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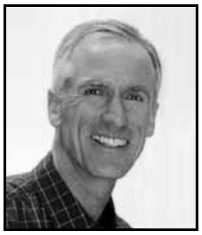
FIELD DAY 2009

Report of Progress 1014

Kansas State University Agricultural Experiment Station and Cooperative Extension Service

SOUTHWEST RESEARCH-EXTENSION CENTER



ROBERT (BOB) GILLEN, *Research Center Head*

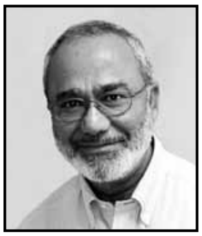
B.S., Colorado State University
Ph.D., Oregon State University

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.

PAUL HARTMAN, *Southwest Area Extension Director*

B.S., M.S., Animal Sciences and Industry, Kansas State University

Paul accepted his current position in 1991. He previously served Kansas State University as a County Extension Agricultural Agent in Stanton County (1977-1980) and Pratt County (1980-1991).



MAHBUB ALAM, *Extension Specialist, Irrigation and Water Management*

M.S., American University of Beirut, Lebanon
Ph.D., Colorado State University

Mahbub joined the staff in 1996. He previously worked for Colorado State University as an Extension Irrigation Specialist. His extension responsibilities are in the areas of irrigation and water management.

DEBRA BOLTON, *Extension Specialist, Family and Consumer Sciences*

B.S., English, St. Mary of the Plains College
M.S., Fort Hays State University

Debra works with county agents on various grant projects, program development, and training. Her research focuses on families in their environments and community development processes.

LARRY BUSCHMAN, *Entomologist*

M.S., Emporia State University
Ph.D., University of Florida

Larry joined the staff in 1981. His research includes studies of the biology, ecology, and management of insect pests, with emphasis on pests of corn, including spider mites.

ROD BUCHELE, *Extension Specialist, 4-H Youth Development*

B.S., Economics, Iowa State University
M.S., Guidance and Counseling, University of Wisconsin-Platteville

Rod joined the staff in fall of 2003 from Colorado State University Cooperative Extension. He previously held positions with University of Florida Cooperative Extension and University of Wisconsin Extension, all in 4-H Youth Development.

RANDALL CURRIE, *Weed Scientist*

B.S., Kansas State University
M.S., Oklahoma State University
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Randall joined the staff in 1991. His research focus is on weed control in corn.

FIELD DAY 2009

Contents

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Debra Bolton	Extension Specialist, Family and Consumer Sciences
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2008 Weather Information for Garden City

J. Elliott

Precipitation for 2008 totaled 17.31 in., which is 1.48 in. below the 30-year average of 18.79 in. As the year progressed, precipitation gradually fell behind normal and was 4.36 in. below average by the end of September. Soaking rains began on October 6 and totaled 4.69 in. for the month. This was the wettest October since 1946, when 6.60 in. fell. The largest daily rainfall was 1.92 in. on October 13. Pea-size hail was recorded on March 17; April 17; May 7, 23, and 24; and September 5 and 6 but caused little harm. Quarter-size hail fell on May 6. Pea- to penny-size hail fell on June 21, causing significant damage to station crops.

Measurable snowfall occurred in the first 3 months and the last 2 months of 2008. Annual snowfall totaled 11.0 in. for the year, compared with 19.51 in. on average. The largest snowfall event was 4.0 in. recorded on February 6. Seasonal snowfall (2007-2008) was 16.7 in.

Open-pan evaporation from April through October was 73.16 in., which is 2.56 in. above normal. Average daily wind speed was 5.02 mph, compared with 5.25 mph on average.

As expected, January was the coldest month, and July was the warmest month in 2008. November was considerably warmer than average with a mean temperature of 45.3 °F vs. 40.5 °F. Annual mean temperature was 53.4 °F, making 2008 the 11th consecutive year above the 30-year average.

One record high temperature was set in 2008: 80 °F on March 2. One record low was also set: 39 °F on September 16. Triple-digit temperatures were observed on 15 days in 2008; the highest temperature, 105 °F, was recorded on August 2 and 5. Subzero temperatures were noted on four occasions: -1 °F on January 17 and 18 and December 15 and 16.

The last spring freeze (32 °F) was on May 11, which is 15 days later than normal. The first fall freeze (32 °F) was on October 24, which is 14 days later than normal. This resulted in a 166-day frost-free-period, which is 1 day shorter than the 30-year average.

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

			Monthly temperatures									
			2008 avg.				2008 extreme		Wind		Evaporation	
Month	Precipitation		Max	Min	Mean	30-year avg.	Max	Min	2008	30-year avg.	2008	30-year avg.
	-----in.-----		------°F------						-------mph-------		-------in.-------	
Jan.	0.30	0.43	44.4	15.9	30.1	28.4	71	-1	4.43	4.68	–	–
Feb.	0.55	0.48	47.6	17.3	32.4	33.7	66	2	4.38	5.39	–	–
Mar.	0.28	1.38	59.8	24.9	42.3	42.3	83	8	5.15	6.72	–	–
Apr.	1.64	1.65	64.8	33.3	49.0	52.1	91	24	6.25	6.73	7.94	8.35
May	1.93	3.39	78.9	46.5	61.6	62.0	94	28	6.37	6.04	11.63	9.93
June	3.10	2.88	89.2	58.4	73.8	72.4	100	48	4.44	5.59	13.20	12.32
July	1.24	2.59	93.8	64.3	79.1	77.4	102	47	4.92	4.85	14.94	13.41
Aug.	2.51	2.56	88.5	63.1	75.8	75.5	105	54	3.70	4.17	10.21	11.19
Sept.	0.70	1.25	80.6	52.5	66.5	67.0	93	38	4.86	4.63	9.05	8.88
Oct.	4.69	0.91	69.5	39.7	54.6	54.9	91	24	5.54	4.84	6.19	6.52
Nov.	0.34	0.86	60.1	30.5	45.3	40.5	80	13	4.51	4.86	–	–
Dec.	0.03	0.41	45.4	16.0	30.7	31.3	73	-1	5.64	4.47	–	–
Annual	17.31	18.79	68.5	38.5	53.4	53.1	105	-1	5.02	5.25	73.16	70.60

Normal latest spring freeze (32°F): April 26. 2008: May 11.
Normal earliest fall freeze (32°F): Oct. 11. 2008: Oct. 24.
Normal frost-free period (> 32°F): 167 days. 2008: 166 days.
30-year averages are for the period 1971-2000. All recordings were taken at 8:00 a.m.

2008 Weather Information for Tribune

D. Bond and D. Nolan

Total yearly precipitation was 15.37 in., which is 2.07 in. below normal. Ten months had below-normal precipitation.

August (4.79 in.) was the wettest month. The largest single amount of precipitation was 1.10 in. on July 18. January was the driest month (0.07 in.). Snowfall for the year totaled 9.5 in.: 1.0 in. in January, 4.0 in. in February, 1.3 in. in November, and 3.2 in. in December for a total of 11 days of snow cover. The year began with four straight days of snow cover (January 1-4), which was the longest consecutive period.

Record high temperatures were recorded on 2 days: March 2 (81°F) and July 12 (106°F). Record high temperatures were tied on 2 days: August 2 (105°F) and November 3 (80°F). No record low temperatures were recorded. A record low temperature was tied on December 16 (-2°F). July was the warmest month with a mean temperature of 78.5°F. The hottest day of the year (106°F) was July 12. The coldest days of the year (-3°F) were January 17 and 22. January was the coldest month with a mean temperature of 28.5°F.

Mean air temperature was above normal for 8 months. November had the greatest departure above normal (5.7°F), and August had the greatest departure below normal (-1.6°F). There were 19 days of 100°F or above temperatures, which is 9 days above normal. There were 60 days of 90°F or above temperatures, which is 2 days below normal. The last day of 32°F or lower in the spring was May 11, which is 5 days later than the normal date, and the first day of 32°F or lower in the fall was October 23, which is 20 days later than the normal date. This produced a frost-free period of 165 days, which is 15 days more than the normal of 150 days.

April through September open-pan evaporation totaled 78.96 in., which is 8.31 in. above normal. Wind speed for this period averaged 5.1 mph, which is 0.4 mph less than normal.

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

	Precipitation		Monthly temperatures: 2008 avg.		Monthly temperatures: Normal		Monthly temperatures: 2008 extreme		Wind		Evaporation	
Month	2008	Normal	Max	Min	Max	Min	Max	Min	2008	Normal	2008	Normal
	---------in.---------		------------------------------------°F------------------------------------						-------mph-------		---------in.---------	
Jan.	0.07	0.45	43.5	13.4	42.2	12.8	67	-3	–	–	–	–
Feb.	0.24	0.52	48.0	18.3	48.5	17.1	68	2	–	–	–	–
Mar.	0.74	1.22	58.5	26.1	56.2	24.2	81	11	–	–	–	–
Apr.	0.89	1.29	64.0	32.8	65.7	33.0	90	21	5.4	6.3	9.11	8.28
May	0.37	2.76	78.6	44.5	74.5	44.1	96	25	5.9	5.8	16.46	10.88
June	1.23	2.62	89.4	54.8	86.4	54.9	101	43	4.3	5.3	15.96	13.88
July	2.56	3.10	95.2	61.7	92.1	59.8	106	45	5.8	5.4	18.50	15.50
Aug.	4.79	2.09	84.8	60.5	89.9	58.4	105	53	4.7	5.0	10.20	12.48
Sept.	0.83	1.31	78.7	48.9	81.9	48.4	93	39	4.7	5.2	8.73	9.63
Oct.	2.95	1.08	68.7	38.5	70.0	35.1	89	21	–	–	–	–
Nov.	0.37	0.63	58.9	28.9	53.3	23.1	81	17	–	–	–	–
Dec.	0.33	0.37	44.6	14.8	44.4	15.1	72	-4	–	–	–	–
Annual	15.37	17.44	67.8	37.0	67.1	35.5	106	-4	5.1	5.5	78.96	70.65

Normal latest spring freeze (32°F): May 6. 2008: May 11.
Normal earliest fall freeze (32°F): Oct. 3. 2008: Oct. 23.
Normal frost-free period (> 32°F): 150 days. 2008: 165 days.
Normal for precipitation and temperature is the 30-year average (1971-2000) from the National Weather Service.
Normal for latest freeze, earliest freeze, wind, and evaporation is the 30-year average (1971-2000) from Tribune weather data.

Long-Term Nitrogen and Phosphorus Fertilization of Irrigated Corn

A. Schlegel

Summary
Long-term research shows that phosphorus (P) and nitrogen (N) fertilizer must be applied to optimize production of irrigated corn in western Kansas. In 2008, N applied alone increased yields about 60 bu/a, whereas P applied alone increased yields about 20 bu/a. When N and P were applied together, however, yields were increased up to 120 bu/a. Averaged over the past 9 years, corn yields were increased up to 130 bu/a by N and P fertilization. Application of 120 lb/a N (with P) was sufficient to produce greater than 90% of maximum yield in 2008, which was similar to the 9-year average. In 2008, P increased corn yields more than 50 bu/a when applied with at least 120 lb/a N. Application of 80 instead of 40 lb/a P_2O_5 increased yields only 3 bu/a.

Introduction
This study was initiated in 1961 to determine responses of continuous corn and grain sorghum grown under flood irrigation to N, P, and potassium (K) fertilization. The study was 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
A field study was conducted at the Tribune Unit of the Southwest Research-Extension Center. Initial fertilizer treatments in 1961 were 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. Treatments were changed in 1992; the K variable was replaced by a higher rate of P (80 lb/a P_2O_5). All fertilizers were broadcast by hand in the spring and incorporated prior to planting. The soil is a Ulysses silt loam. Corn hybrids Pioneer 33A14 (2000), Pioneer 33R93 (2001 and 2002), DeKalb C60-12 (2003), Pioneer 34N45 (2004 and 2005), Pioneer 34N50 (2006), Pioneer 33B54 (2007), and Pioneer 34B99 (2008) were planted at about 30,000 to 32,000 seeds per acre in late April or early May. Hail damaged the 2005 and 2002 crops. Corn was irrigated to minimize water stress. Furrow irrigation was used in 2000, and sprinkler irrigation has been used since 2001. The center two rows of each plot were machine harvested after physiological maturity. Grain yields were adjusted to 15.5% moisture. After harvest in 2005, soil samples were collected and analyzed for soil test P (Mehlich-3) for the 0- to 6-in. depth and for inorganic N in the 0- to 24-in. depth (Table 1).

Results and Discussion
Application of 40 lb/a P_2O_5 annually has maintained soil test P levels similar to the start of the study, whereas soil test P levels have been increased when higher rates of fertilizer P have been applied since 1992 (Table 1). Without application of P fertilizer, soil test P levels have decreased to less than 10 ppm (Mehlich-3). As expected, residual inorganic

N levels are higher with increased rates of fertilizer N. Residual inorganic N levels are also higher when no fertilizer P is applied because of lower yields and less N removal in the grain.

Corn yields in 2008 were less than the 9-year average (Table 2). Nitrogen alone increased yields by 60 bu/a, whereas P alone increased yields by 20 bu/a. However, N and P applied together increased corn yields up to 120 bu/a. Only 120 lb/a N with P was required to obtain greater than 90% of maximum yield, which is similar to the 9-year average. Corn yields (averaged across all N rates) were only 3 bu/a greater with 80 than with 40 lb/a P_2O_5 in 2008, which is less than the 9-year average.

Table 1. Soil chemical properties after 45 years of nitrogen and phosphorus fertilizer application, Tribune, 2005

Nitrogen rate	Phosphorus rate	Mehlich 3-P 0 to 6 in.	NH_4-N 0 to 24 in.	NO_3-N 0 to 24 in.
--------------lb/a--------------		------------------------ppm------------------------		
0	0	7	3.0	1.7
	40	51	3.4	1.9
	80	79	3.2	1.8
40	0	7	3.6	3.6
	40	27	4.2	3.3
	80	64	3.5	2.7
80	0	10	4.0	5.7
	40	15	3.7	3.4
	80	49	3.5	3.7
120	0	6	3.6	8.5
	40	13	4.2	5.5
	80	49	3.4	4.4
160	0	7	4.6	10.5
	40	14	4.8	6.2
	80	32	3.7	5.9
200	0	6	4.1	13.3
	40	14	3.9	7.6
	80	35	3.4	9.5

continued

Table 1. Soil chemical properties after 45 years of nitrogen and phosphorus fertilizer application, Tribune, 2005

Nitrogen rate	Phosphorus rate	Mehlich 3-P 0 to 6 in.	NH_4-N 0 to 24 in.	NO_3-N 0 to 24 in.
--------------lb/a--------------		-----------------------ppm-----------------------		
ANOVA (P<F)				
Nitrogen		0.001	0.027	< 0.001
Linear		0.001	0.013	< 0.001
Quadratic		0.001	0.125	0.229
Phosphorus		0.001	0.054	< 0.001
Linear		0.001	0.152	< 0.001
Quadratic		0.001	0.050	0.026
Zero P vs. P		0.001	0.799	< 0.001
40 P vs. 80 P		0.001	0.017	0.977
Nitrogen*Phosphorus		0.001	0.901	0.211
Means				
Nitrogen	0 lb/a	45	3.2	1.8
	40	32	3.7	3.2
	80	25	3.8	4.2
	120	23	3.7	6.2
	160	18	4.4	7.5
	200	18	3.8	10.1
	LSD (0.05)	6	0.6	1.8
Phosphorus	0 lb/a	7	3.8	7.2
	40	22	4.0	4.6
	80	51	3.5	4.6
	LSD (0.05)	4	0.5	1.3

Table 2. Effect of nitrogen and phosphorus fertilization on irrigated corn yield, Tribune, 2000-2008

Fertilizer		Corn yield									
N	P_2O_5	2000	2001	2002	2003	2004	2005	2006	2007	2008	Mean
------- lb/a -------		------- bu/a -------									
0	0	131	54	39	79	67	49	42	49	36	60
0	40	152	43	43	95	97	60	68	50	57	74
0	80	153	48	44	93	98	51	72	51	52	74
40	0	150	71	47	107	92	63	56	77	62	81
40	40	195	127	69	147	154	101	129	112	105	126
40	80	202	129	76	150	148	100	123	116	104	128
80	0	149	75	53	122	118	75	79	107	78	95
80	40	205	169	81	188	209	141	162	163	129	161
80	80	211	182	84	186	205	147	171	167	139	166
120	0	143	56	50	122	103	66	68	106	65	87
120	40	204	177	78	194	228	162	176	194	136	172
120	80	224	191	85	200	234	170	202	213	151	186
160	0	154	76	50	127	136	83	84	132	84	103
160	40	203	186	80	190	231	170	180	220	150	179
160	80	214	188	85	197	240	172	200	227	146	185
200	0	165	130	67	141	162	109	115	159	99	127
200	40	207	177	79	197	234	169	181	224	152	180
200	80	218	194	95	201	239	191	204	232	157	192

continued

Table 2. Effect of nitrogen and phosphorus fertilization on irrigated corn yield, Tribune, 2000-2008

Fertilizer		Corn yield									
N	P_2O_5	2000	2001	2002	2003	2004	2005	2006	2007	2008	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
Linear		0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Quadratic		0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Phosphorus		0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Linear		0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Quadratic		0.001	0.001	0.007	0.001	0.001	0.001	0.001	0.001	0.001	0.001
N × P		0.008	0.001	0.133	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Means											
Nitrogen, lb/a											
0		145	48	42	89	87	53	61	50	48	69
40		182	109	64	135	132	88	103	102	91	112
80		188	142	73	165	178	121	137	146	115	141
120		190	142	71	172	188	133	149	171	118	148
160		190	150	71	172	203	142	155	193	127	156
200		197	167	80	180	212	156	167	205	136	167
LSD (0.05)		10	15	8	9	11	10	15	11	9	8
P_2O_5, lb/a											
0		149	77	51	116	113	74	74	105	71	92
40		194	147	72	168	192	134	149	160	122	149
80		204	155	78	171	194	139	162	168	125	155
LSD (0.05)		7	10	6	6	8	7	11	8	6	5

Nitrogen Management to Reduce Nitrate Leaching While Optimizing Profitability[1]

A. Schlegel, D. Mengel[2], L. Maddux[2], L. Stone[2], C. Thompson[2], T. Dumler, M. Alam, and J. Holman

Summary

Grain yield was increased by nitrogen (N) applications and resulted in increased grain N uptake and whole plant N uptake. Grain yields were similar for preplant, split, and sensor-based N applications. Neither the GreenSeeker nor chlorophyll meter indicated a need for supplemental N above the 120 lb/a N applied preplant. Water use and water use efficiency were increased by N applications. Optimal N rates did not exceed 160 lb/a. Optimal yields were obtained with less than 0.9 lb of fertilizer N per bushel of grain yield.

Introduction

This study was initiated in 2007 to provide information on the effect of N management practices on soil nitrate movement, water utilization, and profitability for irrigated corn. Higher N fertilizer costs have increased interest in improving efficiency of fertilizer use for corn production. Refined best management practices may increase N use efficiency, permit greater production in high productivity years, allow reduced N inputs by monitoring plant N status, and reduce N leaching potential by optimizing N fertilization and irrigation. Determining the effect of N management practices on nitrate movement, crop production, and producer profitability will allow for better use of scarce irrigation resources and reduce potential for nitrate leaching.

Procedures

A field study was initiated at the Tribune Unit of the Southwest Research-Extension Center. This site has deep silt loam soils formed from loess materials and relatively deep groundwater in the Ogallala Aquifer. The treatments consist of 10 N management strategies involving preplant only, split applications, and variable rates based on sensor technologies. Preplant-only treatments consist of three rates (120, 160, and 200 lb/a N). Split applications were made at the same N rates (120, 160, and 200 lb/a N) with 50% applied preplant and the remainder applied as a side-dress application (about 8-leaf stage). Three variable rate treatments are based on recently developed crop sensor technologies (GreenSeeker) and/or a chlorophyll meter. With these treatments, a preplant application of 100 lb/a N was made; the optical sensors were used to estimate yield potential at the 8-leaf stage, and additional N was applied accordingly.

Corn was planted in early May. Herbicides were used to control in-season weeds in all plots. Irrigations were scheduled to minimize water stress without excessive applications. Soil water content was measured throughout the growing season to confirm adequate (without excessive) irrigation. Whole plant samples were taken at the 6- to 8-leaf stage and after physiological maturity to determine N uptake. All plots were machine

[1] This project was supported by the Kansas Fertilizer Research Fund.

[2] K-State Dept. of Agronomy, Manhattan, KS

harvested with grain yields adjusted to 15.5% moisture. Grain samples were collected at harvest to determine N content.

Results and Discussion

In the second year of the project at Tribune, grain yield (despite being affected by hail damage) was increased by N applications (Table 1). The increase in yield was due to increased kernels per ear. The increase in grain yield resulted in increased grain N uptake and whole plant N uptake.

Grain yields were similar for preplant, split, and sensor-based N applications. Neither the GreenSeeker nor chlorophyll meter indicated a need for supplemental N above the 120 lb/a N applied preplant. Similar to grain yield, water use was greater following N applications. However, even with greater water use, water use efficiency was increased by N applications.

Optimal N rates did not exceed 160 lb/a. Total N uptake (grain plus stover) was generally equal to N applications when N fertilizer was applied at the optimal rate. Optimal yields were obtained with less than 0.9 lb of fertilizer N per bushel of grain yield.

Table 1. Nitrogen management of irrigated corn, Tribune, 2008

Starter N	Preplant N	Side-dress N[1]	Total N	Grain yield	Plant pop.	Ear pop.	Kernel weight	Kernel number	WUE[2]	Grain N	Grain N uptake	Stover	Stover N uptake	Total N uptake
-------lb/a-------				bu/a	----1000/a----		oz/1000	no./ear	lb/in.	%	-------lb/a-------			
20	0	0	20	106	31.4	30.2	12.07	257	246	1.32	68	4918	25	93
20	100	0	120	152	30.7	29.6	12.55	372	327	1.29	92	5833	29	122
20	140	0	160	187	31.9	30.8	12.84	423	399	1.37	122	6922	40	162
20	180	0	200	156	31.1	30.2	13.19	353	330	1.41	104	5563	41	145
20	40	60	120	146	32.0	31.0	12.40	341	310	1.34	93	5510	29	122
20	60	80	160	165	31.1	30.1	12.88	384	355	1.36	106	5746	35	141
20	80	100	200	168	30.9	29.9	13.20	383	346	1.37	109	6212	45	153
20	100	GS	120	153	31.7	30.5	12.72	360	316	1.36	98	5963	30	128
20	100	CH	120	168	30.8	30.4	12.64	391	345	1.35	107	6238	33	140
20	100	GS+CH	120	153	31.5	30.1	12.62	364	317	1.32	95	5719	32	127
LSD (0.05)				35	1.3	1.4	1.10	93	91	0.12	22	1449	10	26
ANOVA (P>F)														
Treatment				0.012	0.401	0.649	0.605	0.104	0.177	0.778	0.005	0.376	0.008	0.001
Selected contrasts														
Control vs. Treated				0.001	0.796	0.794	0.087	0.002	0.009	0.501	0.001	0.056	0.011	0.001
Preplant vs. Side-dress				0.571	0.803	0.714	0.919	0.620	0.554	1.000	0.576	0.493	0.913	0.609
Sensor vs. Preplant or Side-dress				0.607	0.751	0.832	0.497	0.849	0.408	0.661	4.424	0.979	0.055	0.157

[1] GS = GreenSeeker used at 6- to 8-leaf stage to determine side-dress N rate, no N required; CH = chlorophyll meter used at silking to determine in-season N rate, no N required; GS+CH = GreenSeeker used at 6- to 8-leaf stage to determine side-dress N rate plus chlorophyll meter at silking to determine additional in-season N if needed, no N required.

[2] Water use efficiency is pounds of grain per inch of water use.

No-Till Limited Irrigation Cropping Systems[1]

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

Summary
Research was initiated under sprinkler irrigation to evaluate limited irrigation in a no-till crop rotation. With limited irrigation (10 in. annually), continuous corn has been more profitable than multi-crop rotations including wheat, sorghum, and soybean primarily because of spring freeze and hail damage to wheat in the multi-crop rotations. In multi-crop rotations, relatively poor results with one crop (in this case wheat) can reduce profitability compared with a monoculture, especially when the monoculture crop does well. However, the multi-crop rotation can reduce economic risk when the monoculture crop does not perform as well. All multi-crop rotations had net returns about $50/a less than continuous corn. However, relatively small changes in prices or yields could result in any of the rotations being more profitable than continuous corn, indicating the potential for alternate crop rotations under limited irrigation.

Procedures
Research was initiated under sprinkler irrigation at the Tribune Unit of the Southwest Research-Extension Center in the spring of 2001. Objectives of this research are to determine the effect of limited irrigation on crop yield, water use, and profitability in several crop rotations. All crops are grown no-till; other cultural practices (hybrid selection, fertility practices, weed control, etc.) are selected to optimize production. All phases of each rotation are present each year and replicated four times. All rotations have annual cropping (no fallow years). Irrigations are scheduled to supply water at the most critical stress periods for the specific crops and are limited to 1.5 in./week. Soil water is measured at planting, during the growing season, and at harvest in 1-ft increments to a depth of 8 ft. Grain yields are determined by machine harvest. An economic analysis determines optimal crop rotations. Rotations include 1-, 2-, 3-, and 4-year rotations. Crop rotations are (1) continuous corn, (2) corn-winter wheat, (3) corn-wheat-grain sorghum, and (4) corn-wheat-grain sorghum-soybean (a total of 10 treatments). All rotations are limited to 10 in. of irrigation water annually, but the amount of irrigation water applied to each crop within a rotation varies depending on expected responsiveness to irrigation. For example, continuous corn receives the same amount of irrigation each year, but more water is applied to corn than to wheat in the corn-wheat rotation. Irrigation amounts are 15 in. to corn in 2-, 3-, and 4-year rotations, 10 in. to grain sorghum and soybean, and 5 in. to wheat.

Results and Discussion
Wheat followed corn in all rotations and received 5 in. of irrigation. All rotations were limited to 10 in. of irrigation; however, corn following wheat received 15 in. because the wheat received only 5 in. This extra 5 in. of irrigation increased corn yields up to 42 bu/a

[1] This research project received support from the Kansas Corn, Grain Sorghum, and Soybean Commissions, Western Kansas Groundwater Management District #1, and the Ogallala Aquifer Initiative.
[2] K-State Dept. of Agronomy, Manhattan, KS

compared with the continuous corn, which received only 10 in. of irrigation (Table 1). Corn yields following soybean were much less in 2008 than in previous years. This was the first year that corn following soybean yielded less than corn following wheat or grain sorghum. Grain sorghum yields were similar in the 3- and 4-year rotations.

Averaged over the past 6 years, corn yields were 35 to 38 bu/a greater in the multi-crop rotations with an additional 5 in. of irrigation compared with continuous corn (Table 2). Wheat and grain sorghum yields were similar regardless of length of rotation.

An economic analysis (based on October grain prices and input costs from each year) found that the most profitable rotation was continuous corn (Table 3). All multi-crop rotations had net returns of about $50/a less than continuous corn. Lower returns in the multi-crop rotations were mostly due to low returns from wheat. In about 50% of the years, wheat yields have been poor for a variety of reasons but mainly because of hail and spring freeze injury.

Table 1. Grain yield in 2008 of four crops as affected by rotation

	Grain yield			
Rotation	Corn	Wheat	Sorghum	Soybean
	----------bu/a----------			
Continuous corn	147	–	–	–
Corn-wheat	189	17	–	–
Corn-wheat-sorghum	179	17	144	–
Corn-wheat-sorghum-soybean	146	13	154	44

Table 2. Average grain yields from 2003-2008 of four crops as affected by rotation

	Grain yield			
Rotation	Corn	Wheat	Sorghum	Soybean
	----------bu/a----------			
Continuous corn	168	–	–	–
Corn-wheat	206	33	–	–
Corn-wheat-sorghum	205	37	140	–
Corn-wheat-sorghum-soybean	203	34	143	47

Table 3. Net return to land, irrigation equipment, and management from four rotations, 2003-2008[1]

	Net return			
Crop	CC	C-W	C-W-GS	C-W-GS-SB
	----------------------------	---------------------$/a	-----------------------------	
Corn	192	268	265	247
Wheat	–	0	-3	-3
Sorghum	–	–	147	155
Soybean	–	–	–	188
Net for rotation	192	134	136	137

[1] CC = continuous corn, C-W = corn-wheat, C-W-GS = corn-wheat-grain sorghum, C-W-GS-SB = corn-wheat-grain sorghum-soybean.

Four-Year Rotations with Wheat and Grain Sorghum

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

Summary

Research on 4-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) and wheat-sorghum-sorghum-fallow (WSSF) along with continuous wheat (WW). Soil water at wheat planting averages about 9 in. following sorghum, which is about 3 in. more than the second wheat crop in a WWSF rotation. Soil water at sorghum planting was approximately 1.2 in. less for the second sorghum crop compared with sorghum following wheat. Grain yield of recrop wheat averaged about 80% of wheat following sorghum. Grain yield of continuous wheat averaged about 70% of the yield of wheat grown in a 4-year rotation following sorghum. In most years, recrop wheat and continuous wheat yielded similarly. 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 averages about 70% 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 4-year and continuous cropping systems.

Procedures

Research on 4-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 12-year period. Water at planting of the second wheat crop in a WWSF rotation generally was less than 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 the first wheat crop in the rotation. Continuous wheat averaged about 0.75 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 in. over 13 years. Water at planting of the second sorghum crop in a WSSF rotation was generally less than the first sorghum crop but was slightly greater in 2008. Averaged across the entire study period, the first sorghum crop had about 1.2 in. more available water at planting than the second crop.

Grain Yields

In 2008, wheat yields were average for wheat following fallow but considerably lower than average for wheat following wheat (Table 1). Averaged across 12 years, recrop wheat (the second wheat crop in a WWSF rotation) yielded about 82% 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, however, recrop wheat yields were more than double the yield in all other rotations. This is possibly due to 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. Generally, there has been little difference in wheat yields following one or two sorghum crops. In most years, continuous wheat yields have been similar to recrop wheat yields; however, in 2007 and 2003, recrop wheat yields were considerably greater than continuous wheat yields.

Sorghum yields in 2008 were much lower than average (Table 2). This corresponds to the less than normal amount of soil water at planting. Similarly, in 2002, low yields corresponded to lower than normal available soil water at planting. Sorghum yields in 2008 were similar following one or two wheat crops, which is consistent with the long-term average. The second sorghum crop yield typically averages about 70% of the yield of the first sorghum crop, and in 2008, second-year sorghum yields were 60% of the first sorghum crop yield.

Table 1. Wheat response to rotation, Tribune, 1997-2008

	Wheat yield												
Rotation[1]	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	Mean
	---bu/a---												
Wssf	57	70	74	46	22	0	29	6	45	28	75	40	41
Wwsf	55	64	80	35	29	0	27	6	40	26	61	40	39
wWsf	48	63	41	18	27	0	66	1	41	7	63	5	32
WW	43	60	43	18	34	0	30	1	44	2	41	6	27
LSD (0.05)	8	12	14	10	14	–	14	2	10	8	14	5	3

[1] Capital letters denote current year crop.

Table 2. Grain sorghum response to rotation, Tribune, 1996-2008

	Grain sorghum yield													
Rotation[1]	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	Mean
	---bu/a---													
wSsf	58	88	117	99	63	68	0	60	91	81	55	101	50	72
wsSf	35	45	100	74	23	66	0	41	79	69	13	86	30	51
wwSf	54	80	109	90	67	73	0	76	82	85	71	101	57	73
LSD (0.05)	24	13	12	11	16	18	–	18	17	20	15	9	12	3

[1] Capital letters denote current year crop.

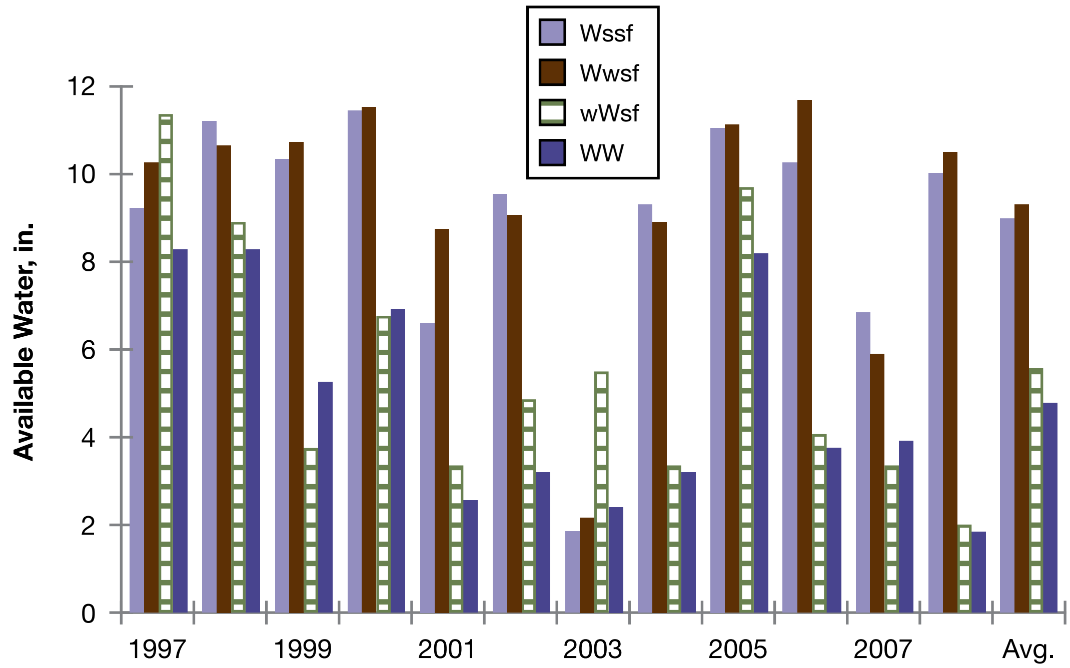

Figure 1. Available soil water at planting of wheat in several rotations, Tribune, 1997-2008.
Capital letter denotes current crop in rotation.

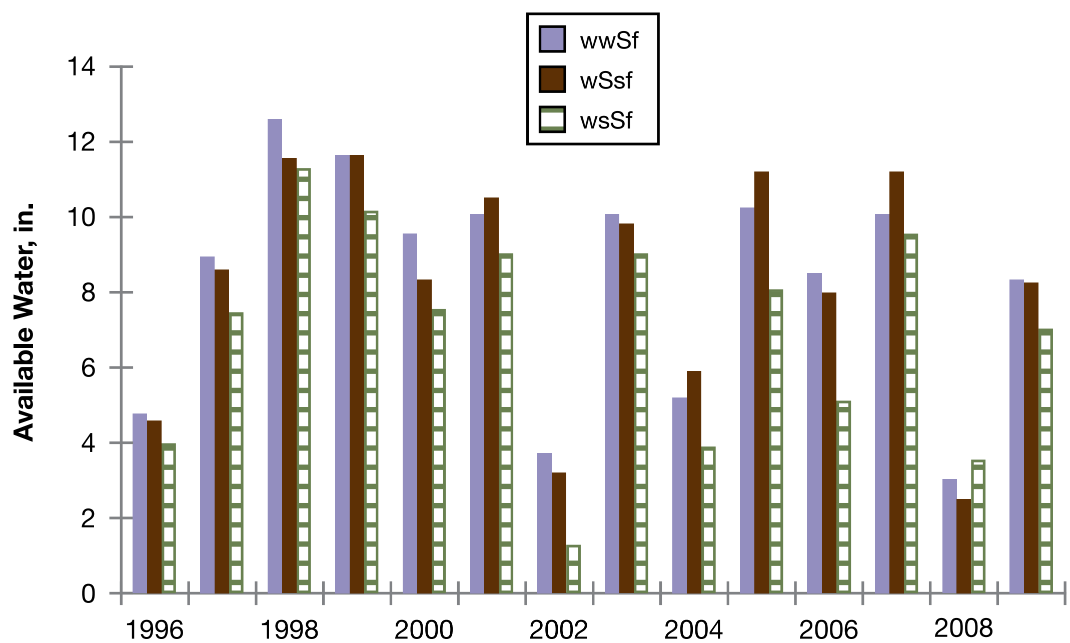

Figure 2. Available soil water at planting of sorghum in several rotations, Tribune, 1996-2008.
Capital letter denotes current crop in rotation. Last set of bars is average across years.

Conservation Tillage 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 8 years, no-till (NT) wheat yields were 4 bu/a greater than reduced tillage (RT) yields and 7 bu/a greater than conventional tillage (CT) yields. However, in 2008, NT wheat yields were less than yields with RT or CT. In contrast, grain sorghum yields in 2008 were 24 bu/a greater with NT than CT. Averaged over the past 8 years, NT sorghum yields were 23 bu/a greater than RT yields and 35 bu/a greater than CT yields.

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 CT, RT, and 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 by lack of precipitation in 4 of 8 years. Reduced tillage and NT increased wheat yields (Table 1). On average, wheat yields were 7 bu/a higher for NT (22 bu/a) than CT (15 bu/a). Wheat yields for RT were 3 bu/a greater than CT, even though both systems had tillage prior to wheat. In 2008, wheat yields for CT and RT were similar and greater than NT yields. This is the first year that NT yielded significantly less than CT.

The yield benefit from RT was greater for grain sorghum than wheat. Grain sorghum yields for RT averaged 12 bu/a more than CT, whereas NT averaged 23 bu/a more than RT (Table 2). For sorghum, both the 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 NT. In 2008, sorghum yields were 15 bu/a greater with NT than RT. 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 8 years, long-term NT has produced 23 bu/a more sorghum than short-term NT (51 vs. 28 bu/a).

[1] This research project was partially supported by the Ogallala Aquifer Initiative.

[2] K-State Dept. of Agronomy, Manhattan, KS

Table 1. Wheat response to tillage in a wheat-sorghum-fallow rotation, Tribune, 2001-2008

	Wheat yield				ANOVA (P>F)		
Year	Conven-tional	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		
Mean	15	18	22	3	0.001	0.001	0.001

Table 2. Grain sorghum response to tillage in a wheat-sorghum-fallow rotation, Tribune, 2001-2008

	Grain sorghum yield				ANOVA (P>F		
Year	Conven-tional	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	65	0.130		
2006	4	3	29	10	0.001		
2007	26	43	62	42	0.196		
2008	16	25	40	20	0.071		
Mean	16	28	51	6	0.001	0.001	0.001

Application of Animal Wastes for Irrigated Corn[1]

A. Schlegel, L. Stone[2], D. Bond, and M. Alam

Summary

Animal wastes are routinely applied to cropland to recycle nutrients, build soil quality, and increase crop productivity. This study evaluates established best management practices for land application of animal wastes on irrigated corn. Swine (effluent water from a lagoon) and cattle (solid manure from a beef feedlot) wastes have been applied annually since 1999 at rates to meet estimated corn phosphorus (P) or nitrogen (N) requirements along with a rate double the N requirement. Other treatments were N fertilizer (60, 120, and 180 lb/a N) and an untreated control. Corn yields were increased by application of animal wastes and N fertilizer. Overapplication of cattle manure has not had a negative effect on corn yield. Overapplication of swine effluent has not reduced corn yields, except in 2004 when the effluent had a much greater salt concentration than in previous years; this caused reduced germination and poor early growth.

