Kansas State University

FIELD DAY 2005

Southwest Research–Extension Center

Report of Progress
945

Kansas State University
Agricultural Experiment Station
and Cooperative Extension Service

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Larry Buschman—Entomologist. Larry received his M.S. at Emporia State University and his Ph.D. at the University of Florida. He 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.

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Contribution 05-340 -S from the Kansas Agricultural Experiment Station.

WEATHER INFORMATION FOR GARDEN CITY

by

Jeff Elliott

The biggest weather story of 2004 was precipitation. Year-to-date precipitation at the beginning of May was 4.83 inches, 0.89 inches *above* the 30-year average. By the end of May, precipitation totals had dropped *below* the average year-to-date moisture by 2.10 inches. May, which is normally the wettest month, totaled only 0.40 inches of precipitation. This was the driest May since 1966, and tied for the third-driest May since recordkeeping began in 1908. The driest May on record (1927) had only 0.16 inches of moisture. Only 3 days recorded measurable precipitation in May 2004, compared with 9.5 days in an average May.

Then the "rains came." In the four-month period from June through September, 17.13 inches of rain were recorded, compared with 9.28 inches in an average year. Notable events included measurable precipitation on 8 straight days, beginning June 15, totaling 4.6 inches. Snowfall for 2004 was 6 inches, 11.7 inches below average. Total precipitation for 2004 was 24.69 inches of moisture, nearly 6 inches above the 30 year average.

May 2004 was also hot. The average maximum daily temperature for May was 83.1°F, 8 degrees above the 30-year average, and the warmest since 1962. In spite of this warmth, a record *low* temperature of 28°F was tied on May 14, 2004; the next morning 32°F was recorded. This was the last spring freeze of the year, and was 19 days later than the average freeze date of April 26. As expected, July had the warmest average daily mean, and January had the coldest. The annual mean temperature for the entire year was 54.4°F and was above the 30-year average for the seventh consecutive year.

There were below-zero temperatures on three occasions, with the extreme of -10°F on Christmas Eve. Record lows occurred on May 14 (28°F), July 25 through July 29 (54°F, 53°F, 54°F, 56°F, 57°F, respectively), November 30 (5°F), December 24 (-10°F), and December 25 (-8°F). Triple-digit temperatures occurred on five occasions, with the highest being 101°F on July 16. Record highs occurred on January 3 (65°F), March 24 (83°F), May 6 (96°F), December 12 (70°F), and December 21 (70°F).

As noted, the last spring freeze was on May 15. The first fall freeze was recorded on October 14. This resulted in a 152-day frost-free period, 15 days less than the 30-year average.

Open-pan evaporation for the months of April through October totaled 66.17 inches, compared with 70.60 inches in an average year. Mean wind speed was 4.60 mph, which is below the 30-year average of 5.25 inches.

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

	Precipitation inches		Temperature (°F) 2004 Average		Mean		2004 Extreme		Wind MPH		Evaporation inches	
Month	2004	Avg.	Max.	Min.	2004	Avg.	Max.	Min.	2004	Avg.	2004	Avg.
January	0.10	0.43	47.5	16.1	31.8	28.4	67	-4	3.98	4.68		
February	0.50	0.48	47.7	18.2	33.0	33.7	75	0	5.40	5.39		
March	1.55	1.38	64.7	34.5	49.6	42.3	85	23	5.80	6.72		
April	2.68	1.65	67.7	37.4	52.5	52.1	90	19	4.82	6.73	7.58	8.35
May	0.40	3.39	83.1	50.6	66.8	62.0	99	28	5.57	6.04	12.30	9.93
June	5.47	2.88	85.0	57.1	71.1	72.4	100	45	4.27	5.59	10.97	12.32
July	3.16	2.59	87.7	61.6	74.7	77.4	101	53	3.60	4.85	10.36	13.41
August	4.28	2.56	84.9	57.7	71.3	75.5	100	48	3.89	4.17	9.73	11.19
September	4.22	1.25	85.0	54.4	69.7	67.0	98	43	5.28	4.63	10.37	8.88
October	0.91	0.91	69.2	42.6	55.9	54.9	83	30	4.06	4.84	4.86	6.52
November	1.38	0.86	52.3	30.1	41.2	40.5	79	5	4.85	4.86		
December	0.04	0.41	51.7	17.9	34.8	31.3	73	-10	3.69	4.47		
Annual	**24.69**	**18.79**	**68.9**	**39.9**	**54.4**	**53.1**	**101**	**-10**	**4.60**	**5.25**	**66.17**	**70.60**

Average latest freeze in spring	April 26	2004:	May 15
Average earliest freeze in fall	October 11	2004:	October 14
Average frost-free period	167 days	2004:	152 days

All averages are for the period 1971-2000.

Southwest Research-Extension Center

WEATHER INFORMATION FOR TRIBUNE

by

Dewayne Bond and Dale Nolan

Precipitation in 2004 was 8.77 inches above normal for a yearly total of 26.21inches, with 6 months having above-normal precipitation. June was the wettest month with 7.43 inches. The largest single amount of precipitation was 2.27 inches on June 16. May was the driest month, with 0.01 inches of precipitation. Snowfall for the year totaled 12.4 inches; 1.3 inches in January, 3.2 inches in February, 3.9 inches in November and 4.0 inches in December, for a total of 18 days of snow cover. The longest consecutive period of snow cover, seven days, occurred from February 1 to February 7.

Record high temperatures were recorded on 4 days: March 20, 85°F; March 27, 86°F; May 7, 96°F; and December 12, 69°F. On April 17, 87°F tied the record. The only record low temperature this year was 49°F on July 26. May 31, 37F°; and July 24, 53°F, both tied records set in previous years. The hottest day of the year was June 8, 104°F. July was the warmest month, with a mean temperature of 72.1°F and an average high of 85.1°F. The coldest day of the year was December 24, -15°F. January was the coldest month of the year, with a mean temperature of 31.9°F and an average low of 16.3°F.

For eight months, the air temperature was above normal. March and August had the greatest departures from normal, 7.0°F above and 4.3°F below, respectively. There was only one day of 100°F or above temperatures, 9 days below normal. There were 50 days of 90°F or above temperatures, 12 days below normal. The last day of 32°F or less in the spring on May 14 was 8 days later than the normal date, and the first day of 32°F or less in the fall on October 14 was 11 days later than the normal date. This produced a frost-free period of 153 days, 3 days more than the normal of 150 days.

April through September open-pan evaporation totaled 65.88 inches, 4.77 inches below normal. Wind speed for the same period averaged 4.9 mph, 0.6 mph less than normal.

Table 1. Weather data. Southwest Research-Extension Center, Tribune, Kansas.

	Precipitation inches		Temperature (°F) 2004 Average		Temperature (°F) Normal		Temperature (°F) 2004 Extreme		Wind MPH		Evaporation inches	
Month	2004	Normal	Max.	Min.	Max.	Min.	Max.	Min.	2004	Avg.	2004	Avg.
January	0.08	0.45	47.5	16.3	42.2	12.8	69	-13				
February	0.43	0.52	46.8	17.9	48.5	17.1	72	1				
March	1.02	1.22	63.2	31.3	56.2	24.2	86	20				
April	4.11	1.29	66.5	35.9	65.7	33.0	90	16	5.1	6.3	7.50	8.28
May	0.01	2.76	81.5	46.7	74.5	44.1	96	27	5.7	5.8	15.12	10.88
June	7.43	2.62	83.8	54.5	86.4	54.9	104	44	5.2	5.3	12.9	13.88
July	4.27	3.10	85.1	59.2	92.1	59.8	99	49	4.0	5.4	10.71	15.50
August	3.59	2.09	83.8	56.0	89.9	58.4	99	46	3.8	5.0	9.34	12.48
September	2.32	1.31	83.3	53.1	81.9	48.4	98	40	5.6	5.2	10.31	9.63
October	0.79	1.08	68.7	39.7	70.0	35.1	84	26				
November	1.91	0.63	51.3	28.7	53.3	23.1	79	5				
December	0.25	0.37	50.5	20.7	44.4	15.1	69	-15				
Annual	**26.21**	**17.44**	**67.7**	**38.4**	**67.1**	**35.5**	**104**	**-15**	**4.9**	**5.5**	**65.88**	**70.65**

Average latest freeze in spring[1]	May 6	2004:	May 14
Average earliest freeze in fall	October 3	2004:	October 14
Average frost-free period	150 days	2004:	153 days

[1]Latest and earliest freezes recorded at 32 °F. Average precipitation and temperature are 30-year averages (1971-2000) calculated from National Weather Service. Average temperature, latest freeze, earliest freeze, wind, and evaporation are for the same period calculated from station data.

FOUR-YEAR CROP ROTATIONS WITH WHEAT AND GRAIN SORGHUM[1]

by
Alan Schlegel, Troy Dumler, and Curtis Thompson

SUMMARY

Wheat yields were poor in 2004 because of a mid-May freeze. Grain yield of continuous wheat averages about 78% of the yield of wheat grown in a 4-yr rotation following sorghum. Except in 2003, there has been no difference in yield of continuous wheat and recrop wheat grown in a wheat-wheat-sorghum-fallow (WWSF) rotation. Yields are similar for wheat following one or two sorghum crops. Average sorghum yields also were the same when following one or two wheat crops. Yield of recrop sorghum in a wheat-sorghum-sorghum-fallow (WSSF) rotation averaged 70% of the yield of the first crop.

PROCEDURES

Research on 4-yr crop rotations with wheat and grain sorghum was initiated at the K-State Southwest Research-Extension Center near Tribune in 1996. The rotations were wheat-wheat-sorghum-fallow and wheat-sorghum-sorghum-fallow, along with a continuous wheat rotation. No-till was used for all rotations.

RESULTS AND DISCUSSION

Wheat yields in 2004 were very poor because of a freeze in mid-May (Table 1). Averaged across 8 years, recrop wheat (the second wheat crop in a WWSF rotation) yielded almost 90% of the yield of first-year wheat in either WWSF or WSSF rotations. Before 2003, recrop wheat yielded about 70% of the yield of first-year wheat. In 2003, however, the recrop wheat yields were more than double the yield in all other rotations. This is possibly due to the failure of the first-year wheat in 2002, resulting in a period from 2000 sorghum harvest to 2003 wheat planting without a harvestable crop. There has been no difference in wheat yields following one or two sorghum crops. The continuous-wheat yields may have been similar to recrop wheat yields, except in 2003.

Table 1. Wheat response to rotation, Tribune, Kansas, 1997 through 2004.

Rotation*	1997	1998	1999	2000	2001	2002	2003	2004	Mean
	- - - - - - - -	- - - -	- - - -	- - - -	bu/a	- - - -	- - - -	- - - -	- - - -
WHEAT-sorghum-sorghum-fallow	57	70	74	46	22	0	29	6	38
WHEAT-wheat-sorghum-fallow	55	64	80	35	29	0	27	6	37
wheat-WHEAT-sorghum-fallow	48	63	41	18	27	0	66	1	33
Continuous WHEAT	43	60	43	18	34	0	30	1	29
LSD (0.05)	8	12	14	10	14	—	14	2	3

* Capital letters denote current-year crop.

Sorghum yields in 2004 were greater than the long-term yield average for each rotation (Table 2). The recrop sorghum yield averages about 70% of the yield of the first sorghum crop following wheat; in 2004, however, recrop yields were 87% of the first-year sorghum yield. Although variable from year to year, there was no significant difference in average yields if sorghum followed one or two wheat crops.

Table 2. Grain sorghum response to rotation, Tribune, Kansas, 1996 through 2004.										
Rotation*	1996	1997	1998	1999	2000	2001	2002	2003	2004	Mean
	- - - - - - - - - - - - - - - - - - - bu/a - - - - - - - - - - - - - - - - - - -									
wheat-SORGHUM-sorghum-fallow	58	88	117	99	63	68	0	60	91	71
wheat-sorghum-SORGHUM-fallow	35	45	100	74	23	66	0	41	79	51
wheat-wheat-SORGHUM-fallow	54	80	109	90	67	73	0	76	82	70
LSD (0.05)	24	13	12	11	16	18	—	18	17	4

* Capital letters denote current year crop.

An economic analysis using current costs and average annual commodity prices from 1996 through 2004 was conducted to determine which rotation had the greatest return to land and management. The estimated returns do not include government payments or insurance indemnity payments. Average returns from 1996 through 2004 were $-9.84, $-11.97, and $-16.54 for the WWSF, WSSF, and WW rotations, respectively. If the disaster year of 2002 is removed, however, returns averaged $34.91, $47.77, and $-7.91, respectively, for the WWSF, WSSF, and WW rotations.

NO-TILL LIMITED IRRIGATED CROPPING SYSTEMS[1]

by

Alan Schlegel, Loyd Stone[2], and Troy Dumler

SUMMARY

Research was initiated under sprinkler irrigation to evaluate limited irrigation in a no-till crop rotation. In rotations with limited irrigation (10 inches annually), continuous corn was more profitable in 2004 than were multi-year rotations including wheat, sorghum, and soybean. A freeze in mid-May reduced wheat yields, which reduced the profitability of the multi-crop rotations.

PROCEDURES

Research was initiated under sprinkler irrigation at the Tribune Unit, Southwest Research-Extension Center near Tribune in the spring of 2001. The objectives are to determine the impact 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 are 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 inches/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. The rotations include 1-, 2-, 3-, and 4-year rotations. The 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 inches of irrigation water annually, but the amount of irrigation water applied to each crop within a rotation varies, depending upon 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. The irrigation amounts are 15 in. to corn in 2-, 3-, and 4-yr rotations, 10 in. to grain sorghum and soybean, and 5 in. to wheat.

