Soil test P remained relatively constant across years even without the application of P fertilizer (Table 2). Considerable increase in soil test P was observed with P rates of 40 lb/a P_2O_5 or greater.

Table 1. Grain yield of irrigated grain sorghum as affected by phosphorus (P) rate, Tribune, KS, 2004–2011

P_2O_5 rate	2004	2005†	2006	2007	2008	2009	2010	2011	Average
lb/a					bu/a				
0	88	76	124	151	114	120	64	119	107
20	103	99	135	163	135	139	67	138	122
40	104	90	134	172	122	140	72	141	122
80	113	99	142	175	125	144	72	155	128
120	116	96	137	184	130	138	78	152	129
LSD (0.05)	14	16	13	10	23	13	8	16	5
ANOVA ($P > F$)									
Year									0.001
P rate	0.009	0.053	0.110	0.001	0.370	0.012	0.014	0.003	0.001
Year × P rate									0.623

† Hail on August 19, 2005; August 14, 2008; and July 23, 2010.

Table 2. Soil test P (Mehlich-3) in the surface soil (0–6 in.) following annual P applications to irrigated grain sorghum, Tribune, KS, 2005–2011

P_2O_5 rate	2005	2006	2008	2009	2010	2011
lb/a			ppm			
0	12	12	9	10	13	16
20	12	15	16	15	14	16
40	14	16	22	26	30	47
80	19	27	52	52	47	51
120	24	35	95	87	83	90
LSD (0.05)	3	7	19	14	9	18
ANOVA ($P > F$)						
P rate	0.001	0.001	0.001	0.001	0.001	0.001

Weed Control with 9 Tank Mixes of Saflufenacil, Dimethenamid-P, Atrazine, and Pyroxasulfone Herbicide in Irrigated Glyphosate-Resistant Corn

R. Currie and J. Jester

Summary

Pyroxasulfone (experimental number KIH 485) is projected to be labeled for sale by June of 2012. Although its strengths are grassy weed control, pyroxasulfone tank mixes seem to provide Palmer amaranth control as well. The degree and duration of control appears to be contingent on the application rate.

Introduction

As many weed species develop resistance to common herbicide modes of action, labeling new compound novel modes of action becomes even more important. Pyroxasulfone has been exhaustively researched at the Southwest Research-Extension Center in Garden City, KS, for over a decade with the experimental code name KIH 485. Pyroxasulfone is finally expected to be labeled by June of 2012. Saflufenacil was labeled at the beginning of the 2011 growing season. The objective of this study was to measure the effects of various tank mixes of saflufenacil and pyroxasulfone with other known herbicide standards for Palmer amaranth control.

Procedures

Palmer amaranth control was evaluated in the glyphosate-resistant corn variety DKC 64-83 at the Kansas State Research Center located near Garden City, KS. Corn was planted on May 5, 2011, with preemergence herbicides applied within 24 hours of planting. Preemergent application conditions of air temperature, soil temperature, wind speed, relative humidity, and soil moisture were 62°F, 55°F, 5 mph, 83%, and adequate, respectively. Soil was Ulysses silt loam, and organic matter, soil pH, and cation exchange capacity (CEC) were 1.4%, 8, and 18.4. All herbicide treatments were applied with a tractor-mounted CO_2 pressurized windshield sprayer calibrated to deliver 20 gpa at 30 psi at 4.1 mph. All plots were treated with 32 oz/a of glyphosate to remove any emerged plants from the plots. Adjuvant and ammonium sulfate (AMS) were added per manufacturer recommendations. The first post-herbicide application was made on June 13, 2011, when corn was 14 in. tall. Air temperature, soil temperature, wind speed, relative humidity, and soil moisture were 78°F, 68°F, 7 mph, 58%, and adequate. The second post-application herbicide application was made on June 15, 2011, with air temperature, soil temperature, wind speed, relative humidity, and soil moisture at 72°F, 70°F, 5 mph, 26%, and adequate. Trial was established as a randomized complete block design with four replications, and plots were 10 ft by 30 ft. Crop injury and percentage weed control were visually rated.

Results and Discussion

No crop injury was observed. Palmer amaranth was controlled 95% or better with treatments 3, 6, and 7 at 49 days after planting (DAP) compared with 0 to 13% in untreated checks. By 113 DAP, only treatments 6 and 7 had greater than 97% control compared with 0% control in the untreated check (Table 1). Due to extraordinary drought conditions, corn yield varied widely based on when maximal drought stress occurred. Although the planting date of this trial produced the highest yields of any near this test site, the highest yields still ranged from 40 to 50 bu/a. The primary value of pyroxasulfone is as a control agent for grassy weeds; it also appears to have activity on Palmer amaranth, a small-seed broadleaf weed. Previous work has shown that this result occurs two out of three years and is dependent on herbicide rate and rainfall. This pattern of control is consistent with other grass herbicides. In this study, saflufenacil and pyroxasulfone tank mixes appear to provide Palmer amaranth control. The degree and duration of control appears to be contingent on the rate used. The price of pyroxasulfone has yet to be determined and will not be static over the next several years, but after a few years, market forces will establish its value. When the price is known, the economical rate to use the compound will be more easily determined.

Table 1. Palmer amaranth control 49 and 113 days after planting (DAP)

				% control	
Treatment	Active ingredient	Rate	Timing[1]	49 DAP	113 DAP
1	Untreated check		A	0	0
2	Dimethenamid-P + saflufenacil	15 fl oz/a	A	81.3	80
	Atrazine	1 qt/a	A		
3	Dimethenamid-P + saflufenacil	15 fl oz/a	A	95	90
	Glyphosate	22 fl oz/a	B		
	Dicamba	4 oz wt/a	B		
4	Dimethenamid-P + saflufenacil	13 fl oz/a	A	75	45
	Pyroxasulfone	2 oz wt/a	A		
5	Saflufenacil	2.5 fl oz/a	A	80	88
	Pyroxasulfone	2 fl oz/a	A		
6	Dimethenamid-P + saflufenacil	13 fl oz/a	A	99	99
	Pyroxasulfone	2 oz wt/a	B		
	Dicamba	3 oz wt/a	B		
	Glyphosate	22 fl oz/a	B		
7	Pyroxasulfone	2 oz wt/a	A	100	97
	Saflufenacil	1 fl oz/a	A		
	Pyroxasulfone	1 oz wt/a	B		
	Dicamba	3 oz wt/a	B		
	Glyphosate	22 fl oz/a	B		
8	Acetochlor, flumetsulam, clopyralid, dichlormid	1.75 pt/a	A	85	88
	Glyphosate	24 oz/a	C		
9	Acetochlor, flumetsulam, clopyralid, dichlormid	1.75 pt/a	B	88	86
	Glyphosate	24 oz/a	B		
	LSD (0.10)			23	26

[1] A is preemergence, B is 39 DAP, C is 42 DAP.

Weed Control with 15 Herbicide Tank Mixes of Isoxaflutole, Tembotrione Thiencarbazone-methyl, Atrazine, Trileton, S-metolachlor, and Mesotrione Herbicide in Irrigated Glyphosate-Resistant Corn

R. Currie and J. Jester

Summary

No preemergence treatment alone produced sufficient control 49 days after planting (DAP). With only one exception, all preemergence treatments followed by a postemergence application provided greater than 95% control 106 DAP. All of these treatments contained more than one herbicide mode of action.

Introduction

With the advent of weeds with herbicide resistance to multiple modes of herbicide activity, tank mixes have become increasingly complex. Furthermore, a single preemergence application of even a complex mix of modes of herbicide action is seldom sufficient for commercial levels of control. The objective of this study was to test several preemergence and postemergence tank-mix combinations.