Introduction

This study was initiated in 1999 to determine the effect of land application of animal wastes on crop production and soil properties. The two most common animal wastes in western Kansas were evaluated: solid cattle manure from a commercial beef feedlot and effluent water from a lagoon on a commercial swine facility.

Procedures

The rate of waste application was based on the amount needed to meet estimated crop P requirement, N requirement, or twice the N requirement (Table 1). The Kansas Department of Agriculture Nutrient Utilization Plan Form was used to calculate animal waste application rates. Expected corn yield was 200 bu/a. Allowable P application rates for the P-based treatments were 105 lb/a P_2O_5 because soil test P levels were less than 150 ppm Mehlich-3 P. The N recommendation model uses yield goal less credits for residual soil N and previous manure applications to estimate N requirements. For the N-based swine treatment, residual soil N levels after harvest in 2001, 2002, 2004, and 2006 were great enough to eliminate the need for additional N the following year. So, no swine effluent was applied to the 1X N treatment in 2002, 2003, 2005, and 2007 or to the 2X N requirement treatment because it is based on the 1X treatment (Table 1). The same situation occurred for the N-based treatments using cattle manure in 2003. Nutrient values used to calculate initial applications of animal wastes were 17.5 lb available N and 25.6 lb available P_2O_5 per ton of cattle manure and 6.1 lb available N and 1.4 lb available P_2O_5 per 1000 gal of swine effluent (actual analysis of animal wastes as applied varied somewhat from the estimated values, Table 2). Subsequent applications were based on previous analyses. Other nutrient treatments were three rates of N fertilizer (60, 120, and 180 lb/a N) and an untreated control. The N fertilizer treatments also received a uniform application of 50 lb/a P_2O_5. The experimental design was a randomized complete block with four replications. Plot size was 12 rows wide by 45 ft long.

[1] This project has received support from the Kansas Fertilizer Research Fund, Kansas Department of Health and Environment, and the Ogallala Aquifer Initiative.

[2] K-State Dept. of Agronomy, Manhattan, KS

The study was established in border basins to facilitate effluent application and flood irrigation. Swine effluent was flood-applied as part of a preplant irrigation each year. Plots not receiving swine effluent were also irrigated at the same time to balance water additions. Cattle manure was hand broadcast and incorporated. The N fertilizer (granular NH_4NO_3) was applied with a 10-ft fertilizer applicator. The entire study area was uniformly irrigated during the growing season with flood irrigation from 1999 through 2000 and sprinkler irrigation from 2001 through 2008. The soil is a Ulysses silt loam. Corn was planted at about 33,000 seeds per acre in late April or early May each year. Grain yields are not reported for 1999 because of severe hail damage. Hail also damaged the 2002 and 2005 crops. The center four rows of each plot were machine harvested after physiological maturity with yields adjusted to 15.5% moisture.

Results and Discussion

Corn yields were increased by all animal waste and N fertilizer applications in 2008, as has been the case for all years except 2002, when yields were greatly reduced by hail damage (Table 3). Type of animal waste affected yields in 7 of the 9 years, with higher yields achieved with cattle manure than with swine effluent. Averaged over the 9-year period, corn yields following application of cattle manure were 18 bu/a greater than yields following application of swine effluent on an N application basis. Overapplication (2X N) of cattle manure did not have a negative effect on grain yield in any year. In one year (2004), overapplication of swine effluent reduced corn yield. However, no adverse residual effect from the overapplication has been observed.

Table 1. Application rates of animal wastes, Tribune, 1999-2008

	Cattle manure									
Application basis[1]	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
	ton/a									
P requirement	15.0	4.1	6.6	5.8	8.8	4.9	3.3	6.3	5.9	7.6
N requirement	15.0	6.6	11.3	11.7	0	9.8	6.8	6.3	9.8	10.2
2X N requirement	30.0	13.2	22.6	22.7	0	19.7	13.5	12.6	19.6	20.4
	Swine effluent									
	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
	1000 gal/a									
P requirement	28.0	75.0	61.9	63.4	66.9	74.1	73.3	66.0	70.9	50.0
N requirement	28.0	9.4	37.8	0	0	40.8	0	16.8	0	17.6
2X N requirement	56.0	18.8	75.5	0	0	81.7	0	33.7	0	35.2

[1] Animal waste applications are based on the estimated requirement of nitrogen (N) and phosphorus (P) for a 200 bu/a corn crop.

Table 2. Analysis of animal waste as applied, Tribune, 1999-2008

	Cattle manure									
Nutrient content	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
	lb/ton									
Total N	27.2	36.0	33.9	25.0	28.2	29.7	31.6	38.0	18.8	26.0
Total P_2O_5	29.9	19.6	28.6	19.9	14.6	18.1	26.7	20.5	11.7	17.2
	Swine effluent									
	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
	lb/1000 gal									
Total N	8.65	7.33	7.83	11.62	7.58	21.42	13.19	19.64	10.09	13.22
Total P_2O_5	1.55	2.09	2.51	1.60	0.99	2.10	1.88	2.60	1.09	1.47

Table 3. Effect of animal waste and nitrogen fertilizer on irrigated corn, Tribune, 2000-2008

	Rate	Grain yield									
Nutrient source	basis[1]	2000	2001	2002	2003	2004	2005	2006	2007	2008	Mean
		bu/a									
Cattle manure	P	197	192	91	174	241	143	236	232	169	186
	N	195	182	90	175	243	147	217	230	165	183
	2X N	195	185	92	181	244	155	213	228	156	183
Swine effluent	P	189	162	74	168	173	135	189	217	128	159
	N	194	178	72	167	206	136	198	210	128	165
	2X N	181	174	71	171	129	147	196	216	128	157
N fertilizer	60 lb/a	178	149	82	161	170	96	178	112	99	136
	120 lb/a	186	173	76	170	236	139	198	195	144	169
	180 lb/a	184	172	78	175	235	153	200	225	146	174
Control	0	158	113	87	97	94	46	123	45	53	91
LSD (0.05)		22	20	17	22	36	16	18	15	18	10
ANOVA											
Treatment		0.034	0.001	0.072	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Selected contrasts											
Control vs. treatment		0.001	0.001	0.310	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Manure vs. fertilizer		0.089	0.006	0.498	0.470	0.377	0.001	0.001	0.001	0.001	0.001
Cattle vs. swine		0.220	0.009	0.001	0.218	0.001	0.045	0.001	0.001	0.001	0.001
Cattle 1X vs. 2X		0.900	0.831	0.831	0.608	0.973	0.298	0.646	0.730	0.316	0.936
Swine 1X vs. 2X		0.237	0.633	0.875	0.730	0.001	0.159	0.821	0.399	0.977	0.102
N rate linear		0.591	0.024	0.639	0.203	0.001	0.001	0.021	0.001	0.001	0.005
N rate quadratic		0.602	0.161	0.614	0.806	0.032	0.038	0.234	0.001	0.006	0.005

No yields reported for 1999 because of severe hail damage. Hail reduced corn yields in 2002 and 2005.

[1] Rate of animal waste applications are based on the amount needed to meet estimated crop phosphorus requirement (P), nitrogen requirement (N), or twice the N requirement (2X N).

Yield and Dry Matter Partitioning of Grain Sorghum Grown in Clumps

L. A. Haag and A. Schlegel

Summary
Clump planting has been proposed as a strategy to increase and/or stabilize dryland grain sorghum yields. Previous research has shown that planting in clumps reduces tiller development and early season vegetative growth. Results from 1 year of data show that planting geometry affected reproductive dry matter partitioning and the tillers per plant and heads per plant yield components. Mean values for kernels per head appeared to compensate for changes in the other yield components, leading to the numerical increase in grain yield for clump-planted sorghum.

Introduction
Seeding of grain sorghum in western Kansas typically occurs under favorable conditions for early plant growth and development. An important characteristic of grain sorghum is its ability to initiate tillers when environmental conditions are favorable. This flexible yield component allows sorghum to compensate during years of exceptionally good growing conditions. Alternatively, in years when growing conditions deteriorate after tiller initiation, plant available water has already been expended to develop tillers that seldom contribute to final grain yield. These tillers produce leaves that contribute to the transpirational demand of the plant and thus negatively affect the plant's water use efficiency. Previous research at Bushland, TX, and Tribune, KS, showed that growing grain sorghum in clumps reduced tiller initiation and development, reduced vegetative growth, and increased grain yields at yield potentials of less than 96 bu/a. Objectives of these two studies were to evaluate clump-planted sorghum in production-scale crop rotation plots and investigate differences in dry matter partitioning and the yield components of sorghum planted in clumps and conventionally.

Procedures
Studies are ongoing at the Southwest Research-Extension Center dryland station near Tribune, KS. From 2006 through 2008, the same sorghum hybrid was planted both conventionally and in a clump (four plants per clump) geometry within a large-scale dryland crop rotation study. Sorghum in both geometries was seeded at a rate of 33,000 seeds per acre in the first week of June. Starter fertilizer (10-34-0) at a rate of 8 gal/a was applied at planting as a surface dribble. Nitrogen was broadcast prior to planting at a rate of 100 lb/a N as urea-ammonium nitrate solution. At physiological maturity, plots measuring 20 × 450 ft or 20 × 900 ft were harvested with a commercial combine. Plot weights were obtained with a weigh wagon.

In 2008, an area within each large-scale plot was selected for use in dry matter partitioning and yield component analysis. Total plants, tillers, and heads were counted. At physiological maturity, 10 row-feet of sorghum plants were harvested at ground level. Aboveground biomass was partitioned in the field into leaf, reproductive, and stalk components. Biomass samples were dried at 140°F until they had reached oven dry weight.

Grain was harvested from the reproductive biomass samples with a stationary thresher. Seed weights were obtained from counting, drying, and weighting a subsample of 300 seeds from each plot.

Results and Discussion

Grain yields from the wheat-sorghum-fallow rotation in large-scale plots were analyzed across years (2006-2008). Planting geometry affected grain yield ($P = 0.0482$). Sorghum planted in clumps yielded 58 bu/a; this is 6.8 bu/a greater than conventionally planted sorghum, which yielded 51.2 bu/a.

In 2008, planting geometry affected reproductive partitioning of dry matter with clump-planted sorghum partitioning approximately 3% more dry matter into reproductive structures (panicle and grain) than conventionally planted sorghum (Table 1). Dry matter partitioning into stalks was less for clump-planted sorghum (LSD $\alpha = 0.10$). Leaf dry matter was also numerically lower for clump-planted sorghum. The difference in reproductive partitioning is reflected in the mean grain yield and harvest index for each treatment, with higher values for clump-planted sorghum. Tillers per plant and heads per plant were both reduced by planting sorghum in clumps. These two yield components were offset largely by an apparent increase in kernels per head.

Additional site-years of data will be necessary to robustly evaluate dry matter partitioning and yield component flexibility with regard to clump planting of sorghum. However, the dry matter partitioning and yield component differences observed in this year and the yield difference across years suggest that proposed theories regarding clump planting may have merit.

Table 1. Dry matter partitioning and yield components of clump and conventional planted grain sorghum, Tribune, 2008

Planting geometry	Biomass	Leaf dry matter[1]	Reproductive dry matter	Stalk dry matter	Grain yield	Harvest index	Tillers/ Plant	Heads/ Plant	Kernels/ Head	Kernel weight
	lb/a				bu/a					g/1000
Clump	8,276	0.160	0.526a	0.314	59.0	0.354	1.02b	1.97b	967	18.275
Conventional	7,890	0.170	0.496b	0.334	45.1	0.311	2.82a	3.72a	769	18.125
					ANOVA (P>F)					
Source										
Geometry	0.6662	0.1680	0.0252	0.0952	0.2376	0.1924	0.0016	0.0027	0.2741	0.7636
LSD (0.05)	–	–	0.0228	–	–	–	0.5217	0.6152	–	–

[1] Dry matter partitions are expressed as a decimal fraction of total biomass.
Within columns, means followed by the same letter are not significantly different at LSD = 0.05.

Effect of Stubble Height in a No-Till Wheat-Corn/Grain Sorghum-Fallow Rotation[1]

L. A. Haag and A. Schlegel

Summary
Various studies have been conducted since 2001 to evaluate the effect of winter wheat stubble height on subsequent grain yield of summer crops. A study started in 2006 was designed to evaluate the effect of three wheat stubble heights on grain yields of both corn and grain sorghum. Corn grain yields increased as stubble height increased. Grain sorghum yield response to stubble height was less apparent in any individual year but exhibited a quadratic response in an across-years analysis. Corn grain yields, averaged over previous studies starting in 2004 through the current study in 2008, were 55, 60, and 65 bu/a for the short cut, tall cut, and stripped stubble treatments, respectively. From 2001 through the present, neither tall cut nor stripped stubble has resulted in lower corn grain yields than short cut stubble. Data from this study and others suggest producers should increase cutting heights or adopt stripper header technology where practical.

Introduction
Seeding of summer row crops throughout the west-central Great Plains typically occurs following wheat. Wheat residue provides numerous benefits including evaporation suppression, delayed weed growth, improved capture of winter snowfall, and soil erosion reductions. Stubble height affects wind velocity profile, surface radiation interception, and surface temperatures, all of which affect evaporation suppression and winter snow catch. Taller wheat stubble is also beneficial to pheasants in postharvest and over-winter fallow periods. Use of stripper headers increases harvest capacity and provides taller wheat stubble than previously attainable with conventional small grains platforms. Increasing wheat cutting heights or using a stripper header should further improve the effectiveness of standing wheat stubble. The purpose of this study is to evaluate the effect of wheat stubble height on subsequent summer row crop yields.

Procedures
Studies are ongoing at the Southwest Research-Extension Center dryland station near Tribune, KS. In 2007 and 2008, corn and grain sorghum were planted into standing wheat stubble of three heights. Optimal cutter bar height is the height necessary to maximize both grain harvested and standing stubble remaining (typically around two thirds of total plant height), the short cut treatment was half of optimal cutter bar height, and the third treatment was stubble remaining after stripper header harvest. In 2007, these heights were 7, 14, and 22 in. In 2008, heights of 10, 20, and 30 in. were obtained. Corn and grain sorghum were seeded at rates of 15,000 and 33,000 seeds per acre, respectively. Nitrogen was applied to all plots at a rate of 100 lb/a N. Starter fertilizer (10-34-0) was applied in-row at rates of 7 and 9 gal/a for corn and sorghum, respectively. Plots measured 40 × 60 ft with treatments arranged in a randomized complete block design. Two rows from the center of each plot were harvested with a plot combine for

[1] This research project receives support from the Kansas Department of Wildlife and Parks.

yield and yield component analysis. Soil water measurements were obtained by neutron attenuation to a depth of 6 ft in 1-ft increments at seeding and harvest to determine water use and water use efficiency.

Results and Discussion

2008

The 2008 growing season started off with below normal available soil water and in-season precipitation. High levels of surface residue and cool temperatures were believed to help reduce soil water evaporation and enabled the crop to progress until precipitation was received in the later portion of the growing season (late July into August). As a result, respectable dryland yields for both corn and grain sorghum were observed in the study. Corn grain yields increased from 67 to 77 bu/a as stubble height increased (Table 1). Final plant population and kernels per ear increased with stubble height, indicating lower rates of in-season plant mortality and better kernel set at silking. Kernel weight for the stripped treatment was lower than for either the high or low cut stubble. The trend in corn yields, although not statistically significant, resembles results from a similar, 2-year study at Tribune in which corn yields averaged 39, 45, and 49 bu/a for low, high, and stripped stubble treatments, respectively. Grain sorghum yields were not different among stubble height treatments at $P < 0.10$ (Table 2). The kernels per head yield component was higher for the stripped and high cut stubble treatments (Table 2.)

2007-2008 Across Years

An across-years analysis was conducted with data from this study. Over the 2 years, corn grain yield increased from 69 to 80 bu/a as stubble height increased (Table 3). Increased grain yields are the result of the effect of stubble height on two critical yield components. In-season plant mortality was, on average, 466 plants per acre less in the stripped stubble than either the high or low cut stubble. Kernels per ear also increased with increasing stubble height from 393 for the low cut to 449 for the stripped stubble treatment. Corn grown in stripped stubble produced higher grain yields without a proportional increase in water use as water use efficiency increased from 300 lb/in. for the short cut stubble to 346 lb/in. for the stripped stubble treatment.

Over the 2 years, sorghum grain yields exhibited a quadratic response to stubble height with high cut stubble producing grain yields 6 to 7 bu/a higher than either the stripped or short cut treatment (Table 4). An examination of yield components revealed that kernels per head increased with increasing stubble height. Although no statistical differences were observed, heads per plant yield also exhibited a quadratic response to stubble height. Future efforts in this study will involve more emphasis on yield components, specifically tillers per plant, in an effort to identify any interaction between tillering and the production environment created by stripped stubble. Such an interaction may need to be compensated for by increasing seeding rates.

Acquiring long-term data sets is important for evaluating the effects of stubble height across a wide range of environments. Additional years of observation are needed to identify any potential effect of stubble height on the yield components of grain sorghum.

Table 1. Corn yield and yield components as affected by stubble height, Tribune, 2008

Stubble height	Grain yield	Moisture	Test weight	Plant population	Ear population	Residue	Residue/ Yield	Kernel weight	Kernels/ Ear	WUE[1]
	bu/a	%	lb/bu	1,000 plants/a	1,000 ears/a	lb/a	lb/lb	oz/1000		lb/in.
Strip	77	20.5	55.3	14.0a	15.4	5,682	1.3	10.94b	406	334
High	74	21	55.0	13.4b	14.6	6,940	1.7	11.28a	403	320
Low	67	21.4	54.4	13.2b	14.5	6,208	1.7	11.44a	363	290
					ANOVA (P>F)					
Source										
Stubble	0.183	0.121	0.07	0.016	0.236	0.471	0.413	0.013	0.243	0.179
LSD (0.05)	–	–	0.8	0.5	–	–	–	0.31	–	–

[1] WUE = water use efficiency.
Within columns, means followed by the same letter are not significantly different at LSD = 0.05.

Table 2. Sorghum yield and yield components as affected by stubble height, Tribune, 2008

Stubble height	Grain yield	Moisture	Test weight	Plant population	Head population	Residue	Residue/ Yield	Kernel weight	Kernels/ Head	WUE[1]
	bu/a	%	lb/bu	1,000 plants/a	1,000 heads/a	lb/a	lb/lb	oz/1000		lb/in.
Strip	72	12.7	56.5	15.9	52.3	5,231	1.3	0.76	1,610a	317
High	78	12.9	57.2	16.0	54.9	5,354	1.2	0.83	1,540a	344
Low	71	12.7	56.7	17.1	54.0	5,938	1.5	0.85	1,392b	313
					ANOVA (P>F)					
Source										
Stubble	0.389	0.732	0.550	0.669	0.538	0.139	0.195	0.312	0.016	0.401
LSD (0.05)	–	–	–	–	–	–	–	–	138	–

[1] WUE = water use efficiency.
Within columns, means followed by the same letter are not significantly different at LSD = 0.05,

Table 3. Corn yield and yield components as affected by stubble height, Tribune, 2007-2008

Stubble height	Grain yield	Moisture	Test weight	Plants/ Acre	Ears/ Acre	Residue	Residue/ Yield	Kernel weight	Kernels/ Ear	Ears/ Plant	WUE[1]
	bu/a	%	lb/bu			lb/a	lb/lb	oz/1000			lb/in.
Strip	80.0a	16.7	57.5	14,641a	15,222	6,081	1.37	10.54	449a	1.04	346a
High	75.0ab	16.8	57.4	14,157b	14,617	6,804	1.66	10.69	432ab	1.04	325ab
Low	69.1b	16.8	57.1	14,193b	14,702	6,082	1.58	10.81	393b	1.04	300b
						ANOVA (P>F)					
Source											
Stubble	0.0240	0.7516	0.2247	0.0190	0.0997	0.3162	0.1810	0.1106	0.0497	0.9353	0.0286
LSD (0.05)	7.6	–	–	362	–	–	–	–	45	–	33

[1] WUE = water use efficiency.
Within columns, means followed by the same letter are not significantly different at LSD = 0.05.

Table 4. Sorghum yield and yield components as affected by stubble height, Tribune, 2007-2008

Stubble height	Grain yield	Moisture	Test weight	Plants/ Acre	Heads/ Acre	Residue	Residue/ Yield	Kernel weight	Kernels/ Head	Heads/ Plant	WUE[1]
	bu/a	%	lb/bu			lb/a	lb/lb	oz/1000			lb/in.
Strip	90.0ab	12.2	58.6	18,670	47,589	5,324	1.11	0.92	1,857	2.68	402ab
High	95.9a	12.2	59.0	18,719	49,598	5,607	1.08	0.97	1,820	2.78	427a
Low	88.9b	10.1	58.6	18,961	48,775	5,616	1.21	0.97	1,718	2.68	398b
						ANOVA (P>F)					
Source											
Stubble	0.0696	0.5763	0.5147	0.9296	0.4088	0.6287	0.3891	0.2265	0.1377	0.7660	0.0863
LSD (0.05)	6.3	–	–	–	–	–	–	–	–	–	27

[1] WUE = water use efficiency.
Within columns, means followed by the same letter are not significantly different at LSD = 0.05.

Corn and Grain Sorghum Production with Limited Irrigation

N. Klocke and R. S. Currie

Introduction

Soil water management during the growing and non-growing seasons can be enhanced with crop residues. Capture and retention of soil water plus irrigation at critical growth stages can maximize limited irrigation resources. This research quantified the water use and irrigation requirements of corn and grain sorghum grown with optimum water management through water conservation techniques. Corn grain yields declined with less than full irrigation, but sorghum grain yields remained nearly constant. Net economic returns increased as more irrigation was applied to corn but decreased with additional irrigation on sorghum. When irrigation was reduced in corn and sorghum production, there was less effect on grain yield from the same proportional decrease in irrigation. For example, a 50% reduction in full irrigation caused a 20% reduction in corn grain yields. Sorghum grain yields were reduced by 8% with a 72% reduction in irrigation. However, net economic return from corn production increased at the same rate with additional irrigation. Additional irrigation decreased annual net returns from sorghum production. Irrigators, responding to economic returns from their irrigation practices, would tend to fully irrigate corn and reduce irrigation for sorghum.

Objectives

The overall goal of the project was to conduct cropping systems field research with an emphasis on crop yield response to full and limited irrigation. Specific objectives were to:

1. Measure grain production of corn and grain sorghum with deficit irrigation and no-till management.
2. Determine soil water during the growing season and non-growing season to assess the effects of irrigation on soil water storage and use.
3. Find the net economic returns of corn and grain sorghum receiving irrigation from deficit to fully irrigated management.

Procedures

The cropping systems project was located at the Southwest Research-Extension Center near Garden City, KS. Deficit irrigation strategies and no-till management strategies were used to test crop responses to limited water supplies. Six irrigation treatments, replicated four times, ranged from 3 to 12 in. for corn and 2 to 8 in. for sorghum. If rainfall was sufficient to fill the soil profile to field capacity, irrigation was not applied. Irrigation treatments were the same for each plot from year to year, so the antecedent soil water carried over to the next year. The days between irrigation events increased as growing season irrigation decreased (Table 1). The same net irrigation (1 in.) was applied for each irrigation event. Soil water was measured once every 2 weeks with the neutron attenuation method in increments of 12 in. to a depth of 8 ft. Ending season and beginning season soil water measurements were used to calculate soil water accumulations during the non-growing season and soil water use during the growing season. The

soil was a Ulysses silt loam with an available water capacity of 2 in./ft and volumetric water content of 33% at field capacity and 17% at permanent wilting. Cultural practices, including hybrid selection, no-till planting techniques, fertilizer applications, and weed control, were the same across irrigation treatments. Yield-irrigation relationships were used along with current commodity price and crop production costs to determine net economic returns from corn and sorghum crops across irrigation treatments.

Results and Discussion

Relative yields were calculated as the ratio of irrigation treatment yields to fully irrigated yields for corn and sorghum (Table 2). Relative yield results were expressed as percentages of yields for the fully irrigated treatment. In the same fashion, relative irrigation was calculated as the ratio of irrigation amount of each treatment to the fully irrigated treatment. For example, the corn treatment that received 9 in. of water produced 92% of the yield of the fully irrigated treatment with 74% of the irrigation. Corn grain yields decreased at a decreasing rate as irrigation was reduced. Sorghum yields from the driest irrigation treatment produced only 5 bu/a less that the fully irrigated treatment. The driest irrigation treatment produced 96% of full yield with 28% of the water.

Results in Table 2 are 4-year averages for each irrigation treatment. Variation in crop yields from year to year is important to evaluate income risk. Data for each irrigation treatment each year of the study are shown in Figures 1 and 2. Trends of corn relative yields (the line in Figure 1) show decreasing yields with less irrigation, but sorghum relative yields remained constant. The distance of the data points from the trend line indicates the variation in yields from year to year. Corn yield variation increased for less than 10 in. of irrigation. Variation in sorghum yields remained constant from the most to least irrigation. Yield variation can influence crop rotation choices.

Soil water accumulated during the non-growing season (Table 3). As irrigation decreased, the crop developed roots deeper into the soil and extracted more soil water, creating more room to store water during the following non-growing season (data not shown). There was a correspondence between water stored and water used during the following season. More soil water use followed more water storage. More water accumulated prior to sorghum than corn because there was more time to accumulate soil water from wheat harvest to sorghum planting.

Yield results from the field study and crop prices were used to calculate gross income for corn sorghum (Tables 4 and 5). Net income was calculated as the difference in gross income and production costs including irrigation costs. These commodity prices and production costs can vary over time and from one producer to the next. In this example, corn could be planted on the entire field or planted on half the field and rotated with sorghum. Irrigation pumping capacity can limit the amount of irrigation that can be delivered to the crop. If 9 in. of irrigation were available during the growing season, the net return would be approximately $280/a, or $36,400 for a 130-acre field. If corn was rotated with sorghum and 12 in. of irrigation were applied to corn, the net return would be $350/a for corn. Sorghum would receive 6 in. of water for a net return of $125/a. The combined net return for 130 acres would be $30,800. The difference in net return between continuous corn and the rotation is not the only consideration. Income variability from one year to the next would be less for the rotation because the corn yield would be less variable.

Table 1. Days between irrigation events for irrigation treatments

Irrigation treatment	Corn	Sorghum
	---days---	
1 High	4.5	4.9
2	5.5	5.6
3	6.0	6.3
4	8.3	11.1
5	10.8	13.2
6 Low	13.8	15.7

Table 2. Average grain yields, relative grain yields, irrigation, and relative irrigation for corn after corn and sorghum after wheat for 2004-2007

Corn after corn 2004-2007				Sorghum after wheat 2004-2007			
Average yield	Relative yield	Annual irrigation	Relative irrigation	Average yield	Relative yield	Annual irrigation	Relative irrigation
bu/a	%	in.	%	bu/a	%	in.	%
205	100	12	100	122	100	7	100
199	99	10	85	125	100	6	86
185	92	9	74	124	100	5	72
163	81	6	52	117	100	4	48
141	70	5	39	117	96	3	34
119	59	3	29	117	96	2	28

Table 3. Stored soil water gains during the previous non-growing season and stored soil water use during the growing season for corn following corn and sorghum following wheat

Corn			Sorghum		
Irrigation	Soil water gain	Soil water use	Irrigation	Soil water gain	Soil water use
			---in.---		
12	3.3	1.8	8	6.8	4.3
10	4.9	2.3	6.7	6.4	4.7
8	4.9	3.2	5.3	7.5	5.5
6	5.9	2.9	4	7.8	5.8
4.5	5.7	3.9	3	8.0	6.3
3	6.0	4.3	2	7.9	6.9

Table 4. Net returns (gross income – production costs) for corn after corn

Net irrigation	Corn price	Grain yield	Gross income	Irrigation cost	Production costs[1]	Net return
in.	$/bu	bu/a	$/a	$/a-in.	----------$/a----------	
11.5	4	205	820	9	471	349
9.8	4	199	796	9	507	289
8.5	4	185	740	9	474	266
6	4	163	652	9	427	225
4.5	4	141	564	9	380	185
3.3	4	119	476	9	344	132

[1] Includes irrigation costs.

Table 5. Net returns (gross income – production costs) for irrigated sorghum after wheat

Net irrigation	Sorghum price	Grain yield	Gross income	Irrigation cost	Production costs[1]	Net return
in.	$/bu	bu/a	$/a	$/a-in.	----------$/a----------	
7.3	3.5	119	416	9	301	115
6.3	3.5	116	406	9	286	120
5.3	3.5	114	400	9	270	131
3.5	3.5	107	376	9	253	123
2.5	3.5	109	382	9	246	136
2.0	3.5	109	381	9	235	146

[1] Includes irrigation costs.

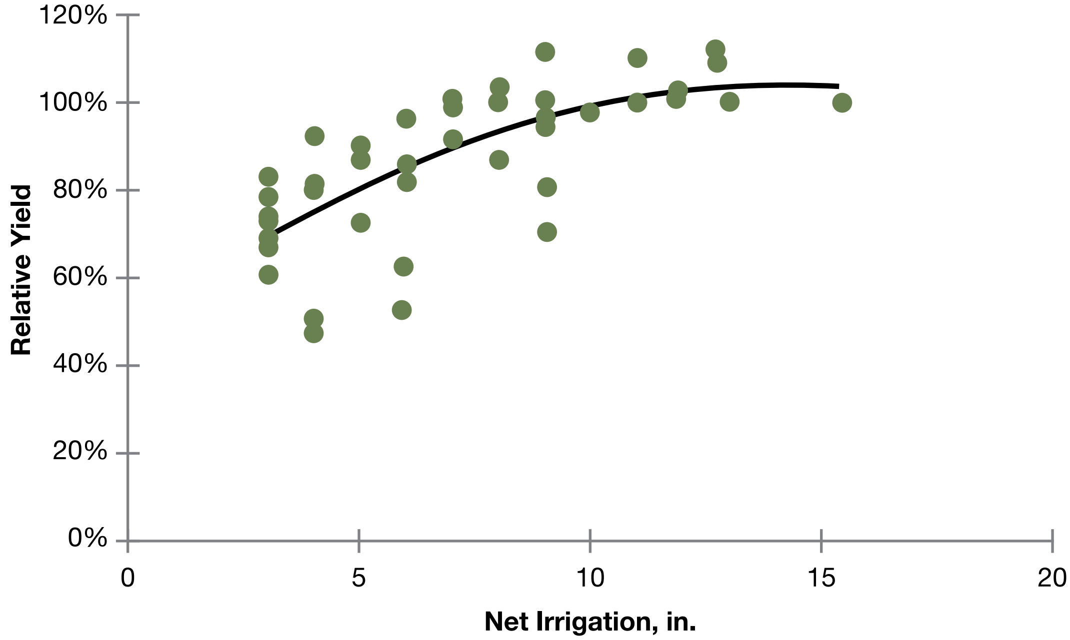

Figure 1. Trend and variation in relative yields for corn.

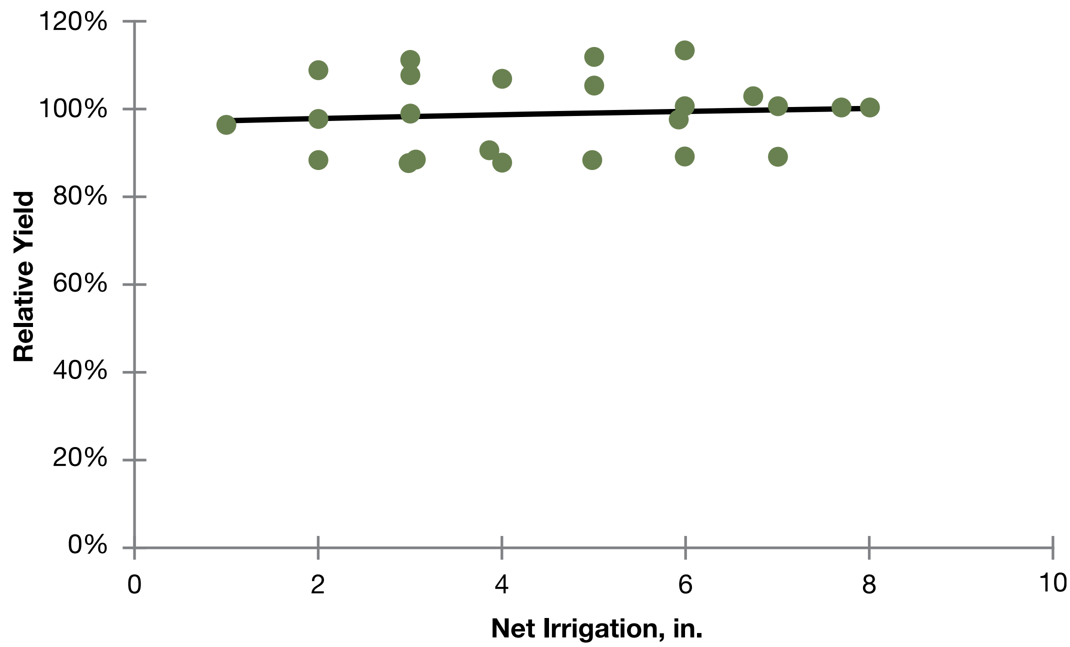

Figure 2. Trend and variation in relative yields for sorghum.

Managing Irrigation with Diminished Capacity Wells[1]

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

Summary
Corn yields were increased an average of 13 bu/a by preseason irrigation. As expected, grain yields increased with increased well capacity. Grain yields (averaged across preseason irrigation and plant population) were 15% greater when well capacity was increased from 0.1 to 0.2 in./day. Optimum plant population varied with irrigation level. A plant population of 22,500 plants per acre was adequate with the lowest well capacity and without preseason irrigation. When well capacity increased to 1.5 in./day, 27,500 plants per acre were required to optimize yields without preseason irrigation; with preseason irrigation, a higher population was required. With a well capacity of 0.2 in./day, 32,500 plants per acre provided greater yields with or without preseason irrigation. Preseason irrigation increased available soil water at planting by about 2 in. Preseason irrigation is a viable practice when in-season well capacity cannot fully meet crop needs. Plant populations should be adjusted for irrigation level, taking into account both well capacity and preseason irrigation.

Procedures
An ongoing field study is being conducted at the Tribune Unit of the Southwest Research-Extension Center to evaluate preplant irrigation (0 and 3 in.), well capacities (0.1, 0.15, and 0.2 in./day capacity), and plant population (22,500, 27,500, and 32,500 plants per acre). Irrigation treatments are whole plots; plant populations are subplots. Each treatment combination is replicated four times and applied to the same plot each year. Corn is planted in late April or early May each year. All plots are machine harvested; grain yields are adjusted to 15.5% moisture. Plant populations are determined along with yield components. Soil water measurements (8-ft depth, 1-ft increments) are taken throughout the growing season by neutron attenuation. Crop water use is calculated by summing soil water depletion (soil water at planting less soil water at harvest) plus in-season irrigation and precipitation. In-season irrigations were 9.55, 12.61, and 19.01 in. in 2006; 7.21, 10.10, and 15.62 in. in 2007; and 8.22, 10.96, and 14.77 in. in 2008 for the 0.1, 0.15, and 0.2 in./day well capacity treatments, respectively. In-season precipitation was 6.93 in. in 2006, 8.08 in. in 2007, and 9.36 in. in 2008. Water use efficiency is calculated by dividing grain yield (lb/a) by crop water use.

Results and Discussion
Preseason irrigation increased grain yields an average of 19 bu/a (Table 1). Although not significant, the effect was greater at lower well capacities. For example, with 27,500 plants per acre, preseason irrigation (3 in.) increased grain yield by 26 bu/a with a well capacity of 0.1 in./day but only by 5 bu/a with a well capacity of 0.2 in./day. As

[1] This research project was partially supported by the Ogallala Aquifer Initiative.
[2] K-State Dept. of Agronomy, Manhattan, KS

expected, grain yields increased with increased well capacity. Grain yields (averaged across preseason irrigation and plant population) were 38% greater when well capacity increased from 0.1 to 0.2 in./day. Number of seeds per ear increased with increased well capacity and preseason irrigation.

Optimum plant population varied with irrigation level. A plant population of 22,500 plants per acre was adequate with the lowest well capacity and without preseason irrigation. However, if preseason irrigation was applied, a higher plant population (27,500 plants per acre) increased yields even at the lowest well capacity. When well capacity increased to 0.15 in./day, 27,500 plants per acre were required to optimize yields without preseason irrigation; with preseason irrigation, a higher population was required. With a well capacity of 0.2 in./day 32,500 plants per acre provided greater yields with or without preseason irrigation.

Water use efficiency was greatest at the highest well capacity (Table 1). Preseason irrigation tended to increase water use efficiency. Similar to grain yields, the effect of plant population varied with irrigation level. At lower irrigation levels, a plant population of 27,500 plants per acre tended to optimize water use efficiency, whereas at the highest well capacity, higher plant population improved water use efficiency.

Crop water use increased with increased well capacity and preseason irrigation (Table 2). Soil water at harvest increased with increased well capacity, but this caused less soil water to accumulate during the winter. Preseason irrigation increased available soil water at planting by about 2 in. Seeding rate had minimal effect on soil water at planting or harvest, water accumulation during fallow, or crop water use.