RESULTS AND DISCUSSION

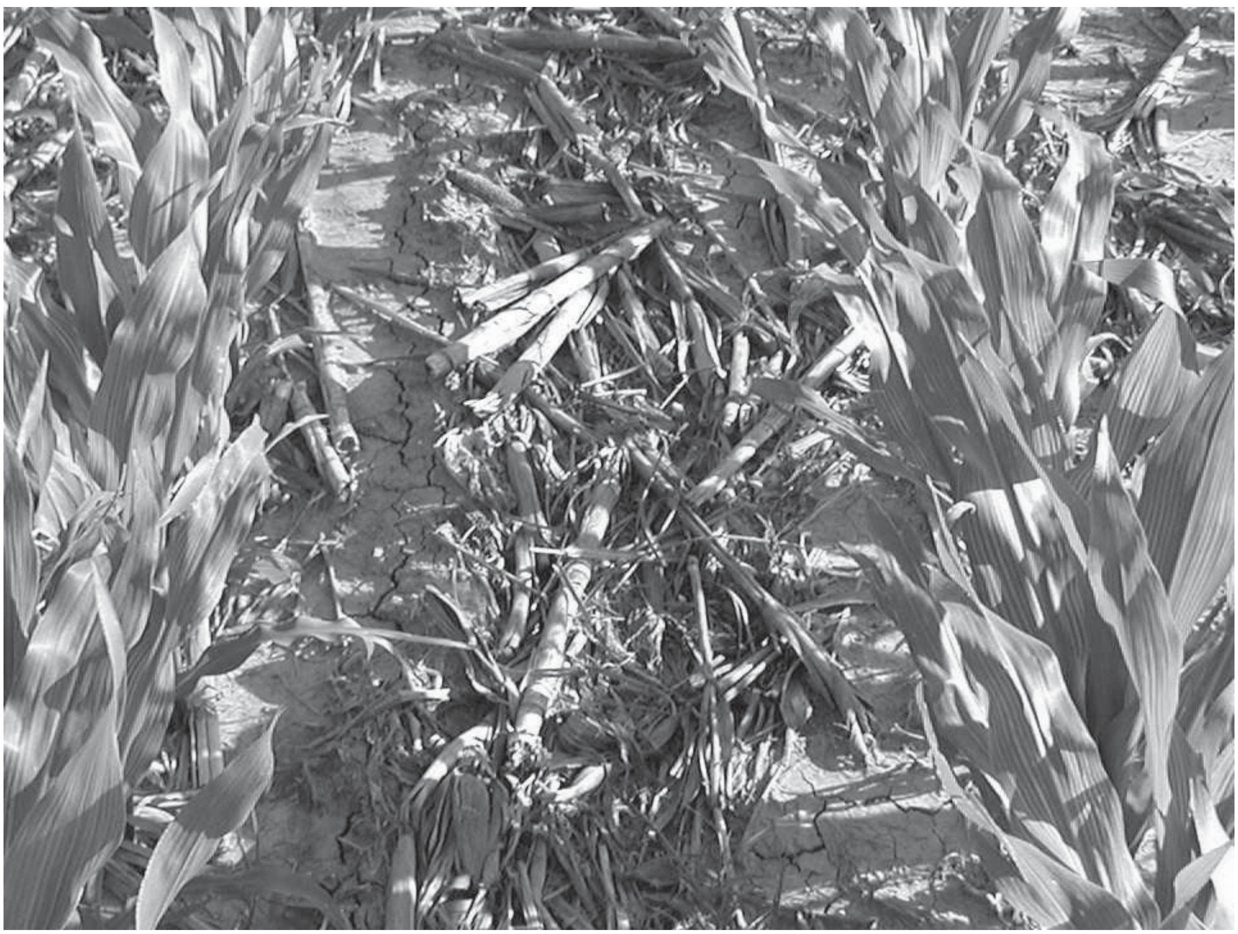
The wheat in all rotations followed corn and received 5 in. of irrigation. Wheat yields were reduced by freeze damage in mid-May (Table 1). All rotations were limited to 10 in. of annual irrigation, but the corn following wheat received 15 in. inasmuch as the wheat only received 5 in. This extra 5 in. of irrigation increased corn yields about 30 bu/a, compared_with the yield of continuous corn (which only received 10 in. of irrigation). Results of the limited-irrigation study suggest that additional irrigation would not have been beneficial for sorghum or soybean this year (Table 1).

[1]Project receives support from the Kansas Corn Commission, Kansas Grain Sorghum Commission, Kansas Soybean Commission, Western Kansas Groundwater Management District #1, and the Ogallala Aquifer Initiative.

[2]Department of Agronomy, Kansas State University, Manhattan.

Table 1. Grain yield of four crops, as affected by rotation, Tribune, Kansas, 2004.				
Rotation	Corn	Wheat	Sorghum	Soybean
	- - - - - - - -	- - - - bu/a -	- - - - - - - -	- - - - - - - -
cont. corn	210	—	—	—
corn-wheat	243	28	—	—
corn-wheat-sorghum	239	27	138	—
corn-wheat-sorghum-soybean	239	29	145	58

An economic analysis was performed to determine returns to land, irrigation equipment, and management for all four rotations. The most profitable rotation in 2004 was continuous corn, with a return of $160/a. The least profitable was a 3-yr rotation of corn/wheat/sorghum, with a return of $80/a. The 2- and 4-yr rotations had similar returns of $86-94/a. Because of the very good corn yields in 2004, the differences in economic returns between continuous corn and the multi-crop rotations were greater than in 2003.



NITROGEN MANAGEMENT FOR NO-TILL DRYLAND CORN[1]

by
Alan Schlegel, Curtis Thompson, Troy Dumler, Dale Leikam[2], and Brian Olson[3]

SUMMARY

Dryland corn acreage in the central Great Plains (western Kansas and Nebraska and eastern Colorado) has increased more than 1 million acres during the past decade (1991 to 2000). The majority of dryland corn is grown by using no-tillage practices to optimize water conservation, but there is limited information available on N management for no-till dryland corn. The objectives of this research were to determine the impact of N fertilizer placement and time of application on N utilization by no-till dryland corn in western Kansas. The N treatments were a factorial of applications methods, time of application, and N rates. The methods of application were surface broadcast, surface dribble, and sub-surface injection. The times of application were early pre-plant and pre-emergence after planting. The N rates were 0, 30, 60, 90, and 120 lb N/a using 28% UAN solution. Average grain yields ranged from 36 to 76 bu/a at the four sites. Yields were increased by N fertilization at only one site (about 20% with 60 lb N/a). Early-season growth and grain yields were greater with pre-emergence than with early-preplant N applications at half of the sites. Injected N applications produced greater early-season growth than did broadcast N at two sites. At one of the responsive sites, grain yields were also greater with injected than broadcast N, whereas injected N produced the lowest yields at the other site. The limited yield potential of dryland corn in these studies limited the need for N fertilization.

INTRODUCTION

Dryland corn acreage in the central Great Plains rapidly increased during the past decade. The majority of dryland corn is grown by using no-tillage practices to optimize water conservation, but there is limited information available on N management for no-till crop production in western Kansas, with no current information for dryland corn. Increased surface residue cover in no-till systems has been shown to impact N utilization from surface N fertilizer applications. Therefore, N fertilizer recommendations may need to be adjusted to optimize production of no-till dryland corn. Injection of N fertilizer below the residue layer is one means for avoiding the problems with plant residue reducing N utilization. But this requires a separate operation and precludes applying fluid N fertilizer with herbicides in a surface broadcast application. A one-pass application reduces application costs and labor requirements, but may also reduce N fertilizer effectiveness. The overall objectives of this project are to determine the impact of N fertilizer placement and time of application on N utilization by no-till dryland corn in western Kansas.

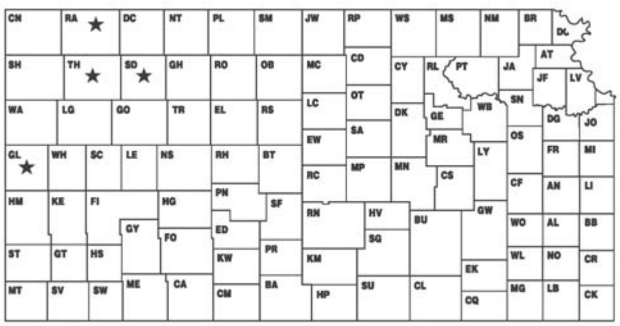
PROCEDURES

Study sites were established in the spring of 2004 at four locations in west-central and northwestern Kansas (Figure 1). The Greeley County site is at the Tribune Unit, KSU-Southwest Research-Extension Center and the Thomas County location is at the KSU-Northwest Research-Extension Center near Colby. The other two sites were on farmer cooperator fields in Rawlins and Sheridan counties. At all sites, dryland corn was no-till planted into standing wheat stubble. The N treatments were a factorial of applications methods, time of application, and N rates, with four replications at each site. The three methods of application were surface broadcast, surface dribble, and sub-surface injection. The times of application were early pre-plant (April 5 to April 8) and pre-emergence after planting (May 12 to May 14). The N rates were 0, 30, 60, 90, and 120 lb N/acre. Fluid N

[1]Project supported by Kansas Fertilizer Research Fund and Fluid Fertilizer Foundation.
[2]Department of Agronomy, Kansas State University, Manhattan.
[3]Multicounty Extension Agronomist.

[28% N as UAN solution] was the N source. A coulter injection fertilizer unit was used to place the N fertilizer below the soil surface on 15" centers for the injection treatments. The dribble applications were made by using the same coulter applicator, operated with the coulters about 11 inches above the soil surface. A 10-ft spray boom with four spray tips at 30-inch spacing was mounted on the back of the coulter injection unit and used to apply the broadcast treatments. Plot size was 10 (four 30-in. rows) by 40 ft.

Figure 1. Sites for N management of dryland corn in 2004.



Site selection was based on cooperator interest and residual soil N content. Sites with the most potential for yield response from N fertilizer were selected. Surface soil samples (0 to 6 in.) were taken after planting and analyzed for pH, soil-test P, and organic matter content (Table 1). Residual soil inorganic N was determined for the surface 2 ft. Whole-plant samples at about the 6- to 8-leaf stage were collected, dried, weighed, and analyzed for N content (data not yet available). After the crop reached physiological maturity, the center two rows of each plot were combine harvested. Grain yields were adjusted to 15.5% moisture. Grain samples were analyzed for N content (data not yet available).

The early-preplant N applications were made in early April (Table 2). Corn was planted in May at all sites, with N applications made shortly after planting. Hybrid selection and seeding rate were determined by the cooperator and differed among sites.

Table 1. Selected soil chemical properties at corn planting in 2004 at 4 sites in western Kansas.

Site	(0-6") pH	(0-6") OM	Bray - 1 P (0-6")	Soil N (0-24") NO_3	Soil N (0-24") NH_4	Soil N (0-24") Total
		%	- - - - ppm - - - -	- - - - - - ppm - - - - - -		
Greeley	7.7	2.5	16	3.3	2.9	6.2
Sheridan	5.8	2.1	21	6.0	5.6	1.6
Rawlins	6.5	2.0	22	5.6	2.8	8.4
Thomas	6.3	3.0	37	14.1	3.1	17.2

Table 2. Time of N fertilizer applications and planting information for 2004.

Site	N application Early preplant	N application After planting	Planting Date	Planting Hybrid
Greeley	April 5	May 12	May 7	DeKalb C53-34 @15,000 seeds/a
Sheridan	April 8	May 12	May 6	Pioneer 33B49 @16,600 seeds/a
Rawlins	April 7	May 14	May 12	NC+ 4880 @17,300 seeds/a
Thomas	April 6	May 14	May 3	Ottilie 5170RR @18,000 seeds/a

RESULTS AND DISCUSSION

Average grain yields in 2004 ranged from 36 bu/a at the Thomas County site to 76 bu/a at the Rawlins County site. Yields were increased by N fertilization at only one site (Sheridan County;Table 3). At this site, yields were increased about 20% (11 bu/a) with 60 lb N/a, compared with yields of the untreated control. Early-season growth also was not affected by increasing N rates at any site. The lack of response to N fertilization indicates that sufficient N (residual soil N and mineralized N) was available for the yields obtained at these sites.

Early pre-plant application of N produced slightly less early growth than pre-emergence applications did at 50% of the sites, with no differences at the other two sites (Table 4). Grain yields also were greater at two sites from pre-emergence N applications, compared with early preplant applications, but the sites that showed greater early growth with pre-emergence applications were not the sites with greater grain yields.

Injected N applications produced greater early-season growth than broadcast N did at two sites; at the other sites there was no difference in plant growth due to application method (Table 5). At one of the responsive sites (Greeley County), grain yields were also greater with injected than broadcast N; at the other site (Thomas County) grain yields with injected N were the lowest. The Thomas County site also had the lowest yields (average of 36 bu/a), so N requirements would be expected to be minimal.

Table 3. Effect of N rate on early plant growth and grain yield of dryland corn in western Kansas, 2004.

	Biomass				Grain yield			
N rate	Greeley	Sheridan	Rawlins	Thomas	Greeley	Sheridan	Rawlins	Thomas
lb/a	- - - - - - - - - - - lb/a - - - - - - - - - - - -				- - - - - - - - - - - - - bu/a - - - - - - - - - -			
0	92	432	126	530	56	54	74	41
30	98	391	114	558	65	60	72	3
60	83	405	115	515	55	65	71	34
90	103	415	117	508	57	66	81	35
120	92	384	123	533	55	66	79	34
LSD(0.05)	23	45	13	67	9	7	9	8

Table 4. Effect of time of application on early plant growth and grain yield of dryland corn in western Kansas, 2004.

Time of	Biomass				Grain yield			
application	Greeley	Sheridan	Rawlins	Thomas	Greeley	Sheridan	Rawlins	Thomas
	- - - - - - - - - - - lb/a - - - - - - - - - - - - -				- - - - - - - - - - - - bu/a - - - - - - - - - - -			
Early preplant	94	382	113	534	50	66	78	32
Pre-emergence	94	416	122	523	66	63	74	37
LSD (0.05)	16	32	9	47	6	5	7	5

Table 5. Effect of method of application on early plant growth and grain yield of dryland corn in western Kansas, 2004.