Procedures

Palmer amaranth control was evaluated in the glyphosate-resistant corn variety DKC 64-83 at the Kansas State Research Center located near Garden City, KS. Corn was planted on May 15, 2011, with preemergence herbicides applied within 24 hours of planting. Preemergent application conditions of air temperature, soil temperature, wind speed, relative humidity, and soil moisture were 47°F, 65°F, 10 mph, 74%, and adequate, respectively. Soil was Ulysses silt loam, organic matter, soil pH, and cation exchange capacity (CEC) were 1.4%, 8, and 18.4. All herbicide treatments were applied with a tractor-mounted CO_2 pressurized windshield sprayer calibrated to deliver 20 gpa at 30 psi and 4.1 mph. All treatments included 32 oz/a of glyphosate to remove any emerged plants from the plots. Adjuvant and ammonium sulfate (AMS) were added per manufacturer recommendations. Post-herbicide application was made on June 15, 2011, when corn was 14 in. tall. Post-application conditions of air temperature, soil temperature, wind speed, relative humidity, and soil moisture were 83°F, 76°F, 4 mph, 26%, and adequate, respectively. The trial was established as a randomized complete block design with four replications. Plots were 10 ft by 30 ft. Crop injury and percentage weed control were visually rated.

Results and Discussion

No crop injury was observed. Palmer amaranth control 49 DAP was greater than 95% in all but treatments 9, 10, and 14 compared with 0% in untreated checks (Table 1). With the exception of treatments 8, 9, and 10, all treatments provided greater than 93% control by 106 DAP. Although yield data was collected due to drought, yield was too poor for the data to be useful. No preemergence treatment alone produced sufficient control 49 days after planting (DAP). With only one exception, all preemergence treatments followed by a postemergence application provided greater than 95% control 106 DAP. All of these treatments contained more than one herbicide mode of action.

Table 1. Palmer amaranth control 49 and 106 days after planting (DAP)

				Palmer amaranth control, %	
Treatment	Active ingredient	Rate	Timing[1]	49 DAP	106 DAP
1	Untreated check			0	0
2	Isoxaflutole + thiencarbazone-methyl	3 oz/a	A	95	95
	Atrazine	1 qt/a	A		
	Trileton/isoxazoline	3 oz/a	B		
	Atrazine	1 pt/a	B		
3	Isoxaflutole + thiencarbazone-methyl	3 oz/a	A	98	98
	Atrazine	1 qt/a	A		
	Glyphosate	22 oz/a	B		
4	Isoxaflutole	3 oz/a	A	95	99
	Atrazine	1 qt/a	A		
	Trileton/isoxazoline	3 oz/a	B		
	Atrazine	1 pt/a	B		
5	Isoxaflutole	3 oz/a	A	99	99
	Atrazine	1 qt/a	A		
	Trileton/isoxazoline	3 oz/a	B		
	Glyphosate	22 oz/a	B		
6	Isoxaflutole	3 oz/a	A	98	99
	Atrazine	1 qt/a	A		
	Tembotrine + thiencarbazone-methyl	3 oz/a	B		
	Glyphosate	22 oz/a	B		
7	S-Metolachlor + Atrazine + mesotrione	1.75 qt/a	A	98	98
	Mesatrione + metolachlor + glyphosate	3.6 pt/a	B		
8	Dimethenamid-P + saflufenacil	13 oz/a	A	95	88
	Atrazine	1 qt/a	A		
	Dicamba	2.5 oz/a	B		
	Glyphosate	22 oz/a	B		
9	Isoxaflutole + thiencarbazone-methyl	5 oz/a	A	88	89
	Atrazine	1.3 qt/a	A		
10	Isoxaflutole	5 oz/a	A	85	91
	Atrazine	1.3 qt/a	A		
11	Tembotrine + thiencarbazone-methyl	3 oz/a	B	96	98
	Atrazine	1	qt/a	B	

continued

Table 1. Palmer amaranth control 49 and 106 days after planting (DAP)

				Palmer amaranth control, %	
Treatment	Active ingredient	Rate	Timing[1]	49 DAP	106 DAP
12	Tembotrine + thiencarbazone-methyl	3 oz/a	B	95	93
	Glyphosate	22 oz/a	B		
13	Tembotrine + thiencarbazone-methyl	3 oz/a	B	99	98
	Atrazine	1 qt/a	B		
	Glyphosate	22 oz/a	B		
14	S-Metolachlor + Atrazine mesotrione	3 qt/a	A	70	95
15	Mesotrione + metolachlor	3.6 pt/a	B	96	96
	Glyphosate				
	LSD (0.10)			20	9

[1] A is preemergence, B is 31 DAP.

Weed Control with 21 Tank Mixes of Rimsulfuron, Mesotrione, and Atrazine and Isoxaflutole Herbicide in Irrigated Glyphosate-Resistant Corn

R. Currie and J. Jester

Summary
Although corn yields were very low due to severe drought, treatments that produced greater than 95% control 98 days after planting (DAP) had the highest yields. These treatments all contained some level of atrazine.

Introduction
As their patents expire or approach expiration, products are often augmented with newer compounds to extend their useful life in the marketplace. The objective of this study was to determine how rimsulfuron and atrazine effectiveness could be enhanced with various tank mixes of other products.

Procedures
Palmer amaranth control was evaluated in the glyphosate-resistant corn variety DKC 64-83 at the Southwest Research-Extension Center near Garden City, KS. Corn was planted on May 20, 2011, with preemergent herbicides applied within 24 hours of planting under air temperature, soil temperature, wind speed, relative humidity, and soil moisture of 52°F, 63°F, 6 mph, 75%, and adequate, respectively. Soil was Ulysses silt loam, and organic matter, soil pH, and cation exchange capacity (CEC) were 1.4%, 8, and 18.4. All herbicide treatments were applied with a tractor-mounted CO_2 pressurized windshield sprayer calibrated to deliver 20 gpa at 30 psi at 4.1 mph. All plots were treated with 32 oz/a of glyphosate to remove any emerged plants from the plots. Adjuvant and ammonium sulfate (AMS) were added per manufacturer recommendations. The first post-herbicide application was made on June 15, 2011, when corn was 14 in. tall and air temperature, soil temperature, wind speed, relative humidity, and soil moisture were 85°F, 76°F, 4 mph, 26%, and adequate, respectively. The second post-herbicide application was made on June 29, 2011, with air temperature, soil temperature, wind speed, relative humidity, and soil moisture of 70°F, 77°F, 15 mph, 55%, and adequate. Trial was established as a randomized complete block design with four replications and plots were 10 by 30 ft. Crop injury and percentage weed control were visually rated.

Results and Discussion
No crop injury was observed. Palmer amaranth control was 93% or greater with herbicide treatments 3, 7, 9, 10, 17, 20, and 22 at 41 DAP compared with 0% in untreated checks (Table 1). Only treatments 7, 10, 18, 21, and 22 had greater than 95% control 69 DAP compared with 0% control in the untreated check. All of these treatments contained atrazine. Treatments 18, 19, and 22 provided 95% or greater control of Palmer amaranth 98 DAP (data not shown). Although yield data were gathered, they

were not included because the highest-yielding treatment produced only from 28 to 50 bu/a due to historic drought conditions. These highest-yielding treatments also had the best weed control 98 DAP (data not shown).