Table 1. Crop parameters as affected by well capacity, preseason irrigation, and seeding rate, Tribune, 2006-2008

Well capacity	Preseason	Seed rate	Yield	WUE[1]	Plant pop.	Ear pop.	Barren	Ear weight	1000 seed	Kernel	
in./day		10^3/a	bu/a	lb/in.	---10^3/a---		%	lb	oz	no./head	no./ft^2
0.10	no	22.5	140	376	22.5	21.3	5	0.36	13.12	441	223
		27.5	143	388	27.1	24.5	10	0.31	12.63	407	240
		32.5	139	370	31.5	28.4	10	0.26	12.35	347	239
	yes	22.5	161	401	21.9	21.3	3	0.42	13.26	513	255
		27.5	169	413	27.1	25.2	7	0.37	12.99	458	271
		32.5	169	412	31.8	29.2	8	0.32	12.63	406	280
0.15	no	22.5	161	381	22.2	20.9	6	0.42	13.07	521	256
		27.5	164	395	27.4	26.1	5	0.35	12.73	445	270
		32.5	154	368	31.5	29.1	8	0.29	12.83	366	252
	yes	22.5	179	410	22.5	22.0	3	0.45	13.21	552	279
		27.5	188	433	27.2	26.1	4	0.40	12.89	499	302
		32.5	192	433	31.6	30.1	5	0.35	12.69	452	316
0.20	no	22.5	198	420	22.4	22.0	2	0.51	13.08	619	311
		27.5	209	427	27.3	26.9	1	0.44	12.85	544	335
		32.5	220	452	32.1	31.4	2	0.39	12.52	502	361
	yes	22.5	201	412	22.2	21.7	2	0.52	13.37	621	309
		27.5	214	428	27.3	26.9	1	0.45	13.05	549	338
		32.5	225	451	32.1	31.3	3	0.40	12.57	515	368

continued

Table 1. Crop parameters as affected by well capacity, preseason irrigation, and seeding rate, Tribune, 2006-2008

Well capacity	Preseason	Seed rate	Yield	WUE[1]	Plant pop.	Ear pop.	Barren	Ear weight	1000 seed	Kernel	
in./day		10^3/a	bu/a	lb/in.	---10^3/a---		%	lb	oz	no./head	no./ft^2
Means											
	Well capacity	0.10	153	393	27.0	25.0	7	0.34	12.83	429	251
		0.15	173	403	27.0	25.7	5	0.38	12.90	472	279
		0.20	211	431	27.2	26.7	2	0.45	12.91	558	337
		LSD (0.05)	14	31	0.2	0.7	2	0.03	0.35	28	19
	Preseason	no	170	397	27.1	25.6	5	0.37	12.80	466	276
		yes	189	421	27.1	26.0	4	0.41	12.96	507	302
		LSD (0.05)	11	26	0.2	0.6	2	0.02	0.29	23	16
	Seed rate	22,500	173	400	22.3	21.5	3	0.45	13.18	544	272
		27,500	181	414	27.2	25.9	5	0.39	12.86	484	293
		32,500	183	414	31.8	29.9	6	0.34	12.60	431	303
		LSD (0.05)	4	10	0.2	0.3	1	0.01	0.11	12	7

[1] WUE = water use efficiency.

Table 2. Soil profile available water for corn as affected by well capacity, preseason irrigation, and seeding rate, Tribune, 2006-2008

			Available water				
Well capacity	Preseason	Seed rate	Previous harvest	Planting	Harvest	Water use	Fallow accum.
in./day		10^3/a	---------in./8 ft profile---------			in.	in./8 ft. profile
0.10	no	22.5	4.52	8.38	5.03	19.79	3.07
		27.5	4.39	8.22	4.89	19.78	2.89
		32.5	4.18	8.13	4.46	20.11	2.83
	yes	22.5	5.00	10.80	5.23	22.01	5.25
		27.5	4.75	10.75	4.77	22.43	5.44
		32.5	5.04	11.02	4.97	22.50	5.28
0.15	no	22.5	5.46	9.21	5.44	23.12	3.03
		27.5	5.76	9.27	6.06	22.55	2.73
		32.5	5.41	9.18	5.66	22.86	3.20
	yes	22.5	5.85	10.63	5.85	24.13	3.93
		27.5	5.41	10.28	5.59	24.04	4.63
		32.5	5.41	10.57	5.38	24.54	4.69
0.20	no	22.5	8.86	10.53	8.68	26.43	2.13
		27.5	7.14	9.91	7.15	27.35	3.08
		32.5	8.27	10.53	7.89	27.23	2.47
	yes	22.5	10.28	13.11	10.40	27.30	2.84
		27.5	9.73	12.97	9.57	27.99	3.16
		32.5	9.73	12.75	9.48	27.86	3.13
Means							
	Well capacity	0.10	4.65	9.55	4.89	21.11	4.13
		0.15	5.55	9.86	5.66	23.54	3.70
		0.20	9.00	11.63	8.86	27.36	2.80
		LSD (0.05)	1.80	1.44	1.72	0.48	0.54
	Preseason	no	6.00	9.26	6.14	23.25	2.83
		yes	6.80	11.43	6.81	24.76	4.26
		LSD (0.05)	1.47	1.18	1.40	0.40	0.44
	Seed rate	22.5	6.66	10.44	6.77	23.80	3.37
		27.5	6.20	10.23	6.34	24.02	3.66
		32.5	6.34	10.36	6.31	24.18	3.60
		LSD (0.05)	0.30	0.25	0.24	0.21	0.39

Previous harvest available water and fallow accumulation include only 2007 and 2008 data.

A Survey of Center Pivot Sprinkler Packages and Characteristics in Kansas[1]

M. Alam, D. Rogers[2], and L. K. Shaw[3]

Summary
The dominant center pivot nozzle package of western Kansas is a fixed plate nozzle positioned near to the ground using a drop tube. The dominant system in south central Kansas is a moving plate nozzle positioned near truss height. Center pivot systems with greater than 10 spans length are visible mostly in western Kansas.

Introduction
A road survey of center pivot irrigation systems was conducted in select counties across Kansas on two separate occasions. A county road map for the selected counties was divided into three transects north/south and three transects east/west. The survey was conducted in the fall of 2003 in Barton, Edwards, Pawnee, and Stafford counties. The counties surveyed in 2006 were Finney, Ford, Grant, Gray, Haskell, Scott, Stevens, and Thomas.

The purpose of the survey was to obtain useful information to characterize the types of center pivot nozzle packages currently being used and to gather baseline data for future surveys. The survey information consisted of observations on field location, degree of rotation, number of spans, nozzle type, pressure regulation, general nozzle type, nozzle height, number of spans and overhang, outlets on overhang, and end gun presence and type. Because the surveyor made observations from the road and not directly from the field, the exact type of nozzle packages could not always be determined. Therefore, nozzles were generally characterized as impact sprinklers, fixed plate nozzles, or moving plate nozzles, which were recognizable configurations.

Survey results are presented in two groups: the south central survey and the western survey.

South Central Kansas Survey Results
A summary of observations from the south central region of Kansas is shown in Table 1. Most of the 325 systems that were observed were typical quarter section center pivots (data not shown), and 95% of those systems could make a complete revolution. The most common type of nozzle package in the area was moving plate nozzles (rotator, I-wobbler, etc.), and each nozzle package was likely to be pressure regulated.

[1] This work was supported in part by Kansas Water Plan Funds in support of the Mobile Irrigation Lab Project and the USDA-ARS Ogallala Aquifer Project.

[2] K-State Dept. of Biological and Agricultural Engineering, Manhattan, KS

[3] Mobile Irrigation Lab Project, K-State Research and Extension Southwest Area Office, Garden City, KS

Observations on nozzle spacing and height were divided into three height categories and five height locations. The most common nozzle spacing was medium (8 to 12 ft), and the most common nozzle height was a mounting just below the center pivot truss.

The observation of primary interest for this region was the number of end guns used on the sprinkler systems. More than one third (37.5%) of the systems were equipped with a big gun or traditional end gun, which requires a booster pump, and 48.9% of the systems were equipped with either double or single large impact sprinklers, which are pressurized with existing system pressure. Almost 13% of the systems did not have a different nozzle at the outer end compared with the rest of the center pivot system.

Western Kansas Survey Results

A total of 659 systems were observed in the western Kansas survey. Center pivots larger than the typical quarter section system are more common in western Kansas, so the survey results of the number of spans ranged from 4 to 19 (Table 2). Of the total observations in western Kansas, 483 were either seven or eight spans in length, and only 10 systems were fewer than six spans in length. Seventy-six systems were either nine or 10 spans in length, and almost 15% of the observed systems were 15 spans or larger. Approximately 50% of the systems that were 11 spans or larger were operated as partial circles, compared with about 7% for systems of 10 spans or smaller.

As shown in Table 3, 78% of the observed systems were pressure regulated, and 89% used a fixed plate nozzle package.

End guns, defined as either traditional big guns or impact sprinklers, accounted for only slightly more than 15% of the systems (Table 4).

Observations were also made on the placement of the nozzle for both spacing and height (Table 5). The most common observation was a mixed spacing configuration, which means that the first several spans had wider spacing than the outer spans. Only three systems had wide spacing. The majority of the systems used drop nozzles located at less than a 4-ft height (Figure 1), followed by systems that had heights above 4 ft but more than 2 ft below the truss.

Information was also collected on the ability of the center pivot to make a full revolution; 88 systems (13%) could make only partial revolutions.

Additional analyses looked at various combinations of observations. Table 7 shows nozzle type vs. nozzle spacing, Table 8 outlines nozzle height vs. nozzle type, Table 9 compares nozzle height and nozzle spacing, and Table 2 shows the number of spans vs. the degree of rotation.

Ninety percent of the observed systems had nozzles that were placed in the two lower placement categories: “less than 4 ft” or “greater than 4 ft but less than 2 ft below truss.” Sixty-three percent of all fixed plate nozzles were within 4 ft of the ground, whereas only 12% of moving plate nozzles fit that category. Sixty-two percent of the moving plate nozzles were observed in the “greater than 4 ft” category, compared with 29% of fixed plate nozzles.

Moving plate nozzles tend to use higher and wider spacing configurations than fixed plate nozzles. Approximately three-fourths of the fixed plate nozzles used a mixed spacing configuration. Sixty-one percent of the moving plate nozzles used medium spacing, and another 10% fit into the mixed spacing category.

The large center pivots, which have a greater number of spans, are more likely to be associated with partial rotations. Only 7% of systems with 11 spans or less did not have full rotation. Approximately half of the systems with span numbers greater than 11 could do full circles. These results are expected because of the likelihood of physical constraints in larger fields, water-right and land ownership constraints, and irrigation capacity issues for large systems.

A three-way observation of nozzle spacing, nozzle height, and nozzle type is shown in Table 10. Fixed plate nozzles are usually spaced closer and lower to the ground than moving plate nozzles; this is necessary because of the operational characteristics of the two nozzle types. Moving plate nozzles are most commonly used with medium spacing in the "greater than 4 ft" height category.

Regional Survey Comparisons and Contrasts

The south central and western Kansas results were similar in that both regions predominately used systems with lengths of seven or eight spans. Approximately 21% of the systems in either region had span lengths of eight or greater. However, in the south central region, only two systems were greater than 10 spans in length, whereas 13% of the western systems were larger than 10 spans. These results are expected because the terrain of the south central area requires systems that have a higher irrigation capacity for serving sandy soils. These systems are often problematic, though, because of friction losses and limitations of well capacities. In addition, more of the south central systems (95.1%) completed full circles than the western systems (86.6%), although this trend is likely related to the number of larger systems in the west.

The most common type of sprinkler package in the south central survey was a moving plate type nozzle; the fixed plated nozzle was most common in western Kansas. Higher capacity systems and sandy soils both make the use of moving plate nozzles and higher nozzle placement a preferred design selection for the general soils and slopes of south central Kansas.

End guns are commonly used on sprinkler systems in south central Kansas. Only approximately 13% of the systems in south central Kansas did not have some type of end nozzle. Conversely, only 15% of western Kansas systems actually used an end gun. More than one third (37.5%) of the south central systems were equipped with a big gun (traditional end gun), and about half (48.9%) were equipped with either double or single large impact sprinklers.

Note: A summary of this research is available in K-State Research and Extension Publication MF2870, *Kansas Center Pivot Survey*; available at www.ksre.ksu.edu/library.

Table 1. Summary of pivot nozzle package survey for Barton, Edwards, Pawnee, and Stafford counties surveyed in 2003

Characteristic	Number of observations	Percentage
Degree of rotation		
Full circle	309	95
Partial circle	16	5
Total	325	100
Nozzle type		
Fixed plate	19	5.8
Impact	22	6.8
Mixed	5	1.5
Moving plate	244	75.1
Unknown	35	10.8
Pressure regulators		
Yes	90	27.7
No	91	28
Unknown	144	44.3
Total	325	100
Nozzle spacing		
Close (< 8 ft)	64	19.7
Medium (8-12 ft)	187	57.5
Wide	66	20.3
Unknown	8	2.5
Nozzle height		
< 4 ft above ground	25	7.7
> 4 ft above ground	42	12.9
Truss to 2 ft below truss	221	68.0
Within truss	1	0.3
Top of pivot	27	8.3
Unknown	8	2.5
End gun type		
Big gun	122	37.5
Double large impact	78	24.0
None	42	12.9
Single large impact	81	24.9
Unknown	2	0.6

Table 2. Center pivot survey results for number of spans and degree of rotation in western Kansas

Number of spans	Number observed	Number with full rotation	Number with partial rotation	Percentage partial
4	1	0	1	< 1
5	2	2	0	0
6	10	8	2	< 1
7	276	258	18	2.7
8	207	188	19	2.8
9	26	24	2	< 1
10	50	49	1	< 1
11	1	0	1	< 1
12	2	1	1	< 1
13	4	4	0	0
14	4	2	2	< 1
15	6	2	4	< 1
16	28	12	14	2.1
17	20	9	11	1.7
18	16	6	10	1.5
19	6	5	1	< 1

Table 3. Center pivot survey results for pressure regulation use and nozzle type

Pressure regulation	Number	Percentage	Nozzle type	Number	Percentage
Yes	515	78.2	Fixed plate	589	89.4
No	136	20.7	Moving plate	62	13.6
Unknown	8	12.1	Impact	2	< 1
			Mixed	1	< 1
			Unknown	5	< 1

Table 4. Center pivot survey results for use of end guns

End gun type	Number	Percentage
Big gun	7	1.1
Single large impact sprinkler	22	3.3
Double large impact sprinkler	73	11.1
None (last nozzle same type as system)	557	84.5

Table 5. Center pivot survey results for nozzle spacing and nozzle height

Nozzle spacing	Number	Percentage	Nozzle height	Number	Percentage
Close (< 8 ft)	214	32.7	Less than 4 ft	385	58.4
Medium (8-12 ft)	197	29.9	Greater than 4 ft	212	32.2
Mixed	245	37.2	Truss to 2 ft below	55	8.3
Wide	3	< 1	Within truss	4	< 1
			Top of lateral	3	< 1

Table 6. Center pivot survey results for rotations

Degree of rotation	Number	Percentage
Full (360 degrees)	571	88.6
Partial (less than 360 degrees)	88	11.4

Table 7. Center pivot survey results for nozzle type and nozzle spacing

Nozzle type	Nozzle spacing	Number	Percentage
Fixed plate	Close (< 8 ft)	196	33.3
	Medium (8-12 ft)	155	26.3
	Wide (> 12 ft)	1	< 1
	Mixed	237	40.2
	Total	589	
Impact	Close (< 8 ft)	0	–
	Medium (8-12 ft)	0	–
	Wide (> 12 ft)	2	100
	Total	2	
Mixed	Medium (8-12 ft)	1	100
	Total	1	
Moving plate	Close (< 8 ft)	18	29.0
	Medium (8-12 ft)	38	61.3
	Mixed	6	9.7
	Total	62	
Unknown	Medium (8-12 ft)	3	60
	Mixed	2	40
	Total	5	

Table 8. Center pivot survey results for nozzle height and nozzle spacing

Nozzle height	Nozzle spacing	Observations
< 4 ft	Close (< 8 ft)	131
	Medium (8-12 ft)	41
	Mixed	213
	Total	385
> 4 ft above ground	Close (< 8 ft)	64
	Medium (8-12 ft)	118
	Wide (> 12 ft)	29
	Mixed	1
	Total	212
Truss to 2 ft below truss	Close (< 8 ft)	18
	Medium (8-12 ft)	35
	Mixed	2
	Total	55
Within truss	Close (< 8 ft)	1
	Medium (8-12 ft)	2
	Mixed	1
	Total	4
Top of pivot	Medium (8-12 ft)	1
	Wide (> 12 ft)	2
	Total	3

Table 9. Center pivot survey results for nozzle height and nozzle type

Nozzle height	Nozzle type	Number	Percentage
< 4 ft	Fixed plate	371	96.4
	Moving plate	12	3.1
	Mixed	2	< 1
	Total	385	
> 4 ft above ground	Fixed plate	183	86.3
	Moving plate	27	12.7
	Unknown	2	< 1
	Total	212	
Top of pivot	Impact	2	67
	Fixed plate	1	33
	Total	3	
Truss to 2 ft below truss	Fixed plate	41	74.5
	Moving plate	13	23.6
	Mixed	1	1.9
	Total	55	
Within truss	Fixed plate	4	100
	Total	4	

Table 10. Center pivot survey results for nozzle spacing, nozzle height, and nozzle type

Nozzle spacing	Nozzle height	Nozzle type	Number	Percentage
Close < 8 ft.	< 4 ft	Fixed plate	126	98.5
		Moving plate	5	1.5
		Total	131	
	> 4 ft above ground	Fixed plate	55	85.9
		Moving plate	9	14.1
		Total	64	
	Truss to 2 ft below truss	Fixed plate	14	77.8
		Moving plate	4	22.2
		Total	18	
	Within truss	Fixed plate	1	100
		Moving plate	0	0
		Total	1	
Close < 8 ft. total			214	
Medium (8-12 ft)	< 4 ft	Fixed plate	36	87.8
		Moving plate	5	12.2
		Total	41	
	> 4 ft above ground	Fixed plate	90	76.3
		Moving plate	26	22.0
		Unknown	2	1.7
		Total	118	
	Truss to 2 ft below truss	Fixed plate	26	74.2
		Moving plate	7	20.0
		Mixed	1	2.9
		Unknown	1	2.9
		Total	35	
	Within truss	Fixed plate	2	100
		Moving plate	0	0
		Total	2	
	Top of pivot	Fixed plate	1	100
		Total	1	
Medium (8-12 ft) total			197	

continued

Table 10. Center pivot survey results for nozzle spacing, nozzle height, and nozzle type

Nozzle spacing	Nozzle height	Nozzle type	Number	Percentage
Mixed	< 4 ft above ground	Fixed plate	209	98.1
		Moving plate	2	< 1
		Unknown	2	< 1
		Total	213	
	> 4 ft above ground	Fixed plate	26	89.6
		Moving plate	3	10.4
		Total	29	
	Truss to 2 ft below truss	Fixed plate	1	50
		Moving plate	1	50
		Mixed	0	
		Total	2	
	Within truss	Fixed plate	1	100
		Moving plate	0	0
	Truss to 2 ft below truss	Total	1	
Mixed total			245	
Wide (> 12 ft)	> 4 ft above ground	Fixed plate	1	33.3
	Top of lateral	Impact	2	66.7
Wide (> 12 ft) total			3	

Figure 1. Sprinkler with drop nozzles and closer spacing in western Kansas.

Are Other Crops Better than Corn Under Limited Irrigation?[1]

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

Summary
Research was initiated under sprinkler irrigation to compare limited irrigation of corn with three other summer crops (grain sorghum, soybean, and sunflower) grown with no-till practices. Corn responded the most to increased irrigation. Because of changes in growing conditions, the crop that is most profitable changes from year to year. Growing different crops when irrigation is limited can reduce risk and increase profitability. Averaged across the past 8 years, corn has been the most profitable crop at higher irrigation amounts, whereas at the lowest irrigation level, profitability was similar for all crops.

Introduction
Most groundwater pumped from the High Plains (Ogallala) Aquifer in western Kansas is used for irrigation, and corn is the predominant crop. Groundwater withdrawal from the aquifer has reduced saturated thickness and well capacities. Although corn responds well to irrigation, it also requires substantial amounts of water for maximum production. There is increased interest in reducing the amount of irrigation, and producers question whether crops other than corn would make more profitable use of limited amounts of irrigation.

Materials and Methods
A study was initiated under sprinkler irrigation at the Tribune Unit of the Southwest Research-Extension Center in the spring of 2001. Objectives were to determine the effect of limited irrigation on grain yield, water use, and profitability of several summer row crops. Irrigation amounts were 5, 10, and 15 in. annually. Irrigations were scheduled to supply water at the most critical stress periods for the specific crops and were limited to 1.5 in./week. All water levels were present each year and replicated four times. Irrigation amounts for a particular plot remain constant throughout the study regardless of crop. Crops evaluated were corn, grain sorghum, soybean, and sunflower (a total of 12 treatments). The crop rotation was corn-sunflower-grain sorghum-soybean (alternating grass and broadleaf crops). All crops were grown no-till; other cultural practices (hybrid selection, fertility practices, weed control, etc.) were selected to optimize production. Seeding rate (seeds per acre) was 30,000 for corn, 80,000 for grain sorghum, 150,000 for soybean, and 23,500 for sunflower. Soil water was measured at planting, during the growing season, and at harvest in 1-ft increments to a depth of 8 ft by neutron attenuation. The center four rows of each plot were machine harvested after physiological maturity with yields adjusted to 15.5% moisture for corn, 10% moisture for sunflower, and 12.5% moisture for grain sorghum and soybean. An economic analysis determined economic returns to land, management, and irrigation equipment for all crops and irrigation amounts. Custom rates were used to determine machinery operation costs. Costs of

[1] This project was supported in part by the Kansas Corn, Grain Sorghum, and Soybean Commissions, Western Kansas Groundwater Management District #1, and the Ogallala Aquifer Initiative.
[2] K-State Dept. of Agronomy, Manhattan, KS

inputs (seed, fertilizer, herbicide, etc.) were based on individual year costs for the area, and grain prices were harvest prices for the area. No government program payments or crop insurance costs or proceeds were included in the analyses.

Results and Discussion

Summer precipitation was near normal when averaged across the 8-year period (Figure 1). However, there were considerable differences among years. June precipitation ranged from about 1 in. to more than 5 in. Similar variation was observed in the other months.

Available soil water in the profile (8 ft) at planting was affected more by irrigation amount than crop (Figure 2). With 5 in. of irrigation, profile available water ranged from 6.5 to 8 in. With greater irrigation amounts, profile available water was 10 to 11 in. regardless of crop.

Profile available soil water at harvest was about 4 in. for all crops receiving 5 in. of irrigation (Figure 3). With 10 in. or more of irrigation, profile available soil water at harvest was 8 to 10 in. for all crops.

Crop water use was affected more by irrigation amount than crop (Figure 4). At higher irrigation levels, crop water use tended to be slightly greater with corn and least with sunflower.

Water use efficiency (WUE) was greater with feed grains than oilseed crops (Figure 5). For feed grains, corn made more efficient use of water than grain sorghum. Corn was also the only crop that had higher WUE with 10 in. of irrigation than with 5 in. of irrigation. For all other crops, WUE was similar for all irrigation amounts.

Average grain yields (2001-2008) of all crops responded positively to increased irrigation (Table 1). When irrigation was increased from 5 to 10 in., yield increases were 52% for corn, 18% for sorghum, 35% for soybean, and 16% for sunflower. When irrigation amounts were increased past 10 in., yield increases were 17% for corn, 11% for sorghum, 12% for soybean, and only 4% for sunflower. Corn yields increased by 78% when irrigation was increased from 5 up to 15 in., whereas grain sorghum increased by 31%, soybean by 52%, and sunflower by 20%.

An economic analysis (based on October grain prices each year and input costs from each year) found that at the lowest irrigation level, average net returns (2001-2008) were similar for all crops (Figure 6). At the higher irrigation levels, corn was the more profitable crop. Corn was the only crop for which profitability increased appreciably with more than 10 in. of irrigation.

Conclusions

With very limited amounts of irrigation, several crops (grain sorghum, soybean, and sunflower) can be grown that are as profitable as corn. These crops may also provide additional benefits in breaking pest cycles (weed, insect, and disease) that can arise with production of continuous corn. However, when irrigation amounts of 10 in. or more are available annually, corn is the most profitable crop.

Table 1. Average grain yield (2001-2008) of four crops as affected by irrigation amount, Southwest Research-Extension Center, Tribune Unit

Irrigation amount	Corn	Grain sorghum	Soybean	Sunflower
acre-in.	-----------------------	bu/a	-----------------------	lb/a
5	113	94	31	1800
10	172	111	42	2080
15	201	123	47	2160

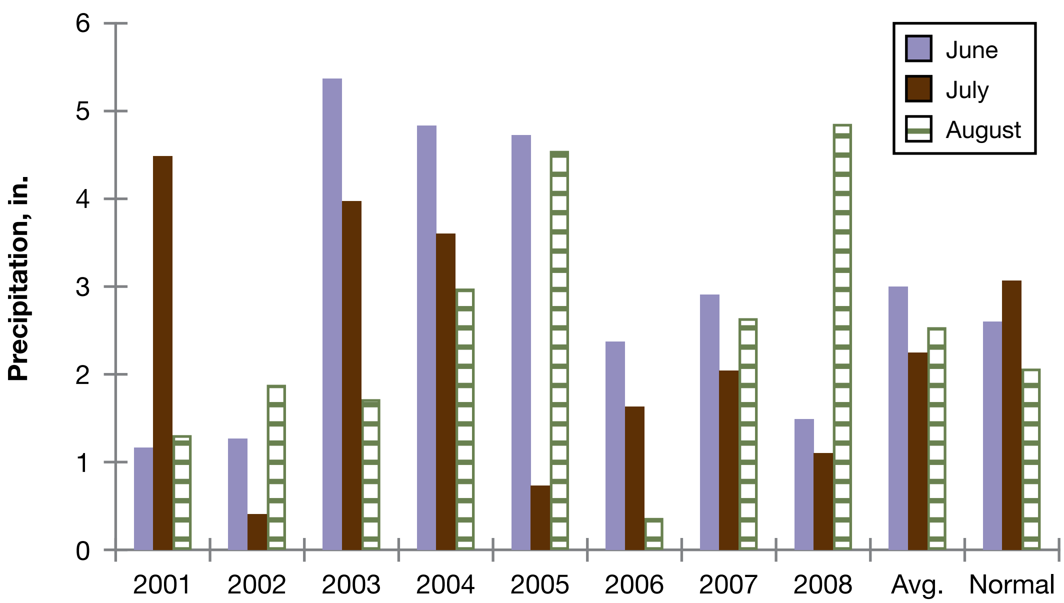

Figure 1. Summer precipitation at the Southwest Research-Extension Center, Tribune Unit Irrigation Field, 2001-2008.

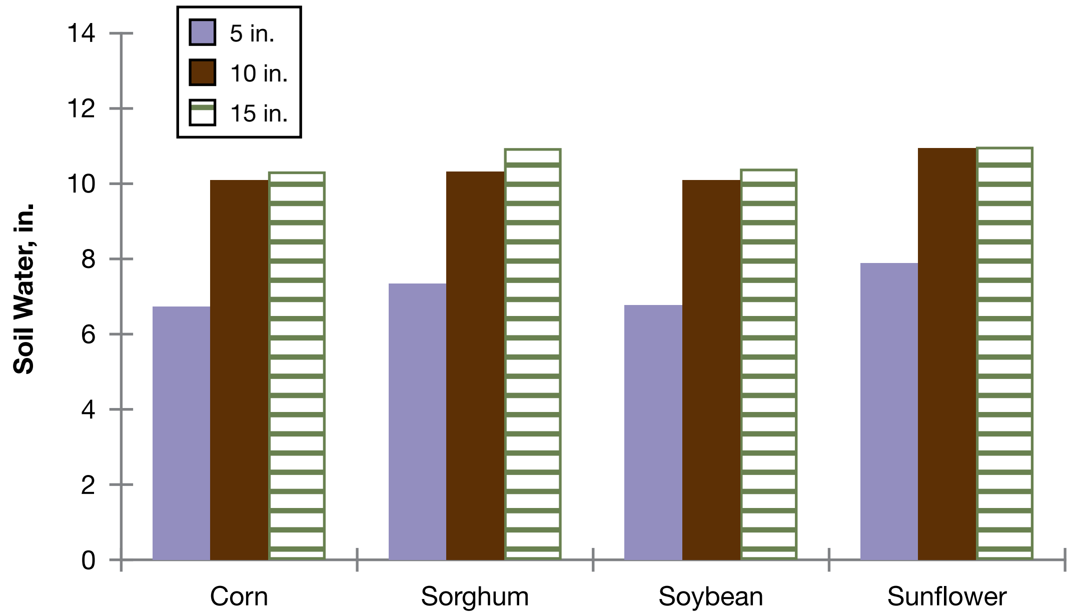

Figure 2. Available soil water at planting for four summer crops under various irrigation levels, Southwest Research-Extension Center, Tribune Unit, 2001-2008.

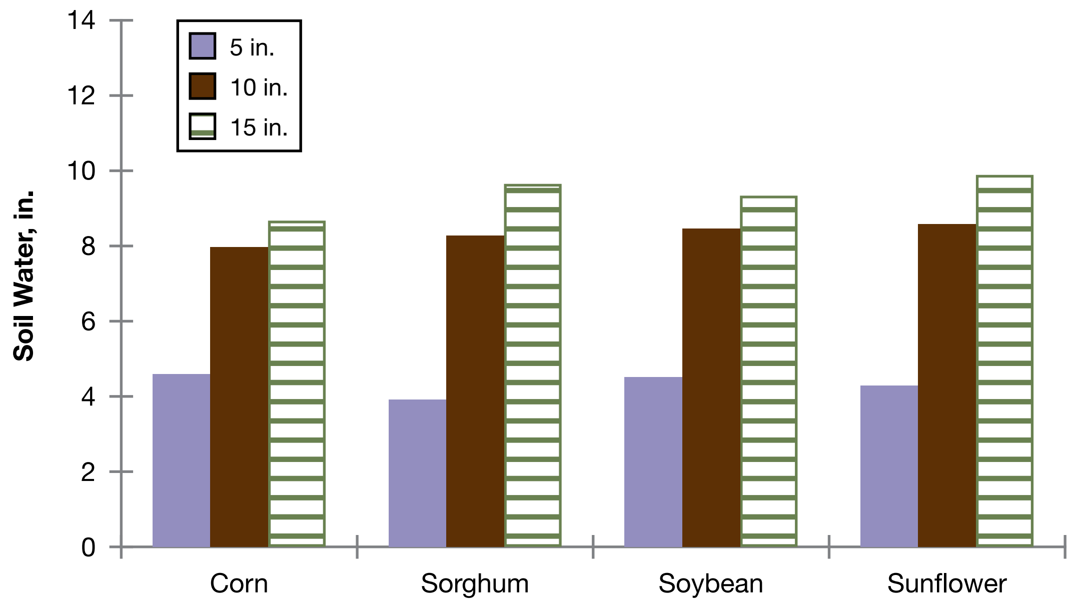

Figure 3. Available soil water at harvest for four summer crops under various irrigation levels, Southwest Research-Extension Center, Tribune Unit, 2001-2008.

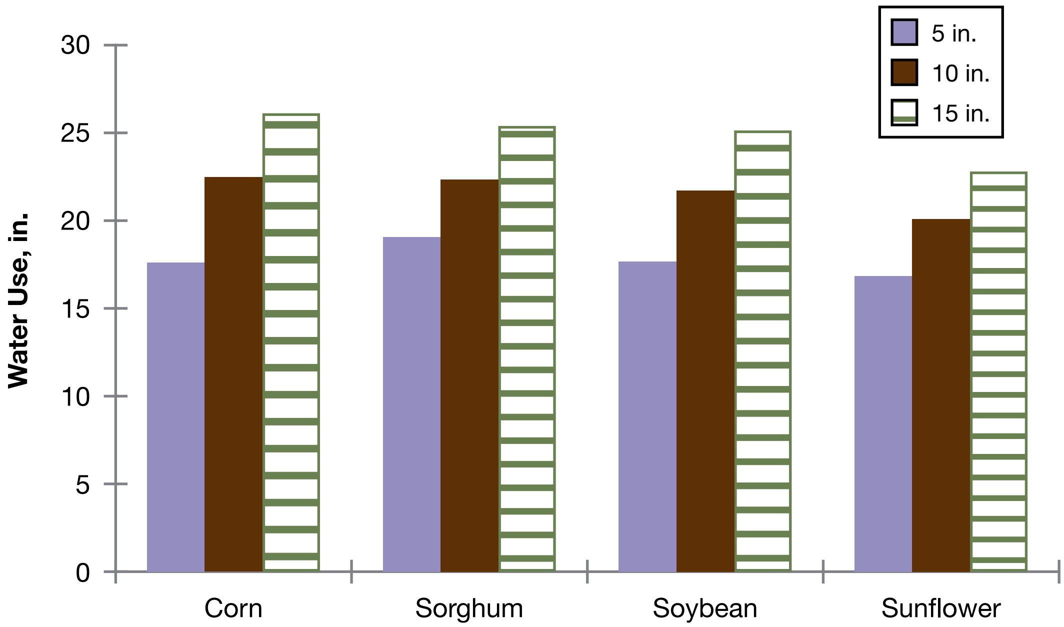

Figure 4. Crop water use for four summer crops under various irrigation levels, Southwest Research-Extension Center, Tribune Unit, 2001-2008.

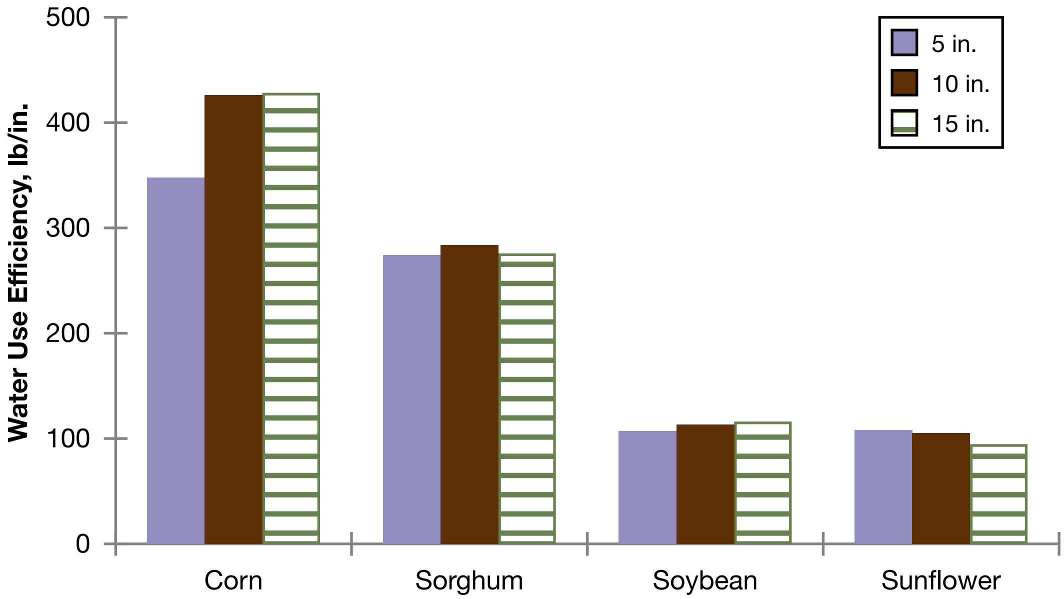

Figure 5. Water use efficiency for four summer crops under various irrigation levels, Southwest Research-Extension Center, Tribune Unit, 2001-2008.

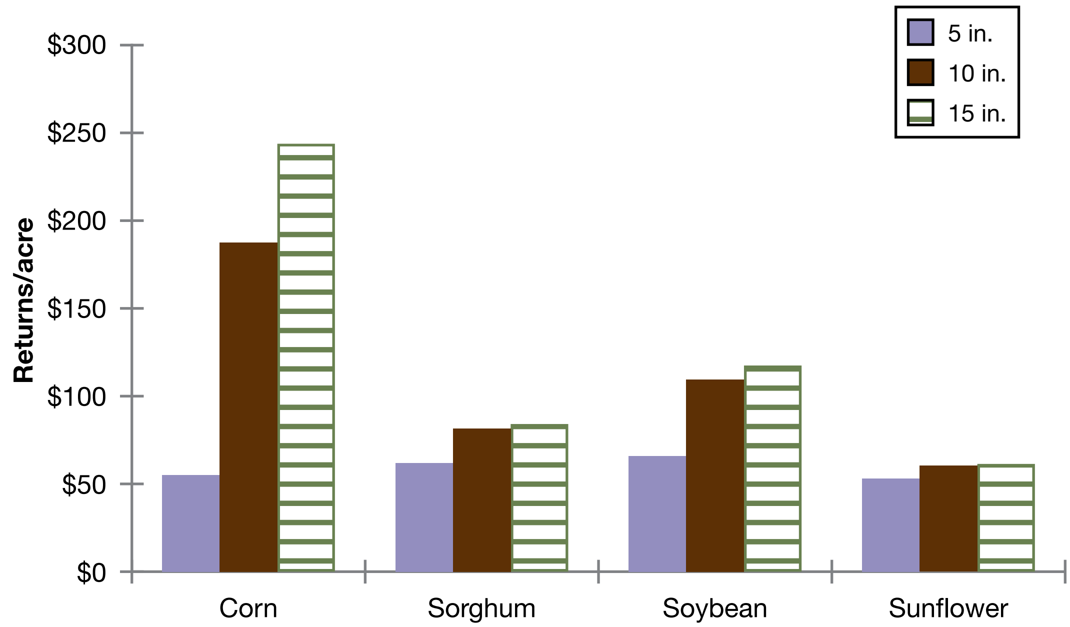

Figure 6. Average (2001-2008) net returns to land, management, and irrigation equipment, Southwest Research-Extension Center, Tribune Unit.

Herbicide Tank Mixes for Control of Glyphosate-Resistant Kochia

R. S. Currie

Summary
As seen in kochia populations from Stevens County, KS, a kochia population from eastern Finney County, KS, appeared to have a large proportion of glyphosate-resistant plants. Of 26 tank mixes tested, only a tank mix of atrazine and Roundup applied postemergence to the kochia and preemergence to the corn or a tank mix of Roundup plus Harness applied preemergence to the corn application followed by Roundup and status 16 days after planting provided 100% control. More than half of the tank mixes tested provided 95% or greater control. Three tank mixes produced from 36 to 83% control. We speculate that tank mixes that produce less than 90% control will enrich the future population with glyphosate-resistant kochia plants.

Introduction
Kochia is becoming more difficult to control with glyphosate in western Kansas. A suspected glyphosate-resistant population of kochia was reported by a grower in eastern Finney County in 2007. Thompson and Peterson (2008) reported confirmation of glyphosate-resistant kochia based on greenhouse trials from Stevens County, KS, in December 2008. Therefore, our objective was to test the effectiveness of several herbicide tank mixes at controlling a suspected glyphosate-resistant kochia population.

Procedures
The test site was a field approximately 4 miles north of Ingalls, KS, that had been in glyphosate-resistant crops for 4 of the last 5 years. At this site in 2007, the producer had difficulty controlling kochia in glyphosate-resistant soybean with repeated applications of glyphosate. Two studies (preemergence and postemergence) were conducted at this site. The entire plot area was treated with paraquat applied at 0.5 lb/a 11 days prior to planting. At planting, kochia had recovered from the paraquat treatment. Corn was no-till planted into soybean stubble. Studies were arranged in a randomized complete block design with four replications. The treatments for the preemergence and postemergence studies are listed in Tables 1 and 2, respectively. Preemergence treatments were applied 3 days after planting. In the postemergence test, the entire plot area received an application of acetochlor + glyphosate at 1.75 + 0.75 lb/a 2 days prior to corn emergence.