Method of	Biomass				Grain yield			
application	Greeley	Sheridan	Rawlins	Thomas	Greeley	Sheridan	Rawlins	Thomas
	- - - - - - - - - -lb/a - - - - - - - - -				- - - - - - - - - - bu/a - - - - - - - - - -			
Broadcast	80	400	122	494	54	63	79	35
Dribble	100	378	114	528	57	64	73	39
Injection	103	417	117	563	62	65	76	30
LSD(0.05)	20	39	11	58	8	6	8	7

TILLAGE EFFECTS ON SOIL WATER AND GRAIN YIELD IN A WHEAT-SORGHUM-FALLOW ROTATION

by
Alan Schlegel, Loyd Stone, Troy Dumler, and Curtis Thompson

SUMMARY

A study was initiated in west-central Kansas near Tribune to evaluate the long-term effects of tillage intensity on soil water and grain yield in a wheat-sorghum-fallow rotation. Grain yields of wheat and grain sorghum increased with decreased tillage intensity. Averaged across 14 yr, yield of no-till (NT) wheat was 3 bu/a greater than that of reduced-tillage (RT) wheat and 8 bu/a greater than wheat produced with conventional tillage (CT). Average NT sorghum yields were 12 bu/a greater than yields of RT sorghum and 34 bu/a greater than that of sorghum produced with CT. For grain sorghum, in particular, the advantage of reducing tillage intensity has increased with time. For instance, NT sorghum yields were 118 bu/a in 2004, compared with 67 bu/a for RT sorghum and 44 bu/a for sorghum produced with CT.

PROCEDURES

Research on different tillage intensities in a wheat-sorghum-fallow (WSF) rotation at the K-State Southwest Research-Extension Center at Tribune was initiated in 1991 on land just removed from native sod. The three tillage intensities 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 4 to 5 tillage operations per year, usually with a blade plow or field cultivator. The RT system through 2000 used a combination of herbicides (1 to 2 spray operations) and tillage (2 to 3 tillage operations) to control weed growth during the fallow period. Since 2001, the RT system has used a combination of NT from wheat harvest through sorghum planting and CT from sorghum harvest to 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. Plot size was 50 by 100 ft, with four replications.

Grain yield was determined by machine harvesting the center of each plot after crop physiological maturity. Profile soil water was measured near planting and after harvest of each crop to a depth of 8 ft.

RESULTS AND DISCUSSION

SOIL WATER

The amount of soil water accumulation during fallow varied widely among years for both crops (Fig. 1 and 2). In some years, there was a loss of stored soil water from harvest to planting, whereas in other years, water accumulation during fallow exceeded 10 inches. On average, CT was the least effective in accumulating soil water for both crops. Before wheat, water accumulation during fallow averaged 4.43 inches for CT, compared with 5.52 inches for RT and 5.07 inches for NT. Somewhat surprising was that the NT did not accumulate more water than RT. Results were similar for sorghum; before sorghum, water accumulation during fallow averaged 4.04 inches for CT, compared with 5.32 inches for RT and 5.02 inches for NT. Fallow efficiency (amount of water accumulated during fallow divided by precipitation during fallow) ranged from less than 0 to more than 50%, and averaged 24% for CT, compared with 32% for RT and 28% for NT.

Figure 1. Soil water accumulation during fallow before wheat in a wheat-sorghum-fallow rotation, 1991 through 2004, Tribune, Kansas.

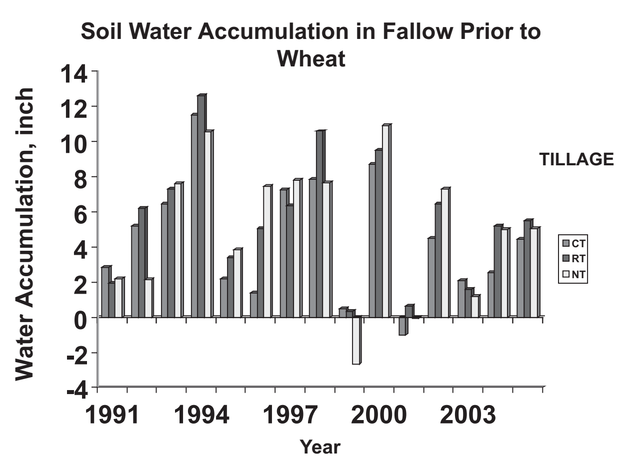
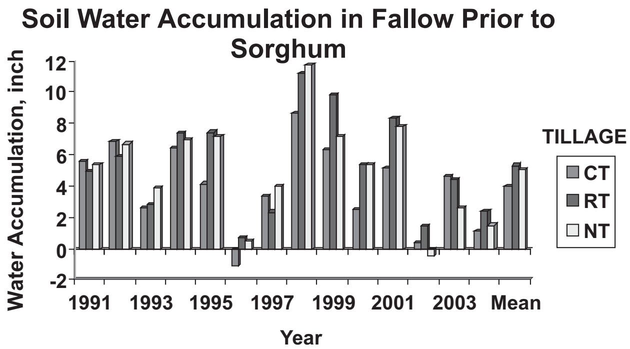


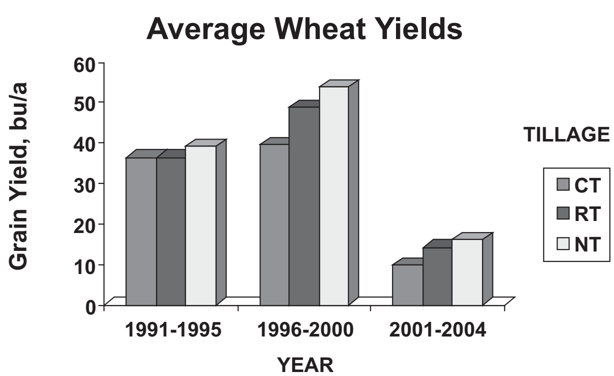
Figure 2. Soil water accumulation during fallow prior to sorghum in a wheat-sorghum-fallow rotation, 1991 through 2004, Tribune, Kansas.



GRAIN YIELD OF WHEAT AND GRAIN SORGHUM

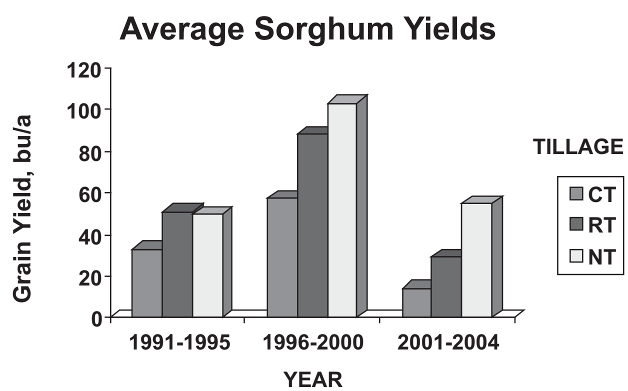
Wheat yields increased with decreases in tillage. On average (1991 through 2004), wheat yields were 8 bu/a higher for NT (38 bu/a) than for CT (30 bu/a). Wheat yields for RT were 5 bu/a greater than CT. During the first 5 yr of the study, wheat yields were similar for CT and RT, with NT wheat yields 3 bu/a greater (Fig. 3). During the late1990s (1996 through 2000), NT wheat yields were 5 bu/a greater than RT and 14 bu/a greater than CT. The 2 yr with the lowest wheat yields (less than 5 bu/a) of the entire study occurred in the past 4 yr (2002 because of drought and 2004 because of a mid-May freeze). Although average yields during this 4-yr period are very low, using NT produced 6 bu/a more wheat than did using CT.

Figure 3. Average wheat yields as affected by tillage in a wheat-sorghum-fallow rotation, Tribune, Kansas.



The yield benefit from reduced tillage was greater for grain sorghum than for wheat (Fig. 4). Grain sorghum yields under CT averaged 36 bu/a for the entire study period, compared with 58 bu/a for RT sorghum and 70 bu/a for NT sorghum. The yield benefit from reduction in tillage has increased throughout the duration of the study. During the first 5 yr, sorghum yields were about 17 bu/a greater with RT or NT, compared with yields from CT. During the late 1990s, with generally good growing conditions, CT sorghum averaged 57 bu/a, compared with 88 bu/a for RT and 103 bu/a for NT treatments. Similar to results with wheat, there have been two poor sorghum years since 2000 (2002 and 2003), but the relative advantage through reducing tillage has increased. Averaged across the past 4 yr, NT sorghum yields were 55 bu/a, compared with 29 bu/a for RT sorghum and only 14 bu/a for CT sorghum. In 2004, NT sorghum yields were 118 bu/a, compared with 67 bu/a for RT sorghum and 44 bu/a for CT sorghum.

Figure 4. Average grain sorghum yields as affected by tillage in a wheat-sorghum-fallow rotation, Tribune, Kansas.



An economic analysis using current costs and average commodity prices during the period 1991 through2004 was conducted to determine which tillage system had the greatest return to land and management. The estimated returns do not include government payments or insurance indemnity payments. Wheat returns averaged $-2.19/a, $13.18/a, and $1.64/a for CT, RT, and NT systems, respectively. Average returns for sorghum were $-30.81/a, $-6.75/a, and $2.14/a, for CT, RT, and NT systems, respectively. On a rotation basis, RT and NT had similar returns of $4.28 and $2.50/a, whereas CT had considerably lower returns of $-22.00/a.

LIMITED IRRIGATION OF FOUR SUMMER CROPS IN WESTERN KANSAS[1]

by

Alan Schlegel, Loyd Stone, and Troy Dumler

SUMMARY

Research was initiated under sprinkler irrigation to evaluate limited irrigation with no-till for four summer crops. In 2004, corn yields were very good, with yields in excess of 200 bu/acre with only 5 inches of irrigation. Corn was the only crop that responded to increased irrigation amounts. Corn was also the most profitable crop at all irrigation rates. Increasing the seeding rate did not affect corn or sunflower yields, but slightly increased soybean yields. Sorghum yields were greater with the increased seeding rate, but a longer-season hybrid was also used with the higher seeding rate. Averaged across the past 4 years, soybean was the most profitable crop at the smallest irrigation amount and corn the most profitable at larger irrigation amounts.

PROCEDURES

A study was initiated under sprinkler irrigation at the Tribune Unit, Southwest Research-Extension Center near Tribune in the spring of 2001. The objectives are to determine the impact of limited irrigation on crop yield, water use, and profitability. All crops are grown no-till, and other cultural practices (hybrid selection, fertility practices, weed control, etc.) are selected to optimize production. Irrigation amounts are 5, 10, and 15 inches annually. All water rates are present each year and are replicated four times. Irrigations are scheduled to supply water at the most critical stress periods for the specific crops, and are limited to 1.5 inches/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 water allocations. The crops evaluated are corn, grain sorghum, soybean, and sunflower grown in a 4-yr rotation (a total of 12 treatments). The crop rotation is corn-sunflower-grain sorghum-soybean (alternating grass and broadleaf crops). The irrigation amounts for a particular plot remain constant throughout the study (e.g., a plot receiving 5 inches of water one year when corn is grown will also receive 5 inches in the other years when grain sorghum, sunflower, or soybean is grown).

RESULTS AND DISCUSSION

Crop production was generally very good in 2004. Precipitation from June through August was 11.49 inches (47% above normal). Corn was the only crop that responded appreciably to irrigation amounts greater than 5 inches (Table 1). Higher plant populations did not increase corn or sunflower yields, but there was a slight increase for soybean. Sorghum yields increased considerably, but a longer-season hybrid was used in conjunction with the larger plant population. Average grain yields from 2001 through 2004 are shown in Table 2. In 2002, hail reduced grain yields, particularly for corn and sunflower.

[1]This research project receives support from the Kansas Corn Commission, Kansas Grain Sorghum Commission, Kansas Soybean Commission, Western Kansas Groundwater Management District #1, and the Ogallala Aquifer Initiative.

Table 1. Grain yield of four crops as affected by irrigation amount, Southwest Research-Extension Center, Tribune, Kansas, 2004.

Irrigation amount	Corn	Sorghum	Soybean	Sunflower
inches	- - - - - - - - - - - -	bu/acre	- - - - - - - - - -	lb/acre
5	204 (178)	111 (134)	49 (43)	2532 (2253)
10	245 (240)	103 (140)	52 (55)	2607 (2748)
15	260 (256)	106 (126)	49 (56)	2775 (2482)

*Yields in parentheses are with 20% greater seeding rate. The same hybrid/variety were used for both seeding rates for all crops except sorghum, for which a longer season hybrid was used at the higher seeding rate.

Table 2. Average grain yield of four crops as affected by irrigation amount, Southwest Research-Extension Center, Tribune, Kansas, 2001-2004.

Irrigation amount	Corn	Sorghum	Soybean	Sunflower
inches	- - - - - - - - - - - -	bu/acre	- - - - - - - - - -	lb/acre
5	108	88	32	1464
10	168	107	42	1866
15	186	120	46	1866

Figure 1. Economic returns to four crops as affected by irrigation amount in 2004.

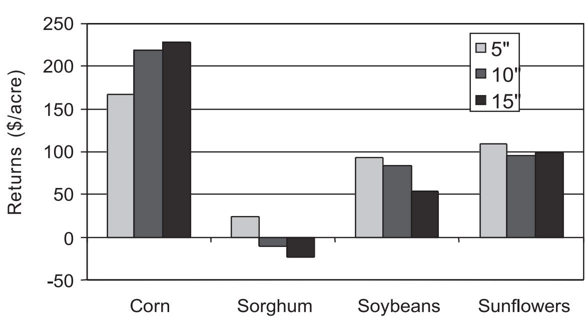


Figure 2. Economic returns to four crops as affected by irrigation amount in 2004, with alternate sorghum hybrid.

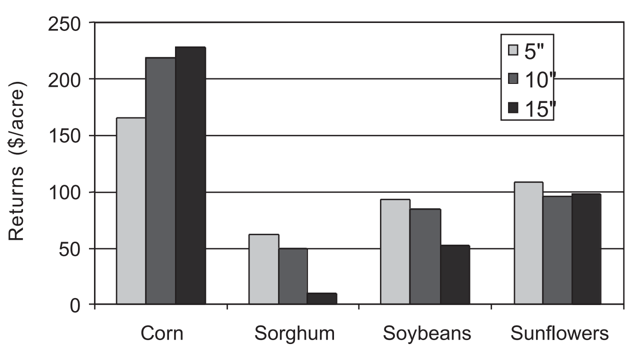
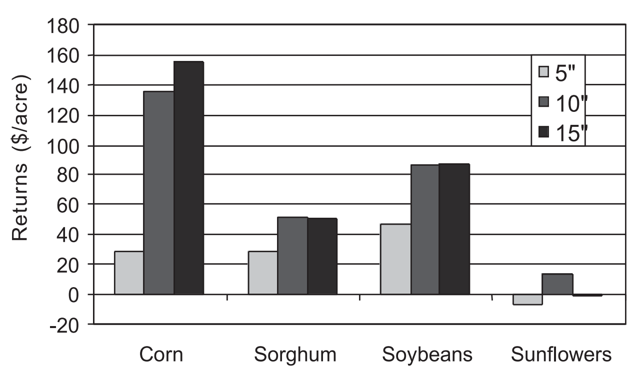


Figure 3. Four-year average returns to limited irrigation.