Table 1. Palmer amaranth control 41 and 69 days after planting (DAP)

				% control	
Treatment	Active ingredient	Rate	Timing[1]	41 DAP	69 DAP
1	Untreated check			0	0
2	Rimsulfuron	0.3 oz a/a	B	88	93
	Mesotrione	1.25 oz a/a	B		
	Glyphosate	32 fl oz/a	B		
	Atrazine	1 lb/a	B		
3	Rimsulfuron	0.3 oz a/a	B	98	71
	Mesotrione	1.25 oz a/a	B		
	Atrazine	1 lb/a	B		
	Glyphosate	32 fl oz/a	C		
4	Atrazine + S-metolachlor	1 qt/a	A	85	96
	Rimsulfuron	0.3 oz a/a	B		
	Mesotrione	1.25 oz a/a	B		
5	Atrazine + S-metolachlor	1 qt/a	A	88	88
	Rimsulfuron	0.3 oz a/a	B		
	Mesotrione	1.25 oz a/a	B		
	Glyphosate	32 fl oz/a	B		
6	Rimsulfuron	0.3 oz a/a	A	90	93
	Isoxaflutole	0.5 oz a/a	A		
	Atrazine	1 lb/a	A		
	Rimsulfuron	0.3 oz a/a	B		
	Mesotrione	1.25 oz a/a	B		
7	Rimsulfuron	0.3 oz a/a	A	99	100
	Isoxaflutole	0.5 oz a/a	A		
	Rimsulfuron	0.3 oz a/a	B		
	Mesotrione	1.25 oz a/a	B		
	Atrazine	1 lb/a	B		
8	Rimsulfuron	0.3 oz a/a	A	81	84
	Isoxaflutole	0.5 oz a/a	A		
	Atrazine	1 lb/a	A		
	Rimsulfuron	0.3 oz a/a	B		
	Mesotrione	1.25 oz a/a	B		
	Glyphosate	32 fl oz/a	B		
9	Rimsulfuron	0.3 oz a/a	A	95	90
	Isoxaflutole	0.5 oz a/a	A		
	Atrazine	1 lb/a	A		
	Glyphosate	32 fl oz/a	B		

continued

Table 1. Palmer amaranth control 41 and 69 days after planting (DAP)

				% control	
Treatment	Active ingredient	Rate	Timing[1]	41 DAP	69 DAP
10	Atrazine + S-metolachlor	1 qt/a	B	94	93
	Rimsulfuron	0.3 oz a/a	B		
	Mesotrione	1.25 oz a/a	B		
	Glyphosate	32 fl oz/a	C		
11	Mesotrione + metolachlor + glyphosate	3.6 pt/a	C	0	23
12	Rimsulfuron	0.25 oz a/a	A	83	90
	Mesotrione	2.25 oz a/a	A		
13	Rimsulfuron	0.375 oz a/a	A	90	93
	Mesotrione	2.25 oz a/a	A		
14	Rimsulfuron	0.25 oz a/a	A	84	80
	Thifensulfuron	0.25 oz a/a	A		
	Mesotrione	2.25 oz a/a	A		
15	Rimsulfuron	0.25 oz a/a	A	93	96
	Mesotrione	2.25 oz a/a	A		
	Atrazine	1 lb a/a	A		
16	Rimsulfuron	0.375 oz a/a	A	88	90
	Mesotrione	2.25 oz a/a	A		
	Atrazine	1 lb a/a	A		
17	Rimsulfuron	0.25 oz a/a	A	93	93
	Thifensulfuron	0.25 oz a/a	A		
	Mesotrione	2.25 oz a/a	A		
	Atrazine	1 lb a/a	A		
18	Rimsulfuron	0.25 oz a/a	A	96	99
	Mesotrione	2.25 oz a/a	A		
	Atrazine	1 lb a/a	A		
	Glyphosate	32 fl oz/a	BB		
19	Rimsulfuron	0.25 oz a/a	A	89	91
	Mesotrione	2.25 oz a/a	A		
	Atrazine	1 lb a/a	A		
	Glyphosate	32 fl oz/a	BB		
20	Rimsulfuron	0.25 oz a/a	A	93	98
	Thifensulfuron	0.25 oz a/a	A		
	Mesotrione	2.25 oz a/a	A		
	Atrazine	1 lb a/a	A		
	Glyphosate	32 fl oz/a	BB		
21	S-Metolachlor + atrazine + mesotrione	3 qt/a	A	96	96
22	S-Metolachlor + atrazine + mesotrione	3 qt/a	A	99	100
	Glyphosate	32 fl oz/a	BB		
	LSD (0.10)			17	15

[1] A is preemergence, B is V2-V4, C is 40 DAP, BB is 28 DAP.

Reductions in Corn Leaf Area Induced by Drought Stress and Level of Irrigation Impacts Weed Control

R.Currie, N. Klocke, J. Jester

Summary
When irrigation was less than 50% of full irrigation requirements, Palmer amaranth biomass increased from 6- to 31-fold compared with fully irrigated corn. When irrigation was below 30% of full irrigation requirements, however, Palmer amaranth biomass was 51 to 82 lb/a. When corn was irrigated with more than 60% of full irrigation, it was able to compete with Palmer amaranth. Between irrigation levels of 30 and 50%, Palmer amaranth was able to utilize the remaining water better than the corn. When irrigation was below 30%, drought severely reduced both weed and crop growth. Fully irrigated corn yielded from 178 to 203 bu/a, but yield decreased to a minimum of 0 to 3.5 bu when irrigated with less than 30% of full irrigation requirements. Palmer amaranth biomass was from 9 to 38 lb/a in fully irrigated corn. Palmer amaranth biomass increased from 1.5- to 4-fold as irrigation decreased to 60% of full irrigation.

Introduction
In a 2011 long-term experiment to measure the dose-response relationship of irrigation and corn grain yield, corn production was reduced by a severe drought. Corn biomass and leaf area decreased as irrigation decreased, causing late-season Palmer amaranth growth. Previous work in hail-injured corn showed that reductions in leaf area index (LAI) also allowed late-season Palmer amaranth growth (Currie and Klocke, 2008). Therefore, the objective of this work was to measure corn differentially injured by drought as indexed by leaf area.

Procedures
Corn was grown in three locations where the objective was to maintain weed-free conditions. For the five years prior to 2011, weed control was pursued with aggressive herbicide tank mixes. In 2011, corn first received a preemergence application of glyphosate, atrazine, isoxaflutole, dimethenamid, and saflufenacil at 1, 1.7, 0.031, 0.78, and 0.08 lb ai/a, respectively, followed by postemergence application of fluroxypyr, glyphosate, S-metolachlor, and tembotrione at 0.13, 1, 1.43, and 0.082 lb/a, respectively. Additional postemergence applications of glyphosate at 0.75 lb/a were applied, as needed, to maintain weed-free conditions at canopy closure. The treatments, replicated four times, were 100, 84, 71, 55, 42, and 30% of what locally derived models predicted for non-rate-limited irrigation. As a result, the net irrigation amounts were 18, 14, 10, 7, 4, and 1 in./a across irrigation treatments, which resulted in 25, 20, 16, 13, 11, and 7 in. of total water use per acre (evapotranspiration), respectively. Total water use was based on soil water measurements up to 8 ft, total in-season rainfall, and total net irrigation. Corn populations for each treatment decreased as level of irrigation decreased . Populations were 32,000, 27,000, 24,500, 22,000 and 9,500, plants/a, respectively.These populations were based on previous models for the level of irrigation to be applied. Corn

LAI was measured as described in a previous study (Currie and Klocke, 2008). Palmer amaranth biomass samples were taken at corn harvest.