Results and Discussion
In the preemergence test, single applications of Roundup tank mixed with Harness alone or Harness in combination with Impact or Balance failed to provide 90% control. All other tank mixes with glyphosate provided greater than 90% control. In the postemergence study, kochia survived the first Roundup treatment applied at corn planting. Impact alone or tank mixed with Roundup without crop oil concentrate or Roundup tank mixed with less than 0.5 lb a.i./a dicamba failed to provide 90% control of these escaped kochia. Second applications of glyhposate tank mixed with all other treatments 16 to 22 days after planting provided greater than 93% control.

As seen in populations of kochia from Stevens County, a kochia population from eastern Finney County appeared to have a large proportion of glyphosate-resistant plants. Of 26 tank mixes tested, only a tank mix of atrazine and Roundup applied postemergence to the kochia and preemergence to the corn or a tank mix of Roundup plus Harness applied preemergence to the corn application followed by Roundup and status 16 days after planting provided 100% control. More than half of the tank mixes tested provided 95% or greater control. Three tank mixes produced from 36 to 83% control. We speculate that tank mixes that produce less than 90% control will enrich the future population with glyphosate-resistant kochia. Further work is in progress to determine the status of suspected glyphosate-resistant kochia in several other Kansas counties.

References

Thompson, C.R., and D.E. Peterson. 2008. A Kansas kochia population found resistant to a use rate of glyphosate. Proceedings of the North Central Weed Science Society, 63:62.

Table 1. Control of glyphosate-resistant kochia with tank mixes of preemergence compounds and Roundup

Treatment		Rate	Unit	Growth stage	Kochia control (%)
1.	Untreated check				0
2.	Bicep II Magnum	2.75	lb a.i./a	PRE[1]	100
3.	Lumax	2.37	lb a.i./a	PRE	95
4.	Harness Xtra 5.6	3.36	lb a.i./a	PRE	100
5.	Harness	1.4	lb a.i./a	PRE	73
6.	Harness	1.4	lb a.i./a	PRE	83
	Balance Pro	0.031	lb a.i./a	PRE	
7.	Harness	1.4	lb a.i./a	PRE	73
	Balance Pro	0.047	lb a.i./a	PRE	
8.	Harness	1.4	lb a.i./a	PRE	36
	Impact	0.011	lb a.i./a	PRE	
9.	Prowl H_2O	0.83	lb a.i./a	PRE	96
	Aatrex 4L	1	lb a.i./a	PRE	
10.	Balance Pro	0.031	lb a.i./a	PRE	90
	Impact	0.0164	lb a.i./a	EPOST[2]	
	Crop oil concentrate	1	% v/v	EPOST	
	Ammonium sulfate	2	% v/v	EPOST	
11.	Balance Pro	0.031	lb a.i./a	PRE	99
	Clarity	0.25	lb a.i./a	EPOST	
	Nonionic surfactant	0.25	% v/v	EPOST	
LSD (P = 0.10)					10.5

[1]All preemergence treatments were tank mixed with 0.75 lb a.i./a Roundup.
[2] EPOST = Early postemergence treatments were applied 16 days after planting.

Table 2. Postemergence treatments for control of glyphosate-resistant kochia[1]

Treatment		Rate	Unit	Growth stage	Kochia control (%)
1.	Harness	1.75	lb a.i./a	PRE[2]	0
2.	Harness	1.75	lb a.i./a	PRE	89.3
	Impact	0.0164	lb a.i./a	EPOST[3]	
	Crop oil concentrate	1	% v/v	EPOST	
	Ammonium sulfate	2	% v/v	EPOST	
3.	Harness	1.75	lb a.i./a	PRE	99.9
	Impact	0.0164	lb a.i./a	EPOST	
	Crop oil concentrate	1	% v/v	EPOST	
	Ammonium sulfate	2	% v/v	EPOST	
	Roundup PowerMax	0.75	lb a.i./a	EPOST	
4.	Harness	1.75	lb a.i./a	PRE	89.3
	Impact	0.0164	lb a.i./a	EPOST	
	Roundup PowerMax	0.75	lb a.i./a	EPOST	
	Ammonium sulfate	2	% v/v	EPOST	
5.	Harness	1.75	lb a.i./a	PRE	95.3
	Status	0.26	lb a.i./a	EPOST	
	Nonionic surfactant	0.25	% v/v	EPOST	
	Ammonium sulfate	2	% v/v	EPOST	
6.	Harness	1.75	lb a.i./a	PRE	100
	Status	0.26	lb a.i./a	EPOST	
	Roundup PowerMax	0.75	lb a.i./a	EPOST	
	Ammonium sulfate	2	% v/v	EPOST	
7.	Harness	1.75	lb a.i./a	PRE	98.9
	Starane	0.125	lb a.i./a	EPOST	
	Atrazine	0.5	lb a.i./a	EPOST	
8.	Harness	1.75	lb a.i./a	PRE	98.3
	Starane	0.125	lb a.i./a	EPOST	
	Atrazine	0.5	lb a.i./a	EPOST	
	Roundup PowerMax	0.75	lb a.i./a	EPOST	
	Ammonium sulfate	2	% v/v	EPOST	
9.	Harness	1.75	lb a.i./a	PRE	93.5
	Buctril	0.25	lb a.i./a	EPOST	
	Atrazine	0.5	lb a.i./a	EPOST	

continued

Table 2. Postemergence treatments for control of glyphosate-resistant kochia[1]

Treatment		Rate	Unit	Growth stage	Kochia control (%)
10.	Harness	1.75	lb a.i./a	PRE	98.6
	Buctril	0.375	lb a.i./a	EPOST	
	Atrazine	0.75	lb a.i./a	EPOST	
11.	Harness	1.75	lb a.i./a	PRE	97
	Buctril	0.25	lb a.i./a	EPOST	
	Atrazine	0.5	lb a.i./a	EPOST	
	Roundup PowerMax	0.75	lb a.i./a	EPOST	
12.	Harness	1.75	lb a.i./a	PRE	90.9
	Clarity	0.25	lb a.i./a	EPOST	
	Nonionic surfactant	0.25	% v/v	EPOST	
13.	Harness	1.75	lb a.i./a	PRE	98.6
	Clarity	0.5	lb a.i./a	EPOST	
	Nonionic surfactant	0.25	% v/v	EPOST	
14.	Harness	1.75	lb a.i./a	PRE	98.8
	Clarity	0.25	lb a.i./a	EPOST	
	Roundup PowerMax	0.75	lb a.i./a	EPOST	
15.	Harness	1.75	lb a.i./a	PRE	99.8
	Buctril	0.25	lb a.i./a	EPOST	
	Starane	0.062	lb a.i./a	EPOST	
	Aatrex 4L	0.5	lb a.i./a	EPOST	
16.	Harness	1.75	lb a.i./a	PRE	97
	Status	0.35	lb a.i./a	MPOST[4]	
	Nonionic surfactant	0.25	% v/v	MPOST	
	Ammonium sulfate	2	% v/v	MPOST	
17.	Harness	1.75	lb a.i./a	PRE	97.6
	Status	0.35	lb a.i./a	MPOST	
	Roundup PowerMax	0.75	lb a.i./a	MPOST	
	Ammonium sulfate	2	% v/v	MPOST	
LSD ($P = 0.10$)					6.7

[1] Entire plot area was treated with 0.75 lb/a Roundup prior to planting.
[2] PRE = preemergence treatments were applied 2 days prior to corn emergence.
[3] EPOST = early postemergence treatments were applied 16 days after corn planting.
[4] MPOST = mid-postemergence treatments were applied 22 days after corn planting.

Effect of Hail and Glyphosate-Resistant Volunteer Corn in Irrigated Corn

R. S. Currie, P. Westra[1], and M. Moechnig[2]

Summary
The number of volunteer corn plants needed to produce a 10% yield loss varied a great deal at different locations. When a proportion of the volunteer corn was in the form of parts of an ear growing in a clump, the number of individual volunteer corn plants necessary to produce a 10% yield loss ranged from 4,000 to 17,000 single plants per acre. In plots without clumps of volunteer corn produced by portions of whole ears, 8,700 to 11,000 volunteer corn plants per acre were required to produce a 10% yield loss. At the Garden City, KS, location, where the corn was severely injured by hail at the V7 stage, the volunteer corn produced grain, and the yield of these plants increased linearly with increasing population. This is consistent with previous work on naturally occurring hail injury that suggested that corn tolerated this injury better at higher populations.

Introduction
Glyphosate-resistant corn hybrids are very popular with producers who grow continuous corn. This has led to concern among growers about the effect of volunteer corn on the subsequent irrigated corn crops. To determine the economic threshold for this problem, five studies were conducted in 2007 with a range of volunteer corn populations (Currie et al., 2008). These studies were repeated in 2008 at three more locations.

Procedures
Naturally dropped ears were collected in the early winter of 2008 from a field planted with a glyphosate-resistant corn hybrid in the 2007 growing season. A portion of these ears were shelled, and the balances of these ears were broken into three pieces. In Garden City during the first week in May 2008, corn was planted with no-till techniques with a commercially available glyphosate-resistant corn hybrid at 32,000 kernels per acre. To simulate volunteer corn, seed from the shelled ears was stab planted randomly by hand over eight plots per block to populations ranging from 4,800 to 58,000 kernels per acre in a randomized complete block design with four replicates. In an additional five plots per block, broken ears were planted with a hoe and trod in to simulate 650 dropped ears per acre. These plots were then seeded with the shelled corn to simulate corn populations of 14,000 to 58,000 kernels per acre.

Previous work at Garden City in 2007 suggested that one source of variation in the data was yield elevations from grain produced by the volunteer corn. Therefore, at the Garden City location in 2008, corn was hand harvested from each volunteer corn plant or clump prior to combine harvest of the non-volunteer corn. This experiment was repeated with conventional tillage near Fort Collins, CO, and Brookings, SD. Volunteer corn populations were established from 4,000 to 86,000 plants per acre at Fort Collins and 4,000 to 36,000 plants per acre at Brookings. All locations, with and without dropped ears,

[1] Colorado State University, Fort Collins, CO
[2] South Dakota State University, Brookings, SD

were fertilized and irrigated for maximum yield except the Brookings location, which was not irrigated. Plots were maintained weed free by a preemergence application of acetochlor and atrazine and postemergence applications of glyphosate as needed. Yield of individual volunteer corn plants or clumps was not harvested at these locations. Simple linear regression equations for each location were used to predict the level of volunteer corn need to produce a 10% yield loss.

Results and Discussion

There was a broad range of variation within and among locations. In plots without simulated dropped ears, average volunteer corn populations from 8,700 to 11,000 kernels per acre produced a 10% yield loss (Table 1). In plots with dropped ears, simple linear regression models predicted 10% yield loss at average volunteer corn populations from 4,000 to 17,000 kernels per acre. On June 26, 2008, hail defoliated corn at the V7 stage at Garden City. The non-volunteer corn recovered to produce yields of 106 to 126 bu/a. Volunteer corn plants at all levels had some yield. Yield of these plants increased linearly with increasing volunteer corn populations from 0 to 31 bu/a and was well described by the equation: volunteer corn yield = 0.0006 (volunteer corn plants per acre) + 1.97 with an R^2 of 0.97 in plots without clumps.

Although yield elevation was not as great in plots with clumps, it increased linearly with increasing volunteer corn population from 0.1 to 25 bu/a and was well described by the equation: volunteer corn yield = 0.0004 (volunteer corn plants per acre) + 2.2 with an R^2 of 0.96.

It is unknown how much of this corn yield could have been machine harvested. Although it is not known whether similar results would be achieved without hail, reductions in the effect of hail on irrigated corn with increasing corn population have been reported (Currie and Klocke, 2008). Also, some variation at the Garden City location in 2007 was attributed to inconsistent elevation of yield by volunteer corn. Complex environmental factors as well as harvest methods may affect how volunteer corn affects yield.

References

Currie, R., J. Lee, P. Westra, J. Fenderson, J. Tichota, and J. Mueller. 2008. Economic threshold of volunteer glyphosate-resistant corn in irrigated corn. Field Day 2008, Southwest Research-Extension Center. Report of Progress 997. Manhattan, KS: Kansas State University. pp. 38-39.

Currie, R.S., and N.L. Klocke. 2008. Impact of irrigation and hail on Palmer amaranth (Amaranthus palmeri) in corn. Weed Technology, 22:448-452.

Table 1. Equations for yield loss from glyphosate-resistant volunteer corn in 2008

Location	Clumps	Slope	Intercept	R^2	10% yield loss (bu/a)
Colorado	absent	0.0006	3.7	0.75	10,500
Colorado	present	0.0006	7.6	0.84	4,017
South Dakota	absent	0.0011	0.47	0.84	8,649
South Dakota	present	0.0008	0.47	0.95	11,915
Kansas	absent	0.0004	5.9	0.57	10,250
Kansas	present	0.0003	4.9	0.71	17,133

Effect of Volunteer Roundup Ready Corn on Winter Wheat[1]

J. Holman, A. Schlegel, B. Olson[2], G. Miller, S. Maxwell, and T. Dumler

Summary
In a wheat-corn-fallow rotation, volunteer corn can be a problem when Roundup Ready hybrids are used. During the fallow period between corn harvest in the fall and wheat planting the following fall, producers often control weeds with glyphosate or tank mixes of glyphosate and 2,4-D or dicamba. None of those herbicide treatments will control Roundup Ready volunteer corn. To control volunteer Roundup Ready corn, a postemergence grass herbicide such as Select, Assure II, or Poast Plus must be used. It is believed that volunteer corn will reduce the amount of soil moisture during the fallow period and subsequently affect the following winter wheat crop. Wheat yield was reduced 1 bu/a for every 200 volunteer corn plants at Colby, KS, and at Tribune, KS, the first bushel of wheat yield was lost when volunteer corn density was 75 plants per acre. Producer fields averaged 455 volunteer corn plants per acre. On the basis of the test results in Colby and Tribune from 2008, a density of 455 plants per acre would cause an estimated wheat yield loss of 4.3 bu/a. The estimated breakeven cost to apply a selective postemergence herbicide, like Select, to volunteer corn would be approximately 250 plants per acre with the price of wheat at $5.00/bu and the cost of herbicide plus application at $14.00/a.

Introduction
Introduction of herbicide-tolerant crops has increased weed control options and allowed for selectively controlling weeds such as jointed goatgrass in-crop that previously had few or no herbicide control methods available. The predominant herbicide tolerance technology used in U.S. crops is glyphosate, or Roundup Ready. Glyphosate has also been an integral component of successful no-till cropping systems. No-till cropping systems in western Kansas are critical for reducing soil erosion, increasing water infiltration, improving and sustaining soil quality, and maintaining high crop yields. A comparison of long-term no-till and conventional tillage systems at Tribune found a no-till yield advantage of 26% in wheat and 94% in grain sorghum compared with conventional tillage.

Producers who grow glyphosate-tolerant corn are challenged by volunteer corn during the fallow period in a dryland wheat-corn-fallow rotation. Volunteer corn comes from kernels and ears that remain in the field after harvest. Volunteer corn germinates throughout the entire fallow period, causing producers to apply herbicides several times during the fallow period and occasionally into the subsequent wheat crop, which results in increased weed control costs. Some producers may till the soil to control the volunteer corn; this has negative effects on the soil and environment. The objective of this study was to determine common levels of volunteer corn in producer fields and to quantify the effect of volunteer corn on soil moisture during the fallow period and the subsequent effect on winter wheat yield, protein, and test weight.

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[1] This research is funded in part by the Kansas State University Integrated Pest Management Implementation Mini-Grant.

[2] K-State Northwest Research-Extension Center, Colby, KS

Procedures

A study was established across three locations in western Kansas (Colby, Garden City, and Tribune) during the 2007-2008 and 2008-2009 growing season and will be replicated again during the 2009-2010 growing season. The cropping system was a no-till winter wheat-summer crop-fallow rotation with the treatments implemented during the fallow phase of the rotation. Main plots were eight targeted volunteer corn populations of 0, 250, 500, 1,000, 2,000, 4,000, 6,000, and 8,000 plants per acre at each site. Plots were planted with F1 Roundup Ready corn seed in a randomized complete block design with four replications. F1 corn seed was planted May 5, 2007, and Apr. 29, 2008, at Colby; Apr. 27, 2007, and Apr. 29, 2008, at Garden City; and May 10, 2007, and June 10, 2008, at Tribune with 30-in. row spacing.

Weeds other than volunteer corn were controlled with glyphosate. F1 Roundup Ready corn seed segregated to 25% homozygous glyphosate resistant, 25% homozygous glyphosate susceptible, and 50% heterozygous glyphosate resistant, and seeding rates were increased by 25% to adjust for segregation. Actual established volunteer corn densities were often lower than targeted densities because of the segregation back to glyphosate susceptible and low soil moisture that reduced plant emergence. Actual established densities ranged from 0 to 3,969 plants per acre at Colby, 0 to 4,729 plants per acre at Garden City, and 0 to 8,000 plants per acre at Tribune in 2007 and 0 to 7,000 plants per acre at Colby, 0 to 8,007 plants per acre at Garden City, and 0 to 8,000 plants per acre at Tribune in 2008.

Gravimetric soil moisture was determined every foot to a 5-ft soil depth before and after volunteer corn growth. Soil moisture was determined from two locations per block before corn growth and one location per plot from within the corn row of the very center of the plot at the end of corn growth. Winter wheat was planted across the study following volunteer corn. A large sample size was collected at wheat harvest to minimize yield variability caused by spatial variability of corn plants at the low density treatments. Winter wheat fall tiller density, yield, protein, and test weight were measured in each plot. In 2008, wheat at Garden City was hailed out 1 week before harvest, and no yield data were able to be collected. Data were analyzed with PROC REG in SAS (SAS Institute, Inc., Cary, NC). Treatment effects were determined significant at $P \leq 0.05$.

Additionally, four producer fields were sampled during the fallow phase near Garden City on July 18, 2007, and July 28, 2008, to determine common volunteer corn densities in production fields. Fields were sampled by using ten 10-m^2 quadrates per field.

Results and Discussion

Volunteer Corn Density in Production Fields

Volunteer population counts in producer fields ranged from one to seven plants per 10 m^2, which was between 400 and 2,800 plants per acre. The average was one plant per quadrate. Populations in 2007 ranged from 0 to 2,800 plants per acre (average = 464 plants per acre). Populations in 2008 ranged from 0 to 2,400 plants per acre (average = 445 plants per acre).

Volunteer Corn Effects on Winter Wheat

Volunteer corn did not affect wheat tiller density at Tribune. Wheat at Garden City was hailed out on June 20, 2008. Volunteer corn did not affect wheat test weight at Colby in 2008.

Conclusions

1. For every 50 to 100 volunteer corn plants per acre, wheat fall tiller density was reduced by one per square foot (Figures 1 and 2).
2. Test weight increased at Tribune likely because there were more resources available for grain fill because there were fewer seeds to fill as a result of the yield loss caused by the volunteer corn (Figure 3).
3. The first bushel of wheat yield was lost when volunteer corn density was 75 plants per acre at Tribune. Yield loss at Tribune indicated a potential yield loss of up to 31% as volunteer corn densities approach infinity (*a*), and a 0.0003% yield loss as volunteer corn density approaches zero (*i*) (Figure 4). Population densities were not high enough at Colby to fit a nonlinear yield response function to volunteer corn, and each volunteer corn plant was estimated to reduce yield by 0.009 bu/a or 1 bu/a for every 200 volunteer corn plants per acre (Figure 5). The linear wheat yield loss estimate at Colby likely underestimated yield loss at low volunteer corn densities and over estimated yield loss at high volunteer corn densities.
4. Production fields averaged 455 volunteer corn plants per acre. On the basis of the test results in Colby and Tribune in 2008, this would have caused an estimated wheat yield loss of 4.3 bu/a.
5. The herbicide cost to treat the entire field for volunteer corn with Select during the fallow period is about $10/a (for the product only, excluding application cost). A volunteer corn density of 250 plants per acre would cause an estimated 2.7 bu/a wheat yield loss. The price of wheat will influence the amount that can be spent to control volunteer corn. With wheat at about $5.00/bu, a yield loss of 2.7 bu would result in a loss of about $13.50/a. That would be near the break-even cost to apply herbicide to the entire field with a volunteer corn density of 250 plants per acre. A field could be spot sprayed to reduce the cost of inputs.

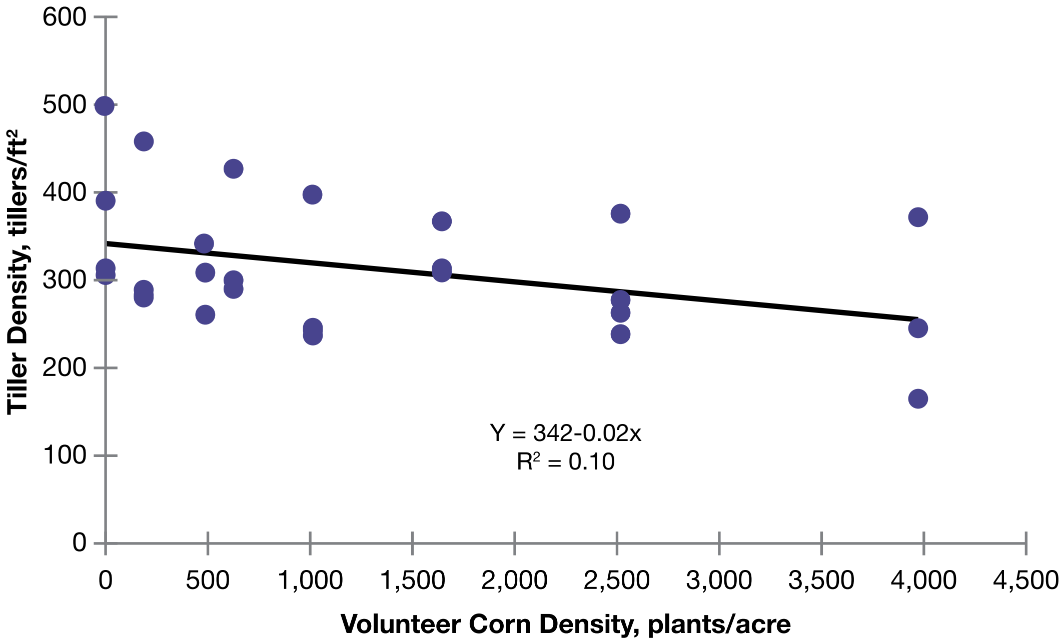


Figure 1. Wheat tiller response to 2007 volunteer corn density at Colby, Mar. 21, 2008.

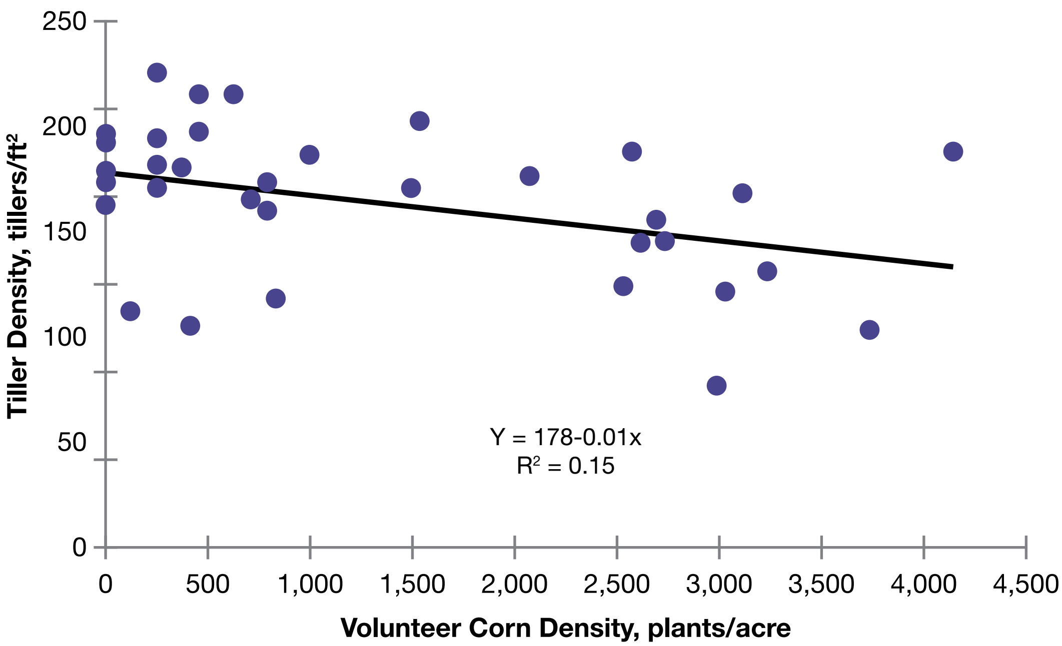


Figure 2. Wheat tiller response to 2007 volunteer corn density at Garden City, Mar. 24, 2008.

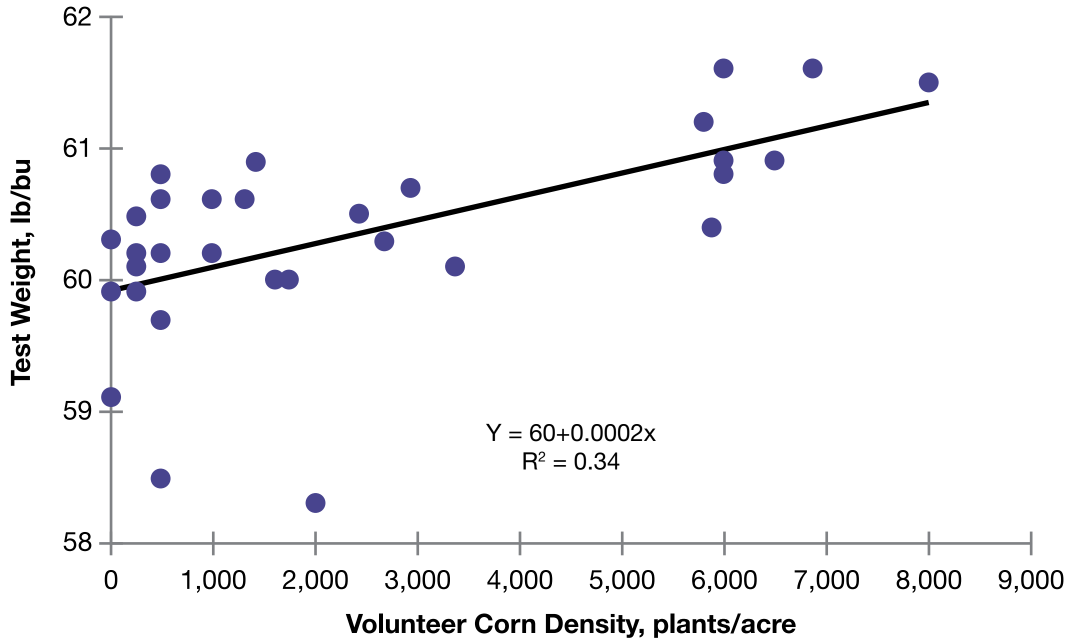


Figure 3. Wheat test weight response to 2007 volunteer corn density at Tribune, 2008.

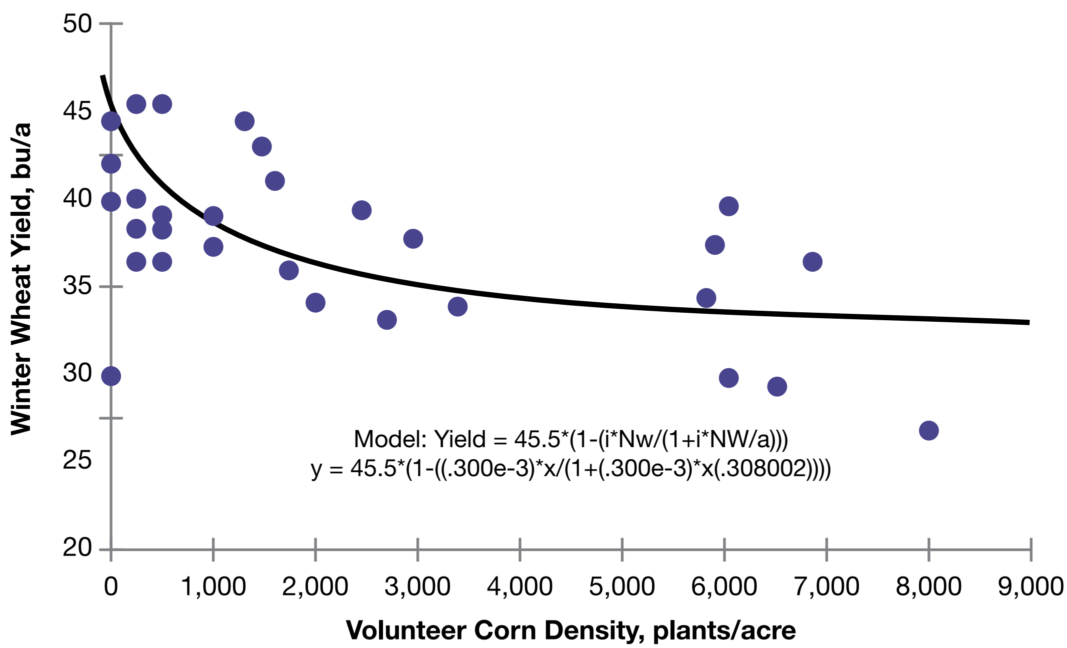


Figure 4. Wheat yield response to 2007 volunteer corn density at Tribune, 2008.

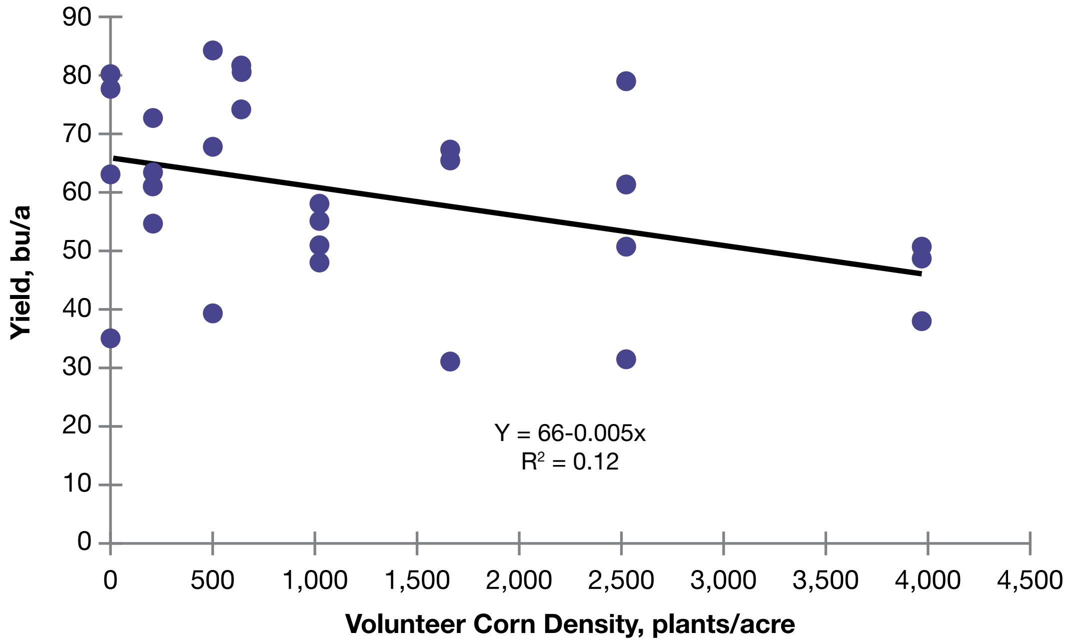


Figure 5. Wheat yield response to 2007 volunteer corn density at Colby, 2008.

Response of Kochia (*Kochia scoparia*) to Fall- and Spring-Sown Cover Crops in a Wheat-Fallow Rotation[1]

J. Petrosino[2], J. Holman, J. A. Dille[2]

Summary

Cover crops can be grown during a fallow period to provide numerous benefits to the producer. Benefits include competing with weeds, fixing nitrogen by legume species, reducing soil and water erosion, and improving soil physical and chemical properties. These principles could be applied in the semiarid region of western Kansas. Cover crops might also help compete with kochia (*Kochia scoparia*), which is a problematic weed species, particularly during fallow periods. An experiment was established in the fall of 2007 at the Southwest Research-Extension Center in Garden City, KS. The objective of the experiment was to determine the effect of cover crops in a wheat-fallow rotation on the life cycle of kochia. Micro-plots were established in winter- and spring-sown cover crop single species and multiple-species mixtures, and kochia was seeded in early March 2008. Kochia emergence and survivorship was monitored during the growing season. At the end of the cover crop growing season, micro-plots were harvested to determine kochia and cover crop biomass. Winter-sown cover crops competed with kochia more effectively than spring-sown crops by reducing Kochia emergence and biomass. Winter cover crop mixtures produced more biomass and reduced kochia infestations more than single species of cover crops. Both treatments reduced kochia emergence and biomass compared with fallow. The effect of kochia on forage production of cover crops varied depending on species and season of planting.

Introduction

Dryland farming in the semiarid regions of the Great Plains, like southwest Kansas, is heavily dependent upon fallow in the crop rotation to store moisture for crop production. However, fallow periods of up to 14 months in a traditional wheat-fallow rotation require inputs by the producer, either mechanical or chemical, for weed control. In more arable regions of the United States, cultural practices like cover cropping have proved successful at affecting key points in the life cycles of weeds, reducing emergence, growth, and fecundity depending on the cover crop and weed species.

Kochia is a problematic weed in dryland crop rotations. Kochia is a broadleaf C4 plant that is well adapted to the semiarid conditions of southwest Kansas. Kochia emerges in early spring, and its prodigious water use makes it fiercely competitive with wheat in the spring. Kochia has been reported to cause yield losses as high as 58% in wheat at densities of 70 kochia plants per square meter. Water use by kochia during the fallow phase of the crop rotation also reduced stored soil water reserves. Therefore, it is important to control kochia in both the wheat and fallow phases of the rotation.

[1] This research is funded in part by the USDA-CSREES North Central Region Integrated Pest Management grants program.

[2] K-State Dept. of Agronomy, Manhattan, KS

In the fall of 2006, a long-term experiment was established to assess the viability of cover cropping in the fallow phase of a no-till winter wheat-fallow rotation at the Southwest Research-Extension Center in Garden City. In 2007, a smaller experiment was established in the cover cropping study to examine the response of kochia to both the presence of cover crops and chemical control.

Procedures

In the fall of 2007 and spring of 2008, cover crops were established in the fallow phase of a winter wheat-fallow rotation. The experiment was a completely randomized block design with four replications. Main plot was cover crop species in plots 30 ft wide × 135 ft long. Each main plot consisted of a winter- or spring-sown cover crop (Table 1) and was split by termination method, either forage harvest or chemical termination with an application of glyphosate at 1 qt/a plus 2,4-D at 3 pint/a. A 1-m^2 micro-plot was established in each termination split plot. Kochia was seeded into the micro-plot at a rate of 46 seeds per square foot. Kochia density was measured on Apr. 28, 2008, for all treatments and on May 14 and 30, 2008, prior to harvest of winter- and spring-sown cover crops, respectively. Prior to harvest of the main plots, micro-plots were clipped, cover crop and kochia were separated and dried, and biomass weight was obtained. Statistical analysis with SAS (SAS Institute, Inc., Cary, NC) and SigmaPlot (Systate Software Inc., San Jose, CA) software packages was used to determine differences in response to treatments and general trends in the data.

Results and Discussion

Weather

During the growing season, from the winter-sown cover crop planting data on Oct. 1, 2007, until harvest of the spring-sown cover crop on May 30, 2008, a total of 4.22 in. of precipitation fell. Rainfall distribution and daily maximum and minimum temperatures are shown in Figure 1.

Response of Kochia to Cover Crop

Kochia response varied by both cover crop planting date and cover crop species. Kochia density was not different among spring-sown cover crops (Table 2), but kochia biomass was different among cover crop species. The broadleaf cover crops lentil and spring pea had the least amount of kochia biomass, whereas spring triticale and mixtures with spring triticale had the highest amount of kochia biomass. An opposite response was observed for kochia in winter-sown cover crops. Contrary to spring cover crops, winter-sown broadleaf crops winter pea and vetch had higher kochia density and biomass than winter triticale and winter triticale mixtures (Table 3). Kochia density and biomass were lower in all winter cover crops compared with fallow. Regression analysis showed kochia density and biomass decreased as cover crop biomass increased (Figures 2 and 3). In the 2007-2008 growing season, winter-sown cover crops provided better suppression of kochia density and biomass than spring-sown crops. This may be due to the faster growth rate of winter crops, which break dormancy with stored nutrient reserves; spring-sown crops emerge and grow at the same time as kochia.

Kochia Effects on Cover Crop Forage Yield

Cover crops responded differently to the presence of kochia. In spring-sown cover crops, spring triticale and the lentil-spring triticale mixture showed reduced forage yield when the crop competed with kochia (Table 4). The other spring-planted cover crops did not lose forage yield when they competed with kochia. The winter-sown broadleaf cover crops and mixtures were not affected by the presence of kochia (Table 5). Winter triticale forage yield was reduced by half when it competed with kochia. Regression analysis (Figures 2 and 3) showed that to minimize kochia density and biomass in the 2007-2008 growing season, a dry matter forage yield of 1,800 lb/a (200 g/m^2) by winter-sown cover crops that competed with kochia would be required. This was easily obtained by the winter-sown cover crop mixtures (Table 5).

Overall, cover crops reduced the density and biomass of kochia compared with fallow. The cover crop mixtures provided the highest forage yield while giving the benefits of adding a grass and broadleaf crop to the rotation. With exception of the lentil/spring triticale mixture, the cover crop mixtures lost the least amount of biomass when they competed with kochia. The winter-sown mixtures produced greater forage yield and reduced kochia density and biomass more than spring-sown cover crops.

Table 1. Cover crops used in the experiment, listed by growing season

Season	Cover crop
Winter	Winter triticale
	Vetch
	Winter pea
	Clover/winter triticale mixture
	Winter tea/winter triticale mixture
	Vetch/winter triticale mixture
Spring	Lentil
	Spring pea
	Spring triticale
	Lentil/spring triticale mixture
	Spring pea/spring triticale mixture

Table 2. Kochia biomass and density response to spring-sown cover crops harvested on May 28, 2008

Cover crop	Kochia biomass	Kochia density
	lb/a	plants/ft^2
Spring pea	771c	12a
Lentil	1,326bc	15a
Lentil/spring triticale	1,653ab	18a
Spring pea/spring triticale	2,193ab	12a
Spring triticale	2,343ab	16a

Within columns, values followed by the same letter are not significantly different at $P \leq 0.05$.