LAND APPLICATION OF ANIMAL WASTES ON IRRIGATED CORN[1]

by
Alan Schlegel, Loyd Stone, H. Dewayne Bond, and Mahbub 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 wastes (effluent water from a lagoon) and cattle wastes (solid manure from a beef feedlot) have been applied annually since 1999, at rates to meet estimated corn P or N requirements, and at a rate double the N requirement. Other treatments were N fertilizer (60, 120, or 180 lb N/a) and an untreated control. Corn yields were increased by application of animal wastes and N fertilizer. Over-application of cattle manure has not had a negative effect on corn yield. For swine effluent, over-application has not reduced corn yields, except in 2004, when the effluent had much greater salt concentration than in previous years, which 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 the estimated crop P requirement, crop N requirement, or double the N requirement (Table 1). The Kansas Dept. of Agriculture Nutrient Utilization Plan was used to calculate animal waste application rates. Expected corn yield was 200 bu/acre. The allowable P application rates for the P-based treatments were 105 lb P_2O_5/acre because soil-test P content was 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, the residual soil N content after harvest in 2001 and 2002 was sufficient to eliminate the need for additional N. So no swine effluent was applied to the 1xN treatment in 2002 or 2003 or to the 2xN requirement treatment because it is based on 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 gallon of swine effluent (actual analysis of animal wastes as applied differed somewhat from the estimated values, Table 2). Subsequent applications were based on previous analyses. Other nutrient treatments were three rates of inorganic N fertilizer (60, 120, and 180 lb N/acre), and an untreated control. The experimental design was a randomized complete block with four replications. Plot size was 12 rows wide by 45 ft long.

The study was established in border basins to facilitate effluent application and flood irrigation. The swine effluent was flood-applied as part of a pre-plant irrigation in spring of each year. Plots not receiving swine effluent were also irrigated at the same time to balance water additions. The cattle manure was hand-broadcast and incorporated. The N fertilizer (granular NH_4NO_3) was applied with a 10-ft fertilizer applicator (Rogers Mfg.). The entire study area was uniformly irrigated during the growing season with flood irrigation in 1999 and 2000 and sprinkler irrigation in 2001 through 2004. The soil is a Ulysses silt loam. Corn was planted at about 33,000 seeds/a in late April or early May each year. Grain yields are not reported for 1999 because of severe hail damage. Hail also

[1] Project supported in part by Kansas Fertilizer Research Fund and Kansas Dept. of Health and Environment.

Table 1. Application rates of animal wastes, Tribune, Kansas, 1999 to 2004.												
Application basis *	Cattle manure						Swine effluent					
	ton/a						1000 gal/a					
	1999	2000	2001	2002	2003	2004	1999	2000	2001	2002	2003	2004
P req.	15.0	4.1	6.6	5.8	8.8	4.9	28.0	75.0	62.0	63.4	66.9	74.1
N req.	15.0	6.6	11.3	11.4	0	9.8	28.0	9.4	38.0	0	0	40.8
2XN req.	30.0	13.2	22.6	22.8	0	19.7	56.0	18.8	76.0	0	0	81.7

* The animal waste applications are based on the estimated requirement of N and P for a 200 bu/a corn crop.

Table 2. Analysis of animal waste as applied, Tribune, Kansas, 1999 to 2004.												
Nutrient content	Cattle manure						Swine effluent					
	lb/ton						lb/1000 gal					
	1999	2000	2001	2002	2003	2004	1999	2000	2001	2002	2003	2004
Total N	27.2	36.0	33.9	25.0	28.2	29.7	8.65	7.33	7.83	11.62	7.58	21.42
Total P_2O_5	29.9	19.6	28.6	19.9	14.6	18.1	1.55	2.09	2.51	1.60	0.99	2.10

damaged the 2002 crop. 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 2004, as has been true for all years except 2002, in which yields were greatly reduced by hail damage (Table 3). The type of animal waste affected yields in 3 of the 5 years, with higher yields from cattle manure than from swine effluent. Averaged across the 5 years, corn yields were 14 bu/acre greater after application of cattle manure than after swine effluent on an N-application basis. Over-application (2xN) of cattle manure has had no negative impact on grain yield in any year, but over-application of swine effluent reduced yields in 2004 because considerably greater salt content (2 to 3 times greater electrical conductivity than any previous year) caused germination damage and poor stands.

Table 3. Effect of animal waste and N fertilizer on irrigated corn, Tribune, Kansas, 2000-2004.							
		Grain yield					
Nutrient source	Rate†	2000	2001	2002	2003	2004	Mean
		bu/acre					
Cattle manure	P	197	192	91	174	241	179
	N	195	182	90	175	243	177
	2 X N	195	185	92	181	244	179
Swine effluent	P	189	162	74	168	173	153
	N	194	178	72	167	206	163
	2 X N	181	174	71	171	129	145
N fertilizer	60 N	178	149	82	161	170	148
	120 N	186	173	76	170	236	168
	180 N	184	172	78	175	235	169
Control	0	158	113	87	97	94	110
$LSD_{0.05}$		22	20	17	22	36	14
ANOVA							
Treatment		0.034	0.001	0.072	0.001	0.001	0.001
Selected contrasts							
Control vs. treatment		0.001	0.001	0.310	0.001	0.001	0.001
Manure vs. fertilizer		0.089	0.006	0.498	0.470	0.377	0.200
Cattle vs. swine		0.220	0.009	0.001	0.218	0.001	0.001
Cattle 1x vs. 2x		0.900	0.831	0.831	0.608	0.973	0.747
Swine 1x vs. 2x		0.237	0.633	0.875	0.730	0.001	0.011
N rate linear		0.591	0.024	0.639	0.203	0.001	0.006
N rate quadratic		0.602	0.161	0.614	0.806	0.032	0.107

†Rate of animal waste applications based on amount needed to meet estimated crop P requirement, N requirement, or double the N requirement.

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

LONG-TERM NITROGEN AND PHOSPHORUS FERTILIZATION OF IRRIGATED CORN

by
Alan 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 2004, N and P applied alone increased yields about 95 and 30 bu/acre, respectively, but N and P applied together increased yields as much as 173 bu/acre. Averaged across the past 10 years, corn yields were increased more than 100 bu/acre by N and P fertilization. Application of 120 lb N/acre (with P) was sufficient to produce ≥95% of maximum yield in 2004, which was consistent with the 10-year average. Phosphorus increased corn yields between 72 and 131 bu/acre (average about 100 bu/acre) when applied with at least 120 lb N/acre. Application of 80 lb P_2O_5/acre increased yields 5 to 9 bu/acre, compared with application of 40 lb P_2O_5/acre, when applied with at least 120 lb N/acre.

INTRODUCTION

This study was initiated in 1961 to determine responses of continuous corn and grain sorghum grown under flood irrigation to N, P, and 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 content did not decline, so the K treatment was discontinued in 1992 and was replaced with a higher P rate.

PROCEDURES

Initial fertilizer treatments in 1961 were N rates of 0, 40, 80, 120, 160, and 200 lb N/acre without P and K; with 40 lb P_2O_5/acre and zero K; and with 40 lb P_2O_5/acre and 40 lb K_2O/acre. In 1992, the treatments were changed, with the K variable being replaced by a higher rate of P (80 lb P_2O_5/acre). All fertilizers were broadcast by hand in the spring and incorporated before planting. The corn hybrids were Pioneer 3225 (1995-97), Pioneer 3395IR (1998), Pioneer 33A14 (2000), Pioneer 33R93 (2001 and 2002), DeKalb C60-12 (2003), and Pioneer 34N45 (2004), planted at about 32,000 seeds/acre in late April or early May. Hail damaged the 2002 crop and destroyed the 1999 crop. The corn was irrigated to minimize water stress. Furrow irrigation was used through 2000, and sprinkler irrigation since 2001. The center 2 rows of each plot were machine harvested after physiological maturity. Grain yields were adjusted to 15.5% moisture.

RESULTS AND DISCUSSION

Corn yields in 2004 were considerably higher than the 10-year average (Table 1). Nitrogen alone increased yields as much as 95 bu/acre; P alone increased yields about 30 bu/acre. But N and P applied together increased corn yields as much as 173 bu/acre. Only 120 lb N/acre with P was required to obtain ≥95% of maximum yields, which is consistent with the 10-year average. Corn yields were 2 bu/acre greater with 80 than with 40 lb P_2O_5/acre, compared with the 10-year average of 4 bu/acre. With N rates of 120 lb N/acre or greater, however, the higher P rate increased yields about 7 bu/acre in 2004.

Table 1. Effect of N and P fertilizers on irrigated corn. Tribune, Kansas, 1995-2004.											
		Grain yield									
Nitrogen	P_2O_5	1995	1996	1997	1998*	2000	2001	2002*	2003	2004	Mean
- - - - lb/acre - - - -		- bu/acre- -									
0	0	22	58	66	49	131	54	39	79	67	63
0	40	27	64	79	55	152	43	43	95	97	73
0	80	26	73	83	55	153	48	44	93	98	75
40	0	34	87	86	76	150	71	47	107	92	83
40	40	68	111	111	107	195	127	69	147	154	121
40	80	65	106	114	95	202	129	76	150	148	121
80	0	34	95	130	95	149	75	53	122	118	97
80	40	94	164	153	155	205	169	81	188	209	157
80	80	93	159	155	149	211	182	84	186	205	158
120	0	39	97	105	92	143	56	50	122	103	90
120	40	100	185	173	180	204	177	78	194	228	169
120	80	111	183	162	179	224	191	85	200	234	174
160	0	44	103	108	101	154	76	50	127	136	100
160	40	103	185	169	186	203	186	80	190	231	170
160	80	100	195	187	185	214	188	85	197	240	177
200	0	62	110	110	130	165	130	67	141	162	120
200	40	106	180	185	188	207	177	79	197	234	173
200	80	109	190	193	197	218	194	95	201	239	182
ANOVA											
N		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
P_2O_5		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	0.007	0.001	0.001	0.001
N x P		0.001	0.001	0.001	0.001	0.008	0.001	0.133	0.001	0.001	0.001
MEANS											
N, lb/a	0	25	65	76	53	145	48	42	89	87	70
	40	56	102	104	93	182	109	64	135	132	108
	80	74	139	146	133	188	142	73	165	178	137
	120	83	155	147	150	190	142	71	172	188	144
	160	82	161	155	157	190	150	71	172	203	149
	200	92	160	163	172	197	167	80	180	212	158
$LSD_{0.05}$		7	10	12	11	10	15	8	9	11	6
P_2O_5, lb/a	0	39	92	101	91	149	77	51	116	113	92
	40	83	148	145	145	194	147	72	168	192	144
	80	84	151	149	143	204	155	78	171	194	148
$LSD_{0.05}$		5	7	9	7	7	10	6	6	8	4

*Note: There was no yield data for 1999 because of hail damage. Hail reduced yields in 2002.

LONG-TERM NITROGEN AND PHOSPHORUS FERTILIZATION OF IRRIGATED GRAIN SORGHUM

by
Alan Schlegel

SUMMARY

Long-term research shows that phosphorus (P) and nitrogen (N) fertilizer must be applied to optimize production of irrigated grain sorghum in western Kansas. In 2004, N and P applied alone increased yields about 43 and 17 bu/acre, respectively; when N and P were applied together, however, yields increased up to 63 bu/acre. Averaged across the past 9 years, sorghum yields were increased more than 50 bu/acre by N and P fertilization. Application of 40 lb N/acre (with P) was sufficient to produce >90% of maximum yield in 2004, which was consistent with the 9-year average. The benefit from P decreased at the higher N rates. Application of K had no significant effect on sorghum yield in 2004 or long term.

INTRODUCTION

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

PROCEDURES

Fertilizer treatments initiated in 1961 were N rates of 0, 40, 80, 120, 160, and 200 lb N/acre without P and K; with 40 lb P_2O_5/acre and zero K; and with 40 lb P_2O_5/acre and 40 lb K_2O/acre. All fertilizers were broadcast by hand in the spring and incorporated before planting. Sorghum (Mycogen TE Y-75 in 1996, Pioneer 8414 in 1997, and Pioneer 8500/8505 from 1998 through 2004) was planted in late May or early June. Irrigation was used to minimize water stress. Furrow irrigation was used through 2000, and sprinkler irrigation has been used since 2001. The center 2 rows of each plot were machine harvested after physiological maturity. Grain yields were adjusted to 12.5% moisture.

RESULTS AND DISCUSSION

Grain sorghum yields in 2004 were slightly less than the 9-year average (Table 1). Nitrogen alone increased yields about 43 bu/acre; P alone increased yields 17 bu/acre. Nitrogen and P applied together increased sorghum yields as much as 63 bu/acre. Only 40 lb N/acre was required to obtain >90% of maximum yields, which was consistent with the 10-year average. At the higher N rates (160 lb N/acre or greater), the response to P was less than at the medium N rates (40 to 120 lb N/acre). Sorghum yields were not affected by K fertilization, which has been true throughout the study period.

Table 1. Effect of N, P, and K fertilizers on irrigated sorghum yields, Tribune, Kansas, 1996-2004.