Results and Discussion

The fully irrigated corn yielded from 178 to 203 bu/a. Grain yield decreased linearly at all locations, to a minimum of 0 to 3.5 bu/a when irrigated with less than 30% of full irrigation requirements. Palmer amaranth biomass was from 9 to 38 lb/a in fully irrigated corn. Palmer amaranth biomass increased from 1.5- to 4-fold as irrigation decreased to 60% of full irrigation. At all three locations, when irrigation was less than 50% of full irrigation requirements, Palmer amaranth biomass increased from 6- to 31-fold compared with fully irrigated corn; however, when irrigation was below 30% of full irrigation requirements, Palmer amaranth biomass was 51 to 82 lb/a. Although corn populations were reduced to match reduced irrigation levels, reducing crop water stress enough to prevent corn leaf loss due to drought was impossible. Severe reduction in the corn canopy allowed late-season Palmer amaranth to emerge.

In our previous study, simple linear models of corn LAI reduced by hail predicted corn yield loss well, with R-squared values well above 0.94 (Currie and Klocke, 2008). Simple linear models of LAI were also predictive of corn yield loss in this study, with R-squared values greater than 0.99. We advise using this data with caution because although it is based on two locations, we used regressions of only 3 points; therefore, the results should be considered only a starting point for future research. Although the previous work showed a strong linear relationship between corn LAI influenced by hail injury and Palmer amaranth biomass, no relationship could be shown using this limited dataset for corn injured by drought stress. When corn was irrigated with more than 60% of full irrigation, it was able to compete with Palmer amaranth. With irrigation levels from 30 to 50%, Palmer amaranth was able to utilize the remaining water better than the corn. When irrigation was below 30%, drought severely reduced both weed and crop growth.

References

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Kochia Seedling Emergence Patterns Across the Central Great Plains

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Summary
The rate of kochia emergence was studied and found to be slower in cropland than in non-cropland environments. From 70 to 95% of the kochia seedlings emerged between the first two observation dates across all locations. High seedling emergence occurring very early in the season emphasizes the need for early weed control; however, the high number of seedlings that appear in the second flush (from 5 to 30% of the total population) emphasizes the need for extended periods of early season kochia management.

Introduction
Kochia has developed resistance to glyphosate herbicide in many parts of the Great Plains. Detailed studies of the basic biology of this emerging weed problem are scarce. Timing of control measure applications is largely influenced by date of emergence and subsequent weed size, but little is known about this aspect of kochia biology. Therefore, the objective of this study was to measure the timing and duration of kochia seedling emergence.

Procedures
Emergence patterns of kochia populations in cropland and non-cropland sites were monitored in 2010 and again in 2011 in Colorado (Fort Collins [irrigated and dryland cropland]), Kansas (Garden City [cropland], Hays [cropland, non-cropland], Manhattan [non-cropland], Ness City [non-cropland], and Stockton [non-cropland]), Nebraska (Mitchell [non-cropland] and Scottsbluff [non-cropland]), Wyoming (Lingle [non-cropland]), and South Dakota [cropland]. Quadrats (0.25 to 1-m^2) were marked in which weekly observations of emergence were documented and emerged seedlings were removed by hand or sprayed with glyphosate. Observations were initiated as early as March 2 and continued through July 30 or until no new emergence was evident on consecutive observation dates.

Results and Discussion
Total season population densities varied among locations and ranged from as few as 10 to almost 332,000 seedlings/m^2 (Table 1). Earliest observed emergence occurred soon after March 2 across locations in 2010 and occurred even earlier in 2011 (Table 2). Although the calendar dates shift from March to April as location moves from south to north, the growing degree days (GDD) for 10% cumulative kochia emergence based on air temperatures since January 1 revealed that fewer GDD were needed before seedling emergence occurred in the north than in the south. This result may indicate a lower critical temperature for kochia in more northern latitudes. In general, the rate of kochia emergence was slower in cropland than in non-cropland environments. From 70 to 95% of the kochia seedlings emerged between the first two observation dates across all locations. High seedling emergence very early in the season emphasizes the need for

early weed control, and the high number of seedlings that appear in the second flush (from 5 to 30% of the total population) emphasizes the need for extended periods of early season kochia management.

Table 1. Mean density and range (low and high) of maximum kochia emergence (number/m²) observed across locations, sites, and years

Location	Site	Year	Maximum kochia emergence		
			Mean	Low	High
			---------- no./m² ----------		
Lingle, WY	West	2010	5950	341	12723
	West	2011	2152	1369	2941
	East	2011	65	37	96
Mitchell, NE	NC	2010	11074	6234	15422
		2011	18218	16496	19854
Scottsbluff, NE	NC	2010	8480	2964	12291
		2011	4780	4140	6322
Stockton, KS	NC	2010	297	91	584
		2011	42	29	63
Manhattan, KS	NC	2011	1463	414	3296
Hays, KS	Crop	2010	451	149	692
	Crop	2011	21415	13390	32980
	NC	2010	331975	310500	379100
	NC	2011	68140	61560	75930
Garden City, KS	notill	2010	10	4	22
	notill	2011	58	21	135
	tilled	2011	86	17	193

Table 2. Predicted cumulative growing degree days (GDD) and corresponding calendar date for start (10%) and duration (10 to 90%) of kochia emergence across locations and sites in 2010 and 2011

Year	Location	Site	GDD to 10%	Calendar date	GDD duration (10 to 90%)
2010	Lingle, WY	West	76	3/21	115
	Mitchell, NE	No crop	84	3/17	372
	Scottsbluff, NE	No crop	69	3/15	346
	Stockton, KS	No crop	282	4/3	61
	Hays, KS	Crop	238	3/18	127
		No crop	137	3/31	36
	Garden City, KS	No-till crop	283	3/31	773
2011	Lingle, WY	West	109	3/10	70
		East	657	5/22	112
	Mitchell, NE	No crop	102	3/12	77
	Scottsbluff, NE	No crop	99	3/2	181
	Stockton, KS	No crop	267	3/21	733
	Manhattan, Ks	No crop	174	3/15	130
	Hays, KS	Crop	136	3/10	54
		No crop	110	2/24	300
	Garden City, KS	No-till crop	292	3/22	972
		Tilled crop	460	4/9	509

Alternatives to Glyphosate for Kochia Control in Dryland No-Till Corn

P.W. Stahlman, D.A. Brachtenbach, P.W. Geier, and S.S. Reddy

Summary
The greatest and most consistent season-long kochia control, averaged across three experiments, was achieved with preemergence-applied Balance Flexx + Aatrex 4L at 4 + 20 oz/a or Lumax at 2.5 qt/a. Postemergence treatments of Laudis (3 oz/a) or Impact (0.75 oz/a) + Aatrex 4L at 8 oz + 1% w/v AMS and 1% v/v MSO were similarly effective as several preemergence treatments at mid-season, but end-of-season control declined considerably. This study indicates the need for a preplant or preemergence application followed by an in-crop postemergence herbicide treatment to obtain maximum kochia control.

Introduction
The widespread presence of glyphosate-resistant kochia throughout western Kansas underscores the need for alternatives to glyphosate for weed control in corn. Our objective was to compare the performance of several herbicide treatments other than glyphosate for kochia control in no-till corn.