Table 3. Kochia biomass and density response to winter-sown cover crops compared with fallow harvested on May 14, 2008

Cover crop	Kochia biomass	Kochia density
	lb/a	plants/ft^2
Fallow	93a	20a
Vetch	17b	10b
Winter pea forage	6c	5c
Winter triticale	1cd	4cd
Clover/winter triticale	1cd	1cd
Vetch/winter triticale	0.6d	3cd
Winter pea/winter triticale	0.1d	1cd

Within columns, values followed by the same letter are not significantly different at $P \leq 0.05$.

Table 4. Dry matter yield of spring-sown forage cover crops and cover crops that competed with kochia

Crop	Cover crop yield	Yield of cover crop that competed with kochia
	------------------------lb/a------------------------	
Lentil	780d	1,326dc
Spring pea	1,611bc	771d
Lentil/spring triticale	2,327a	1,653bc
Spring triticale	2,699a	2,343a
Spring pea/spring triticale	2,730a	2,193ab

Forage yield values followed by the same letter are not significantly different at $P \leq 0.05$.

Table 5. Dry matter yield of winter-sown forage cover crops and cover crops that competed with kochia

Crop	Cover crop yield	Yield of cover crop that competed with kochia
	-----------------lb/a-----------------	
Winter pea	877c	1,229c
Vetch	939c	1,126c
Winter triticale	3,249ab	1,547c
Clover/winter triticale	3,595ab	3,084ab
Winter pea/winter triticale	3,700ab	2,928ab
Vetch/winter triticale	3,911a	2,739ab

Forage yield values followed by the same letter are not significantly different at $P \leq 0.05$.

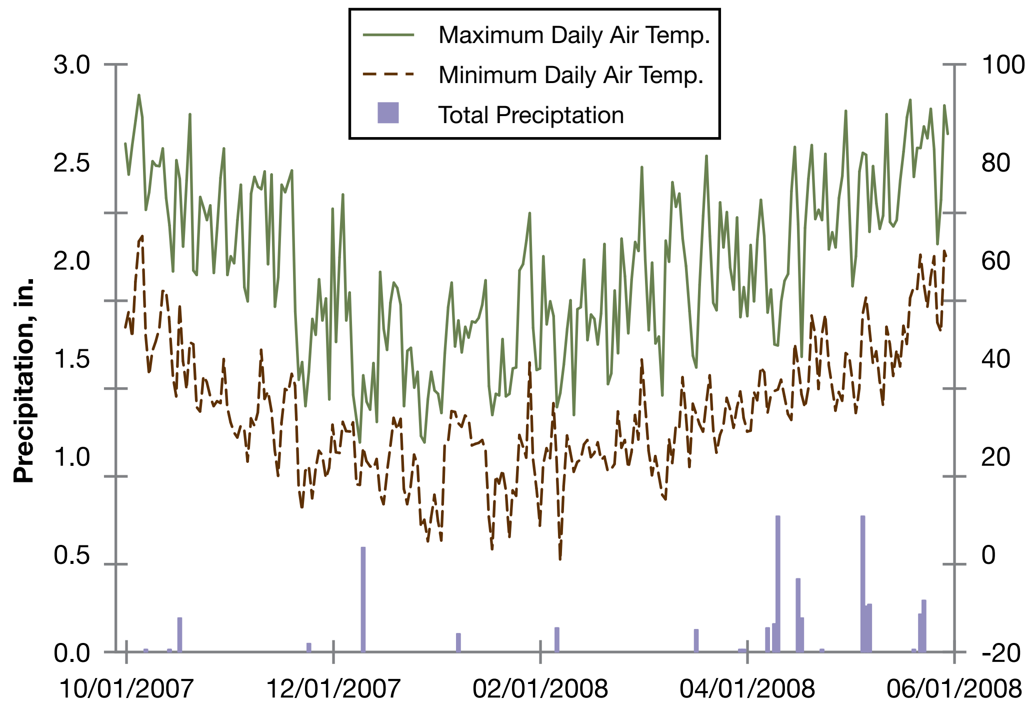


Figure 1. Weather conditions from Oct. 1, 2007, to July 15, 2008.

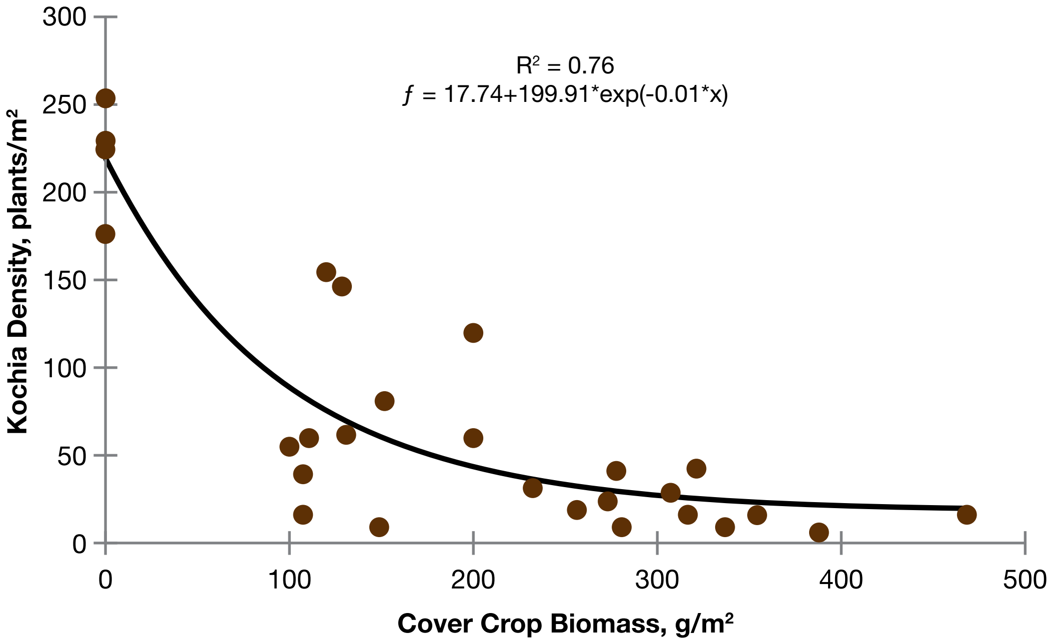


Figure 2. Response of kochia density to cover crop biomass.

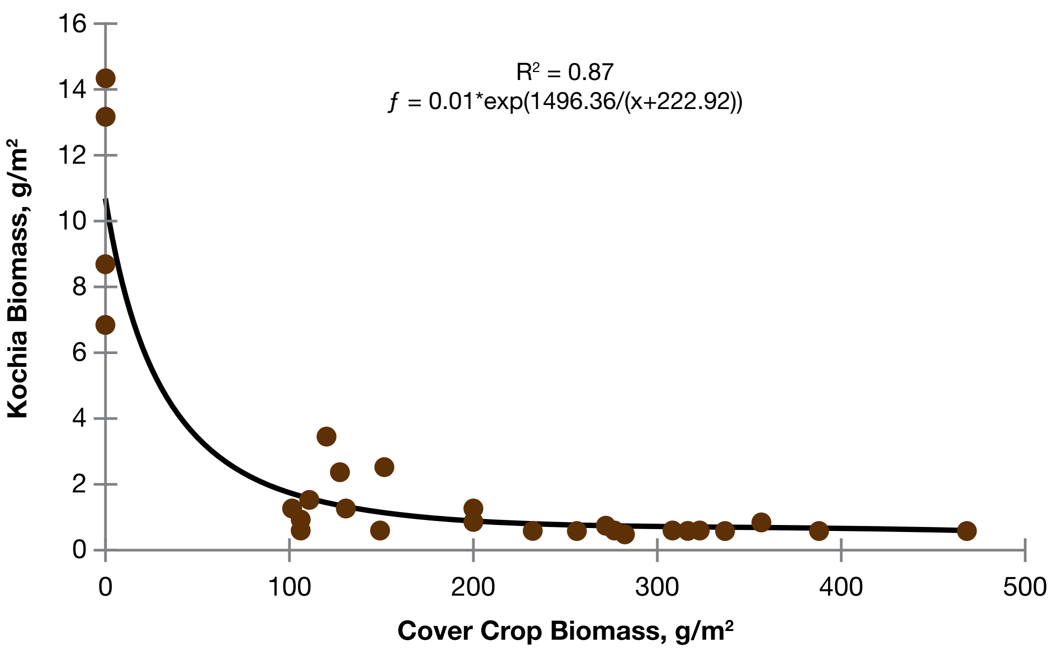


Figure 3. Response of kochia biomass to cover crop biomass.

Yield Losses Associated with *Dectes* Stem Borers in Soybean and Efficacy of Fipronil Seed Treatments in Controlling *Dectes* Stem Borers, Scandia, 2008[1]

T. Niide[2], L. Buschman, B. Gordon[3], P. Sloderbeck, A. Joshi

Summary

Fipronil soybean seed treatments were evaluated in large plots (8 rows by 65 ft) near Scandia, KS. *Dectes* infestations were quite high; 75% of plants were infested in untreated plots. The fipronil seed treatment gave 100% control of the *Dectes* stem borer. Plots with treated seed had 5.6 and 7.6 bu/a more grain yield than plots with untreated seed at normal and late harvest for changes of 7.5 and 11.5%, respectively. The late harvest was also associated with significant yield losses, 10.1 bu/a for untreated seed and 8.1 bu/a for treated seed. These results revealed significant physiological yield loss of 8.2% and a plant lodging loss of 2.9% associated with *Dectes* stem borer infestations. Fipronil seed treatment could be a useful technology to protect soybean grain yield from *Dectes* stem borer, but it is not yet registered for use on soybean. Timely harvest is also successful in reducing grain yield loss caused by lodging and pod shattering.

Procedures

Soybean seed (Pioneer 93M92, maturity group III) was divided into two lots; one was treated with fipronil (Regent 500TS) at 100 mg a.i./100 kg seed, and the other was left untreated. Plots were machine planted May 16 at 16 seeds per row-foot at the North Central Kansas Experiment Field near Scandia with a small-plot row-crop planter. The treated and untreated main plots were eight rows wide and 65 ft long. Four-row subplots were harvested October 8 when the plants dried down enough to harvest (normal harvest) and on November 18 after the *Dectes*-infested plants had lodged (late harvest). This was almost 6 weeks later. *Dectes* stem borer observations were recorded on September 30 by dissecting five consecutive plants taken from each of the two center rows in each subplot for a total of 10 plants per subplot. We recorded entry nodes, upper stem tunneling, tunneling that reached the base of the plant, and the number of live larvae present. A small plot combine with a grain header was used to collect grain yield from the two center rows. Grain yield was converted to bushels per acre based on 13% moisture. The experimental plan was a split-plot randomized block design with two factors, seed treatment and harvest time, and five replications. The SAS-ANOVA procedure was used to analyze the data. Means were compared by LSD.

[1] This research is sponsored by the Kansas Soybean Commission

[2] K-State Dept. of Entomology, Manhattan, KS

[3] K-State Research and Extension Irrigation and North Central Kansas Experiment Fields, Scandia, KS

Results and Discussion

Dectes infestations were quite high; 75% of plants were infested in untreated plots (Table 1 and Figure 1). Fipronil seed treatment significantly suppressed the numbers of entry nodes, stem tunneling, tunneling to the base, and number of live larvae per 10 plants compared with untreated plants. The fipronil seed treatment gave 100% control for each of the *Dectes* observations. These data indicate that the residual activity of the fipronil seed treatments remained effective through August when the *Dectes* stem borer larvae were tunneling in the plant stems.

Effects of the treatments on grain yield were significant across seed treatment as well as harvest date, but the interaction was not significant (Table 1). At the normal harvest, treated seed had 5.6 bu/a more grain, and at the late harvest, there was 7.6 bu/a less grain for differences of 8.2 and 13.0% (Figure 2). Yield losses associated with untreated seed can be attributed to *Dectes* stem borers. The losses at the normal harvest would be mostly physiological yield losses because there was very little lodging. Consequently, very little soybean was left in the plots after harvest.

Late harvest was also associated with significant yield losses: 10.1 bu/a for untreated seed and 8.1 bu/a for treated seed for reductions of 14.7 and 11.8%, respectively (Table 2, Figure 2). Losses for untreated plots can be associated with lodging plus harvest delay (mostly pod shattering). The 10.1 bu/a losses for untreated seed can be attributed to both harvest delay and lodging. Therefore, we can calculate the difference between these to determine lodging losses of 2 bu/a, or 2.9%. These results reveal significant physiological yield loss of 8.2% and plant lodging losses of 2.9% associated with *Dectes* stem borer infestations (Figure 2).

Fipronil seed treatment could be a useful technology to protect soybean grain yield from *Dectes* stem borer, but it is not yet registered for use on soybean. Timely harvest is also successful in reducing grain yield loss caused by lodging and pod shattering.

Table 1. Treatment means, percentage of control, and F-test probability values for ANOVA tests for the two main effects, insecticide treatment and harvest time, Irrigation Experiment Field, Scandia, 2008

	Entry nodes	Stem tunneling	Base tunneling	Live larvae	% of plants infested	Grain yield
	----------	----------	per 10 plants	----------	----------	bu/a
ANOVA F-test probability						
Insecticide treatment	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Harvest timing	–	–	–	–	–	< 0.0001
Insecticide × harvest	–	–	–	–	–	0.3388
Insecticide treatment means						
Untreated	14.9	7.7	6.0	4.3	75.0	63.7
Treated	0.0	0.0	0.0	0.0	0.0	70.2
% Control/Yield increase	100%	100%	100%	100%	100%	+10.6%

Fipronil treatment was applied as a seed treatment.

Table 2. Dectes stem borer yield damage components at Scandia, 2008

Yield loss components	Scandia	
	bu/a	% NH UT
Physiological loss		
(TR NH) – (UT NH)	5.6	8.2
Delay (D)		
(TR NH) – (TR LH)	8.1	11.8
Delay and lodging (D&L)		
(UT NH – (UT LH)	10.1	14.7
Lodging		
(D&L) - D	2.0	2.9
Total losses		
(TR NH) – UT LH)	15.7	22.9

TR = treated; UT = untreated; NH = normal harvest; LH = late harvest, D = delay losses, D&L = delay and lodging losses.

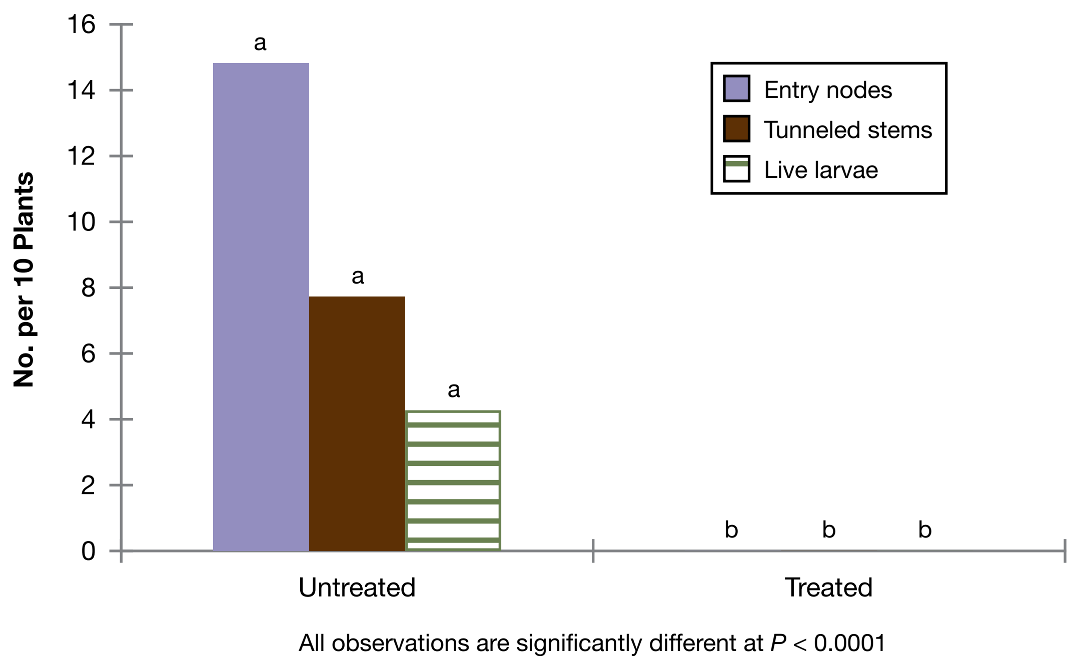


Figure 1. Mean numbers of several *Dectes* stem borer observations (entry nodes, tunneled stems, and live larvae) per 10 plants at Scandia, 2008.

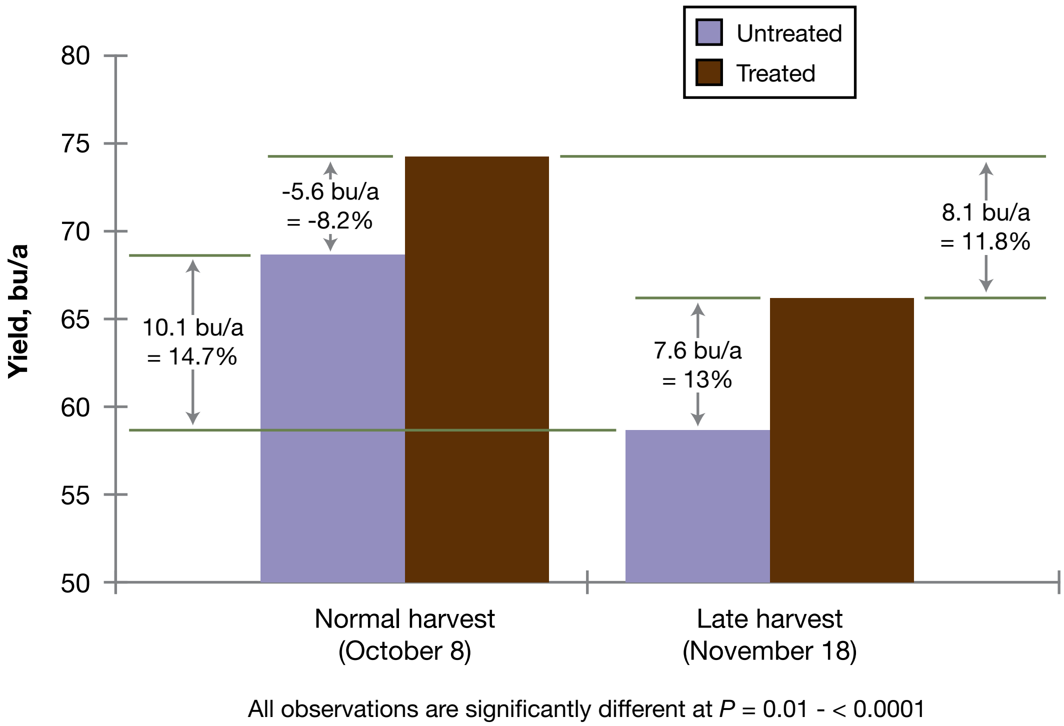


Figure 2. Grain yield at two harvest dates for treated and untreated soybean together with calculated differences used to calculate the *Dectes* stem borer yield damage components at Scandia, 2008.

Yield Losses Associated with *Dectes* Stem Borers in Soybean and Efficacy of Fipronil Seed Treatments, Garden City, 2008[1]

L. Buschman, A. Joshi, P. Sloderbeck and T. Niide[2]

Summary

Fipronil soybean seed treatments were evaluated in large plots (8 rows by 150 ft) at two locations near Garden City (GC), KS. Thrips populations were high on the soybean seedlings, and we found that the fipronil seed treatment was effective in suppressing thrips populations (60%) at both locations. *Dectes* populations were low at GC south (23% of plants infested). At GC north, however, there were substantial *Dectes* populations (84% of plants infested). The fipronil seed treatment was extremely effective in reducing the *Dectes* stem borers, giving 100 and 96 to 98% control at GC south and north, respectively. The fipronil seed treatment did not affect grain yield at GC south, where *Dectes* infestations were low. However, at GC north, the fipronil seed treatment increased grain yield 6.5 bu/a at normal harvest and 9.7 bu/a at late harvest. These results reveal a significant physiological yield loss of 10.2% and a plant lodging loss of 5.0% associated with *Dectes* stem borer infestations. Results from a similar trial at Scandia, KS, reveal a significant physiological yield loss of 8.2% and a plant lodging loss of 2.9%. Fipronil seed treatment could be a useful technology to protect soybean grain yield from *Dectes* stem borer, but it is not yet registered for use on soybean. Timely harvest is also successful in reducing grain yield loss caused by lodging and pod shattering.

Procedures

Soybean seed (Pioneer 93M92, maturity group III) was divided into two lots; one was treated with fipronil (Regent 500TS) at 100 mg a.i./100 kg seed, and the other was left untreated. Plots were machine planted May 21 and 29 at 131,000 and 110,000 seeds per acre at GC south and north, respectively. A 20-ft grain drill with 13-in. rows and a 20-ft row-crop planter with eight rows (30 in.) were used to plant GC south and north, respectively. The treated and untreated main plots were 20 ft (8 rows) wide and 300 ft long. The subplots were 20 ft wide and 150 ft long. To allow plot harvest on two dates, we added 40-ft borders around the main plots that allowed us access to the plots after the borders had been cut. This also allowed the header to overlap the cut border because the combine header was 30 ft wide.

As the soybean germinated, significant numbers of thrips from maturing wheat were found infesting soybean seedlings. Because thrips have been known to cause serious injury to soybean seedlings, we collected 10 soybean seedlings from each plot and placed them in Berlese funnels to force the thrips into jars with 70% methanol. The methanol was then filtered through filter paper, and the trips were counted under a dissecting microscope. During July and August we monitored *Dectes* beetle populations by making 100-sweep samples each week and recording the number of *Dectes* beetles collected. *Dectes* stem borer larval infestations and damage were recorded September 26 by

[1] This research is sponsored by the Kansas Soybean Commission.

[2] K-State Dept. of Entomology, Manhattan, KS

dissecting 20 or 10 plants per subplot at GC south and north, respectively. We collected groups of five consecutive plants from the center of each subplot and recorded entry nodes, upper stem tunneling, tunneling that reached the base of the plant, and the number of live larvae present. At the end of the season, we marked off six 3-ft sections of row at GC north to follow the progression of girdling. The number of standing plants in each section was recorded every 2 days (early October) and once a week (late November and December).

Soybean yields were obtained by using the farmer's field combines to collect grain from the plots. At GC south, the *Dectes* infestations were low and we did not expect to have significant yield reductions, so we harvested both sets of subplots at normal harvest (October 17) with a flex header. The *Dectes* infestations were higher at GC north, so we harvested half of the subplots at normal harvest maturity (October 10) with a flex-header and the other half on October 29 after a period of rainy weather, which allowed the *Dectes*-girdled plants to fall to the ground. Two different headers were available on the second harvest at GC north, so we harvested three replications with the flex header and the other three replications with a row-crop header. At both locations, the harvested grain was transferred to a weigh wagon to be weighed. Grain yield was converted to bushels per acre based on 13% moisture. The experimental plan was a split-plot randomized block design with two factors, seed treatment and harvest time, and six replications. However, some observations were made before harvest, so the design reverted to a simple randomized block design. The SAS-ANOVA procedure was used to analyze the data. Means were compared by LSD.

Results and Discussion

There were substantial thrips populations on soybean seedlings during the seedling stage: 246 and 329 per 10 plants at GC south and north, respectively (Tables 1 and 2). These populations did not lead to damage that required insecticide applications. The fipronil seed treatment was effective in suppressing these populations by 60% at both locations (Figure 1).

Dectes populations were low at GC south. Weekly 100-sweep samples collected only five beetles total throughout July and August with a peak catch of two on July 31. At the end of the season, this field had only 23% of plants infested (Table 1). However, there were substantial *Dectes* populations at GC north. Weekly 100-sweep samples collected 32 beetles total throughout July and August with a peak catch of 12 on August 11. At the end of the season, this field had 84% of the plants infested (Table 2). These beetle populations were substantially lower than in previous years, when up to 50 beetles were collected per 100-sweep sample.

The fipronil seed treatment was extremely effective in reducing the *Dectes* stem borers, giving 100 and 96 to 98% control at GC south and north, respectively (Tables 1 and 2). These data indicate that the residual activity of the fipronil seed treatments remained effective through August when *Dectes* larvae were feeding in the plants (Figures 2 and 3).

Effects of the fipronil seed treatment on grain yield were not significant at GC south (Table 1). This agrees with the adult and larval data that indicated low *Dectes* infestation that was not likely to cause economic damage. At GC north, the effects of fipronil seed

treatment and harvest date were highly significant for grain yield, but the interaction was not significant (Table 2). At normal harvest, plots with treated seed had 6.5 bu/a more grain than plots with untreated seed, and at late harvest, plots with treated seed had 9.7 bu/a more grain than plots with untreated seed (Figure 4). These yield losses appear to be from *Dectes* stem borers because there was no yield loss in GC south, where *Dectes* infestations were less than 25% (GC south location). These data also indicate there were no plant growth effects associated with the fipronil seed treatments and that no other factors (even the thrips) were involved in the yield loss (no yield increase in the absence of *Dectes* stem borer pressure). At normal harvest, the grain yield loss between treated and untreated seed can be attributed to insect damage associated with insect tunneling in the plant (physiological yield loss) because there was very little lodging at normal harvest. At the GC north location, there was a 6.5 bu/a yield difference between the treated and untreated plots at normal harvest. At late harvest, the grain yield losses between treated and untreated plots could be due to a combination of physiological yield losses, delay/shattering yield losses, and lodging yield losses. There was a yield loss of 4.1 bu/a for treated seed between normal and late harvest (Figure 4). This loss can be attributed to harvest delay because these plots were protected from *Dectes* damage. There was a 7.3 bu/a yield loss for untreated seed between normal and late harvest (Figure 4). This loss can be attributed to both harvest delay and plant lodging. Therefore, we can subtract the delay losses (from treated seed) from the combined losses (from untreated seed) to determine lodging losses, which turn out to be 3.2 bu/a, or 5.0% (Table 2). These results reveal a significant physiological yield loss of 10.2% and a plant lodging loss of 5.0% associated with *Dectes* stem borer infestations (Table 3, Figure 4). Similar results from Scandia reveal a significant physiological yield loss of 8.2% and a plant lodging loss of 2.9% (Table 3, Figure 2 in the Scandia article; this report, p. 80). For soybean variety 93M92, girdling started in early October, and the percentage of plants girdled increased rapidly during October, reaching 50% by about November 5 (Figure 5). After that, the increase in girdling slowed and reached a maximum of 78.5% by the end of December.

Fipronil seed treatment could be a useful technology to protect soybean grain yield from *Dectes* stem borer, but it is not yet registered for use on soybean. Timely harvest is also successful in reducing grain yield loss caused by lodging and pod shattering.

Table 1. Treatment means, percentage of control, and F-test probability values for ANOVA tests for the two main effects, insecticide treatment and harvest time, Garden City South, 2008

	Thrips	Entry nodes	Stem tunneling	Base tunneling	Live larvae	Grain yield
	per 10 plants	---------------per 20 plants---------------				bu/a
ANOVA F-test probability						
Insecticide treatment	0.0010	0.0073	0.0045	0.0104	0.0045	0.1139
Insecticide treatment means						
Untreated	246	5.8a	4.6a	2.2a	3.9a	76.8
Treated	99	0.0a	0.0b	0.0b	0.0b	74.3
% Control/Yield increase	60%	100%	100%	100%	100%	–

Fipronil treatment was applied as a seed treatment.
Within columns, means followed by the same letter are not significantly different ($P < 0.05$).

Table 2. Treatment means, percentage of control, and F-test probability values for ANOVA tests for the two main effects, insecticide treatment and harvest time, Garden City North, 2008

	Thrips	Entry nodes	Stem tunneling	Base tunneling	Live larvae	Grain yield
	per 10 plants	---------------per 20 plants---------------				bu/a
ANOVA F-test probability						
Insecticide treatment	0.0026	0.0001	< 0.0001	< 0.0104	< 0.0001	0.0003
Harvest timing	–	–	–	–	–	< 0.0003
Insecticide × harvest	–	–	–	–	–	0.1692
Insecticide treatment means						
Untreated	329a	19.5a	8.4a	5.8a	6.9a	60.3b
Treated	131b	0.5b	0.3b	0.1b	0.2b	68.4a
% Control/Yield increase	60%	97%	96%	98%	97%	13.4%
Harvest timing treatment means						
Normal	–	–	–	–	–	67.2a
Late	–	–	–	–	–	61.5b
% Control/Yield increase						8.5%

Fipronil treatment was applied as a seed treatment.
Within columns, means followed by the same letter are not significantly different ($P < 0.05$).

Table 3. Dectes stem borer yield damage components at Garden City North, 2008

Yield loss components	Garden City	
	bu/a	% NH UT
Physiological loss		
(TR NH) – (UT NH)	-6.5	-10.2
Delay (D)		
(TR NH) – (TR LH)	4.1	6.4
Delay and lodging (D&L)		
(UT NH – (UT LH)	7.3	11.4
Lodging		
(D&L) - D	3.2	5.0
Total losses		
(TR NH) –UT LH)	13.8	21.6

TR = treated; UT = untreated; NH = normal harvest; LH = late harvest, D = delay losses, D&L = delay and lodging losses.

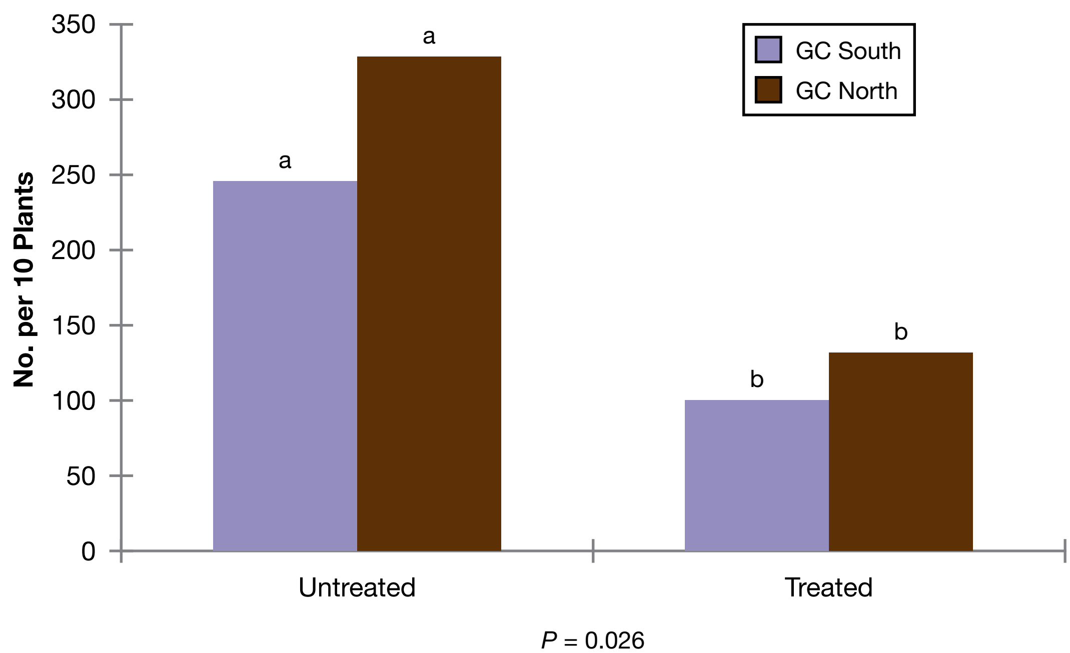
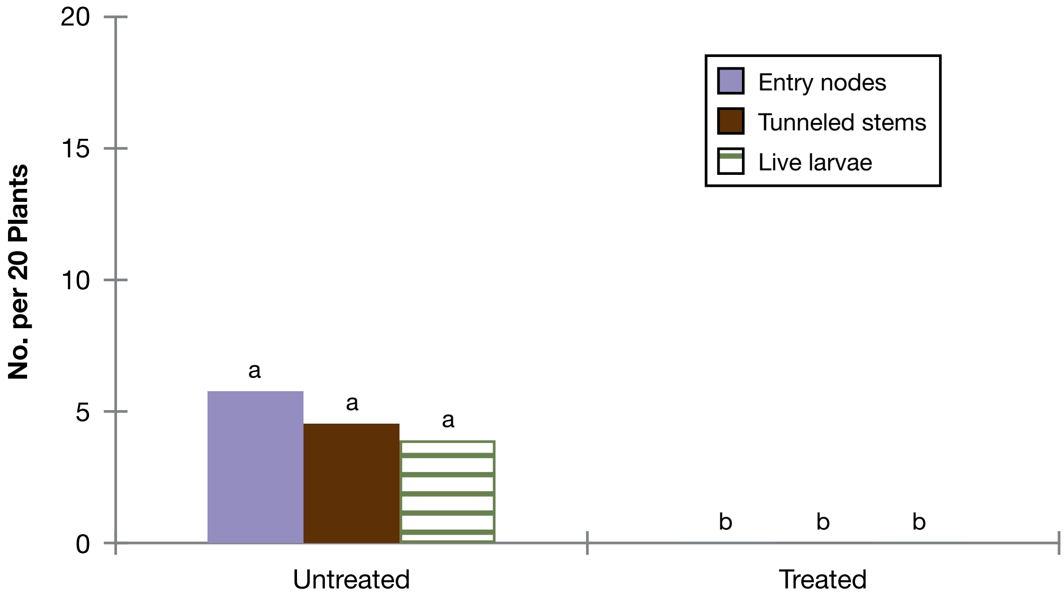
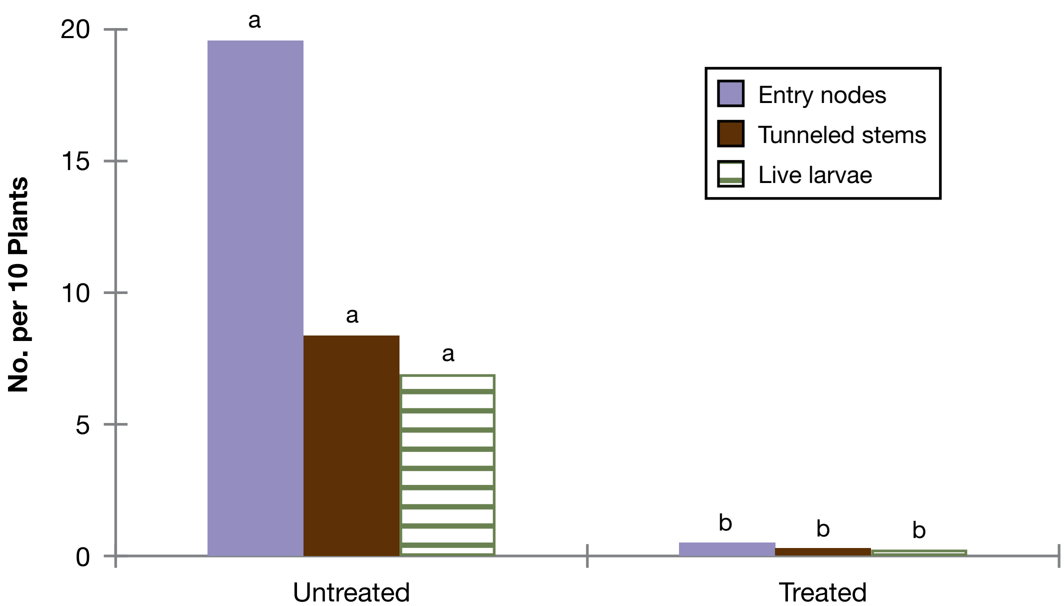


Figure 1. Thrips per 10 plants at Garden City South and Garden City North, 2008.



All observations are significantly different at $P < 0.0001$

Figure 2. Mean numbers for several *Dectes* stem borer observations (entry nodes, tunneled stems, and live larvae) per 20 plants at Garden City South, 2008.



All observations are significantly different at $P < 0.0001$

Figure 3. Mean numbers for several *Dectes* stem borer observations (entry nodes, tunneled stems, and live larvae) per 10 plants at Garden City North, 2008.

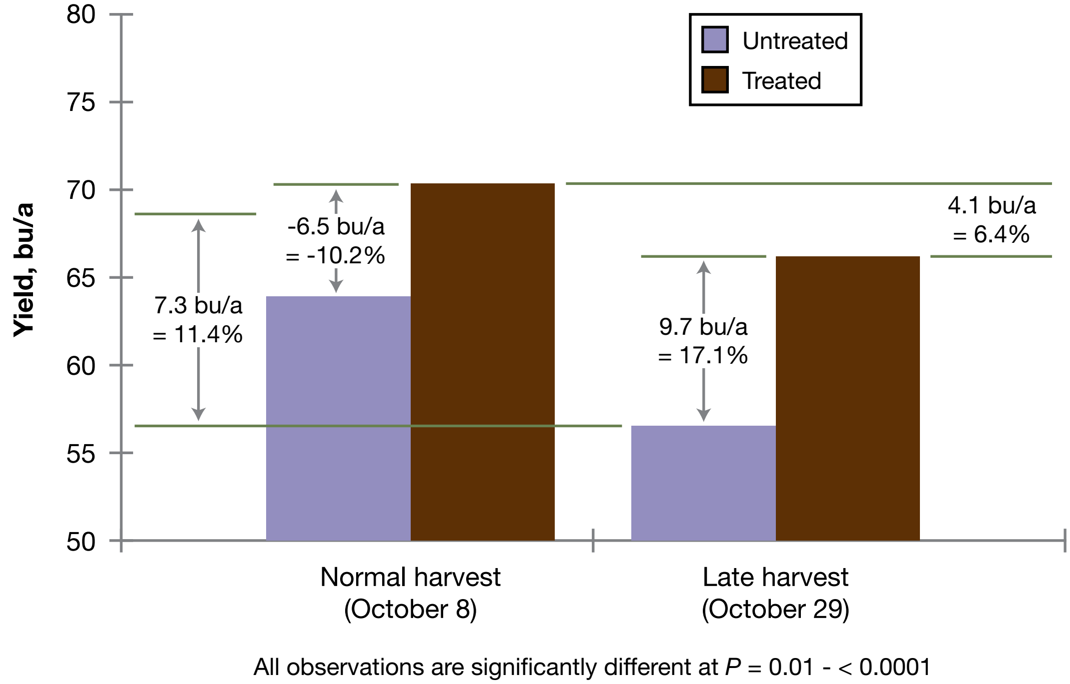


Figure 4. Grain yield at two harvest dates for treated and untreated soybean together with calculated differences used to calculate the *Dectes* stem borer yield damage components at Garden City North, 2008.