			Grain yield									
N	P_2O_5	K_2O	1996	1997	1998	1999	2000	2001	2002	2003	2004	Mean
- - - - - lb/acre - - - -			- - - - - - - - - - - - - - - - bu/acre - - - - - - - - - - - - - - - -									
0	0	0	74	81	77	74	77	76	73	80	57	74
0	40	0	77	75	77	85	87	81	81	93	73	81
0	40	40	79	83	76	84	83	83	82	93	74	82
40	0	0	74	104	91	83	88	92	82	92	60	85
40	40	0	100	114	118	117	116	124	120	140	112	118
40	40	40	101	121	114	114	114	119	121	140	117	118
80	0	0	73	100	111	94	97	110	97	108	73	96
80	40	0	103	121	125	113	116	138	127	139	103	121
80	40	40	103	130	130	123	120	134	131	149	123	127
120	0	0	79	91	102	76	82	98	86	97	66	86
120	40	0	94	124	125	102	116	134	132	135	106	119
120	40	40	99	128	128	105	118	135	127	132	115	121
160	0	0	85	118	118	100	96	118	116	122	86	107
160	40	0	92	116	131	116	118	141	137	146	120	125
160	40	40	91	119	124	107	115	136	133	135	113	120
200	0	0	86	107	121	113	104	132	113	131	100	113
200	40	0	109	126	133	110	114	139	136	132	115	124
200	40	40	95	115	130	120	120	142	143	145	123	127
ANOVA (P>F)												
Nitrogen			0.003	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Linear			0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Quadratic			0.116	0.001	0.001	0.227	0.001	0.001	0.001	0.001	0.018	0.001
P-K			0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Zero P vs. P			0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
P vs. P-K			0.727	0.436	0.649	0.741	0.803	0.619	0.920	0.694	0.121	0.689
N x P-K			0.185	0.045	0.186	0.482	0.061	0.058	0.030	0.008	0.022	0.014

(continued)

Table 1. (cont.) Effect of N, P, and K fertilizers on irrigated sorghum yields, Tribune, Kansas, 1996-2004.

N	P_2O_5	K_2O	Grain yield									
			1996	1997	1998	1999	2000	2001	2002	2003	2004	Mean
- - - - - lb/acre - - - -			- - - - bu/acre - - - -									
MEANS												
Nitrogen	0 lb/a		77	80	76	81	82	80	79	88	68	79
	40		92	113	108	105	106	112	108	124	96	107
	80		93	117	122	110	111	127	119	132	100	115
	120		91	114	118	95	105	122	115	121	96	109
	160		89	118	124	108	110	132	129	134	107	117
	200		97	116	128	115	113	138	131	136	113	121
	$LSD_{0.05}$		9	10	8	13	7	8	9	10	11	7
P_2O_5-K_2O	0 lb/a		79	100	103	90	91	104	94	105	74	94
	40- 0		96	113	118	107	111	126	122	131	105	115
	40-40		95	116	117	109	112	125	123	132	111	116
	$LSD_{0.05}$		7	7	6	9	5	6	6	7	7	5

CROPPING SYSTEMS FOR LIMITED-IRRIGATION MANAGEMENT

by
Norman Klocke, Randall Currie, and Mike Brouk[1]

SUMMARY

Even in the wet year of 2004, crops in no-till management yielded more with less irrigation than those in conventional management. This research demonstrates the role of crop-residue management in converting more of irrigation water into useful, yield-increasing transpiration by limiting evaporation. Corn, soybean, winter wheat, grain sorghum, and sunflower were grown with six water treatments, ranging from nearly dryland to fully irrigated, and were harvested for grain yield. By adoption of crop-residue management techniques, yields could be increased under limited and full irrigation.

INTRODUCTION

Past irrigation-management research has demonstrated that annual grain crops respond best to water applications during flowering and seed-fill growth periods. No-till management systems, which leave crop residues on the surface, have been beneficial in reducing soil water evaporation in sprinkler irrigation. At the same time, there are pressures from the livestock industry to use these same crop residues for livestock forages. This project is designed to combine the best irrigation and crop-residue management techniques into one management system. The products of this project are grain yield-water use and grain yield-irrigation relationships. By harvesting the plots for both grain and forage, the issue of the value of forages for water conservation is also examined.

The objectives of this project were:

1. To measure the grain yield-irrigation and grain yield-water use relationships for corn, soybean, grain sorghum, winter wheat, and sunflower crops, in no-till management with irrigation inputs from nearly zero to full irrigation.
2. For limited-irrigation and fully irrigated corn and grain sorghum, to compare the relationships between whole-plant forage yield, quality, and estimated feed value in a livestock system with the value of the same material as surface residue for water conservation and soil-water evaporation suppression in a grain-production system.

PROCEDURES

The experimental field (18 ac) was subdivided into six cropped strips that were irrigated by a 4-span linear-move sprinkler irrigation system. Because the cropping strips were not replicated, they statistically were treated as individual experiments. The cropping sequence was corn-corn-soybean-winter wheat-sunflower-grain sorghum. The soil was a silt loam with a slope of less than 1%. A soil pH of 8.3 created a challenge for soybean production.

The six treatments, replicated four times, ranged from 3 to 18 inches of seasonal irrigation. Pre-designated amounts of water were applied during vegetative, flowering, and grain-fill growth stages. If rainfall was sufficient to fill the soil profile to field capacity, irrigation was not applied. The extra irrigation allocation was rolled over to the next growth stage. If there was extra allocation at the end of the year, it was not carried over to the next year.

Soil water was measured once every two weeks, with the neutron attenuation method in increments of 12 inches to a depth of 8 ft. There was one sampling site per plot. These measurements were used to calculate evapotranspiration for each two-week period during the season. Irrigation application was calibrated from catch cans, the percentage timer, and a totalizing flow meter.

RESULTS AND DISCUSSION

Cropping year 2004 had above-normal rainfall during May through September (17.4 in. vs. 12.4 in. normal). A hydrologic simulation model developed at Kansas State University, the Kansas Water Budget,

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was used to generate yield-irrigation relationships for conventional crops in Figure 1. A family of curves was generated (not shown) for a range of annual rainfall from 11 to 21 inches. These relationships for corn, grain sorghum, wheat, soybean, and sunflower were based on yield-ET relationships developed for conventionally grown crops from the 1980s and 90s. The simulation results, shown as sets of points, in Figures 1a and 1b are based on 21 inches of annual rainfall. Only a few data points were available in 2004 because of the wet summer and limited use of irrigation. The 2004 data points for corn, sorghum, and sunflower are generally above and to the left of the simulated relationships. The possible influence of crop-residue management and improvements in other management techniques may explain these improved yield-irrigation relationships. Soybean and wheat yield results were less than simulated results. High soil pH may be affecting soybean yields. More years of data are needed to confirm these early results.

Figure 1a. Corn, sorghum, and sunflower yield responses to 21 inches of annual rainfall with conventional management in western Kansas, compared with 2004 no-till management with similar rainfall at the Southwest Research-Extension Center.

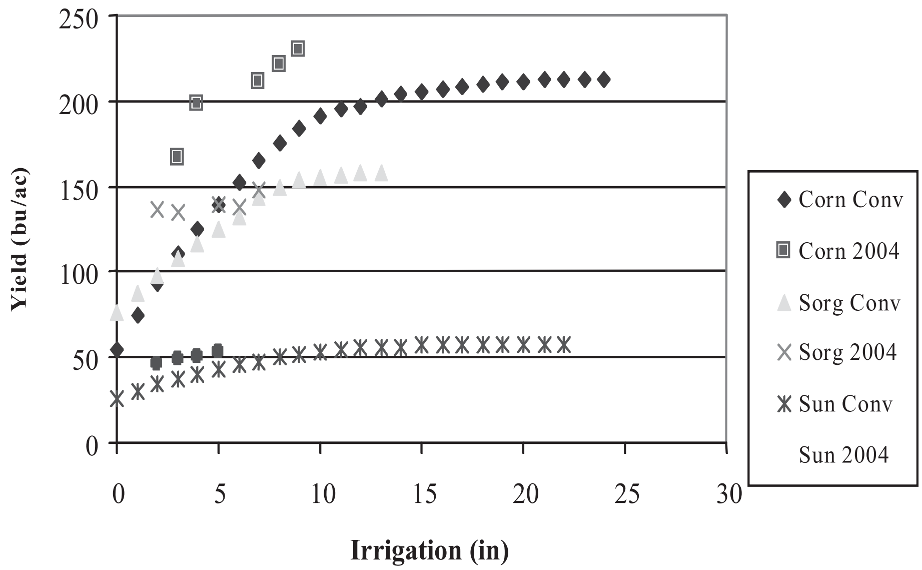
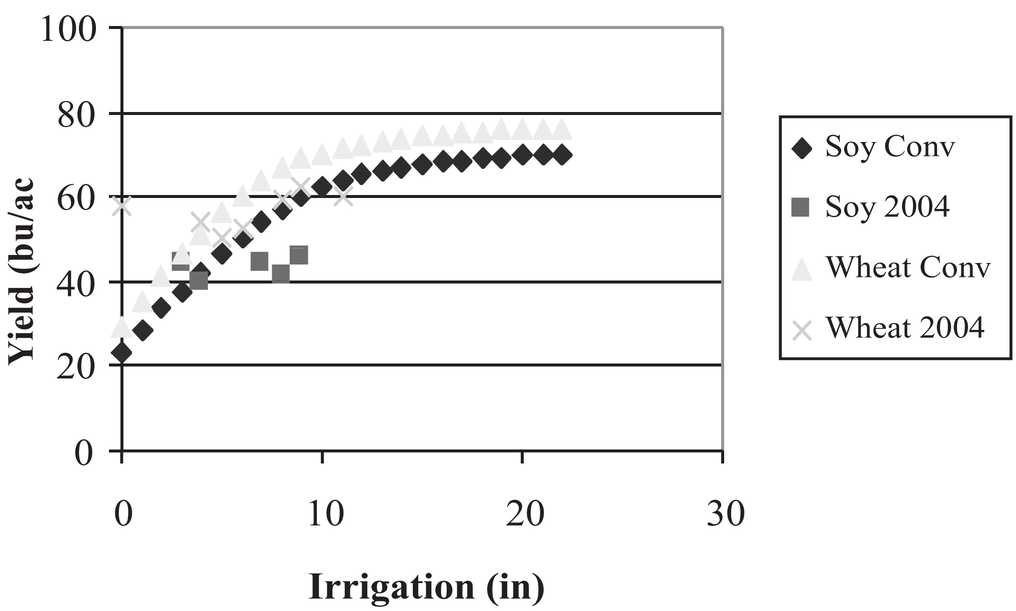


Figure 1b. Soybean and wheat yield responses to 21 inches of annual rainfall with conventional management in western Kansas, compared with 2004 no-till management with similar rainfall at the Southwest Research-Extension Center.



First-year results are promising. More years of data are needed to confirm the effects of crop-residue management. Dry-matter harvest results will help clarify the trade-offs between using forage for livestock feed or for water conservation.

Weed control is intended to be one of the non-limiting factors in this management system. The sequence of crops was chosen in part to minimize weed pressure and accommodate herbicide selection. Corn, soybean, and wheat have the most options for weed control, but grain sorghum and sunflower have the most challenges. Weed control is essential in no-till, limited-irrigation systems.

SOIL WATER EVAPORATION AS INFLUENCED BY CROP RESIDUE MANAGEMENT AND PLANT TRANSPIRATION IN SPRINKLER IRRIGATION SYSTEMS

by

Norman Klocke, Rob Aiken[1], and Loyd Stone

SUMMARY

Soil water evaporation and plant transpiration were measured from sprinkler-irrigated no-till corn and soybeans with mini-lysimeters and sap-flow, heat-gauge techniques, respectively. The frequency and wetting patterns of sprinkler irrigation and tillage practices keep the soil surface vulnerable to evaporation controlled by radiant and convective energy. This study documents the role of irrigation frequency and crop residues on the soil surface in reducing this evaporation. Reducing soil water evaporation with adoption of crop-residue management techniques can lead to reduced pumping and energy costs for irrigators with adequate water and increased crop production for irrigators with limited water supplies.

INTRODUCTION

Frequent irrigation practiced with sprinkler systems leads to a preponderance of energy-limited evaporation. Crop residues left in place on the surface can have an impact on reducing evaporation. Shifts in tillage systems may be influencing evaporation (E) and transpiration (T) partitioning so that yield-ET (evapotranspiration) relationships are evolving and the threshold ET values are changing. We need to better understand the energy balance of the canopy/surface residue/soil surface.

The objectives of the study were to:

1. Measure soil water evaporation in full and limited applications of sprinkler irrigation in corn and soybean crops that have either wheat stubble or corn stover no-till residue management.

2.Normalize soil water-evaporation measurements from mini-lysimeters and plant transpiration with sap-flow techniques with ET from soil water-balance methods.

3. Test a three-layer (canopy/surface residue/soil surface) energy-balance model developed for the Agricultural Research Service (ARS) Root Zone Water Quality Model (RZWQM).

PROCEDURES

Soil water evaporation was measured in corn and soybean canopies of two irrigation treatments, once-per-week and twice-per-week application frequency; treatments were replicated four times. Within each irrigation treatment, three soil surface treatments were imposed: no-till corn stover, no-till wheat stubble, and bare surface. The min-lysimeters, which represented each experimental unit, were each 12 inches in diameter and 5.5 inches deep. Pairs oflysimeters were inserted into buried sleeves between adjacent rows. Evapotranspiration for the mini-lysimeter comparisons was calculated from a soil water balance including soil water differences measured with the neutron attenuation method and measurements of rainfall and irrigation.

To measure transpiration, sap-flow heat gauges (SGB19-WS, Dynamax) were installed on five individual corn plants, in each of four replicated field plots. Gauges were relocated onto a new set of plants in 2- to 4-week intervals. Plant viability was assessed by grain weight of ear at harvest. Temperature differentials and power supplied to resistance heaters in gauges were monitored at 10-second intervals, and were averaged over 15-minute intervals. Energy balance was solved for transpiration flow. Crop evapotranspiration was calculated by the Penman-Monteith equation.

RESULTS AND DISCUSSION

Soil water evaporation was measured in corn and soybean canopies during 2004 at Garden City with

[1]Northwest Research-Extension Center, Colby.

mini-lysimeters. During the reproductive and grain-fill growth periods, there were 4 and 8 irrigation events for the once-per-week and twice-per-week treatments, respectively. Above-normal rains during the growing season reduced irrigation requirements. Table 1 summarizes the water savings from the reductions in soil water evaporation with crop residues and different irrigation frequencies, compared with bare-soil evaporation rates in the same field environment. Crop residues used as surface mulches would also contribute to soil water savings early in the growing season and during the off season. These savings, plus enhancement of infiltration and entrapment of snow, may add another 4 inches of annual water conservation.