Procedures
Experiments were conducted on grower fields (dryland) near Levant, Park, Phillipsburg, and Shields, KS, in 2011. Each field was naturally infested with kochia that was subsequently confirmed as resistant to glyphosate. Experimental areas received a preplant burndown treatment prior to corn planting, and treatments were applied preemergence within 2 days after planting (hybrid of grower's choice) by the farm operator. Spray volume was 15 gal/a at Levant and 12.7 gal/a at Park, Phillipsburg, and Shields. Postemergence treatments were applied at the V5 corn growth stage at Levant when kochia was 1 to 6 in. tall, V4 corn growth stage at Park when kochia was 3 to 6 in. tall, V2 corn stage at Phillipsburg when kochia was 0.5 to 1.5 in. tall, and V4 growth stage at Shields when kochia was 3 to 4 in. tall. Kochia density ranged from 5 to 10 plants/yd^2 at Park and more than 100 plants/yd^2 at Phillipsburg. Treatment costs include herbicides and adjuvants (10% over dealer cost), but not application or program discounts or rebates. Corn in the Park and Shield trials was harvested for silage because of drought, and grain yields of the Levant and Phillipsburg trials are not reported.

Results and Discussion
Averaged across experiments, all but four preemergence treatments controlled kochia 90% or greater at 31 ± 3 days after planting (DAP) (Table 1). Among this group of treatments, Harness Xtra at 2.3 qt/a was less effective than Balance Flexx + Aatrex 4L at 4 + 20 oz/a or Lumax at 2.5 qt/a (90 vs. 98% control), but Harness Xtra was similarly effective as Fierce at 4 oz/a (93%), Clarity + 2,4-D LV4 at 16 + 8 oz/a (94%), and Degree Xtra at 3 qt/a (96%). Verdict at 18 oz/a, Anthem at 7 oz/a, SureStart or TripleFlex at 1 qt/a, and Valor SX at 3 oz/a were 10 to 23% less effective than Harness Xtra, the lowest of the top-performing treatments. At 50 ± 3 DAP, only preemergence-

applied mixtures of Balance Flexx plus Aatrex 4L at 4 + 20 oz/a, Lumax at 2.5 qt/a, and Degree Xtra at 3.0 qt/a controlled kochia 90% or greater (Table 2). Clarity + 2,4-D LV4 was slightly less effective at 86%. Postemergence-applied Laudis (3 oz/a) or Impact (0.75 oz/a) mixed with 8 oz/a Aatrex 4L along with AMS and MSO provided 87% kochia control. Mixing Aatrex 4L with Laudis enhanced control significantly compared with Laudis alone. Kochia control with most treatments, especially those without atrazine, declined significantly at the end of the season compared with mid-season ratings (data not shown); only Balance Flexx plus Aatrex 4L and Lumax treatments maintained control above 80%. Although postemergent applications of Laudis or Impact plus Aatrex 4L and MSO were similarly effective as the most effective preemergence treatments at mid-season, end-of-season control with those two treatments was less than 65%. Herbicide treatment costs ranged from as low as \$7.91 up to \$42.75 per acre. Correlation between treatment cost and kochia control was poor (r = 0.35 or less) at each rating. The greatest and most consistent season-long control averaged across experiments was achieved with Balance Flexx + Aatrex at 4 + 20 oz/a at a cost of \$21.30/a. Lumax provided similar season-long control as Balance Flexx + Aatrex but at considerably higher cost.

Lack of complete or nearly complete kochia control with the preemergence herbicides tested in this study supports the recommendations of K-State weed scientists that producers use a preplant or preemergence herbicide treatment followed by an in-crop postemergence herbicide treatment to obtain maximum kochia control.

Table 1. Kochia control in corn 31 ± 3 days after preemergence herbicide application, 2011

Herbicide treatment	Rate/a	Cost/a[1]	Park	Phillipsburg	Shields	Levant	Mean
			%				
Clarity + 2,4-D LV4	16 + 8 oz	\$12.17	95	99	89	--	94
Verdict	18 oz	\$29.75	65	85	99	--	83
Balance Flexx + Aatrex 4L	4 + 20 oz	\$21.30	99	100	100	95	98
Lumax	2.5 qt	\$42.75	98	98	100	95	98
Harness Xtra	2.3 qt	\$33.14	88	91	100	83	90
Degree Xtra	3.0 qt	\$31.47	97	96	100	92	96
SureStart or TripleFlex	1 qt	\$19.86	55	68	88	--	70
Valor SX	3 oz	\$17.12	76	81	79	--	79
Fierce	4 oz	--[2]	95	83	99	--	93
Anthem	7 oz	--[2]	79	73	93	58	75
LSD (0.05)			10	10	3	2	7

[1] Listed costs are approximate and do not include application or reflect program discounts or rebates.
[2] Product price not yet established.

Table 2. Kochia control in corn 50 ± 3 days after preemergence or 19 ± 3 days after postemergence herbicide application, 2011

Herbicide treatment[1]	Rate/a	Cost/a[2]	Park	Phillipsburg	Shields	Levant	Mean
--------- Preemergence application ----------			----------	----------	%	----------	----------
Clarity + 2,4-D LV4	16 + 8 oz	$12.17	97	78	83	--	86
Verdict	18 oz	$29.75	68	53	85	--	69
Balance Flexx + Aatrex 4L	4 + 20 oz	$21.30	92	99	99	95	96
Lumax	2.5 qt	$42.75	89	97	99	91	94
Harness Xtra	2.3 qt	$33.14	60	73	97	80	77
Degree Xtra	3.0 qt	$31.47	79	94	99	88	90
SureStart or TripleFlex	1 qt	$19.86	58	89	58	--	68
Valor SX	3 oz	$17.10	83	58	65	--	68
Fierce	4 oz	--[3]	73	64	95	--	78
Anthem	7 oz	--[3]	87	92	84	58	80
--------Postemergence application ---------							
Laudis + AMS + MSO	3 oz + 1% + 1%	$19.05	93	74	63	76	77
Laudis + Aatrex 4L + AMS + MSO	3 + 8 oz + 1% + 1%	$19.89	93	90	85	78	87
Impact + Aatrex 4L + AMS + MSO	0.75 + 8 oz + 1% + 1%	$18.54	89	95	80	86	87
LSD (0.05)			9	15	7	11	9

[1] The Laudis, Laudis + Aatrex 4L, and Impact + Aatrex 4L treatments were applied postemergence without benefit of preemergent herbicide. All other treatments were applied preemergence. AMS, ammonium sulfate; MSO, methylated seed oil.

[2] Listed costs do not include application or reflect program discounts or rebates.

[3] Product price not yet established.

Regional Studies on Kochia Management without Glyphosate

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Summary
Tank mixtures of preemergence-applied Clarity (dicamba) and 2,4-D LV4 (2,4-D ester) at 8 oz + 8 oz/a or 16 oz + 16 oz/a provided the greatest and most consistent kochia control of 97 and 98%, respectively, for 5 to 6 weeks after treatment (WAT). Postemergence-applied Gramoxone Inteon (paraquat) at 48 oz/a plus Aatrex 4L (atrazine) at 16 oz/a or Linex 4L (linuron) at 24 oz/a controlled kochia 90 and 87%, respectively, at 3 to 4 WAT averaged across eight trials. No other treatment controlled kochia by as much as 85%.

Introduction
Confirmed glyphosate resistance in multiple kochia (*Kochia scoparia*) populations in western Kansas prompted the need to investigate alternatives to glyphosate for control of kochia.

Procedures
Separate field trials comparing standardized preemergence or postemergence herbicide treatments were conducted at one or more locations in Colorado, Kansas, Montana, Nebraska, and Wyoming to evaluate kochia control effectiveness in spring fallow or prior to crop planting. Only one of the two trials (PRE or POST) was conducted at some locations. Preemergence herbicides were applied in March or April 2011, depending on location, and postemergence treatments were applied along with appropriate adjuvants when the majority of kochia plants were 1–4 in. tall.