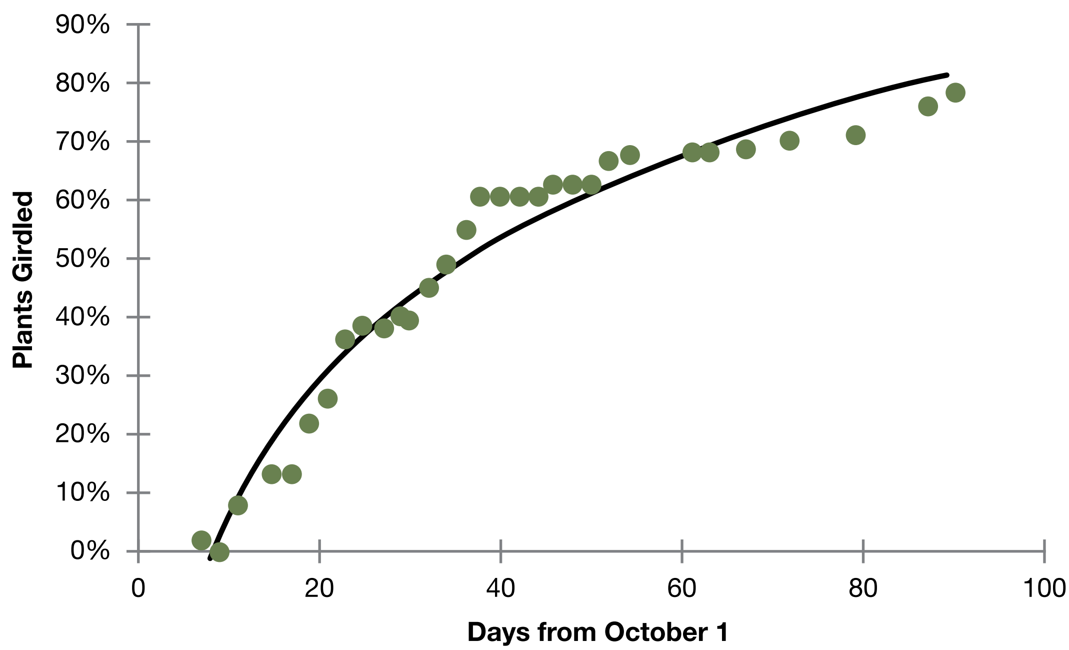


Figure 5. Percentage of plants girdled by the *Dectes* stem borer over time at the end of the season compared with the logarithmic trend line, Garden City North, 2008.

Efficacy of Miticides Applied by Chemigation at Tassel Stage and Standard Sprays Applied at Post-Tassel for Control of Spider Mites in Corn, 2008

L. Buschman and A. Joshi

Summary
Banks grass mites (BGM) peaked at 103 mites per two plants on August 8. Twospotted spider mites (TSM) and predatory mites were nearly absent at the beginning of the experiment but increased during the experiment. Spider mite populations did not reach economic levels in these plots. Of the chemigation treatments studied, only the Onager treatment appeared to give BGM control. Of the post-tassel standard treatments, both Onager and Oberon appeared to give low levels of BGM control. Efficacy of Oberon and Onager did not appear to be as high as when applied pre-tassel. The combinations of Oberon and Onager with Capture were not consistent; however, the combination with Oberon appeared to work better than the combination with Onager.

Procedures
Field corn (Northrup King N70-C 3000GT, 112-day maturity), was planted April 25 with a John Deere MaxEmerge six-row planter at a rate of 35,000 seeds per acre in wheat stubble under a center pivot irrigation system at the Southwest Research-Extension Center (Field S34) in Finney County, KS. A test with nine treatments was set up in a randomized complete block design with four replications (three replications for some treatments). Plots were four rows (10 ft) wide and 50 ft long with a two- or four-row (10 ft) border of untreated corn on each side and a 10-ft alley at each end. The field received 168 lb of N as anhydrous ammonia and was irrigated 13 times for a total of 12.7 in. of irrigation water. The plots were manually infested with BGM on July 1 by tying mite-infested leaves collected from an infested corn field in Stevens County to four plants in each plot, two for each of the two center rows. Pre-tassel simulated chemigation treatments were applied July 25 with three Delavan 100/140 ¾ in. raindrop nozzles mounted on a high clearance sprayer at tassel height between rows. This system was calibrated to deliver the equivalent of a 0.2 in. of irrigation on the two center rows (or 5,227 gal/a). Post-tassel standard foliar treatments were applied on August 5 with a high-clearance sprayer using 10-ft booms with two nozzles directed at each row (one from each side of the row on an 18-in. drop hose). The nozzles were directed to the ear zone of the plants. The sprayer was calibrated to deliver 12 gal/a at 2 mph and 30 psi.

Spider mites were sampled by collecting half the leaves from four plants (four half plants = two plants) from the two center rows in each plot. Early in the season, we sampled plants next to the infested plants. The plant material from each plot was placed in separate paper bags and transported to the laboratory, where the plant material was placed in separate, 76-liter Berlese funnels. A 100-watt light bulb was used to dry the vegetation and drive arthropods down into a collecting jar containing 70% methanol. The alcohol samples were filtered on ruled white filter paper. The spider mites and predator mites were counted under a binocular microscope. A subsample of spider mites (about 20) was mounted on a microscope slide. The mites on the slides were examined with a phase

contrast compound microscope to determine the ratio of BGM to TSM in each plot. Pretreatment spider mite samples were collected July 15, and posttreatment samples for chemigation were collected July 28 (3 days after treatment; DAT) and August 8 (1 week after treatment; WAT), 15 (2 WAT) and 22 (3 WAT). Posttreatment samples for standard foliar spray were collected August 8 (3 DAT), 15 (1 WAT), and 22 (2 WAT). Spider mite counts were transformed with Taylor's power transformation for statistical analysis. Non-transformed numbers of mites per four half plants are used in the presentation. Grain yield was not collected because the mites did not reach economic levels and there was considerable variation in plant height across the plots.

Results and Discussion

In untreated plots, BGM populations peaked at 103 mites per two plants on August 8 and declined to 27 mites per two plants by August 15 (Tables 1 and 2). Spider mite populations during this trial did not reach economic levels.

Of the chemigation treatments, only the Onager treatment appeared to give effective BGM control (Table 2). The Capture treatments appeared to flare up after initially reducing the mite populations (Tables 1 and 2). Of the post-tassel standard treatments, both Onager and Oberon appeared to give BGM control. Efficacy of Oberon applied post-tassel appeared to be more consistent over time than Onager (Table 2). The combinations with Capture were not consistent; however, the combination with Oberon appeared to work better than combinations with Onager.

Populations of TSM were nearly absent at the beginning of the experiment but increased during the experiment (Table 3). By late August, 32% of the spider mite population was TSM (Table 4). Predatory mites also increased during the season (Table 5).

Table 1. Banks grass mites per four half plants (= two plants) in plots treated with miticides, Garden City, 2008

Treatment[1]	Rate	July 15	July 28	Aug. 8	Aug. 15	Aug. 22	Season total
1. Check	–	2.4	98.0	103.4b	26.8abc	41.9ab	385.5b
		Pre-tassel chemigation treatments					
		Pretreat	3 DAT[2]	1 WAT	2 WAT	3 WAT	
2. Comite II	2.25 pt/a	2.0	75.0	108.9b	55.9ab	87.3a	316.7b
3. Oberon 2 SC	8.5 oz/a	5.1	47.5	68.2bc	32.2abc	46.1ab	200.4bc
4. Capture 2 E	6.4 oz/a	17.5	73.7	308.8a	90.9a	209.3a	564.6a
5. Onager 1 E	12 oz/a	4.1	31.2	16.9d	11.7cd	34.6bc	95.1c
		Post-tassel standard treatments					
		Pretreat	Pretreat	3 DAT	1 WAT	2 WAT	
6. Onager 1 E	12 oz/a	7.4	50.9	66.6bc	28.8abc	10.8c	204.6bc
7. Onager 1 E and	12 oz/a	6.7	119.8	121.9b	17.3bcd	33.4bc	385.5b
Capture 2 E	6.4 oz/a						
8. Oberon 2 SC	8.5 oz/a	6.2	134.0	40.4bcd	4.8d	6.6bc	319.5bc
9. Oberon 2 SC and	8.5 oz/a	5.9	62.8	54.4cd	1.3cd	30.5bc	197.4bc
Capture 2 E	6.4 oz/a						
P value <		0.0784	0.1243	0.0014	0.0172	0.0174	0.0072

[1] Pre-tassel chemigation on July 25, 2008, and post-tassel treatments on Aug. 5, 2008.
[2] DAT = days after treatment; WAT = weeks after treatment.
Within columns, means followed by the same letter are not significantly different ($P < 0.05$).

Table 2. Banks grass mites per four half plants and percentage of control of Banks grass mites in plots treated with miticides, Garden City, 2008

Treatment[1]		Rate	July 28	Aug. 8	Aug. 15	Aug. 22	Season total
1.	Check	–	98.0	103.4	26.8	41.9	385.5
			Pre-tassel chemigation treatments				
			3 DAT[2]	1 WAT	2 WAT	3 WAT	
2.	Comite II	2.25 pt/a	-70.4	-148.7	-411.9	-320.4	-112.7
3.	Oberon 2 SC	8.5 oz/a	73.7	21.8	-3.4	34.2	39.2
4.	Capture 2 E	6.4 oz/a	55.6	-71.3	-86.8	-1.6	-25.1
5.	Onager 1 E	12 oz/a	80.7	89.2	72.6	72.4	78.5
			Post-tassel standard treatments				
			Pretreat	3 DAT	1 WAT	2 WAT	
6.	Onager 1 E	12 oz/a	91.0	57.3	26.9	93.0	71.7
7.	Onager 1 E and	12 oz/a	32.1	20.1	65.4	72.3	42.2
	Capture 2 E	6.4 oz/a					
8.	Oberon 2 SC	8.5 oz/a	9.9	73.4	95.8	82.7	67.2
9.	Oberon 2 SC and	8.5 oz/a	46.4	76.0	74.9	69.7	66.8
	Capture 2 E	6.4 oz/a					

Highlighted values are actual numbers of mites in the check plot that were used to calculate percentage of control for other treatments.

[1] Pre-tassel chemigation on July 25, 2008, and post-tassel treatments on Aug. 5, 2008.

[2] DAT = days after treatment; WAT = weeks after treatment.

Table 3. Twospotted spider mites four half plants (= two plants) in plots treated with miticides, Garden City, 2008

Treatment[1]		Rate	July 15*	July 28*	Aug. 8	Aug. 15	Aug. 22	Season total
1.	Check	–	0.0	21.6	8.5	5.7	23.9	57.5
			Pre-tassel chemigation treatments					
			Pretreat	3 DAT[2]	1 WAT	2 WAT	3 WAT	
2.	Comite II	2.25 pt/a	0.0	1.7	6.6	11.5	7.6	21.6
3.	Oberon 2 SC	8.5 oz/a	0.0	4.5	2.4	17.2	69.3	29.6
4.	Capture 2 E	6.4 oz/a	0.0	0.0	11.7	32.6	22.3	49.3
5.	Onager 1 E	12 oz/a	0.0	0.8	3.0	4.9	18.6	9.6
			Post-tassel standard treatments					
			Pretreat	Pretreat	3 DAT	1 WAT	2 WAT	
6.	Onager 1 E	12 oz/a	0.0	0.0	15.2	7.9	4.9	23.2
7.	Onager 1 E and	12 oz/a	0.0	0.0	5.6	4.3	0.0	9.8
	Capture 2 E	6.4 oz/a						
8.	Oberon 2 SC	8.5 oz/a	0.0	0.0	19.7	2.6	1.5	22.3
9.	Oberon 2 SC and	8.5 oz/a	0.0	0.9	0.0	2.9	0.4	4.3
	Capture 2 E	6.4 oz/a						
P value <			–	–	0.8865	0.4094	0.2013	0.6893

[1] Pre-tassel chemigation on July 25, 2008, and post-tassel treatments on Aug. 5, 2008.
[2] DAT = days after treatment; WAT = weeks after treatment.
* Populations were too low to run statistics.

Table 4. Percentage of spider mites that are twospotted spider mites in plots treated with miticides, Garden City, 2008

Treatment[1]	Rate	July 15*	July 28*	Aug. 8	Aug. 15	Aug. 22	Season total
1. Check	–	0.0	17.2	6.2	15.6	31.8	15.3
		Pre-tassel chemigation treatments					
		Pretreat	3 DAT[2]	1 WAT	2 WAT	3 WAT	
2. Comite II	2.25 pt/a	0.0	2.2	5.7	14.1	7.2	5.5
3. Oberon 2 SC	8.5 oz/a	15.3	7.6	3.1	28.7	55.2	9.0
4. Capture 2 E	6.4 oz/a	0.0	0.0	3.6	24.7	8.5	6.1
5. Onager 1 E	12 oz/a	0.0	2.5	14.7	22.2	27.1	6.5
		Post-tassel standard treatments					
		Pretreat	Pretreat	3 DAT	1 WAT	2 WAT	
6. Onager 1 E	12 oz/a	0.0	0.0	17.1	21.4	31.2	13.5
7. Onager 1 E and	12 oz/a	0.0	0.0	4.2	16.0	0.0	3.0
Capture 2 E	6.4 oz/a						
8. Oberon 2 SC	8.5 oz/a	0.0	0.0	30.7	27.9	10.6	9.7
9. Oberon 2 SC and	8.5 oz/a	0.0	1.2	0.0	18.0	10.1	2.4
Capture 2 E	6.4 oz/a						
P value <		–	–	0.3569	0.6296	0.0825	0.6214

[1] Pre-tassel chemigation on July 25, 2008, and post-tassel treatments on Aug. 5, 2008.
[2] DAT = days after treatment; WAT = weeks after treatment.
* Populations were too low to run statistics.

Table 5. Numbers of predator mites in plots treated with miticides, Garden City, 2008

Treatment[1]		Rate	July 15*	July 28*	Aug. 8	Aug. 15	Aug. 22	Season total
1.	Check	–	1.3	5.9	23.8a	3.8	9.2	40.9
			Pre-tassel chemigation treatments					
			Pretreat	3 DAT[2]	1 WAT	2 WAT	3 WAT	
2.	Comite II	2.25 pt/a	0.0	0.0	0.0cd	13.9	10.3	13.9
3.	Oberon 2 SC	8.5 oz/a	0.0	7.3	4.6ab	10.4	10.1	29.6
4.	Capture 2 E	6.4 oz/a	0.3	0.0	2.7bcd	6.5	35.8	9.5
5.	Onager 1 E	12 oz/a	0.0	0.0	0.9bcd	3.2	10.0	4.1
			Post-tassel standard treatments					
			Pretreat	Pretreat	3 DAT	1 WAT	2 WAT	
6.	Onager 1 E	12 oz/a	0.4	0.0	5.8ab	2.5	0.0	8.7
7.	Onager 1 E and	12 oz/a	0.0	0.8	5.3bc	1.9	2.1	8.9
	Capture 2 E	6.4 oz/a						
8.	Oberon 2 SC	8.5 oz/a	0.0	0.0	4.1bcd	1.6	5.2	5.7
9.	Oberon 2 SC and	8.5 oz/a	0.0	6.5	0.0d	0.8	1.7	13.8
	Capture 2 E	6.4 oz/a						
P value <			–	–	0.0024	0.8809	0.1287	0.0706

[1] Pre-tassel chemigation on July 25, 2008, and post-tassel treatments on Aug. 5, 2008.
[2] DAT = days after treatment; WAT = weeks after treatment.
Within columns, means followed by the same letter are not significantly different ($P < 0.05$, LSD).
* Populations were too low to run statistics.

Efficacy of Miticides Applied at Tassel Stage for Control of Spider Mites in Corn, 2008

L. Buschman and A. Joshi

Summary
Spider mite populations peaked at 192 mites per two plants on July 30, 2 weeks after treatment (WAT). The mite population was mainly Banks grass mite (BGM). Populations of twospotted spider mites (TSM) and predatory mites were nearly absent at the beginning of the season but were more common at 3 WAT. The standard miticide, Comite, gave good season-long control. Both rates of Oberon gave excellent season-long control of BGM, but the higher rate of Oberon gave better control during the first week. All three rates of Onager gave excellent season-long control of BGM. When Onager was used in combination with three other miticides, they all gave excellent 98 to 100% control, but only the combination with Nexter appeared to improve BGM control over Onager alone at 3 days after treatment (DAT).

Procedures
Field corn (Northrup King N70-C3000GT, 112-day maturity) was planted April 25 with a John Deere MaxEmerge six-row planter at a rate of 35,000 seeds per acre in wheat stubble under a center pivot irrigation system at the Southwest Research-Extension Center (Field S34) in Finney County, KS. A test with 10 treatments was set up in a randomized complete block design with four replications. Plots were four rows (10 ft) wide and 50 ft long with a two-row (5 ft) border of untreated corn on each side and a 10-ft alley at each end. The field received 168 lb of N as anhydrous ammonia and was irrigated 13 times, receiving 12.7 in. of water. Plots were manually infested with BGM on July 1 by tying mite-infested leaves collected from an infested corn field in Stevens County to four plants in each plot, two for each of the two center rows. The treatments were applied July 15 with a high-clearance sprayer using 10-ft booms with two nozzles directed at each row (one on each side of the row on an 18-in. drop hose). The nozzles were directed up into the plant. The sprayer was calibrated to deliver 12 gal/a at 2 mph and 30 psi.

Spider mites were sampled by collecting half the leaves from four plants (four half plants = two plants) from the two center rows in each plot. Early in the season, we sampled plants next to the infested plants. The plant material from each plot was placed in separate large paper bags and transported to the laboratory, where the plant material was placed in separate, large 76-liter Berlese funnels. A 100-watt light bulb was used to dry the vegetation and drive arthropods down into a collecting jar containing 70% methanol. The alcohol samples were filtered on ruled white filter paper, and spider mites and predator mites were counted under a binocular microscope. A subsample of spider mites (about 20) was mounted on a microscope slide. The slides were examined with a phase contrast compound microscope to determine the ratio of BGM to TSM in each plot. Pretreatment spider mite samples were collected July 11, and posttreatment samples were collected July 18 (3 DAT), 23 (1 WAT), and 30 (2 WAT) and August 6 (3 WAT).

Spider mite counts were transformed with Taylor's power transformation for statistical analysis and were back-transformed to mites per four half plants for presentation. Data were analyzed by one-way ANOVA, and means were separated by Fisher's protected LSD ($P < 0.05$). Grain yield was not collected because mite populations did not reach economic levels and there was considerable variation in plant height across the plots.

Results and Discussion

In untreated plots, BGM populations peaked at 192 mites per two plants on July 30 and declined to 43 mites per two plants by August 6 (Table 1). Overall, the spider mite population pressure during this trial was low.

The standard miticide, Comite, gave excellent season long control (up to 91%), and it held up for 3 weeks (Tables 1 and 2). The higher rate of Oberon gave excellent control for season-long control (up to 97%). The lower rate of Oberon started out with 40% control at 3 DAT but increased to 100% BGM control 2 WAT and then declined to 75% by 3 WAT (Table 2). The lowest rate of Onager gave excellent early control of BMG (up to 99%), but this control was not consistent through the season. The medium rate of Onager was effective only later in the season. Control for the highest rate of Onager was low at 1 WAT but much higher at 2 WAT. Overall, season-long control of BGM for the different rates of Onager varied between 78 and 89%.

When Onager was used in combination with other miticides, the season-long control was excellent, 95 to 99%. Only the combination with Nexter appeared to improve BGM control over Onager alone, giving 97% control at 3 DAT and 100% control through 3 weeks (Table 2). The combinations of Onager with Melbemectin or Fenazaquin gave only 5 to 56% control at 3 DAT, but by 1 WAT, they gave 98 to 100% control. These treatments gave 98 to 100% control for the rest of the experiment.

Populations of TSM and predatory mites were nearly absent at the beginning of the experiment but increased slowly over the 3 weeks of the experiment (Tables 3 and 4).

Table 1. Banks grass mites per four half plants (= two plants) in plots treated with miticides, Garden City, 2008

Treatment[1]		Rate	July 11 Pretreat	July 18 3 DAT[2]	July 23 1 WAT	July 30 2 WAT	August 6 3 WAT	Season total
1.	Untreated check	–	12.0	11.5	14.7	191.7a	42.7	272.4a
2.	Comite II	2.25 pt/a	4.7	1.7	7.2	25.7b	2.7	42.1b
3.	Oberon 2 SC	5.7 oz/a	13.7	5.2	4.3	9.5b	4.2	37.1b
4.	Oberon 2 SC	8.5 oz/a	10.2	1.0	1.0	1.1b	1.2	14.5b
5.	Onager 1 E	8 oz/a	3.5	4.7	4.5	45.7b	22.5	79.6b
6.	Onager 1 E	10 oz/a	12.5	7.5	4.5	4.8b	3.9	33.2b
7.	Onager 1 E	12 oz/a	10.7	6.5	11.4	54.5b	5.2	88.3b
8.	Onager 1 E and	8 oz/a	12.7	4.6	0.7	1.2b	1.2	20.6b
	Melbemectin	9.3 oz/a						
9.	Onager 1 E and	8 oz/a	19.7	10.2	1.5	0.7b	1.0	33.2b
	Fenaxaquin 200 SC	0.67 oz/a						
10.	Onager 1 E and	8 oz/a	9.8	3.0	1.2	0.7b	4.1	18.1b
	Nexter 75 WP	5.9 oz/a						
P value <			0.8410	0.3591	0.2343	0.0063	0.1148	0.0062

[1] Treatments made July 15, 2008, when corn was starting to tassel.
[2] DAT = days after treatment; WAT = weeks after treatment.
Within columns, means followed by the same letter are not significantly different ($P < 0.05$).

Table 2. Banks grass mites per four half plants and percentage of control of Banks grass mites in plots treated with miticides, Garden City, 2008

Treatment[1]		Rate	July 18 3 DAT[2]	July 23 1 WAT	July 30 2 WAT	August 6 3 WAT	Season total
1.	Untreated check	–	11.5	14.7	191.7	42.66	272.4
2.	Comite II	2.25 pt/a	91	89	97	98	93
3.	Oberon 2 SC	5.7 oz/a	40	73	100	75	85
4.	Oberon 2 SC	8.5 oz/a	99	82	100	99	97
5.	Onager 1 E	8 oz/a	99	58	94	74	89
6.	Onager 1 E	10 oz/a	8	37	98	92	81
7.	Onager 1 E	12 oz/a	26	-10	95	98	78
8.	Onager 1 E and	8 oz/a	56	99	100	98	95
	Melbemectin	9.3 oz/a					
9.	Onager 1 E and	8 oz/a	5	98	100	100	95
	Fenaxaquin 200 SC	0.67 oz/a					
10.	Onager 1 E and	8 oz/a	97	100	100	100	99
	Nexter 75 WP	5.9 oz/a					

Highlighted values are actual number of mites in the check plot that were used to calculate percentage of control for other treatments.

[1] Treatments made July 15, 2008, when corn was starting to tassel.

[2] DAT = days after treatment; WAT = weeks after treatment.

Table 3. Twospotted spider mites per four half plants (= two plants) in plots treated with miticides, Garden City, 2008

Treatment[1]		Rate	July 11 Pretreat	July 18 3 DAT[2]	July 23 1 WAT	July 30 2 WAT	August 6 3 WAT	Season total
1.	Untreated check	–	0.0	0.0	0.0	6.7	11.6	18.3
2.	Comite II	2.25 pt/a	0.0	0.0	0.0	0.0	0.0	0.0
3.	Oberon 2 SC	5.7 oz/a	0.0	0.0	0.0	0.0	1.5	1.5
4.	Oberon 2 SC	8.5 oz/a	0.0	0.0	0.0	0.3	0.6	0.9
5.	Onager 1 E	8 oz/a	0.0	0.0	0.0	0.2	1.1	1.3
6.	Onager 1 E	10 oz/a	0.0	0.0	0.0	0.0	0.8	1.8
7.	Onager 1 E	12 oz/a	1.0	0.0	0.0	0.0	6.3	7.0
8.	Onager 1 E and	8 oz/a	0.6	0.0	0.0	0.3	0.2	1.1
	Melbemectin	9.3 oz/a						
9.	Onager 1 E and	8 oz/a	0.5	0.0	0.0	0.3	0.2	0.9
	Fenaxaquin 200 SC	0.67 oz/a						
10.	Onager 1 E and	8 oz/a	0.0	0.0	0.0	0.3	8.6	8.9
	Nexter 75 WP	5.9 oz/a						
P value <			Population was too low to run statistics.					

[1] Treatments made July 15, 2008, when corn was starting to tassel.
[2] DAT = days after treatment; WAT = weeks after treatment.

Table 4. Predator mites per four half plants (= two plants) in plots treated with miticides, Garden City, 2008

Treatment[1]		Rate	July 18 3 DAT[2]	July 23 1 WAT	July 30 2 WAT	August 6 3 WAT	Season total
1.	Untreated check	–	0.0	0.0	4.2	1.3	5.5
2.	Comite II	2.25 pt/a	0.0	0.0	1.5	0.6	2.1
3.	Oberon 2 SC	5.7 oz/a	0.0	1.2	0.0	0.0	1.2
4.	Oberon 2 SC	8.5 oz/a	0.0	0.0	0.2	0.9	1.1
5.	Onager 1 E	8 oz/a	0.0	0.0	0.4	2.2	2.6
6.	Onager 1 E	10 oz/a	0.0	0.3	0.7	0.2	1.2
7.	Onager 1 E	12 oz/a	0.0	0.3	3.5	0.3	4.1
8.	Onager 1 E and	8 oz/a	0.4	0.0	0.3	0.6	1.2
	Melbemectin	9.3 oz/a					
9.	Onager 1 E and	8 oz/a	0.3	3.0	0.2	0.2	3.7
	Fenaxaquin 200 SC	0.67 oz/a					
10.	Onager 1 E and	8 oz/a	0.0	0.0	1.2	0.8	2.0
	Nexter 75 WP	5.9 oz/a					
P value <					Population was too low to run statistics.		

[1] Treatments made July 15, 2008, when corn was starting to tassel.
[2] DAT = days after treatment; WAT = weeks after treatment.

Efficacy of Monsanto Stacked Event Corn Hybrids for Control of Corn Earworm, Rootworm, and Southwestern and European Corn Borer, 2008

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Summary
This trial was conducted to evaluate the efficacy of corn hybrids containing several stacked events for controlling the corn rootworm (CRW), *Diabrotica virgifera virgifera*, European corn borer (ECB), *Ostrinia nubilalis*, southwestern corn borer (SWCB), *Diatraea grandiosella*, corn earworm (CEW), *Helicoverpa zea*, and western bean cutworm (WBC), *Loxagrotis albicosta*. Overall, SmartStax and YGVT3P/HXRW had outstanding efficacy against CEW and SWCB. Feral populations of CRW, ECB, and WBC were too low to test the efficacy of the hybrids. None of the hybrids escaped feeding damage by dusky sap beetle (DSB), *Carpophilus lugubris*.

Procedures
Experimental corn seed (supplied by Monsanto) was machine planted on May 16, 2008, at the Southwest Research-Extension Center (Field 28) in Garden City, KS. Plots were eight rows wide and 20 ft long. There were 10-ft-wide alleys. The study was organized as a randomized block design with four replicates. Four rows of non-Bt corn were planted around the experiment as a border and windbreak. The experiment relied on feral populations of corn pests to infest the plots. SmartStax is a stacked plant that combines YieldGard VT Triple PRO (Monsanto) with Herculex XTRA (Dow AgroSciences) technologies. These plants combine eight transgenic events in one plant, including two corn borer active events, two western corn rootworm active events, and several herbicide resistance traits. The other treatments include various combinations of these traits.

On July 30, a set of 10 corn plants were dug from rows 2 and 3 to make root injury ratings using the 0 to 3 injury rating scale proposed by Olson et al. (2005). On August 19 and 21, 20 ears from rows 4 and 5 were taken to record CEW and WBC feeding in corn ears (by location: ear tip or ear base). Feeding injury was measured by counting the number of harvestable kernels damaged by CEW or WBC and by using the Winstrum scale (centimeters of feeding penetration plus 1 for silk feeding). On October 13, another 10 plants from rows 4 and 5 were evaluated for stalk and ear pests. On October 20, all ears from rows 6 and 7 were picked and weighed to calculate grain yield.

Data were analyzed by one-way ANOVA, and means were separated by Fisher's protected LSD test ($P < 0.05$).

Results and Discussion
Feral CRW pressure, recorded on July 30, was relatively low, 0.06 to 0.07 on the 0 to 3 root rating scale, and there were no significant differences across corn hybrids (Table 1).

Feral CEW pressure was moderate with up to 60% of the corn ears infested and 0.6 CEW larvae per plant on August 19 (Figures 1 and 2, respectively). Compared with the check plots (Treatment 4), significantly fewer infested ears, CEW larvae, and damaged kernels were recorded in the two hybrids that had "VT3P" (Treatments 1 and 2; Table 1, Figures 1, 2, and 3). Feeding injury at the tip of the corn ear (mostly CEW) was significantly lower in the VT3P (Table 1). The Winstrum ratings show the same trends (Table 1). By the second week of October, the rate of ear infestation had increased from 60% in August to 87.5% in check plots (Table 2). The number of kernels damaged increased from 8.6 in August to 25.5 in October as well (Tables 1 and 2, Figures 3 and 5). However, this increase did not change the early season pattern observed across hybrids for kernel damage or Winstrum ratings (Table 2). Only hybrids that included VT3P had significantly lower rates of infestation, kernels damaged, and Winstrum ratings compared with check plots (Figure 4). Ear tip damage had the same trends but did not differ significantly. There was a general increase in ear damage, which was probably due to DSB. None of the Bt corn hybrids appeared to have efficacy on this insect.

There was a moderate infestation of SWCB, 0.2 larvae per plant (Table 2). Although the number of SWCB larvae and the resulting corn borer tunneling were very low in the VT3P and HXX lines (first three treatments), there were few significant differences across the hybrids that were meaningful (Table 2 and Figure 6). Treatment 7 unexpectedly had the most tunneling. Ear base feeding was negligible in all plots in both samples (Tables 1 and 2).

Grain yield was variable across the plots because of stand and irrigation differences, and there were no significant differences among hybrids (Table 2 and Figure 7).

ECB were not observed in the August ear collections, but two ECB were recorded in stems of the non-Bt hybrid (Treatment 4) in the October sample. Nine WBC were observed in the August ear collections, but none were observed in October. Seven WBC were found in Treatment 5.

Overall, SmartStax and VT3P/HXRW had outstanding efficacy against CEW and SWCB. Feral populations of CRW, ECB, and WBC were too low to draw conclusions on efficacy of the corn hybrids against these pests. None of the hybrids escaped DSB feeding.

References

Oleson, J.D., Y. Park, T.M. Nowatzki, and J.J. Tollefson. 2005. Node-injury scale. Journal of Economic Entomology, 98:1-8.

Table 1. Corn rootworm (CRW) rating on July 30 taken from a set of 20 root samples and corn earworm (CEW) observations from 20 ears on Aug. 19 and 21, 2008, Garden City

Treatment	Insect events present	CRW rating	Infested ear	CEW larvae	Ear tip damage	Ear base damage	Kernels damaged	Winstrum rating
		0-3	%	no./ear	---------cm/ear---------		no./ear	
					Means			
1. YGVT3P/HXX	SmartStax[1]	0.06	2.5c	0.0c	0.0c	0	0.1c	0.0d
2. YGVT3P/HXRW	YieldGard VT Triple Pro/Herculex RW[2]	0.07	5.0c	0.0c	0.1c	0.0	0.9c	0.2cd
3. HXX	Herculex XTRA[3]	0.07	28.8b	0.3b	0.4bc	0.0	2.1bc	0.6cd
4. Isoline	–	0.08	60.0a	0.6a	1.0a	0.1	8.6a	1.6ab
5. Isoline and	–	0.07	43.8ab	0.4ab	0.8ab	0.2	7.4a	2.2a
Counter 20 CR	8 oz/1000 row-ft							
6. YGVT	YGVT[4]	0.05	38.8ab	0.3b	0.8ab	0.1	6.0ab	1.0bc
7. YGVT and	YGVT[4]	0.06	45.0ab	0.4ab	0.4ab	0.3	6.4a	1.1bc
Counter 20 CR	8 oz/1000 row-ft							
					ANOVA			
P value <	–	0.6769	0.0001	0.0001	0.0135	0.5892	0.0008	0.0015
CV	–	–	38.57	40.18	76.49	–	59.05	64.00
LSD	–	–	18.31	0.17	0.54	–	3.94	0.92

[1] Combination of YieldGard VT Triple PRO (Events MON89034 (corn borer active) and MON88017 (rootworm active)) and Herculex XTRA (Events TC1507 (corn borer active) and DAS59122 (corn rootworm active)) technologies.
[2] Combination of YieldGard VT Triple PRO (Events MON89034 (corn borer active) and MON88017 (corn rootworm active) and Herculex RW (Event DAS59122 (corn rootworm active)) technologies.
[3] Herculex XTRA (Events TC1507 (corn borer active) and DAS59122 (corn rootworm active) technologies).
[4] YGVT YieldGard VT (Event MON89034 (corn rootworm active)).
Within columns, means followed by the same letter are not significantly different ($P < 0.05$).

Table 2. Southwestern corn borer (SWCB) damage observations on October 13 from 10 plants and grain yield recorded on Oct. 20, 2008, Garden City

Treatment	Insect events present	Infested ear	SWCB larvae	Stalk tunneling	Ear tip damage	Ear base damage	Kernels damaged	Winstrum rating	Grain yield
		%	no./plant	cm/plant	----------cm/ear----------		no./ear		bu/a
		Means							
1. YGVT3P/HXX	SmartStax[1]	15.0b	0	0b	0.4	0.1b	3.5b	0.6b	102.5
2. YGVT3P/HXRW	YieldGard VT Triple Pro/Herculex RW[2]	25.0b	0	0.1b	0.7	0.1b	6.6b	1.0b	129.8
3. HXX	Herculex XTRA[3]	62.5a	0	0b	1.7	0.5b	11.5ab	2.2ab	137.0
4. Isoline	–	87.5a	0.2	1.4b	2.7	0.6b	25.5a	4.1a	116.2
5. Isoline and	–	77.5a	0.2	2.0b	1.4	1.1ab	17.8ab	3.1a	141.6
Counter 20 CR	8 oz/1000 row-ft								
6. YGVT	YGVT[4]	82.5a	0.2	1.5b	1.1	2.1a	24.9a	4.0a	113.4
7. YGVT and	YGVT[4]	90.0a	0.2	6.1a	2.1	1.1ab	18.2ab	3.8a	128.9
Counter 20 CR	8 oz/1000 row-ft								
		ANOVA							
P value <		0.0001	10.87	0.0171	0.2158	0.0151	0.0031	0.0031	0.2824
CV		30.36	–	144.50	–	95.41	48.13	48.13	–
LSD		28.35	–	3.04	–	1.11	1.93	1.93	–

[1] Combination of YieldGard VT Triple PRO (Events MON89034 (corn borer active) and MON88017 (rootworm active)) and Herculex XTRA (Events TC1507 (corn borer active) and DAS59122 (corn rootworm active)) technologies.
[2] Combination of YieldGard VT Triple PRO (Events MON89034 (corn borer active) and MON88017 (corn rootworm active) and Herculex RW (Event DAS59122 (corn rootworm active)) technologies.
[3] Herculex XTRA (Events TC1507 (corn borer active) and DAS59122 (corn rootworm active) technologies).
[4] YGVT YieldGard VT (Event MON89034 (corn rootworm active)).
Within columns, means followed by the same letter are not significantly different ($P < 0.05$).

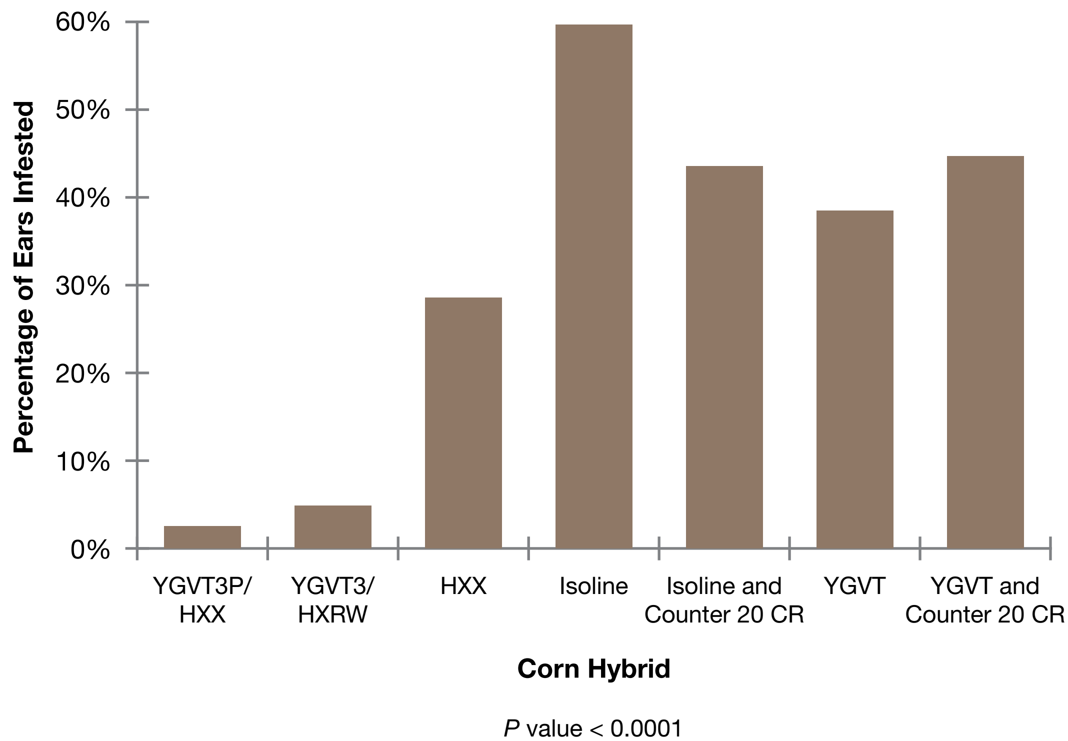

Figure 1. Infestation of corn ears, Aug. 19, 2008.