Table 1. Growing-season (2004) soil water evaporation savings with corn stover and wheat stubble, compared with evaporation from bare soil.

	Soybean 6/9 -- 9/20	Corn 6/2 -- 9/20
Cover*	Soil E —inches—	Soil E —inches—
Corn 1	2.7	2.7
Corn 2	4.2	2.8
Wheat 1	3.1	3.1
Wheat 2	3.8	2.9

*1=weekly and 2=twice-weekly irrigation frequency.

Figure 1. Soil water evaporation as a percentage of crop ET, with the influence of crop residue surface cover during vegetative and full-canopy growth stages of soybean in 2003 and 2004.

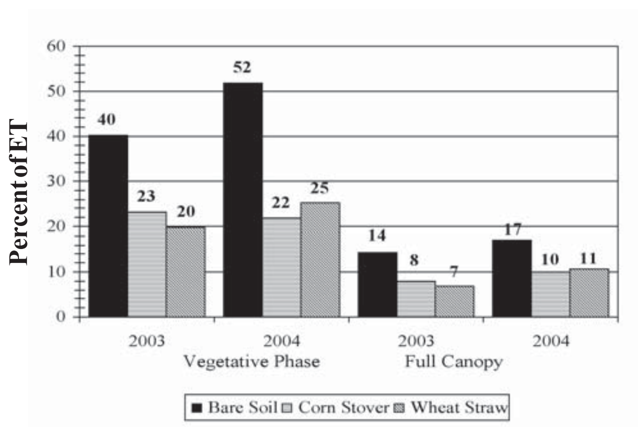
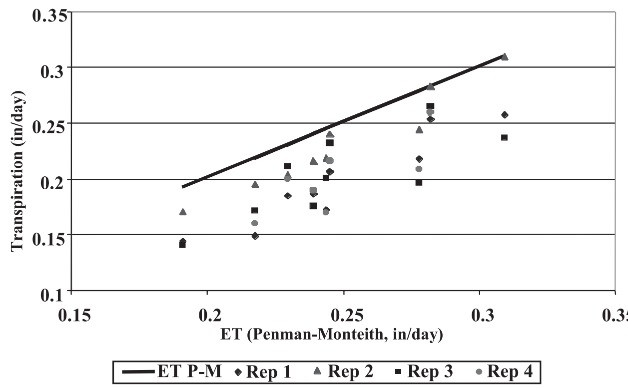


Figure 2. Transpiration from sap flow vs. calculated crop ET, Garden City, 2004 Average seed weight and seed number were correlated with grain yield.



The diurnal variation in transpiration calculated by properly functioning gauges generally corresponded to crop ET calculated by the Penman-Monteith equation. Linear regression indicated that daily transpiration was 84% of ET during mid-grain fill (Figure 2). Hand-harvest of ears from plants after gauge removal indicated a six-fold range of grain yields during the measurement period. Average seed weight and seed number were correlated with grain yield. Anomalies in gauge function included negative values for apparent gauge constants (Ksh), defects in gauge installation, and tissue damage associated with gauge function.

Preliminary results from independent evaluations of evaporation (E) and transpiration (T) data indicate that E during grain fill from bare soil and from 85% cover of corn stover was 25% and 16% of crop ET (water balance), respectively. This was for the twice-weekly irrigation treatment. For the same irrigation treatment, the sap-flow data showed T as 84% of calculated crop ET.. The soil surface cover in the later case was partial corn stover. Both data sets need to be compared on the basis of the same ET, but considering possible measurement errors with both mini-lysimeter and sap-flow methods, the results are very encouraging.

WATER ALLOCATION AMONG CROPS FOR LIMITED-IRRIGATION DECISIONS

by

Norman Klocke, Gary Clark[1], Loyd Stone, and Troy Dumler

SUMMARY

Programming has been completed for a computer software tool (Crop Water Allocator) that irrigators and water policy makers can use to allocate limited water to a selection of crops. Because irrigation-well capacities are dwindling and water allocations are more restrictive, irrigators need to consider different crop combinations. Optimum economic returns are calculated from all possible combinations of crops, irrigation patterns, and land allocations proposed by a user's input scenario. This tool guides irrigators and water professionals to cropping strategies that return the best value from the limited water used in irrigation, from individual fields to a regional analysis.

INTRODUCTION

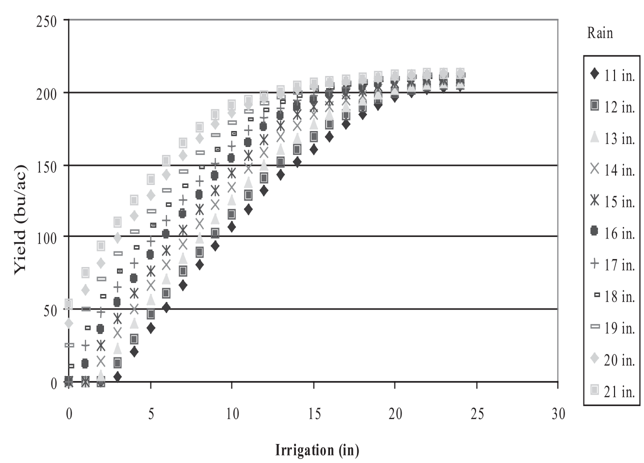
To reduce water use, irrigators are considering shifts in cropping patterns. Irrigators who have shrinking water supplies need to make decisions on the most profitable cropping systems. Furthermore, they need to allocate both land and water resources to multiple crops. Irrigation-scheduling decisions for irrigation managers with limited water resources are not made on a daily basis, as is true for managers of fully irrigated systems. Managers of limited-capacity irrigation systems need to schedule their applications with a fixed amount of cropping-season water, because of limited well capacity or water allocation, and need to plan a cropping-system strategy.

The objective of this study has been to develop and implement an irrigation decision model that will allow irrigators to optimize water and land resources for the best mix of crops and associated water allocations.

PROCEDURES

A crop water allocator (CWA) has been developed at Kansas State university to assist in planning cropping patterns and targeting irrigation to those crops. It is an agronomic/economic model that will predict the net returns of possible cropping options. The model uses crop yield and irrigation relationships that were generated from the Kansas Water Budget, a water-balance simulation model for western Kansas. The Kansas Water Budget used yield-evapotranspiration relationships for each crop and data on annual rainfall (from 11 to 21 inches across western Kansas) as inputs (see Figure 1 for corn results). Crop production costs can be completely controlled by the user with inputs to CWA, or the user can rely on default values from K-State surveys of typical farming operations in western Kansas.

Figure 1. Irrigation-grain yield relationship for corn in western Kansas, for annual rainfall amounts from 11 to 21 inches



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The user first selects possible proportions of crops in the land, considered in percentages of splits such as: 50-50, 75-25, 33-33-33, 50-25-25, and 25-25-25-25. The crop species, maximum crop yields, irrigation-water costs, crop-production costs, and maximum water applied for the season are then entered. The program then iterates, by 10% increments of the irrigation amounts, all possible net-income solutions over all crop combinations. Multiple runs of the model give the user indications of the sensitivities of net returns to commodity prices, production-cost inputs, crop selections, and land allocations.

RESULTS AND DISCUSSION

Crop Water Allocator (CWA) was released on the World Wide Web during December 2004 at www.oznet.ksu.edu/mil. It is available to users to download to their individual computers. Training sessions through the KSU Mobile Irrigation Lab will bring more feedback and initial reactions from users. The program was also introduced independent crop consultants in Kansas, who may be another avenue for presenting water planning ideas to their clientele.

Output from CWA gives irrigators who are planning strategies for their limited water, and those working in water professions, the opportunity to examine trends. Because there are several inputs to the model, there are opportunities for several output variables. For example, multiple runs of the model allow the user to examine combined effects of water allocation, commodity prices, maximum yields, irrigation costs, and production costs. Interpretations of these trends could be quite challenging. Table 1 shows the results of one series of scenarios over a range of water allocations. Corn, sorghum, wheat, and sunflower were considered for a three-crop rotation in this scenario. The selection of the other variables had to be held constant. The resulting net returns were for the whole field (130 acres), and still would need to pay for management, land, and irrigation-equipment costs. At large water allocations or pumping capacities, raising corn gave the best net return. As the water allocations or pumping capacities were reduced to 6 and 10 inches, sunflower and wheat cam into the rotation for best net return. Changes in commodity prices, maximum crop yields, production costs, and irrigation costs can greatly influence the outcome of the model.

It is too early to determine the usage of this decision tool. Reaction to its introduction at workshops has been very favorable. Individual farmers as users of the program can influence outcomes by their own preferences in choosing crop prices and maximum crop yields. The program is sensitive to commodity prices and maximum yields, which will swing results.

Table 1. Crop water allocator example.

Water availability (inches)	Crop land split (33%-33%-33%)	Gross irrigation by crop (inches)	Net return ($/year)*
22	corn/corn/corn	22/22/22	9,170
18	corn/corn/corn	18/18/18	10,320
14	corn/corn/corn	14/14/14	9,490
10	corn/corn/sunflower	12/12/6	6,040
6	wheat/corn/sunflower	0/12.7/5.5	2,380
Crops Considered	Commodity Prices	Maximum Yields	
Corn	$2.10/bu	200 bu/ac	
Sorghum	$2.00/bu	120 bu/ac	
Wheat	$3.00/bu	65 bu/ac	
Sunflower	$11.00/cwt	2800 lb/ac	

Inputs: Land area = 130 acres; annual rainfall = 17 inches.
Irrigation system efficiency = 88%; irrigation costs = $4.30/acre-inch.
Kansas State University default crop production costs used.
*Net return for 130 acres to land, management, and irrigation equipment.

COMPARISON OF 33 HERBICIDE TANK MIXES FOR WEED CONTROL IN GLYPHOSATE-RESISTANT CORN

by
Randall Currie

SUMMARY

With few exceptions, most treatments provided good control of most broadleaf weeds, although only preemergence treatments followed by post-emergence treatments provided 100% control. Although all treatments provided good Palmer amaranth control, 10 of the 33 treatments provided 100% control. This excellent broadleaf control released grassy-weed pressure. No tank mix provided complete grassy-weed control. Only very high rates of preemergence herbicides or combinations of preemergence and Post emergence herbicide treatments provided good grassy-weed control.

INTRODUCTION

Although it is possible to achieve 100% weed control with continuous applications of glyphosate to glyphosate-tolerant corn, as the average farm size increases this can be logistically difficult. Further, as genes for glyphosate tolerance begin to appear in weed populations, it is prudent to expose these populations to several different types of herbicides to reduce the rate at which these weeds spread. Therefore it is desirable to discover a broad range of combinations of preemergence and post emergence tank mixes for weed control in corn. This experiment allows producers to compare weed control and cost of these combinations to allow them to balance the various inputs of capital and labor.

PROCEDURES

Palmer amaranth, yellow foxtail, crabgrass, sunflower, barnyard grass, and shattercane were seeded at 700,000; 344,124; 9,800,000; 40,000; 817,000; and 119,000, respectively, into prepared fields on May 19, before corn was planted. All weeds except shattercane were planted with a carrier mixture of cracked corn at a rate of 40 lb/acre by using a 14-foot Great Plains Drill with tubes removed to allow weed seed to be dropped on the soil surface. Shattercane was drilled separately, with every third hole set at 1 inch deep, at 2 inches deep, or with the tube pulled for seed to be dropped on the soil surface. Weed seed was planted in 10-inch rows, soil temperature was 62°F, and soil moisture was good.

The field was conventionally tilled in the fall. Dekalb DK-6019 RR corn was planted 1.5 inches deep in 30-inch rows at a rate of 36,000 seeds/acre with a John Deere Max Emerge II 6-row planter. Soil temperature at planting was 73°F. Soil moisture was measured to 8 ft weekly from inception of the experiment.

When total soil water was depleted to a depth of 3 ft, biweekly 1-inch irrigations were begun until locally derived irrigation models predicted enough water was available to carry the crop to physiological maturity. Corn harvest was delayed by protracted wet conditions. Although corn harvest was completed and yield data was analyzed, due to harvest difficulties, no statistical differences could be declared. Therefore yield data is not presented.

RESULTS AND DISCUSSION

Although weed control was rated by individual species, and subtle differences were detected among them, information has been consolidated across all broadleaf weeds and all grassy weeds, so the data is further averaged across all multiple-rating dates for the whole season to give an index of the number and duration of weeds present.

All treatments provided some Palmer amaranth control, compared with that in the control plots, but none of the treatments were statistically superior. It is of note that treatments 8, 12, 13, 14, 25, 26, 27, 29, 30, and 32 provided 100% control. All treatments provided some control of the composite of broadleaf weeds, compared with the control. Treatments rated less than 3.8 were not statistically different from

Table 1. Performance of herbicide mixes for weed control in glyphosate-resistant corn, Southwest Research-Extension Center, Garden City, Kansas, 2004.