Results and Discussion
Preemergence-applied Warrant (encapsulated acetochlor) at 2 qt/a, Valor (flumioxazin) at 3 oz/a, and Tripleflex (acetochlor & flumetsulam & clopyralid) at 1 qt/a controlled kochia poorly (<40% in 4 trials) at 5 to 6 WAT (Table 1). Mean kochia control with Verdict (saflufenacil & dimethenamid) at 15 oz/a, Balance Flexx (isoxaflutole) at 5 oz/a, Harness Xtra (acetochlor & atrazine) at 2.3 qt/a, and Spartan (sulfentrazone) at 6 oz/a ranged from 60 to 80% in increasing sequential order. Tank mixtures of preemergence Clarity and 2,4-D LV4 at 8 oz + 8 oz/a or 16 + 16 oz/a provided the greatest and most consistent kochia control of 97 and 98%, respectively. Postemergence-applied Gramoxone Inteon at 48 oz/a plus Aatrex 4L at 16 oz/a or Linex 4L at 24 oz/a controlled kochia 90 and 87%, respectively, at 3 to 4 WAT, averaged across eight trials (Table 2). No other treatment controlled kochia by as much as 85%. Mixtures of Laudis (tembotrione) at 3 oz/a or Impact (topramezone) at 0.75 oz/a in combination with Aatrex 4L at 8 oz/a, and Sharpen (saflufenacil) at 1 oz/a plus Aatrex 4L at 12 oz/a controlled kochia 79 to 83%. Timing of control assessments varied among

locations, making time comparisons difficult because of different numbers of trials with similar times of evaluation. Control percentages between most treatments varied widely both within locations and especially between locations, likely because of differing environmental conditions. Kochia control with Roundup PowerMax (glyphosate) at 32 oz/a was less than 30% in each of four Kansas trials, 43% in one Colorado trial, 82% in one Montana trial, and 93 and 96% in one Nebraska and a second Colorado trial.

Table 1. Kochia control 5 to 6 weeks after preemergence application in early spring averaged across four trials in Kansas, 2011

Herbicide treatment	Product/a	Cost/a[1]	Control, %[1]
Verdict	15 fl oz	$24.90	58cd[2]
Balance Flexx	5 fl oz	$24.00	70bc
Harness Xtra 6.0	2.3 qt	$11.94	73bc
Warrant	2.0 qt	$17.00	23e
Valor SX	3 fl oz	$17.10	29e
TripleFlex	1 qt	$19.59	46d
Spartan	6 fl oz	$14.64	79b
Clarity + 2,4-D LV4	8 oz + 8 oz	$ 6.64	97a
Clarity + 2,4-D LV4	16 oz + 16 oz	$13.28	98a

[1] Listed costs are approximate and do not reflect program discounts or rebates.
[2] Means followed by the same letter are not significantly different.

Table 2. Kochia control 3 to 4 weeks after application averaged across eight trials in Kansas (4), Colorado (2), Montana (1), and Nebraska (1), 2011

Herbicide treatment[1]	Rate, oz/a + % v/v	Cost/a[2]	Control, %[3]
Roundup PowerMax	32	$5.80	48h
Distinct + NIS	4 + 0.5%	$15.07	65fg
Distinct + 2,4-D LV4 + NIS	4 + 8 + 0.5%	$16.21	67efg
Sharpen + 2,4-D LV4 + MSO	1 + 8 + 1%	$10.00	73def
Sharpen + Aatrex 4L + MSO	1 + 12 + 1%	$9.94	79abcd
Laudis + MSO	3 + 1%	$19.17	76bcde
Laudis + Aatrex 4L + MSO	3 + 8 + 1%	$20.59	83abc
Callisto + Aatrex 4L + MSO	3 + 8 + 1%	$17.53	67efg
Impact + Aatrex 4L + MSO	0.75 + 8 + 1.5%	$21.86	80abcd
Starane NXT	14 + 0.5%	$8.81	60gh
Huskie + NIS	15 + 0.5%	$12.67	74cdef
Rage D-Tech + MSO	32 + 2%	$12.17	52h
Linex 4L + Aatrex 4L + COC	24 + 16 + 1%	$16.69	77bcde
Gramoxone Inteon + Aatrex 4L + COC	48 + 16 + 1%	$14.91	90a
Gramoxone Inteon + Linex 4L + COC	48 + 24 + 1%	$27.49	87ab

[1] All treatments included ammonium sulfate. NIS, non-ionic surfactant; MSO, methylated seed oil; COC, crop oil concentrate.
[2] Listed costs are approximate and do not reflect program discounts or rebates.
[3] Means followed by the same letter are not significantly different.

Acknowledgments

The staffs of the Southwest Research-Extension Center and Kansas State University appreciate and acknowledge the following companies, foundations, and individuals for their support of the research that has been conducted in the past year.

Donations

BASF Corp.
Bayer Chemical
CPS – Crop Production Services
DeKalb Genetics Corp.
Dodge City Coop
Drussel Seed
Ehmke Seeds
Farm Credit of Southwest Kansas
Green Cover Seed
Garden City Coop
Helena Chemical
Kansas Wheat Alliance
Monsanto Company
Pioneer Hi-Bred Intl.
Sharp Brothers Seed
Triumph Seed

Grant Support

AgXplore Inc.
BASF Corp.
Bayer CropScience
Dow AgroSciences
DuPont Ag Products
Fluid Fertilizer Foundation
Gowan Company
Great Plains Canola Association
Helena Chemical Company
International Plant Nutrition Institute
Kansas Grain Sorghum Commission
Kansas Water Authority
Kansas Wheat Commission
National Crop Insurance Services
National Sunflower Association
Nutrecology Inc.
Stoller Enterprises Inc.
Syngenta
Tessenderlo Kerley Inc.
United Sorghum Checkoff Program
U.S. Canola Association
USDA/ARS
USDA Canola Project
USDA/Ogallala Aquifer Project
USDA Risk Management Agency
Valent BioSciences
Winfield Solutions

Cooperators/Collaborators

Colorado State University
Dodge City Community College
Kansas Division of Water Resources
Kansas Water Office
Kansas State University Research Foundation
Groundwater Management Districts
Sentek Inc.
South Dakota State University
Sprout Software
Texas A&M University
University of Nebraska
University of Wyoming
USDA/ARS, Bushland, Lubbock, and Weslaco, TX; Akron, CO

Performance Tests

AgriPro Seeds Inc.
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Scott Seed
Stine Seed Farms
Syngenta Sorghum Lines
Triumph Seed Company Inc.
Watley
WestBred
W-L Research

Herbicide Premixes[1,2]