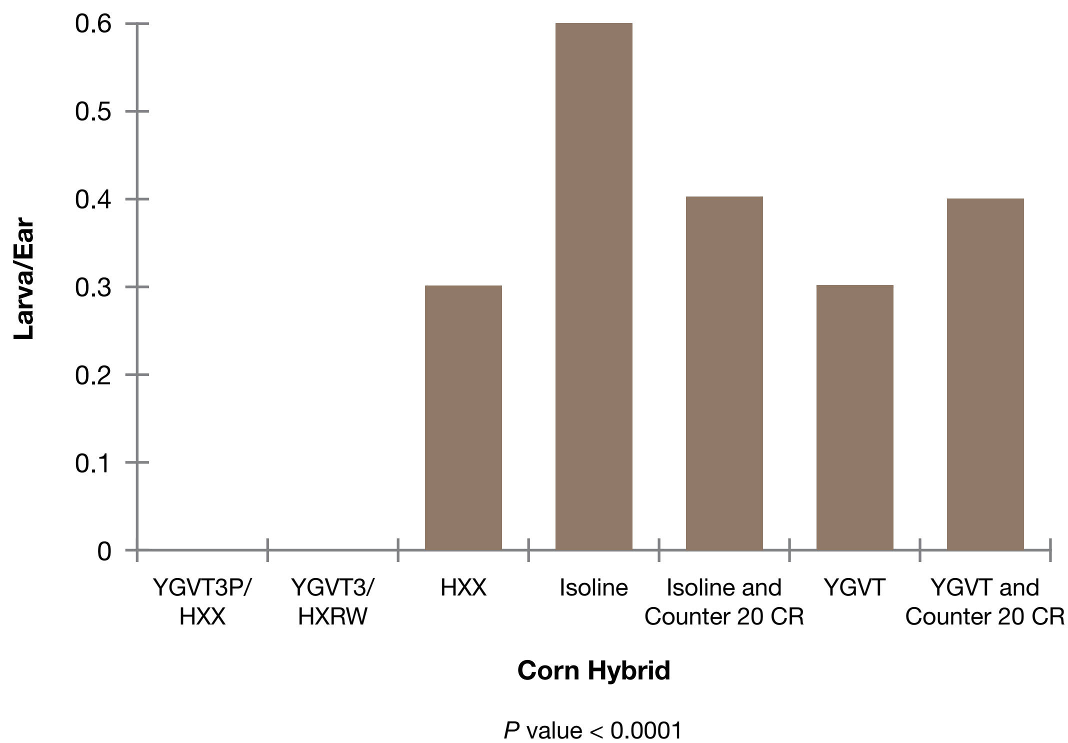

Figure 2. Corn earworm infestation, Aug. 19, 2008.

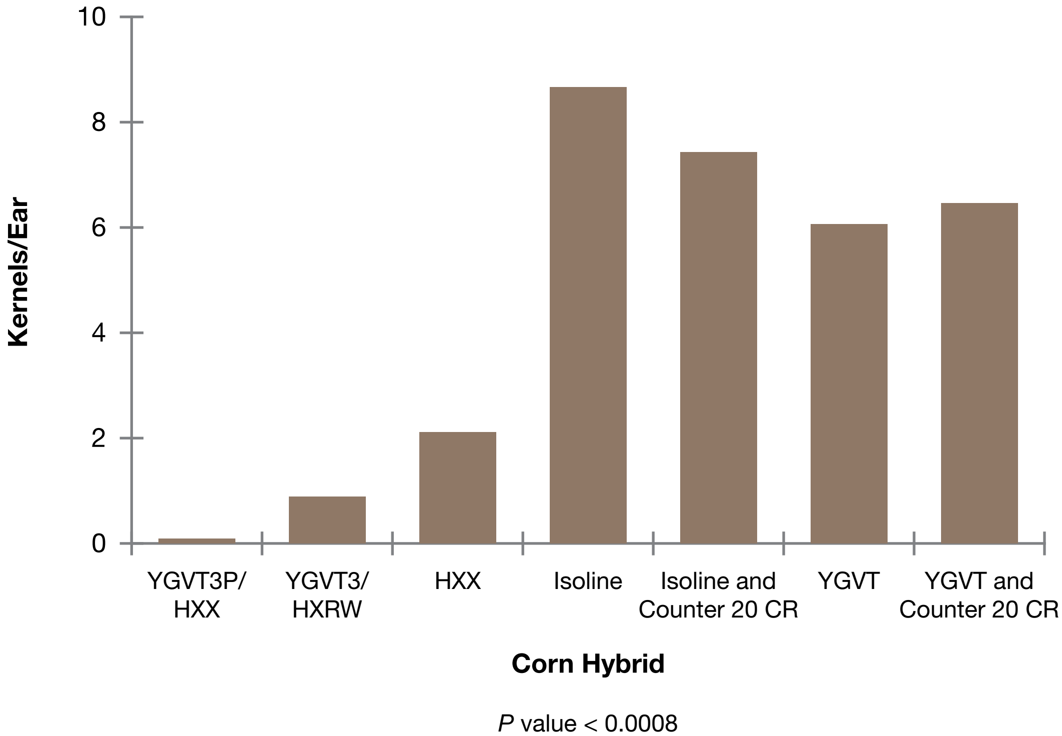

Figure 3. Kernels damaged by corn earworm, Aug. 19, 2008.

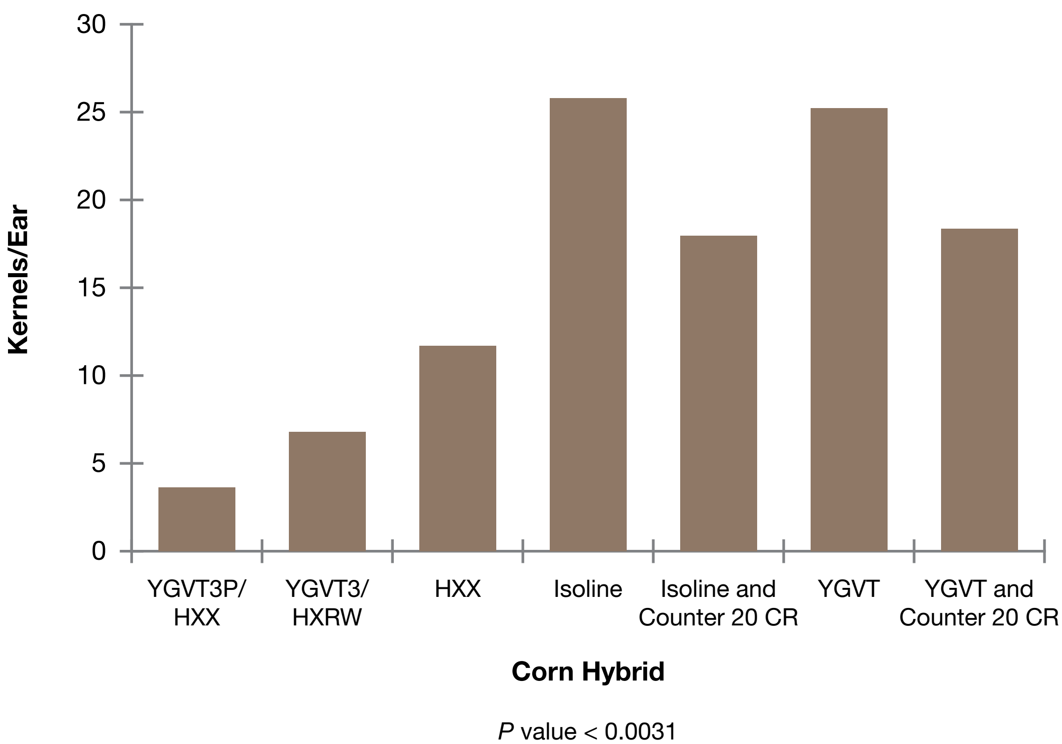

Figure 4. Kernels damaged by corn earworm, Oct. 13, 1008.

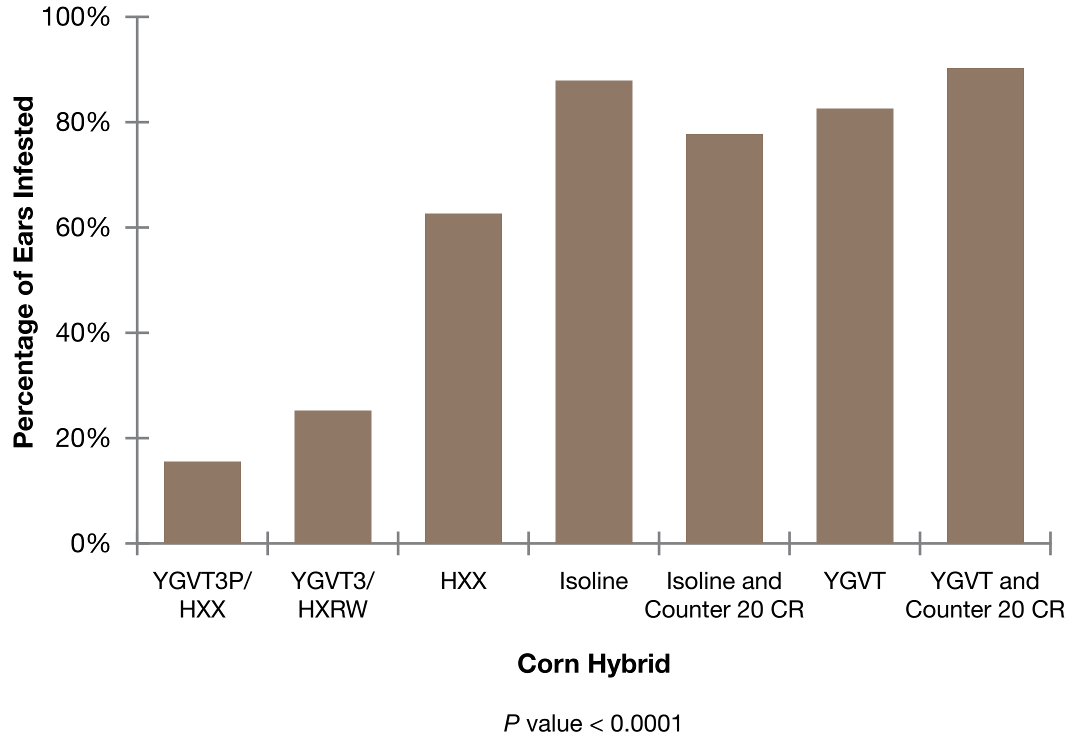

Figure 5. Infestation of corn ears, Oct. 13, 2008.

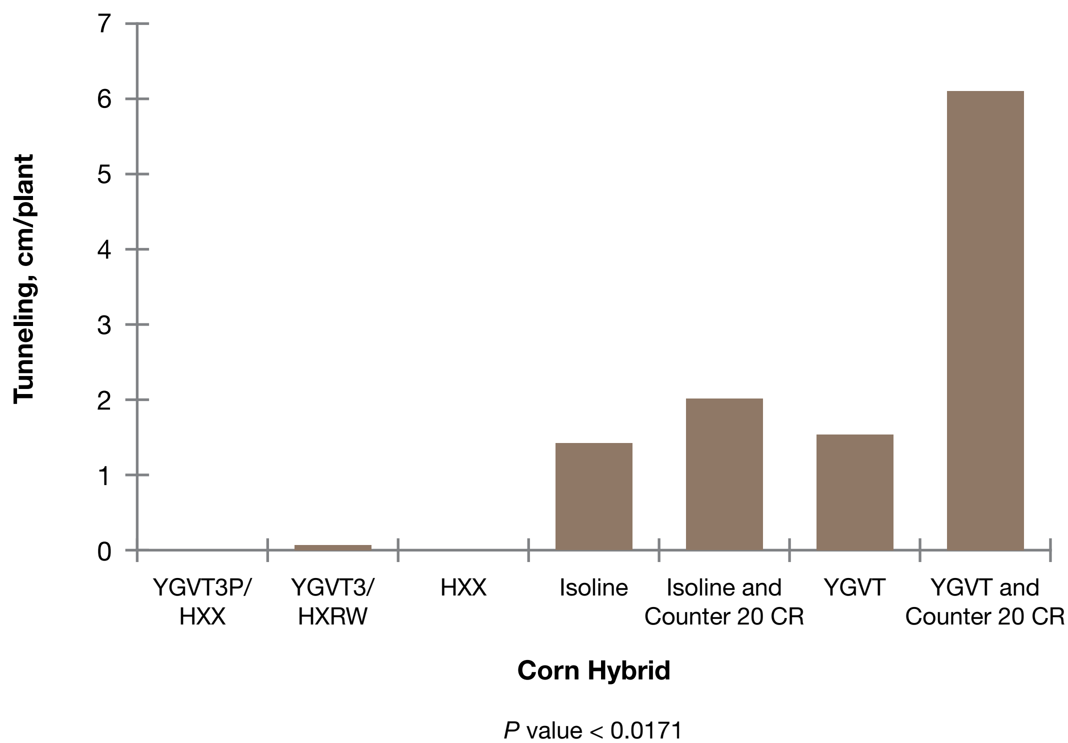

Figure 6. Second generation southwestern corn borer stalk tunneling, Oct. 13, 2008.

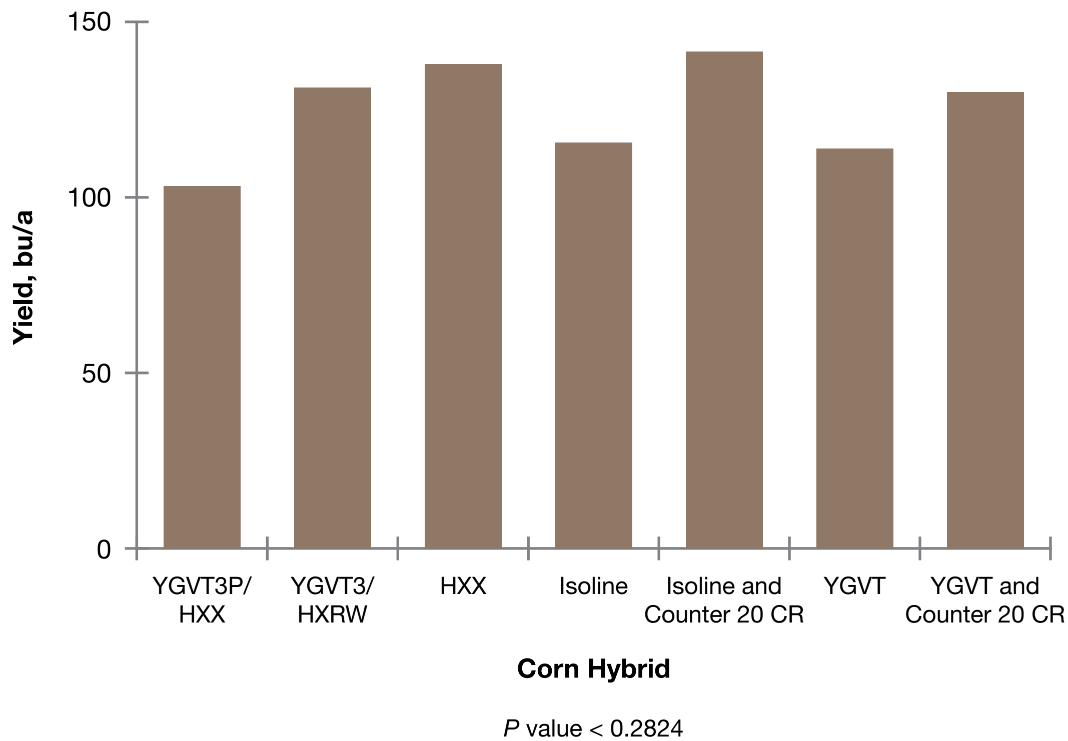

Figure 7. Grain yield from corn hybrids, Oct. 13, 2008.

Effect of Row Spacing, Tillage, Opener, and Coulter on Winter Canola[1]

J. Holman, M. Stamm[2,3], S. Maxwell, G. Miller, C. Godsey[3], K. Roozeboom[2], and V. Martin[2]

Summary
Canola production in Kansas is limited because producers have difficulty establishing a successful stand and achieving winter survival. Once successful canola production systems are identified, it is expected that production will increase, more local grain elevators will purchase the crop, more local processing facilities will process the crop, and local feedlots will be able to use the meal (a by-product of oil crushing) as a soybean meal replacement. This study is in its second year, and results are preliminary; initial findings indicated canola should be planted in conventional tillage with narrow row spacing. Canola, like other crops in western Kansas, was susceptible to hail in 2008 and spring freeze damage in 2009.

Introduction
Winter canola is a broadleaf crop that can be grown in rotation with winter wheat to improve pest management by interrupting pest cycles and increase options available for controlling weeds that are difficult to manage, such as cheat, downy brome, and feral rye. Winter canola has the potential to make a significant effect on agriculture in the southern Great Plains because it is a broadleaf and has a growth period similar to winter wheat. Canola also fits well into the current cropping system. Most equipment needed to produce canola is used for wheat production, which minimizes the need for additional investment in equipment.

A high-value, domestic market already exists for both canola oil and its high-protein meal. On Oct. 6, 2006, the U.S. Food and Drug Administration authorized products containing canola oil to bear a qualified health claim stating the ability of canola oil to reduce the risk of coronary heart disease because of its unsaturated fat content. Because canola oil is lower in saturated fat and higher in omega-3 fatty acids than other common edible oils, demand increased much faster than domestic production in recent years. The U.S. domestic market could easily bear an additional 3 million acres of production. The meal remaining after oil extraction is used as a high-protein livestock feed, and the large, accessible livestock feeding industry in the southern Great Plains provides a market ready for the meal within an inexpensive shipping distance.

Winter canola acreage increased substantially in the southern Great Plains states of Kansas, Oklahoma, and Texas over the past 5 years. In 2003-2004, approximately 2,900 acres of winter canola were grown. A renewed interest in canola as a rotational crop with wheat resulted in the first significant increase in 2004-2005 with 25,000 acres planted. An even larger increase occurred in 2005-2006 with 60,000 acres planted. Severe

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[1] USDA-CSREES Supplemental and Alternative Crops Competitive Grants Program
[2] K-State Dept. of Agronomy, Manhattan, KS
[3] Oklahoma State University Dept. of Plant and Soil Sciences, Stillwater, OK

drought and limited soil moisture reduced planted acres in 2006-2007 to approximately 35,000 acres. Acres have rebounded to 45,000 for 2007-2008 across the Plains. The high level of interest in the region suggests that planted acres will continue to increase.

The first regional crush facility, Producers' Cooperative Oil Mill (PCOM) in Oklahoma City, began accepting the 2008 canola crop. Plains Oilseed Products, a farmer-owned cooperative, contracted with local elevators for delivery to PCOM. These delivery points will alleviate the economic burden on producers whose only prior option was to deliver canola grain to established crushers, often at remote locations.

Interest in canola has outpaced our understanding and ability to establish the crop. Establishing winter canola is more challenging than establishing winter wheat, particularly in years when soil moisture is lacking at fall planting. Stand establishment affects all other periods of the growing season, the most important of which is winter dormancy. Plants that fail to establish adequately in the fall will have limited time to attain the minimum amount of growth necessary to survive the winter in the southern Great Plains. A quality stand provides the greatest opportunity for winter survival and is crucial for harvesting a high-yielding crop.

Winter canola establishes best in moist, firm, well-drained, medium-textured soils. It is imperative that canola has appropriate seed-to-soil contact because of its small seed size and shallow planting depth. Obtaining a uniform seeding depth is a challenge but can be accomplished with properly adjusted seeding equipment. No-till cropping practices are used often across the semiarid Great Plains to conserve surface soil moisture and reduce soil erosion. A canola seedbed that is too fine or overworked will lose soil moisture rapidly, and crusting normally occurs after a heavy rain. Overly coarse seedbeds result in poor seed placement and seed-to-soil contact, and soils dry out rapidly. No-till seeding can help avoid these establishment hindrances. However, winter survival in no-till has been poor. Information on how to successfully establish a stand in conventional tillage and no-till is needed for producers to grow winter canola.

Procedures

An experiment was initiated at the Southwest Research-Extension Center in Garden City, KS, in 2007 and repeated in 2008. The study was part of a larger team project between Kansas State University and Oklahoma State University. The goal of the study was to increase the success of winter canola establishment and production. Objectives of the study at Garden City were to determine the effect of (1) row spacing (8, 12, and 16 in.), (2) tillage (conventional tillage and no-till), (3) opener (double disk and hoe), and (4) double disk opener with and without a fluted coulter on canola stand establishment, winter survival, spring vigor, shattering, lodging, plant canopy height, yield, and test weight.

The experimental design was a randomized complete block with four replications. Soil type was a Ulysses silt loam with overhead sprinkler irrigation applied with a center pivot. Winter canola was planted Sept. 24, 2007, and Sept. 15, 2008, in conventional tillage and no-till. Soil was tilled with a rotary tiller on Aug. 13, 2007, and Sept. 11, 2008. The previous crop both years was soybean grown as a cover crop and terminated prior to grain fill. Canola variety KS9135 was planted in 7.5-ft-wide × 30-ft-long plots. All treat-

ments were planted with either a John Deere double disk opener with adjustable row spacing or a John Deere hoe drill with 12-row spacing. Planting rate was 5 lb/a. Seed was placed 0.5 in. deep. Pendimethalin (Prowl H_2O) was applied at a rate of 3 pint product/a or 1.43 lb a.i./a, and glyphosate (Roundup) was applied at a rate of 1 qt product/a or 0.75 lb a.e./a within 2 days preplant. Within 1 week after planting, 1 in. of irrigation was applied to the entire study area to obtain successful germination and emergence. The crop was fully irrigated throughout the growing season. 10 lb of 11-52-0 plus 10 lb of sulfur were applied with the seed in 2007, and 50 lb of 11-52-0 plus 10 lb of sulfur were applied with the seed in 2008. 50 lb nitrogen (N) (46-0-0) was applied on Mar. 7, 2008, and 50 lb N (46-0-0) was applied on Mar. 31, 2009. Canola was harvested on July 7, 2008, with a small plot Wintersteiger Delta combine.

Treatments are listed in Table 1. Within each plot, four different permanently marked 3-ft row segments were quantified for fall and spring plant density to determine fall stand establishment, winter survival, and spring stand establishment. Fall stand density was quantified on Nov. 1, 2007, and Nov. 25, 2008, and spring stand density was quantified on Apr. 8, 2008. Data from the four row segments were averaged. Stand vigor, lodging, and shattering ratings were based on visual determination. A grain subsample was collected at harvest and measured with a grain analysis computer to determine moisture and test weight. Data were analyzed with PROC MIXED in SAS (SAS Institute, Inc., Cary, NC). Replication and all interactions with replication were considered random effects in the model. Treatment effects were determined significant at $P \leq 0.05$, and when ANOVA indicated, significant effects means were separated with pairwise t-tests at $P \leq 0.05$.

Results and Discussion

Effect of Row Spacing and Coulter in No-Till (Table 2 and Figure 1)

- Fall stand establishment was greater in narrower rows (8 in.) than wider rows (12 and 16 in.).
- Fall stand establishment was greater with a coulter.
- Winter survival was greater in narrower rows (8 in.) than wider rows (12 and 16 in.).
- Winter survival was greater with a coulter.
- Spring vigor was greater with a coulter.
- Spring stand density was greater in narrower rows (8 in.) than wider rows (12 and 16 in.).
- Spring stand density was greater with a coulter.
- Yield was increased by 31% with a coulter, 980 lb/a with coulter compared with 747 lb/a without coulter.
- Shattering, height, lodging, and test weight were not affected by coulter or row spacing.

Effect of Planting Method (Table 3 and Figure 2)

- Fall stand establishment was greater with hoe than disk opener.
- Winter survival was greater in tillage than no-till.
- Spring vigor was greater in tillage than no-till.
- Spring vigor was greater with a coulter.
- Spring stand density was greater in tillage than no-till.
- Spring stand density was greater with hoe than disk opener in no-till.
- Height was greater in tillage than no-till.
- Height was greater with hoe than disk opener in no-till. Yield was 65% greater in tillage than no-till, 1,397 lb/a in tillage compared with 849 lb/a in no-till.
- Shattering, lodging, and test weight were not affected by coulter or row spacing.

Effect of Row Spacing in Conventional Tillage (Table 4)

- Fall stand establishment was greater in narrower rows (8 and 12 in.) than wider rows (16 in.).
- Winter survival was greater in narrower rows (8 in.) than wider rows (12 and 16 in.).
- Spring stand density was greater in narrower rows (8 and 12 in.) than wider rows (16 in.).
- Spring vigor, shattering, lodging, height, yield, and test weight were not affected by row spacing.

Conclusions

- Producing winter canola in western Kansas is difficult. Moisture in the seed zone at planting is necessary, and canola appears to be suitable only under irrigation. Hail destroyed the canola planting date study within 1 week of harvest in 2007, and a spring freeze in 2008 appeared to have damaged canola.
- Narrow rows (8 in.) increased stand establishment, winter survival, and final stand density compared with wide rows (12 and 16 in.).
- A double disk opener with coulter or hoe opener increased stand establishment, winter survival, spring vigor, stand density, and yield in no-till compared with a double disk opener without coulter.
- Conventional tillage increased winter survival, spring vigor, stand density, plant height, and yield compared with no-till.
  - Other research at the Southwest Research-Extension Center indicated planting date was crucial for winter survival, particularly with no-till. In a related planting date study in 2008, no-till planting 2 to 4 weeks earlier had greater winter survival and higher yield potential than the later no-till canola planted in this study.
- These results are based on initial findings and are preliminary. This study and the planting date study will be repeated in 2009-2010.

Table 1. Planting method treatments at Garden City

Treatment no.	Opener	Row spacing (in.)	Coulter	Tillage
1	disk	8	coulter	no-till
2	disk	8	coulter	till
3	disk	8	no coulter	no-till
4	disk	8	no coulter	till
5	disk	12	coulter	no-till
6	disk	12	coulter	till
7	disk	12	no coulter	no-till
8	disk	12	no coulter	till
9	hoe	12	no coulter	no-till
10	hoe	12	no coulter	till
11	disk	16	coulter	no-till
12	disk	16	coulter	till
13	disk	16	no coulter	no-till
14	disk	16	no coulter	till

Table 2. Effects of double disk opener with and without a coulter and row spacing (8, 12, and 16 in.) in no-till in 2008

Opener	Row spacing	Fall density	Winter survival	Spring vigor[1]	Spring density	Shattered	Lodged	Height	Yield[2]	Test weight
	in.	plants/acre	%	visual rating	plants/acre	---------%---------		ft	lb/a	lb/bu
Disk with coulter	8	419,628a	53.1a	3.3a	219,252a	5.0a	0.0a	3.6a	1134a	47.1a
	12	404,745a	28.8b	3.3a	115,253bc	8.8a	0.0a	3.2b	818ab	46.0a
	16	294,030c	42.5ab	3.8a	121,242bc	6.3a	0.0a	3.6a	989ab	46.4a
Disk without coulter	8	361,548ab	43.6ab	2.8b	158,268b	6.3a	0.0a	3.3ab	733ab	45.5a
	12	332,145bc	26.3b	2.3b	84,398c	7.5a	0.0a	3.3ab	784ab	46.3a
	16	275,880c	29.1b	3.0ab	79,860c	8.8a	0.0a	3.4ab	723b	44.2a

[1] Vigor rating was based on visual evaluation between 1 and 5; 5 = excellent, 1 = poor.
[2] Yield was based on 8% moisture content.
Within columns, means followed by the same letter are not significantly different at $P < 0.05$.

Table 3. Effects of opener (disk with coulter, disk without coulter, and hoe) and tillage (no-till and conventional tillage) on winter canola fall stand density, winter survival, and spring vigor in tilled treatment in 2008

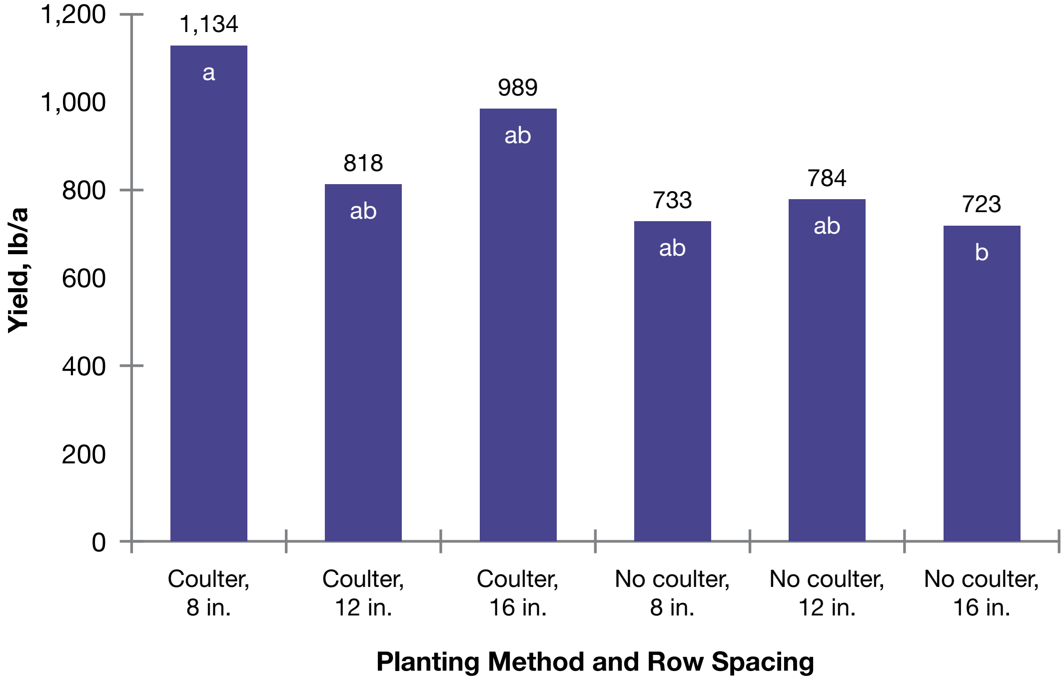
Planting method	Tillage	Fall density	Winter survival	Spring vigor[1]	Spring density	Shattered	Lodged	Height	Yield[2]	Test weight
		plants/acre	%	visual rating	plants/acre	---------%---------		ft	lb/a	lb/bu
Disk with coulter	no-till	404,745c	28.8c	3.3c	115,253c	8.8a	0.0a	3.2c	818b	46.0a
Disk without coulter	no-till	332,145cd	26.3c	2.3d	84,398c	7.5a	0.0a	3.3c	784b	46.6a
Disk without coulter	till	266,805d	69.4a	4.5ab	185,130b	5.0a	0.0a	3.7a	1,418a	47.4a
Hoe	no-till	810,398a	28.9c	3.8bc	225,968b	6.3a	0.0a	3.5b	945b	46.4a
Hoe	till	672,458b	49.3b	5.0a	330,330a	8.8a	0.0a	3.8a	1,375a	47.4a

[1] Vigor rating was based on visual evaluation between 1 and 5; 5 = excellent, 1 = poor.
[2] Yield was based on 8% moisture content.
Within columns, means followed by the same letter are not significantly different at $P < 0.10$.

Table 4. Effects of row spacing with a double disk opener and no coulter on winter canola fall stand density, winter survival, and spring vigor in tilled treatment in 2008

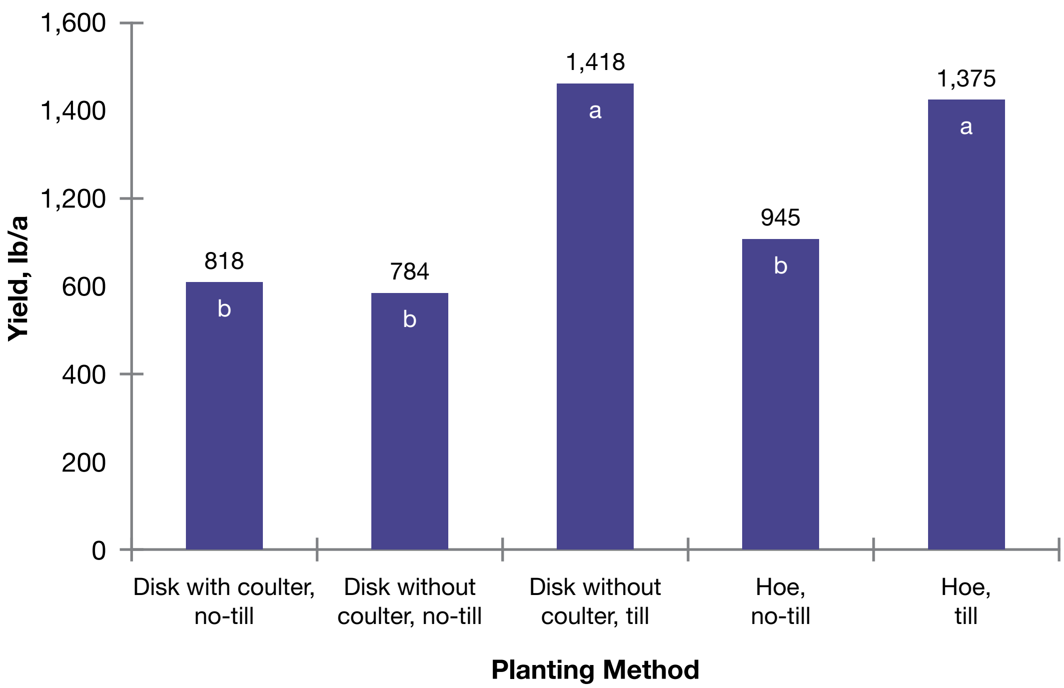
Row spacing	Fall density	Winter survival	Spring vigor[1]	Spring density	Shattered	Lodged	Height	Yield[2]	Test weight
in.	plants/acre	%	visual rating	plants/acre	----------%----------		ft	lb/a	lb/bu
8	277,332a	79a	3.8a	217,800a	6.3a	0.0a	3.7a	1,336a	47.1a
12	266,805a	69b	4.5a	185,130a	5.0a	0.0a	3.7a	1,418a	47.4a
16	233,772b	66b	4.5a	150,282b	6.3a	0.0a	3.7a	1,312a	46.3a

[1] Vigor rating was based on visual evaluation between 1 and 5; 5 = excellent, 1 = poor.
[2] Yield was based on 8% moisture content.
Within columns, means followed by the same letter are not significantly different at $P < 0.10$.



Bars with the same letter are not significantly different at $P < 0.05$

Figure 1. Effect of coulter (with and without) with a double disk opener and row spacing (8, 12, and 16 in.) on winter canola yield in no-till in 2008.



Bars with the same letter are not significantly different at $P < 0.05$

Figure 2. Effect of planting method opener (double disk vs. hoe), coulter (with and without), and tillage (no-till and conventional tillage) on winter canola yield in 2008.

Effects of Planting Date on Winter Canola[1]

J. Holman, M. Stamm[2,3], S. Maxwell, G. Miller, C. Godsey[3], K. Roozeboom[2], and V. Martin[2]

Summary
Determining the optimum planting date of canola is crucial for fall stand establishment and yield. One of the most limiting factors in Kansas canola production is identifying varieties and planting methods that result in successful stand establishment. Once successful canola production systems are identified, it is expected that production will increase, more local grain elevators will purchase the crop, more local processing facilities will process the crop, and local feedlots will be able to use the meal (a by-product of oil crushing) as a soybean meal replacement. In both years of this study, fall stand establishment was successful across planting dates except the earliest planting date in mid-August. In 2007, diamondback moth (*Plutella xylostella* L.) damaged plant stands, and in 2008, rabbit feeding selectively damaged plants from the earliest planting date. In 2007, fall stand density was greatest at the last planting date (October 15) and increased as planting date was delayed. In 2008, fall stand density was greatest at the second (September 2), third (September 11) and fourth (September 29) planting dates. Tillage had no effect on fall stand density in 2007, and tillage increased fall stand density by 9% in 2008. In 2007, winter survival was greatest for the second and third planting dates (September 4 and 17), and no plants survived at the last planting date (October 15). Tillage had no effect on fall survival. At this time, no information is available on winter survival from 2008. Spring regrowth was slowest at the first planting date, but after a couple weeks of spring, vigor was greatest at the first three planting dates. Tillage had no effect on spring vigor. This study will be replicated for at least one more year, but current information suggests planting between September 4 and 17 for successful winter canola stand establishment and survival.

Introduction
See "Effect of row spacing, tillage, opener, and coulter on winter canola" (this report, p. 112) for full introduction.

Interest in canola has outpaced our understanding and ability to establish the crop. Establishing winter canola is more challenging than establishing winter wheat, particularly in years when soil moisture is lacking at fall planting. Stand establishment affects all other periods of the growing season, the most important of which is winter dormancy. Plants that fail to establish adequately in the fall will have limited time to attain the minimum amount of growth necessary to survive the winter in the southern Great Plains. A quality stand provides the greatest opportunity for winter survival and is crucial for harvesting a high-yielding crop.

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[1] USDA-CSREES Supplemental and Alternative Crops Competitive Grants Program
[2] K-State Dept. of Agronomy, Manhattan, KS
[3] Oklahoma State University Dept. of Plant and Soil Sciences, Stillwater, OK

Procedures

The goal of this study was to increase the success of winter canola establishment and production. Objectives were to determine the effect of planting date and tillage on winter canola stand establishment, winter survival, spring vigor, shattering, lodging, plant canopy height, yield, and test weight.

The experimental design was a randomized complete block with four replications. Studies were located at the Southwest Research-Extension Center in Garden City, KS, soil type was Ulysses silt loam, and irrigation was applied with an overhead sprinkler. Winter canola was planted in the fall of 2007 and 2008 at five different planting dates into conventional tillage and no-till. In 2007, canola was planted on August 16; September 4, 17, and 28; and October 15, and in 2008, canola was planted on August 22; September 2, 11, and 29; and October 20. Soil was tilled with a rotary tiller on Aug. 13, 2007, and Aug. 13, 2008. The previous crop both years was soybean grown as a cover crop and terminated prior to grain fill. Canola variety KS9135 was planted in 15-ft-wide × 30-ft-long plots. All treatments were planted with a John Deere double disk opener with fluted coulter and 8-row spacing. Planting rate was 5 lb/a. Seed was placed 0.5 in. deep. Pendimethalin (Prowl H_2O) was applied at a rate of 3 pint product/a or 1.43 lb a.i./a, and glyphosate (Roundup) was applied at a rate of 1 qt product/a or 0.75 lb a.e./a within 2 days preplant. Within 1 week after planting, 1 in. of irrigation was applied to the entire study area to obtain successful germination and emergence. The crop was fully irrigated throughout the growing season. In 2008, soil tests indicated nutrient levels were sufficient, but an additional 1.1 lb nitrogen (N) and 5.2 lb phosphorus (P) were applied at seeding as monoammonium phosphate (11-52-0), and 9 lb sulfur was banded 1 in. to the side and 2 in. deep at time of planting. In 2009, 5.5 lb N and 26 lb P were applied at seeding as monoammonium phosphate (11-52-0), and 9 lb sulfur was banded 1 in. to the side and 2 in. deep at time of planting. An additional 50 lb of N as 46-0-0 was applied Mar. 31, 2009. Severe hail 1 week prior to harvest prevented yield from being taken.