	Treatment	Rate Unit	Application Timing*	Avg. Pigweed	Avg. # Broadleaf	Avg. # Grasses
1	Balance Pro + Harness Xtra	0.5 oz ai/a, 45 oz ai/a	Pre	3 b	2 cd	70 a-e
2	Define SC + Balance Pro +Aatrex 90	8 oz ai/a, 0.5 oz ai/a, 20 oz ai/a	Pre	3 b	2 cd	39 b-e
3	Equip + Distinct + Methylated Seed Oil + UAN 28%	1.5 oz wt/a, 2.8 oz ai/a, 0.71 l/a, 1.42 l/a	Epost	9 b	4 bcd	139 a
4	Option +Distinct + Methylated Seed Oil + UAN 28%	1.5 oz wt/a, 2.8 oz ai/a, 0.71 l/a, 1.42 l/a	Epost	7 b	4 bcd	103 abc
5	Option + Callisto + Methylated Seed Oil + UAN 28%	1.5 oz wt/a, 1 oz ai/a, 0.71 l/a, 1.42 l/a	Epost	19 b	7 bc	109 ab
6	Option + Callisto +Aatrex 90 + Methylated Seed Oil + UAN 28%	1.5 oz wt/a, 1 oz ai/a, 12 oz ai/a, 0.71 l/a, 1.42 l/a	Epost	8 b	4 bcd	99 a-d
7	Option + Define SC + Aatrex 90 + Methylated Seed Oil + UAN 28%	1.5 oz wt/a, 4 oz ai/a, 16 oz ai/a, 0.71 l/a, 1.42 l/a	Epost	5 b	3 bcd	59 b-e
8	Define SC + Aatrex 90 + Option + Distinct + Methylated Seed Oil + UAN 28%	4 oz ai/a, 16 oz ai/a, 1.5 oz wt/a, 1.4 oz ai/a, 0.71 l/a,	Pre/Mpost	0 b	1 cd	41 b-e
9	Bicep II Magnum	46.3 oz ai/a	Pre	1 b	2 cd	74 a-e
10	Lumax	39.4 oz ai/a	Pre	2 b	2 cd	31 b-e
11	A14224	44.3 oz ai/a	Pre	1 b	1 cd	65 a-e
12	Lumax + Aatrex 4L	39.4 oz ai/a, 16 oz ai/a	Pre	0 b	1 cd	59 b-e
13	A14224 + Princep 4L	44.3 oz ai/a, 16 oz ai/a	Pre	0 b	1 cd	69 a-e
14	Bicep II Magnum + Callisto + Aatrex 4L + COC + UAN 28%	46.3 oz ai/a, 1.5 oz ai/a, 8 oz ai/a, 1% v/v, 2.5% v/v	Pre/Post	0 b	0 d	22 cde
15	Harness Xtra	54.7 oz ai/a	Pre	1 b	3 bcd	50 b-e
16	Epic	7 oz ai/a	Pre	7 b	3 bcd	51 b-e
17	Keystone	54.7 oz ai/a	Pre	1 b	1 cd	78 a-e
18	Keystone + Hornet	54.7 oz ai/a, 2.06 oz ai/a	Pre	1 b	0 d	95 a-d
19	Keystone + Balance Pro	27.3 oz ai/a, 1.13 oz ai/a	Pre	2 b	1 cd	101 abc
20	Buccaneer + NIS + Ammonium Sulfate +Prowl H2O	24 fl oz/a, 0.25 % v/v, 3 lb/a, 2.5 pt/a	Post	3 b	2 cd	32 b-e
21	Buccaneer + NIS + Ammonium Sulfate + Prowl H2O + Distinct	24 fl oz/a, 0.25 % v/v, 3 lb/a, 2.5 pt/a, 3 oz wt/a	Post	9 b	4 bcd	24 cde
22	Buccaneer + NIS + Ammonium Sulfate + Guardsman Max + Distinct	24 fl oz/a, 0.25 % v/v, 3 lb/a, 2.5 pt/a, 3 oz wt/a	Post	2 b	1 cd	19 de
23	Weather Max + Ammonium Sulfate	22 fl oz/a, 3 lb/a	Mpost	4 b	2 cd	48 b-e
24	Buccaneer + NIS + Ammonium Sulfate + Distinct	24 fl oz/a, 0.25 % v/v, 3 lb/a, 3 oz wt/a	Mpost	6 b	3 bcd	33 b-e
25	Outlook + Buccaneer + NIS + Ammonium Sulfate +Clarity	12 fl oz/a, 24 fl oz/a, 0.25 % v/v, 3 lb/a, 8 fl oz/a	Pre/Post	0 b	1 cd	38 b-e
26	Guardsman Max + Buccaneer + NIS + Ammonium Sulfate + Distinct	2.5 pt/a, 24 fl oz/a, 0.25 % v/v, 3 lb/a, 3 oz wt/a	Pre/Post	0 b	0 cd	38 b-e
27	Outlook +Buccanee + NIS + Ammonium Sulfate	12 fl oz/a, 24 fl oz/a, 0.25 % v/v, 3 lb/a	Pre/Lpost	0 b	1 cd	43 b-e
28	Guardsman Max + Balance Pro	4 pt/a, 1 fl oz/a	Pre	5 b	2 cd	66 a-e
29	Guardsman Max Lite + Distinct	3 pt/a, 4 oz wt/a	Pre/Mpost	0 b	1 cd	60 b-e
30	Guardsman Max + Prowl H2O	3 pt/a, 2.6 pt/a	Pre/Epost	0 b	2 cd	12 e
31	Outlook	18 fl oz/a	Pre	1 b	3 bcd	101 abc
32	Dual II Magnum	1.67 pt/a	Pre	0 b	5 bcd	30 b-e
33	Stalwart+Atrazine	46.3 oz ai/a	Pre	2 b	3 bcd	56 b-e
34	Untreated Check			23a	11a	74a-e
$LSD_{0.05}$				10.5	3.8	44.0

*Pre = pre-emergence; Post= post-emergence (E, early; M, mid; L, late). Means followed by the same letter do not significantly differ.

broadleaf weeds; only preemergence treatments followed by post-emergence treatments provided 100% control. Although all treatments provided good Palmer amaranth control, 10 of the 33 treatments provided 100% control. This excellent broadleaf control released grassy-weed pressure. No tank mix provided complete grassy-weed control. Only very high rates of preemergence herbicides or combinations of preemergence and post-emergence herbicide treatments provided good grassy-weed control.

COMPARISONS OF HERBICIDE TANK MIX PARTNERS TO ENHANCE GLUFOSINATE'S CONTROL OF PALMER AMARANTH

by
Randall Currie

SUMMARY

Glufosinate often performs poorly on Palmer amaranth in western Kansas, but under the unusually wet and cool conditions seen in the summer of 2004, its performance was difficult to enhance. Although glufosinate is a good post-emergence grass control compound, it has no preemergence activity. Therefore, only a single treatment of an aggressive preemergence broad-spectrum grass and broadleaf weed control tank mix, followed by a later application of glufosinate plus atrazine, provided measurable grass control.

INTRODUCTION

Although glufosinate (Liberty®) provides effective broad-spectrum weed control in humid wet climates found in eastern Kansas, research for more 10 years at this location has shown that it performs poorly on Palmer amaranth. Palmer amaranth is one of the major weed species in this region. Laboratory work done at Kansas State University has shown that this is primarily due to Palmer amaranth's response to low humidity. Therefore, it was the objective of this study to see what herbicides could be added to glufosinate to improve its performance in western Kansas.

PROCEDURES

Palmer amaranth, yellow foxtail, crabgrass, sunflower, barnyard grass, and shattercane were seeded at 700,000; 344,124; 9,800,000; 40,000; 817,000; and 119,000, respectively, into prepared fields on May 19, before corn was planted. All weeds except shattercane were planted with a carrier mixture of cracked corn at a rate of 40 lb/acre by using a 14-foot Great Plains Drill with tubes removed to allow weed seed to be dropped on the soil surface. Shattercane was drilled separately, with every third hole set at 1 inch deep, at 2 inches deep, or with the tube pulled for seed to be dropped on the soil surface. Weed seed was planted in 10-inch rows, soil temperature was 62F, and soil moisture was good.

The field was conventionally tilled in the fall. A glufosinate-resistant corn variety, Triton hx 9461, was planted 1.5 inches deep in 30-inch rows at a rate of 36,000 seeds/acre with a John Deere Max Emerge II 6-row planter. Soil temperature at planting was 73°F. Soil moisture was measured to 8 ft weekly from inception of the experiment.

When total soil water was depleted to a depth of 3 ft, biweekly 1-inch irrigations were begun until locally derived irrigation models predicted enough water was available to carry the crop to physiological maturity. Corn harvest was delayed by protracted wet conditions. Although corn harvest was completed and yield data was analyzed, due to harvest difficulties, no statistical differences could be declared. Therefore yield data is not presented.

RESULTS AND DISCUSSION

All treatments provided greater Palmer amaranth control than the author has ever observed. Although adding Callisto® tripled the control of Palmer amaranth over that of tank mixes with atrazine, the extensive over-all control masked the statistical differences. The exception some times proves the rule. The corn had abundant water available, and rains were followed by a cool wet period. It is assumed that these favorable conditions enhanced glufosinate's control.

Good control of all other broadleaf weeds was also seen. Weed pressure from these other species was somewhat less than that of Palmer amaranth, and control was identical among all tank mixes.

The pressure of grassy weeds was increased by good broadleaf weed control; with the exception the aggressive preemergence tank mix of Define® and atrazine, followed by a post-emergence application of atrazine and glufosinate, no treatment provided grass control statistically superior to the untreated control.

Table 1. Performance of herbicide mixes to enhance glufosinate's control of Palmer amaranth, Southwest Research-Extension Center, Garden City, Kansas, 2004

	Treatment	Rate Unit	Application Timing	Avg. pigweed	Avg. # Broadleaf	Avg. # Grasses
1	Define SC + Liberty + Aatrex 4L + Ammonium Sulfate	12 fl oz/a, 32 fl oz/a, 0.5 qt/a, 3 lb/a	Pre/Post	3 b	3 b	8 ab
2	Aatrex 4L + Liberty +Ammonium Sulfate	1qt/a, 32 fl oz/a, 3 lb/a	Pre/Post	4 b	3 b	11 ab
3	Aatrex 4L + Liberty + amads	1 qt/a, 32 fl oz/a, 1.5 pt/a	Pre/Post	3 b	3 b	13 a
4	Aatrex 4L + Liberty + Distinct + Ammonium Sulfate	1 qt/a, 32 oz/a, 2 oz wt/a, 2 lb/a	Pre/Post	3 b	3 b	8 ab
5	Aatrex 4L + Liberty + Aatrex 4L +Ammonium Sulfate	1 qt/a, 32 oz/a, 0.5 qt/a, 3 lb/a	Pre/Post	3 b	3 b	10 ab
6	Aatrex 4L + Liberty + Callisto + Aatrex 4L + Ammonium Sulfate	1 qt/a, 32 oz/a, 1 oz/a , 0.5 qt/a, 3 lb/a	Pre/Post	1 b	3 b	11 ab
7	Aatrex 4L + Define SC + Liberty +Aatrex 4L + Ammonium Sulfate	1 qt/a, 8 oz/a, 32 oz/a, 0.5 qt/a, 3 lb/a	Pre/Post	2 b	3 b	4 b
8	Untreated Check			19 a	11 a	12 a
$LSD_{0.05}$				9.0	3.5	4.7

Means followed by the same letter do not significantly differ.

IMPACT OF GLYPHOSATE APPLICATION TIME FOR CONTROL OF VOLUNTEER WHEAT ON SEASON-LONG STORED SOIL MOISTURE

by
Randall Currie, Norman Klocke, and Curtis Thompson

SUMMARY

This research suggests that soil-water losses to leaching or evaporation are seldom affected by delaying glyphosate applications for volunteer-wheat control until March or April. We speculate that before March, under no-till conditions, the benefits of the residue outweigh the cost of the water used to grow the volunteer wheat.

INTRODUCTION

Volunteer wheat is a major weed in wheat-fallow-wheat rotations. Although much research has been done on rates and timings to kill wheat with glyphosate, little is known about the impact of these treatments on soil water storage, the main objective of the fallow period.

PROCEDURES

In the winter of 2000-2001, 24 oz/acre of glyphosate was applied on uniform stands of wheat in November, March, April, or May. A bare-soil control received applications of 32 oz/acre of glyphosate as needed for a weed-free control during the winter and spring. Soil water was measured monthly in 1-ft increments to a depth of 8 ft for a year after initial treatment. After wheat senescence, the entire plot was maintained weed free with applications of 32 oz/acre of glyphosate as needed. The experiment was repeated at different locations in 2001, 2002, 2003, and 2004.

RESULTS AND DISCUSSION

Between November and April, the total soil water in the 0- to 6-ft profile was not consistently affected by when glyphosate was applied, so there was no clear trend for timing of application that would indicate reduction of evaporation or leaching losses compared with that of bare soil (Fig. 1). The water storage of bare soil was only superior if glyphosate treatments were delayed until May or April. If glyphosate application was delayed until May, the bare-soil treatment preserved from 1.9 to 2.3 inches more soil water over the 1-yr period than did plots treated in May. Water below 8 ft was considered effectively lost to leaching (Fig. 2). Leaching losses were not significant, were inconsistent, or were small for most treatments in most years (Fig. 3). But in 4 of 5 years, the bare-soil treatment leached more soil water below 6 feet than did the April applications of glyphosate. These losses were small and averaged less than 0.3 inches. When glyphosate treatment was delayed until May, leaching losses were also reduced in 4 of 5 years, and the magnitude of these reductions was doubled, compared with those of April glyphosate treatment. Although leaching losses were often small, November and May glyphosate applications produced greater than 0.7-inch water losses in 1 of 5 years, compared with those of bare-soil treatments. Compared with November applications, March or May glyphosate applications resulted in leaching losses greater than 0.7 inches in 1 of 5 years.

Figure 1. Total water in an 6-foot profile.

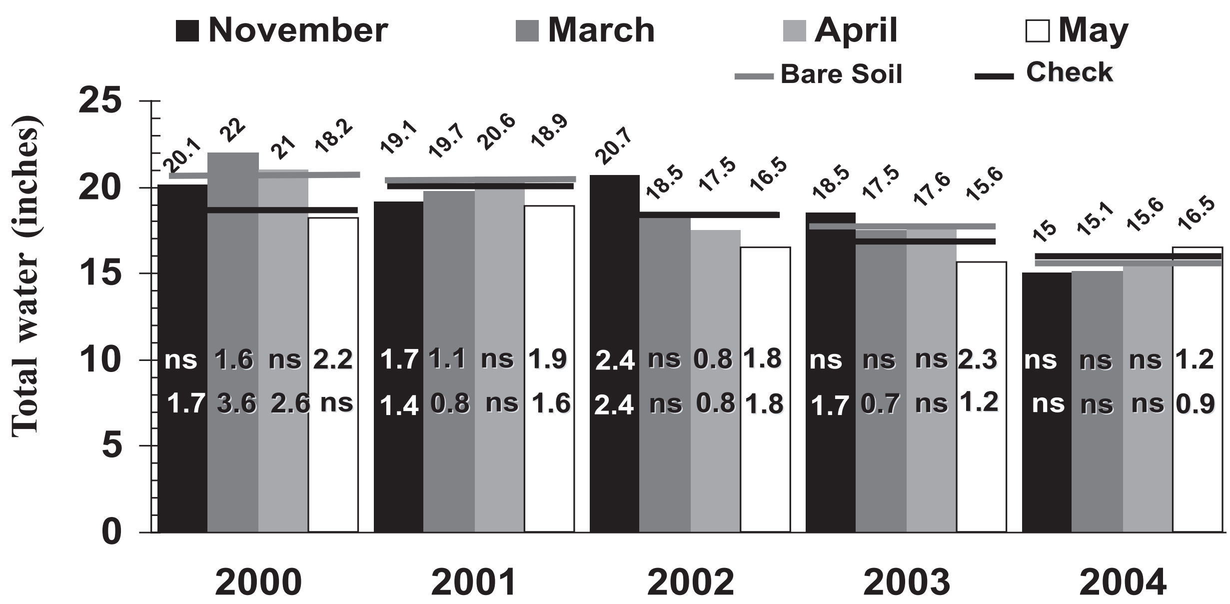


Figure 2. Total water in an 8-foot profile.