Product (Manufacturer)	Ingredients
Accurate/Extra (Cheminova)	37.5% thifensulfuron, 18.8% tribenuron, and 15% metsulfuron
Affinity BroadSpec (DuPont)	25% thifensulfuron (Harmony) and 25% tribenuron (Express)
Affinity TankMix (DuPont)	40% thifensulfuron (Harmony) and 10% tribenuron (Express)
Agility SG (DuPont)	4.7% thifensulfuron (Harmony), 2.4% tribenuron (Express), 1.9% metsulfuron (Ally), and 58% dicamba (Banvel)
Ally Extra SG (DuPont)	27.3% thifensulfuron, 13.6% tribenuron (Harmony Extra), and 10.9% metsulfuron (Ally)
Authority Assist (FMC)	3.33 lb sulfentrazone (Spartan) and 0.67 lb imazethapyr (Pursuit)
Authority First (FMC)	62.1% sulfentrazone (Spartan) and 7.9% cloransulam (FirstRate)
Authority MTZ (FMC)	18% sulfentrazone (Spartan) and 27% metribuzin (Sencor)
Authority XL (FMC)	62% sulfentrazone (Sparton) and 7.8% chlorimuron (Classic)
Banvel K + Atrazine (Arysta)	1.1 lb potassium salt of dicamba and 2.1 lb atrazine per gal
Basis (DuPont)	50% rimsulfuron and 25% thifensulfuron (Harmony)
Basis Blend (DuPont)	20% rimsulfuron (Resolve) and 10% thifensulfuron (Harmony)
Bicep II Magnum (Syngenta)	3.1 lb atrazine and 2.4 lb S-metolachlor (Dual II Magnum) per gal
Bicep Lite II Magnum (Syngenta)	2.67 lb atrazine and 3.33 lb S-metolachlor (Dual II Magnum) per gal
Bison (Winfield)	2 lb bromoxynil (Moxy) and 2 lb MCPA per gal
Boundary (Syngenta)	5.25 lb S-metolachlor (Dual Magnum) and 1.25 lb metribuzin (Sencor) per gal
Brash (Winfield)	1 lb dicamba and 2.87 lb 2,4-D amine per gal
Breakfree ATZ (DuPont)	3 lb acetochlor + 2.25 lb atrazine per gal
Breakfree ATZ Lite (DuPont)	4 lb acetochlor + 1.5 lb atrazine per gal
Bromox + Atrazine (MicroFlo)	1 lb bromoxynil and 2 lb atrazine per gal
Brozine (Platte Chemical)	1 lb bromoxynil and 2 lb atrazine per gal
Buctril + Atrazine (Bayer)	1 lb bromoxynil (Buctril) and 2 lb atrazine per gal
Bullet (Monsanto)	2.5 lb microencapsulated alachlor (Micro-Tech) and 1.5 lb atrazine per gal
Callisto Xtra (Syngenta)	0.5 lb mesotrione (Callisto) and 3.2 lb atrazine (AAtrex 4L)
Camix (Syngenta)	3.3 lb S-metoloachlor (Dual II Magnum) and 0.33 lb mesotrione (Callisto) per gal
Canopy (DuPont)	64.3% metribuzin and 10.7% chlorimuron (Classic)
Canopy EX (DuPont)	22.7% chlorimuron (Classic) and 6.8% tribenuron (Express)
Capreno (Bayer)	2.88 lb tembotrione (Laudis) and 0.57 lb thiencarbazone per gal
Chaparral (Dow AS)	0.525% aminopyralid (Milestone) and 0.0945% metsulfuron (Ally)
Charger Max ATZ (Winfield)	3.1 lb atrazine and 2.4 lb S-metolachlor (Dual II Magnum) per gal
Charger Max ATZ Lite (Winfield)	2.67 lb atrazine and 3.33 lb S-metolachlor (Dual II Magnum) per gal
Chism (Cheminova)	48% metsulfuron and 15% chlorsulfuron
Cimarron Max (DuPont)	1 lb dicamba and 2.87 lb 2,4-D per gal. and 60% metsulfuron co-pack[2]
Cimarron Plus (DuPont)	48% metsulfuron and 15% chlorsulfuron
Cimarron Xtra (DuPont)	30% metsulfuron (Ally) and 37.5% chlorsulfuron (Glean)
Cinch ATZ (DuPont)	3.1 lb atrazine and 2.4 lb S-metolachlor (Cinch) per gal
Cinch ATZ Lite (DuPont)	2.67 lb atrazine and 3.33 lb S-metolachlor (Cinch) per gal
Clearmax (BASF)	1 lb imazamox (Beyond) per gal. and 4 lb MCPA per gal. co-pack[2]
Confidence Xtra (Winfield)	4.3 lb acetochlor (Harness) and 1.7 lb atrazine per gal
Confidence Xtra 5.6L (Winfield)	3.1 lb acetochlor (Harness) and 1.5 lb atrazine per gal
Corvus (Bayer)	1.88 lb isoxaflutole (Balance Flexx) and 0.75 lb thiencarbazone per gal
Crossbow (Dow)	2 lb 2,4-D and 1 lb triclopyr (Remedy) per gal
Curtail (Dow)	2 lb 2,4-D and 0.38 lb clopyralid (Stinger) per gal
Degree Xtra (Monsanto)	2.7 lb acetochlor (Degree) and 1.34 lb atrazine per gal
Dicamba K + Atrazine (MicroFlo)	1.1 lb potassium salt of dicamba and 2.1 lb atrazine per gal

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Herbicide Premixes[1,2]

Product (Manufacturer)	Ingredients
Distinct (BASF)	20% acid of diflufenzopyr and 50% acid of dicamba (Banvel SGF)
Enlite (DuPont)	2.85% chlorimuron (Classic), 36.2% flumioxazin (Valor), and 8.8% thifensulfuron (Harmony)
Envive (DuPont)	9.2% chlorimuron (Classic), 29.2% flumioxazin (Valor), and 2.9% thifensulfuron (Harmony)
Expert (Syngenta)	1.74 lb S-metolachlor (Dual Magnum), 2.14 lb atrazine, and 1.0 lb IPA salt of glyphosate per gal
Extreme (BASF)	0.17 lb ae imazethapyr (Pursuit) and 1.5 lb ae glyphosate per gal
Field Master (Monsanto)	0.75 lb IPA salt of glyphosate (Roundup), 2 lb acetochlor (Harness) and 1.5 lb atrazine per gal
Finesse (DuPont)	62.5% chlorsulfuron (Glean) and 12.5% metsulfuron (Ally)
Finesse Grass & Broadleaf (DuPont)	25% chlorsulfuron (Glean) and 47% flucarbazone (Everest)
Flexstar GT 3.5 (Syngenta)	0.56 lb fomesafen (Flexstar) and 2.26 lb ae glyphosate per gal
ForeFront R&P (Dow)	0.33 lb ae aminopyralid (Milestone) and 2.67 lb ae 2,4-D per gal
FulTime (Dow)	2.4 lb microencapsulated acetochlor (TopNotch) and 1.6 lb atrazine per gal
Fusion (Syngenta)	2 lb fluazifop (Fusilade) and 0.66 lb fenoxaprop (Option II) per gal
Gangster (Valent)	51% flumioxazin (Valor) and 84% cloransulam (FirstRate) co-pack[2]
GlyMix MT (Dow)	4 lb glyphosate IPA salt and 0.4 lb 2,4-D per gal
G-Max Lite (BASF)	2.25 lb dimethenamid-P (Outlook) and 2.75 lb atrazine per gal
Grazon P&D (Dow)	2 lb 2,4-D and 0.54 lb picloram (Tordon) per gal
Guardsman Max (BASF)	1.7 lb dimethenamid-P (Outlook) and 3.3 lb atrazine per gal
Halex GT (Syngenta)	2.09 lb S-metolachlor (Dual Magnum), 2.09 lb glyphosate, and 0.21 lb mesotrione (Callisto) per gal
Harmony Extra SG (DuPont)	33.3% thifensulfuron (Harmony) and 16.7% tribenuron (Express)
Harness Xtra (Monsanto)	4.3 lb acetochlor (Harness) and 1.7 lb atrazine per gal
Harness Xtra 5.6L (Monsanto)	3.1 lb acetochlor (Harness) and 2.5 lb atrazine per gal
Hornet WDG (Dow)	18% flumetsulam (Python) and 60% clopyralid salt (Stinger)
Huskie (Bayer)	0.24 lb pyrasulfotole and 1.92 lb bromoxynil (Buctril) per gal
Journey (BASF)	8.13% imazapic (Plateau) and 21.94% glyphosate
Keystone (Dow)	3 lb acetochlor (Surpass) and 2.25 lb atrazine per gal
Keystone LA (Dow)	4 lb acetochlor (Surpass) and 1.5 lb atrazine per gal
Krovar (DuPont)	40% bromacil (Hyvar) and 40% diuron (Karmex)
Laddok S-12 (Sipcam Agro)	2.5 lb bentazon (Basagran) and 2.5 lb atrazine per gal
Landmark (DuPont)	50% sulfometuron (Oust) and 25% chlorsulfuron (Glean)
Lariat (Monsanto)	2.5 lb alachlor (Lasso) and 1.5 lb atrazine per gal
Lexar (Syngenta)	1.74 lb S-metolachlor (Dual II Magnum), 1.74 lb atrazine, and 0.22 lb mesotrione (Callisto) per gal
Lumax (Syngenta)	2.68 lb S-metolachlor (Dual II Magnum), 0.268 lb mesotrione (Callisto), and 1 lb atrazine per gal
Nimble (Cheminova)	50% thifensulfuron (Harmony) and 25% tribenuron (Express)
NorthStar (Syngenta)	7.5% primisulfuron (Beacon) and 43.9% sodium salt of dicamba
Olympus Flex (Bayer)	6.75% propoxycarbazone (Olympus) and 4.5% mesosulfuron (Osprey)
Optill (BASF)	17.8% saflufenacil (Sharpen) and 50% imazethapyr (Pursuit)
Orion (Syngenta)	0.033 lb florasulam and 2.34 lb MCPA per gal
Overdrive (BASF)	20% acid of diflufenzopyr and 50% acid of dicamba
Pastora (DuPont)	56.2% nicosulfuron (Accent) and 15% metsulfuron (Ally)
PastureGard (Dow)	1.5 lb ae triclopyr (Remedy) and 0.5 lb ae fluroxypyr (Starane) per gal
Perspective (DuPont)	39.5% aminocyclopyrachlor and 15.8% chlorsulfuron (Glean)
Prefix (Syngenta)	4.34 lb S-metolachlor (Dual Magnum) and 0.95 lb fomesafen (Reflex) per gal
Prequel (DuPont)	15% rimsulfuron (Resolve) and 30% isoxaflutole (Balance)