Within each plot, four different permanently marked 3-ft row segments were quantified for fall and spring plant density to determine fall stand establishment and winter survival. Fall stand density was quantified on Nov. 1, 2007, and Nov. 25, 2008, and spring stand density was quantified on Apr. 8, 2008. Pest (insect and rabbit) damage was quantified at time of fall stand measurement. Data from the four row segments were averaged. Stand vigor, lodging, and shattering ratings were based on visual determination. A grain subsample will be collected at harvest and measured with a grain analysis computer to determine moisture and test weight. Data were analyzed with PROC MIXED in SAS (SAS Institute, Inc., Cary, NC). Replication and all interactions with replication were considered random effects in the model. Treatment effects were determined significant at $P \leq 0.05$, and when ANOVA indicated, significant effects means were separated with pairwise t-tests at $P \leq 0.05$. When plant density was zero for a treatment, the analysis was done by dropping that treatment from the model.

Results and Discussion

In 2007, fall stand establishment was successful at all planting dates and ranged from 168,400 plants per acre planted on August 16 to 495,100 plants per acre planted on October 15 (Figure 1). Fall stand density was greatest at the October 15 planting date,

and stand density increased with each later planting date except for the second and third planting dates, which were not significantly different from each other. The first planting date during fall of 2007 (August 16) was heavily infested with diamondback moth. Minor diamondback moth infestation was present on the second planting date (September 4).

In 2008, rabbit feeding damage caused complete stand loss of three replications of tillage and two replications of no-till at the August 22 planting date and caused minor damage to several other plots at the earlier planting dates. Interestingly, rabbit damage varied by plot; some plots were completely damaged, and others had little to no damage, as seen in Picture 1. No diamondback moth damage was noticed in 2008. In 2008, excluding the first planting date, which suffered rabbit damage, plant density ranged from 236,858 plants per acre planted on October 20 to 333,506 plants per acre planted on September 29. Fall stand density was greatest at the second, third, and fourth planting dates (Figure 2). Tillage had no effect on fall stand density in 2007, but stand density was 9% greater in tilled plots (296,272 plants per acre) than no-till plots (272,250 plants per acre) in 2008.

In 2008, winter survival was greatest for the second and third planting dates (September 4 and 17), and winter survival at the first planting date was not significantly different than the second, third, or fourth planting dates (Figure 3). No plants survived at the last planting date (October 15) (Figure 3 and Picture 2). Winter survival of the first planting date might have been reduced by diamondback moth feeding during fall of 2007.

In 2008, spring regrowth was slowest at the first planting date, but after a couple weeks of spring, vigor (visual growth determination) was greatest at the first three planting dates (Figure 3). Spring regrowth at the first planting date might have been delayed because of heavy diamondback moth feeding and winter injury (Figure 4). The fourth planting date had less spring vigor, which might have been caused by winter injury (Figures 3 and 4). The last planting date had no winter survival to rate vigor.

In 2008, spring stand was greatest at the second, third, and fourth planting dates (Figure 5). Spring stand was likely reduced at the earliest planting date because of diamondback moth feeding and winter injury. Separation tended to occur, with no-till stand density being greater than or equal to that of conventional-till at the first three planting dates but less than conventional till at the fourth planting date (Figure 5).

This study will be replicated for at least one more year, but current information suggests planting winter canola between September 4 and 17 for successful winter canola stand establishment and survival.

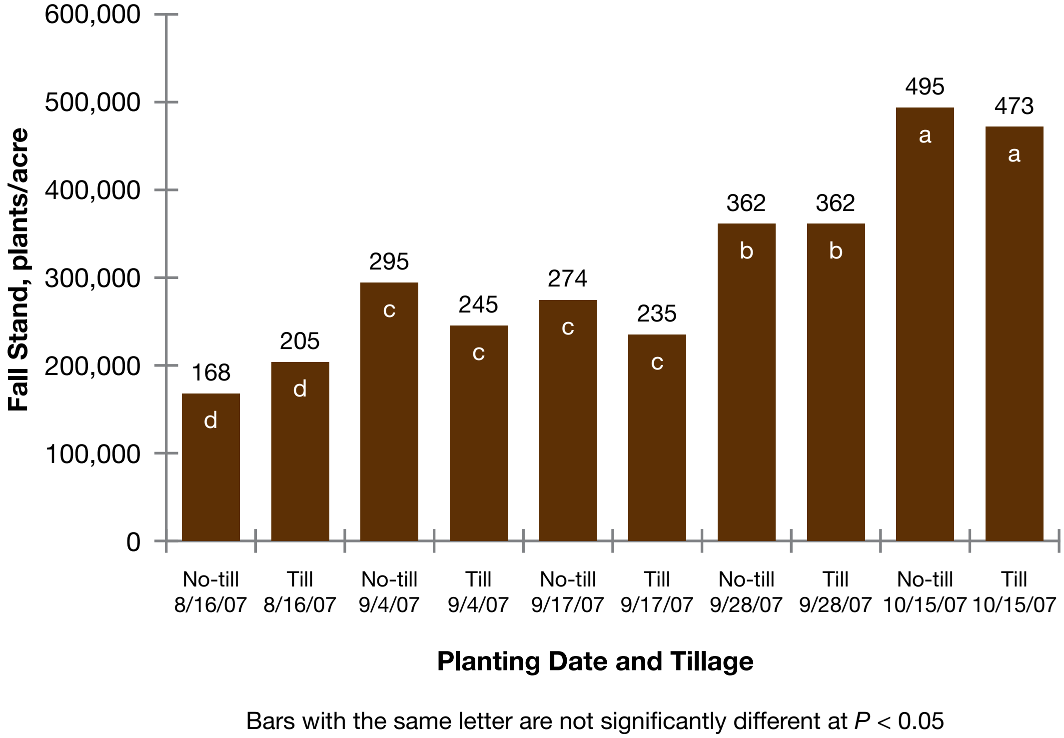

Figure 1. Winter canola fall stand establishment at five different planting dates in tillage and no-till, Garden City, 2008.

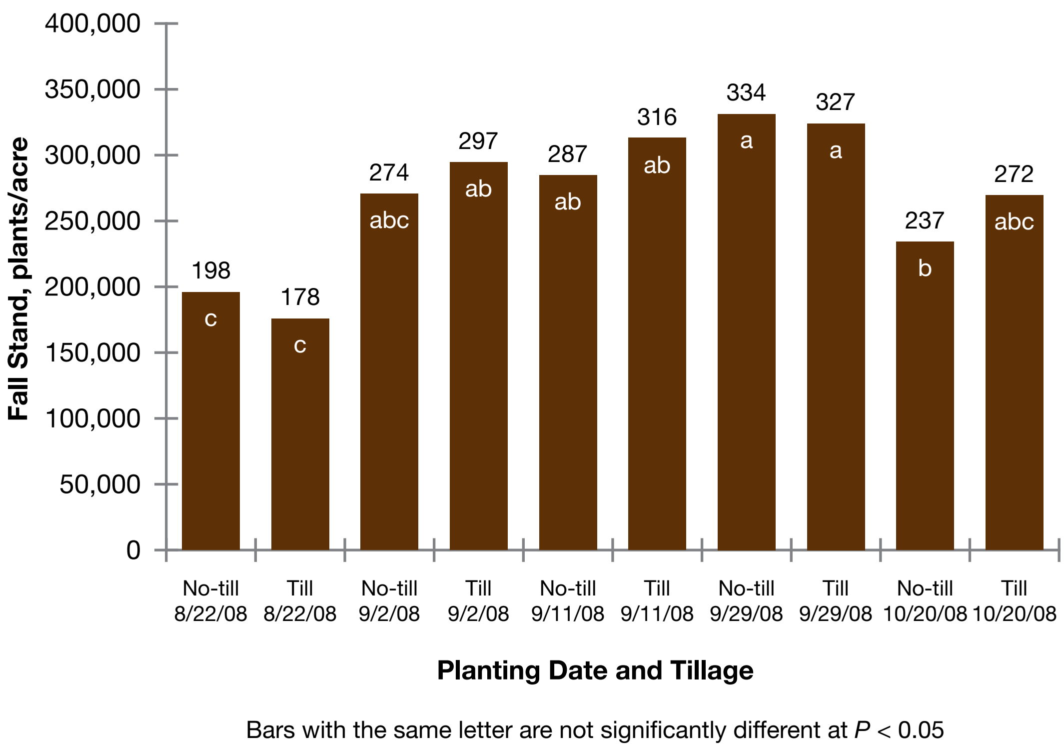

Figure 2. Winter canola fall stand establishment at five different planting dates in tillage and no-till, Garden City, 2009.

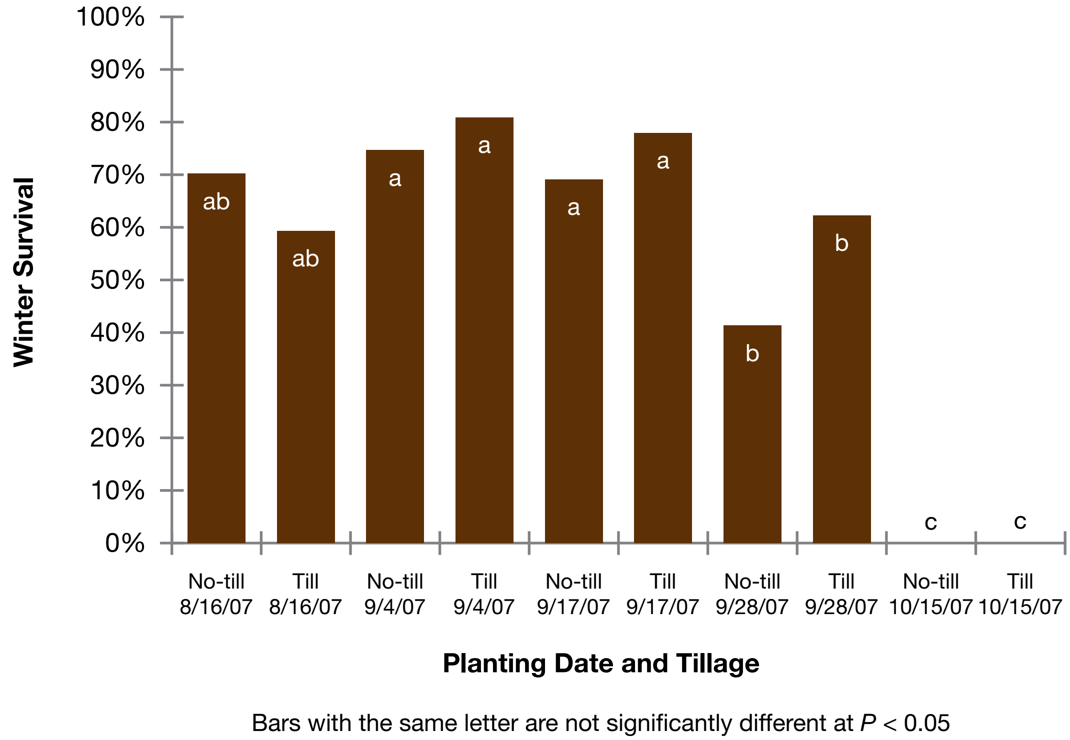

Figure 3. Winter canola winter survival at five different planting dates in tillage and no-till, Garden City, 2008.

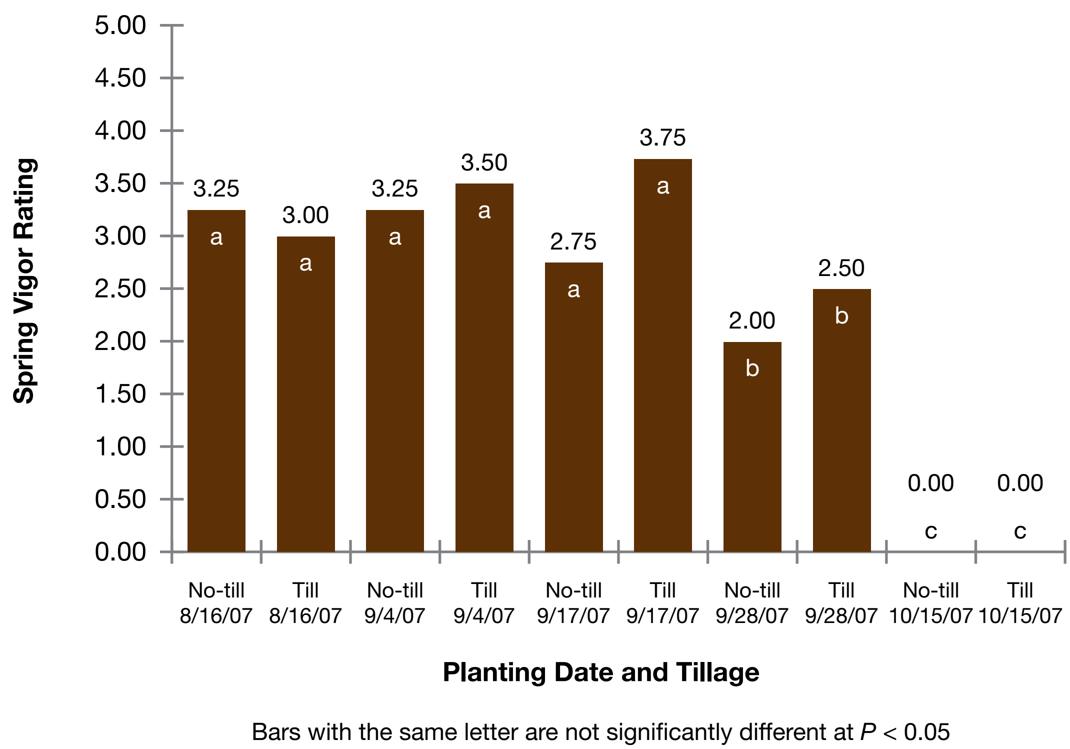

Figure 4. Winter canola spring vigor at five different planting dates in tillage and no-till, Garden City, 2008.

Rating was based on visual evaluation between 1 and 5; 5 = excellent, 1 = poor.

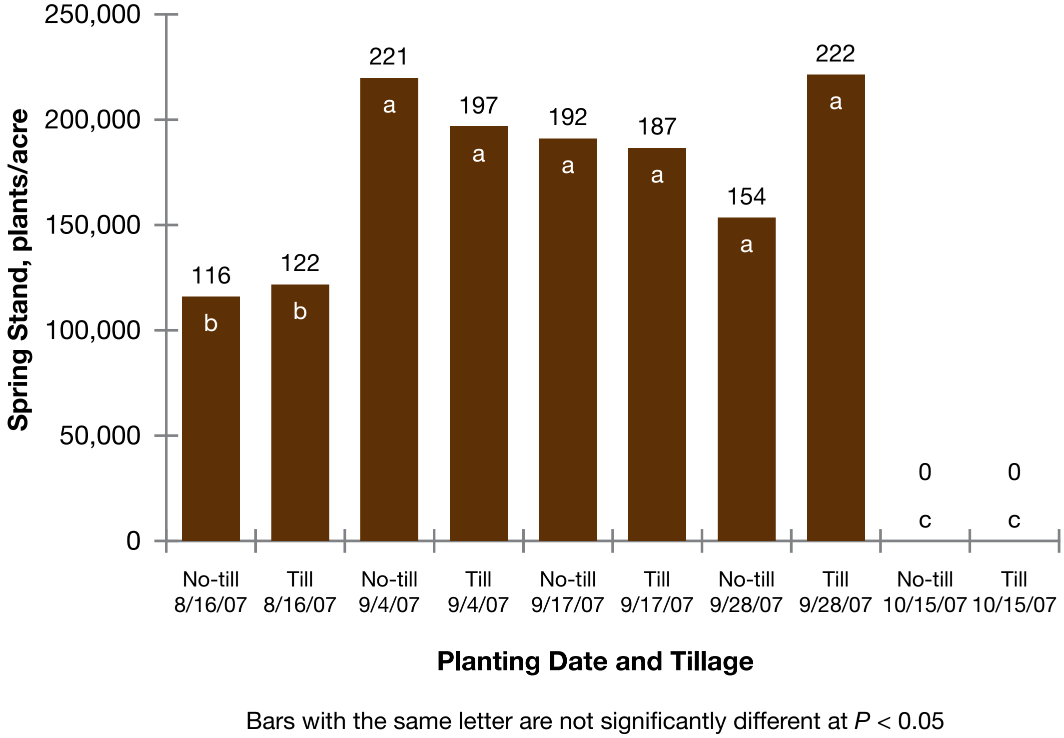

Figure 5. Winter canola fall stand establishment at five different planting dates in tillage and no-till, Garden City, 2009.

Picture 1. Rabbit hole and feeding damage on winter canola on Dec. 11, 2008.

Picture 2. Winter canola on Apr. 11, 2008.

Enhancing Water Efficiency and Sustainability Through Forages[1]

J. Holman, A. Schlegel, M. Warner Holman[2], G. Miller, S. Maxwell, and T. Dumler

Summary

A study evaluating three different annual forage rotations of different cropping intensities was established across the precipitation gradient of the Ogallala Aquifer in western Kansas with sites at Tribune, Garden City, and Dodge City, KS. In dryland and limited-irrigation production systems, including forage crops into the cropping system can increase production opportunities and reduce production risk. Crop rotations established were continuous winter triticale, continuous sorghum-sudangrass, and double cropping winter triticale and sorghum-sudangrass. Forage production and profit will be increased with successful higher intensity cropping systems. Results are preliminary because the study is in its first year of a 3-year study. Initial findings indicate crop yield can be increased about 40% by double cropping.

Introduction

In dryland and limited-irrigation production systems, including forage crops into the cropping system can increase production opportunities and reduce production risk. Because annual forages require less moisture than a grain crop, including annual forages in the crop rotation might allow for opportunistic cropping when soil moisture conditions are favorable. Weed species continue to become resistant to herbicides, and integrating a forage crop into the rotation might help control weed populations. Out of six winter wheat-forage crop rotations studied, winter triticale and sorghum-sudangrass reduced wild oat (*Avena fatua*) and broadleaf weed densities more than all other rotations in the absence of herbicides.

Two annual forage crops suitable to western Kansas are triticale and sorghum-sudangrass. Both crops have production advantages. Triticale can be harvested for hay or grazed in the fall and again in the spring, whereas sorghum-sudangrass is harvested for hay or grazed in the summer. Compared with triticale, sorghum-sudangrass tends to yield higher but is prone to higher nitrate concentration under moisture-limited conditions. Producers in the region usually plant continuous winter triticale or sorghum-sudangrass but are interested in knowing whether the two crops can be double cropped. Double cropping might increase forage production and profit, or it might result in increased production risk and increased nitrate concentration because of increased crop moisture stress. Double cropping might be feasible only in some years when conditions are favorable for opportunistic cropping.

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[1] This research is funded in part by the USDA Ogallalla Aquifer Program.

[2] Dodge City Community College, Dodge City, KS

The specific objectives of this study are to (1) determine forage yield and quality of the different crops and rotations, (2) compare the economic return of the different crop rotations, (3) compare the water-use and fallow efficiency of the different crops and rotations, and (4) determine if yield potential of winter triticale and sorghum-sudangrass can be estimated on the basis of preplant soil moisture content.

Procedures

This study will last 3 years in order to complete a full crop rotation cycle. Gravimetric soil moisture will be measured to a depth of 6 ft with 1-ft increments at planting and each harvest to determine water-use and fallow efficiency of the different cropping systems. Winter triticale will be planted approximately September 25, and sorghum-sudangrass will be planted after soil temperatures reach 60°C for 48 hours on approximately May 15. Crops will be harvested between late boot and early heading to optimize yield and quality (Haun scale 9.5). Crop yield response to plant available water at planting will be used to estimated yield potential and determine when double cropping might be feasible. Most producers use a soil probe rather than gravimetric sampling to determine soil moisture status, so soil penetration with a Paul Brown soil probe will be measured four times per plot at planting to estimate soil water availability. Previous studies have found that a soil moisture probe provides a fairly accurate and easy method of determining soil moisture level and crop yield potential. Forage yield, quality, and nitrate concentration will be measured at each harvest. An enterprise budget will be developed for each of the cropping systems to determine profit and risk.

Results and Discussion

Data were available only from Garden City because all phases of the crop rotation are not yet available from the other locations. Initial results indicate that double-crop yields of winter triticale and forage sorghum-sudangrass were 72 and 71%, respectively of annual cropping ($P \leq 0.05$; Figure 1). Double cropping winter triticale and forage sorghum resulted in about 44% more growing season forage yield than annual cropping (Figure 2). However, crop establishment was more challenging and crop growth was more dependent on growing season precipitation in the double-crop rotation compared with annual cropping. Double cropping might be too intensive of a cropping system for western Kansas.

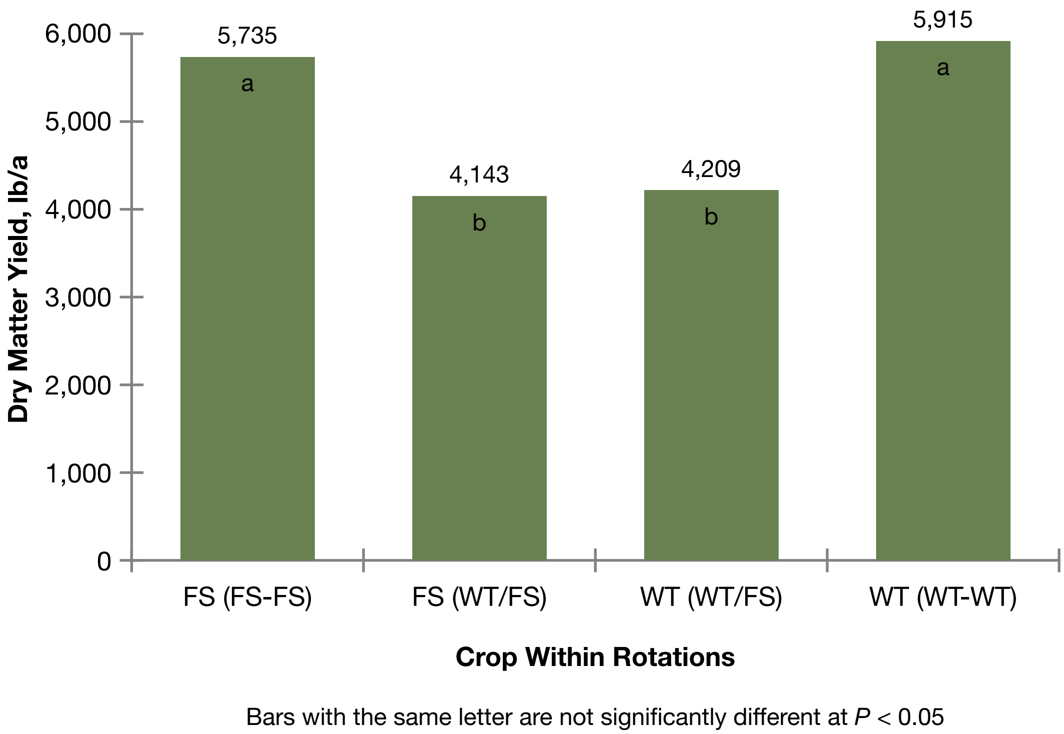

Figure 1. Dry matter yield of forage sorghum (FS) and winter triticale (WT) in different annual forage crop rotations (FS, WT, and WT/FS) at Garden City in 2008.

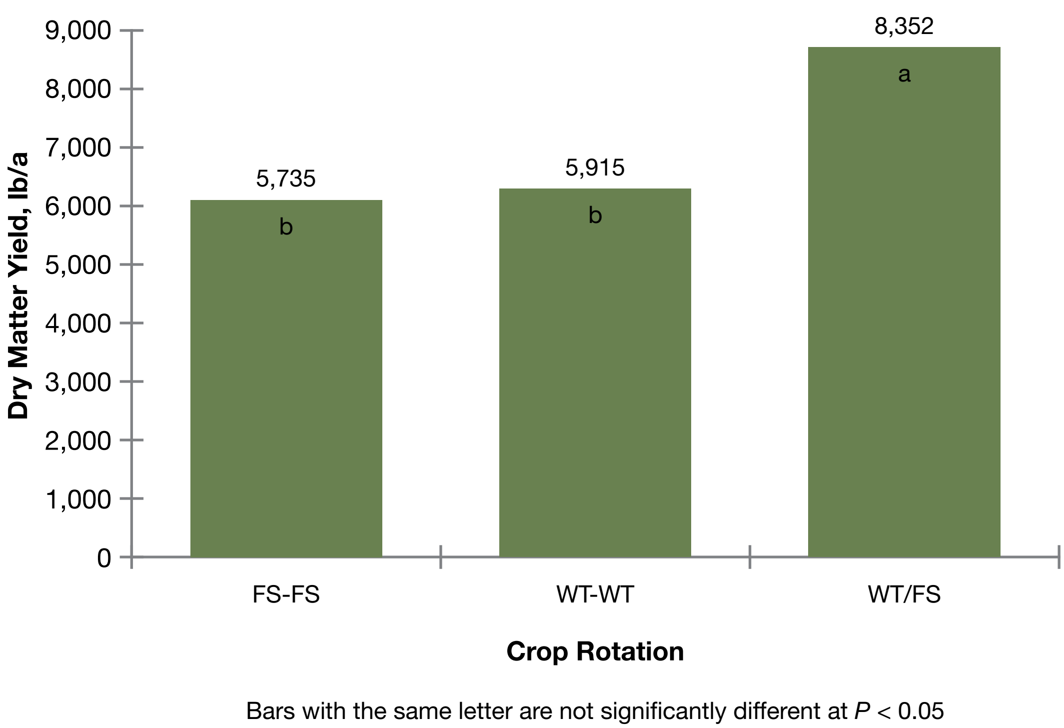

Figure 2. Total dry matter yield of crop rotation at Garden City in 2008.
FS = forage sorghum, WT = winter triticale.

Evaluation of Annual Cover Crops for Forage Yield in a Wheat-Fallow Rotation[1]

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Summary
Producers have expressed interest in growing a cover crop during traditional fallow periods. Western Kansas crop yields are limited by moisture and heat stress, and fallow is an important component of the system because it stores moisture for subsequent crops. Past research has shown the traditional 14-month fallow period of a wheat-fallow rotation to be inefficient at storing soil moisture and that the fallow period can be reduced. This study evaluated replacing the fallow period with either a fall or spring cover crop grown as a green manure or forage crop. This report presents the first 2 years of findings on cover crop forage yields. Triticale and broadleaf mixtures with triticale produced greater forage yield than broadleaf species alone. Winter crops produced more forage yield than spring crops.

Procedures
Beginning in 2007, fall and spring cover crops were planted in the fallow phase of a winter wheat-fallow rotation at the Southwest Research-Extension Center in Garden City, KS. The experiment was a completely randomized block design with four replications. Main plot was cover crop species in plots 30 ft wide × 135 ft long. Each main plot consisted of a winter- or spring-sown cover crop. Fall cover crop species included yellow sweet clover, vetch, winter lentil, winter pea, winter triticale, and all broadleaf species in combination with winter triticale. Spring cover crop species included spring lentil, spring pea, spring triticale, and all broadleaf species in combination with spring triticale. Cover crop species were changed slightly after the first year (Table 1) once suitable cover crop species were identified in a preliminary study. Winter lentil was substituted for winter clover in the third year. Winter cover crops were seeded on Sept. 15, 2007, and Oct. 3, 2008, and spring cover crops were seeded on Mar. 30, 2008, and Mar. 5, 2009. Cover crops were harvested when triticale headed or June 1, whichever came first. In 2007, winter cover crops were harvested on May 15, and spring cover crops were harvested on June 1. In 2008, winter cover crops were harvested on May 13, and spring cover crops were harvested on June 1. Cover crops were harvested with a Carter harvester 3 to 4 in. above the soil surface, and a subsample was oven dried at 60 °C for 48 hours to determine dry matter yield. Data were analyzed with PROC MIXED in SAS (SAS Institute, Inc., Cary, NC). Replication and all interactions with replication were considered random effects in the model. Treatment effects were determined significant at $P < 0.05$, and when ANOVA indicated, significant effects means were separated with pairwise t-tests at $P \leq 0.05$.

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[1] This research is funded in part by the USDA-CSREES North Central Region Integrated Pest Management grants program.

[2] K-State Dept. of Agronomy, Manhattan, KS

Results and Discussion

Triticale and broadleaf mixtures with triticale produced greater forage yield than broadleaf species alone (Figures 1 and 2). In 2008, cover crop mixtures with triticale tended to yield more than triticale alone (Figure 2). Winter crops produced more yield than spring crops, even though spring cover crops were harvested approximately 2 weeks later than winter cover crops (Figures 3 and 4). Yellow sweet clover failed to produce harvestable biomass either year and was replaced by winter lentil in 2009.

Table 1. Cover crop treatments

		Year produced		
Season	Cover crop	2007	2008	2009
Fall	Clover	x	x	
Fall	Clover/winter triticale		x	
Fall	Vetch	x	x	x
Fall	Vetch/winter triticale		x	x
Fall	Winter lentil			x
Fall	Winter lentil/winter triticale			x
Fall	Winter pea	x	x	x
Fall	Winter pea/winter triticale		x	x
Fall	Winter triticale	x	x	x
Spring	Spring lentil	x	x	x
Spring	Spring lentil/spring triticale		x	x
Spring	Spring pea	x	x	x
Spring	Spring pea/spring triticale		x	x
Spring	Spring triticale		x	x

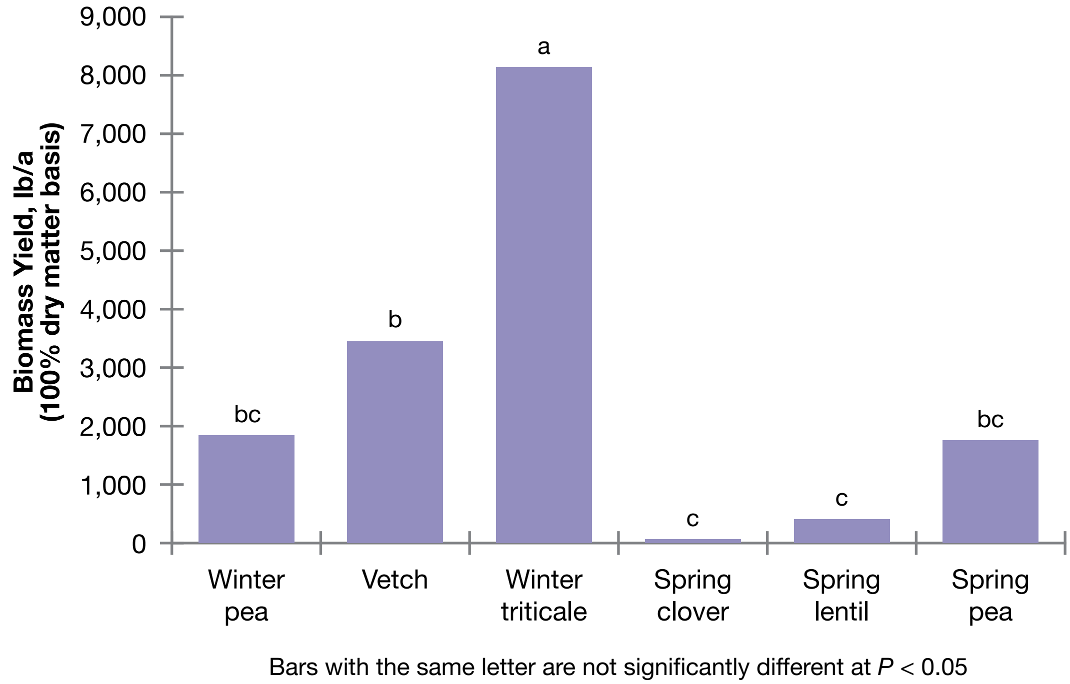


Figure 1. Cover crop forage yield in 2007.

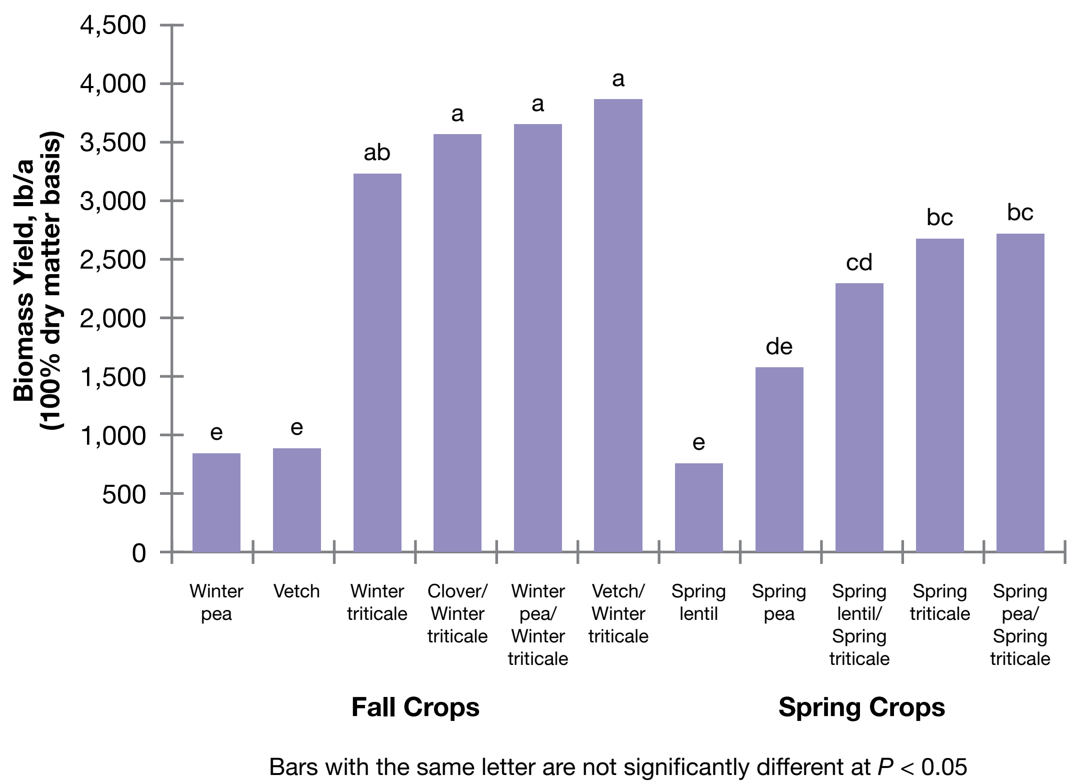
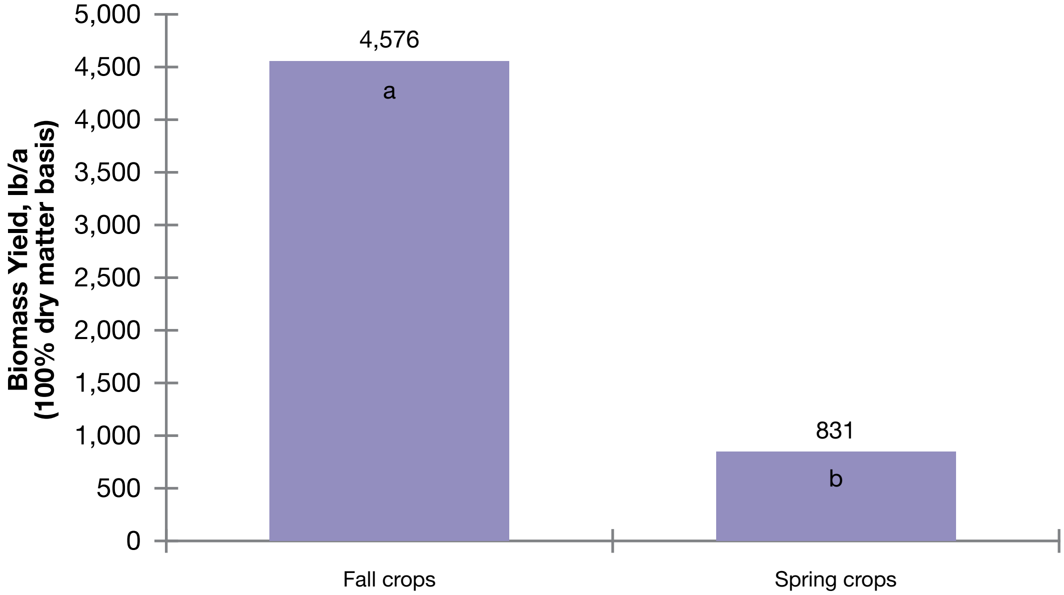
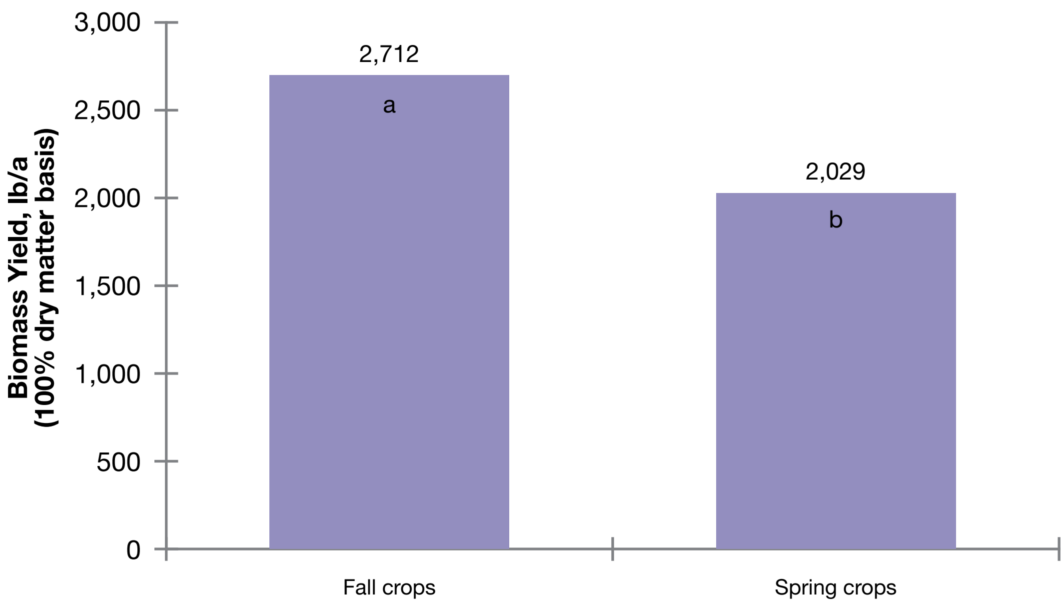


Figure 2. Cover crop forage yield in 2008.



Bars with the same letter are not significantly different at *P* < 0.05

Figure 3. Fall and spring cover crop forage yield averages in 2007.



Bars with the same letter are not significantly different at *P* < 0.05

Figure 4. Fall and spring cover crop forage yield averages in 2008.

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