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Herbicide Premixes[1,2]

Product (Manufacturer)	Ingredients
Pulsar (Syngenta)	0.73 lb ae dicamba (Banvel) and 0.95 lb ae fluroxypyr (Starane) per gal
Pursuit Plus (BASF)	2.7 lb pendimethalin (Prowl) and 0.2 lb imazethapyr (Pursuit) per gal
Rage D-Tech (FMC)	0.13 lb carfentrazone (Aim) and 3.93 lb ae 2,4-D ester per gal
Range Star (Albaugh)	1 lb dicamba and 2.87 lb 2,4-D amine per gal
Rave (Syngenta)	8.8% triasulfuron (Amber) and 50% dicamba (Banvel)
Ready Master ATZ (Monsanto)	2.0 lb glyphosate IPA salt and 2.0 lb atrazine per gal
Realm Q (DuPont)	7.5% rimsulfuron (Resolve) and 31.25% mesotrione (Callisto)
Redeem R&P (Dow)	2.25 lb triclopyr (Remedy Ultra) and 0.75 lb clopyralid (Stinger)
Report Extra (Cheminova)	62.5% chlorsulfuron (Glean) and 12.5% metsulfuron (Ally)
Require Q (DuPont)	6.25% rimsulfuron (Resolve) and 52.9% dicamba
Resolve Q (DuPont)	18.4% rimsulfuron (Resolve) and 4% thifensulfuron (Harmony)
Rezult B&G (BASF)	4 lb bentazon (Basagran) per gal. and 1 lb sethoxydim (Poast Plus) per gal. co-pack[2]
Sahara (BASF)	7.8% imazapyr (Arsenal) and 62.2% diuron (Karmex)
Sequence (Syngenta)	3 lb S-metolachlor (Dual Magnum) and 2.25 lb ae glyphosate per gal
Shotgun (United Agri Products)	2.25 lb atrazine and 1 lb iso-octyl ester of 2,4-D per gal
Sonic (Dow)	62.1 % sulfentrazone (Spartan) and 7.9% cloransulam (FirstRate)
Spartan Charge (FMC)	3.15 lb sulfentrazone (Spartan) and 0.35 lb carfentrazone (Aim) per gal
Spirit (Syngenta)	42.8% primisulfuron (Beacon) and 14.2% prosulfuron (Peak)
Status (BASF)	16% acid of diflufenzopyr, 44% sodium salt of dicamba, and isoxadifen safener
Steadfast ATZ (DuPont)	2.7% nicosulfuron (Accent), 1.3% rimsulfuron (Resolve), and 85.3% atrazine
Steadfast Q (DuPont)	25.2% nicosulfuron (Accent) and 12.5% rimsulfuron (Resolve)
Starane NXT (FMC)	0.58 lb fluroxypyr (Starane) and 2.33 lb bromoxynil per gal
Starane Plus Salvo (UAP)	0.75 lb fluroxypyr (Starane) and 3 lb 2,4-D (Salvo) per gal
Starane Plus Sword (UAP)	0.71 lb fluroxypyr (Starane) and 2.84 lb MCPA (Sword) per gal
Stout (DuPont)	67.5% nicosulfuron (Accent) and 5% thifensulfuron (Harmony)
Stratos (Gharda)	1.1 lb potassium salt of dicamba and 2.1 lb atrazine per gal
Streamline (DuPont)	39.5% aminocyclopyrachlor and 12.6% metsulfuron methyl (Ally)
SureStart (Dow)	3.75 lb acetochlor (Surpass), 0.12 lb flumetsulam (Python), and 0.29 lb ae clopyralid (Stinger) per gal
Surmount (Dow)	0.67 lb picloram (Tordon) and 0.67 lb fluroxypyr (Starane)
Synchrony XP (DuPont)	21.5% chlorimuron (Classic) and 6.9% thifensulfuron (Harmony)
TNT Broadleaf (Gowan)	50% thifensulfuron (Harmony) and 25% tribenuron (Express)
Tordon RTU (Dow)	3% acid equivalent picloram (Tordon) and 11.2% 2,4-D ae per gal
TripleFlex (Monsanto)	3.75 lb acetochlor (Harness), 0.12 lb flumetsulam (Python), and 0.29 lb ae clopyralid (Stinger) per gal
Valor XLT (Valent)	30% flumioxazin (Valor) and 10.3% chlorimuron (Classic)
Velpar AlfaMax (DuPont)	35.3% hexazinone (Velpar) and 42.4% diuron (Karmex)
Velpar AlfaMax Gold (DuPont)	23.1% hexazinone (Velpar) and 55.4% diuron (Karmex)
Verdict (BASF)	0.57 lb saflufenacil (Sharpen) and 5 lb dimethenamid-P (Outlook) per gal
Viewpoint (DuPont)	31.6% imazapyr (Arsenal), 22.8% aminocyclopyrachlor, and 7.3% metsulfuron methyl (Ally)
WeedMaster (NuFarm)	1 lb dicamba and 2.87 lb 2,4-D amine per gal
Weld (Winfield)	1.75 lb MCPA, 0.64 lb fluroxpyr (Starane), and 0.5 lb clopyralid (Stinger) per gal
WideMatch (Dow)	0.75 lb clopyralid (Stinger) and 0.75 lb fluroxypyr (Starane) per gal
Yukon (Gowan)	12.5% halosulfuron (Permit) and 55% sodium salt of dicamba

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FIELD DAY 2012

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Kansas State University Agricultural Experiment Station
and Cooperative Extension Service

SRP 1070 May 2012