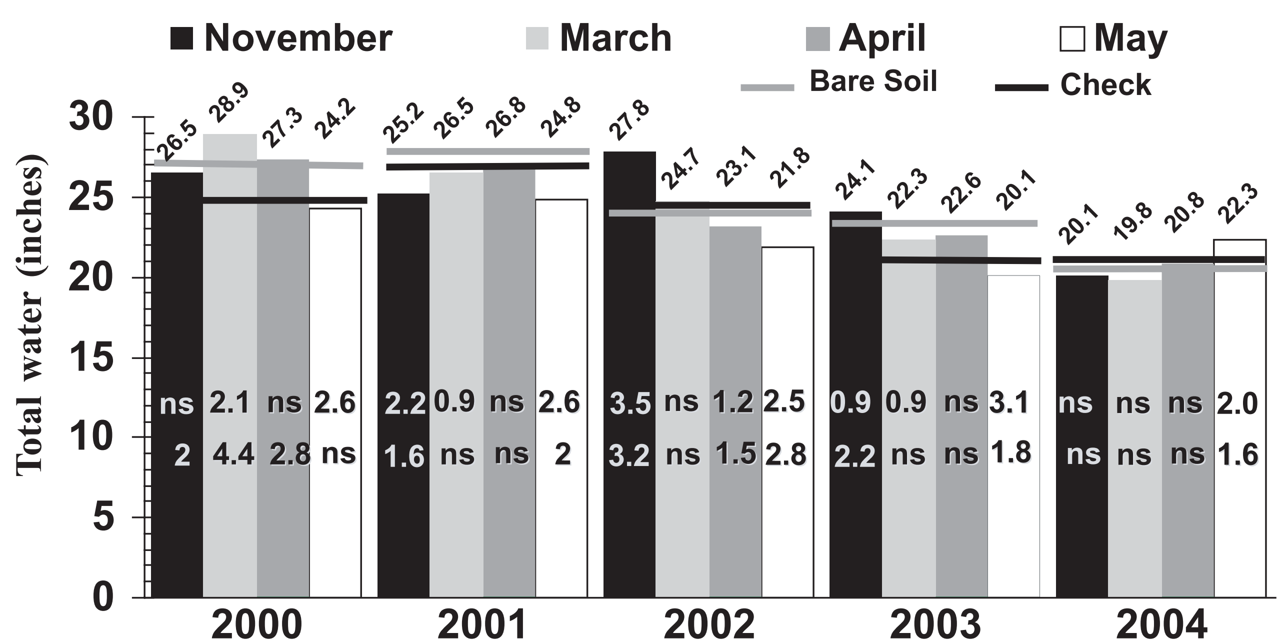
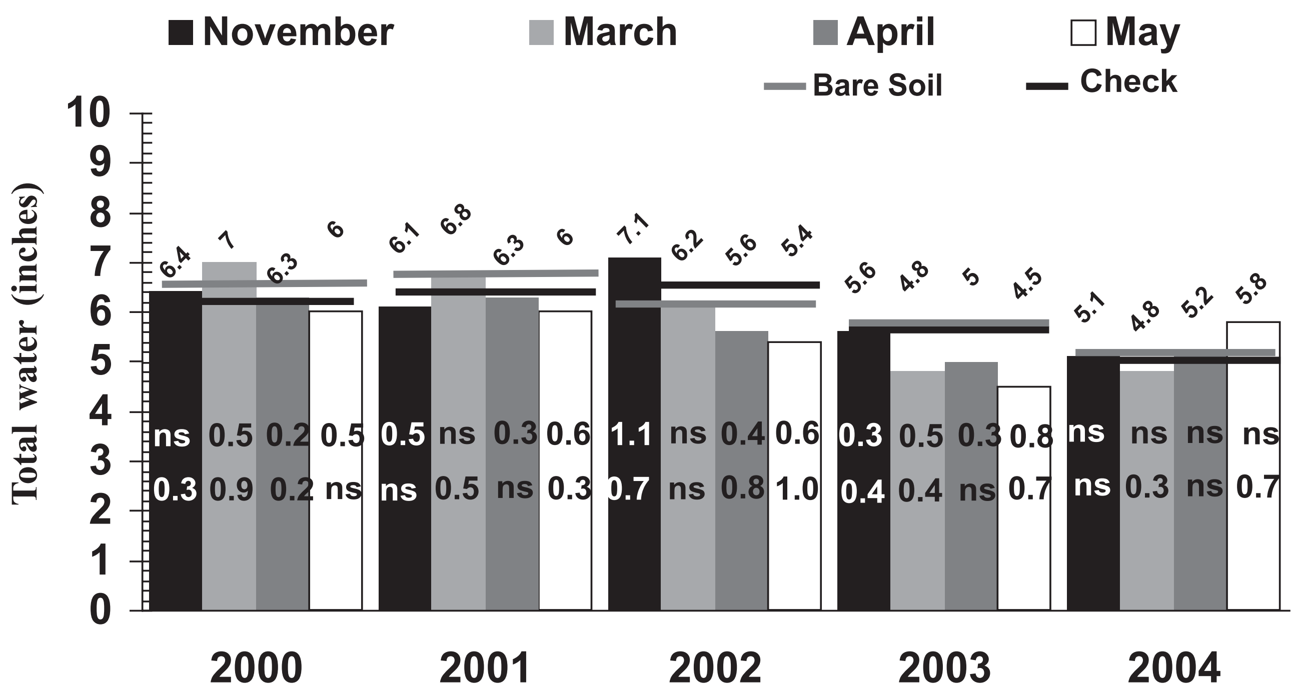


Figure 3. Total water in an 6 to 8-foot profile.



BROADLEAF WEED CONTROL IN WHEAT

by
Curtis Thompson and Alan Schlegel

SUMMARY

Herbicides injured wheat 0 to 8% in two experiments during 2003 and 2004. Wheat yield did not correlate to herbicide injury ratings. Starane and Starane tank mixes provided the best control of kochia, but Starane applied alone gave less control of Russian thistle and volunteer sunflower, compared with other treatments. The 2,4-D products did not control kochia adequately, but they did control Russian thistle and volunteer sunflower. Dicamba products gave better kochia control than 2,4-D products did, but kochia control was not adequate in the 2004 experiment. Earlier application, when weeds and wheat were smaller, may have improved weed control.

INTRODUCTION

Weeds are frequently found in growing wheat during the spring in western Kansas. Left untreated, weeds can reduce wheat yields, as well as interfere with the harvest process. Kochia and Russian thistle are two common spring-emerging weed species that can be difficult to control in wheat. The objectives of these experiments were to evaluate kochia and Russian thistle control with several herbicides for weed control in wheat.

PROCEDURES

Two experiments were established at the Southwest Research-Extension Center at Tribune during 2003 and 2004 to evaluate herbicides for weed control in wheat. All experiments were planted in tilled row-crop stubble and wheat grown under a limited irrigation system.

Stanton and Jagger wheat were planted on October 1, 2002, and October 27, 2003, respectively. Postemergence herbicides were applied with a backpack sprayer equipped with Turbo tee 11001 nozzles and set at 40 psi, delivering 10 gpa. The 2003 treatments were applied to 1-node, jointed wheat and 4- to 10-in kochia, Russian thistle, and volunteer sunflower on May 9. The 2004 treatments were applied to early jointing wheat and 1- to 2-in kochia and Russian thistle on April 20. All wheat injury and weed-control evaluations were made visually on the dates reported in the data tables. Plots were 10 by 30 ft and all treatments were replicated four times. A 5-ft cut through the center of each plot was combine harvested for grain on July 11, 2003, and July 5, 2004.

RESULTS AND DISCUSSION

Wheat injury ranged from 0 to 6% in 2003 (Table 1) and 0 to 8% in 2004 (Table 3). Wheat injury did not cause lower yields in either experiment. Wheat treated with Phenoxy 088 at 1 pt/a yielded 33 bu/a, the lowest yielding treatment in the 2004 experiment, and no visible injury was noted for that treatment.

Kochia control was inadequate with all formulations of 2,4-D herbicides in the 2003 experiment (Table 2). Starane, Starane+Ally, and Starane+Ally Extra controlled kochia 93% or better at the June 26 evaluation. All other herbicides controlled kochia 81% or less. Russian thistle and volunteer sunflower control was excellent with all treatments except Starane applied alone, which controlled 83 to 85% of these weeds, as measured by the June 26 evaluation.

Kochia control was inadequate with all treatments in the 2004 experiment (Table 3). Brash at 1 pt/a or treatments containing experimental AGH 02001 controlled kochia 60% or better at the May 5 evaluation. Only the high rate of Brash maintained 60% control at the July evaluation. Russian thistle control seemed inadequate 2 wk after treatment in the 2004 experiment. Crop competition and a slow death from the herbicide treatments evidently resulted in little Russian thistle remaining in the plots at the July evaluation. Only the lowest rate of Unison and Brash provided less than 90% control of Russian thistle at the July evaluation.

These experiments do show the potential difficulty in controlling weeds like kochia and Russian thistle in wheat. In both experiments, applications to smaller wheat and weeds would have likely provided better weed control. It is important to remember, however, that 2,4-D products should not be used before wheat has completed the tillering stage and that dicamba products should not be used after the wheat has reached the jointing stage.

The use of herbicide trade names is not intended to endorse any particular chemical company, but only to properly identify an herbicide formulation used in the experiment. Rates and application timing of the herbicides used in this experiment may or may not comply with the herbicide label and were intended for experimentation only. Experimental herbicides reported currently may not be registered for weed control in wheat. Use and apply all herbicides according to the guidelines listed on the federal label.

Table 1. Wheat response to herbicides for broadleaf weed control, Tribune, Kansas, 2003.

Treatment	Rate	Yield	Test weight	Grain moisture	Wheat injury May 31	Wheat injury June 26
	(product/a)	(bu/a)	(lb/bu)	(%)	(% control)	
Untreated	—	28	51	11	—	—
2,4-D LV6	0.33 pt	25	50	11	1	1
E99	0.33 pt	30	53	11	3	1
2,4-D LV6	0.67 pt	36	54	10	4	1
E99	0.67 pt	29	52	11	13	3
Phenoxy 088	0.5 pt	31	52	11	1	0
Starane	0.67 pt	31	51	13	3	1
AGH02001 + Preference	0.5 pt + 0.25 % v/v	33	52	12	1	1
Teamwork + 2,4-D LV4 + Preference	0.33 oz + 0.5 pt + 0.25 % v/v	33	52	11	5	1
AGH 02001 + Ally + Preference	0.5 pt + 0.1 oz + 0.25 % v/v	31	51	11	8	4
Teamwork + 2,4-D LV4 + Ally + Preference	0.33 oz + 0.5 pt + 0.1 oz + 0.25 % v/v	28	51	12	9	5
AGH 02001 + Preference	1.0 pt + 0.25 % v/v	32	53	11	9	6
Teamwork + 2,4-D LV4 + Preference	0.33 oz + 1.0 pt + 0.25 % v/v	33	53	11	6	5
AGH 02001 + Ally + Preference	1.0 pt + 0.1 oz + 0.25 % v/v	31	52	10	15	5
Teamwork + 2,4-D LV4 + Ally + Preference	0.33 oz + 1.0 pt +0.1 oz + 0.25 % v/v	28	50	11	9	3
Moxy	1 pt30	52	11	3	0	
Bison	1 pt28	51	11	9	4	
Ally + Starane + Preference	0.1 oz + 0.67 pt + 0.25 % v/v	26	49	10	14	5
Ally Extra + Starane + Preference	0.4 oz + 0.67 pt +0.25 % v/v	28	50	10	16	6
Untreated		30	52	11	—	—
LSD (0.05)		7	3	2	8	4

Table 2. Broadleaf weed control in wheat, Tribune, Kansas, 2003.

Treatment	Rate	Kochia		Russiian thistle		Vol sunflower	
		May 31	June 26	May 31	June 26	May 31	June 26
	(product/a)	(% control)					
Untreated	—	—	—	—	—	—	—
2,4-D LV6	0.33 pt	35	38	99	100	83	98
E99	0.33 pt	39	37	99	100	98	98
2,4-D LV6	0.67 pt	59	51	100	100	84	100
E99	0.67 pt	53	54	100	100	95	100
Phenoxy 088	0.5 pt	19	35	98	100	95	100
Starane	0.67 pt	85	93	85	85	90	83
AGH02001 + Preference	0.5 pt + 0.25 % v/v	82	69	93	100	90	98
Teamwork + 2,4-D LV4 + Preference	0.33 oz + 0.5 pt + 0.25 % v/v	86	78	96	100	99	94
AGH 02001 + Ally + Preference	0.5 pt + 0.1 oz + 0.25 % v/v	84	68	99	100	98	100
Teamwork + 2,4-D LV4 + Ally + Preference	0.33 oz + 0.5 pt + 0.1 oz + 0.25 % v/v	81	74	100	100	96	100
AGH 02001 + Preference	1.0 pt + 0.25 % v/v	85	80	98	100	95	98
Teamwork + 2,4-D LV4 + Preference	0.33 oz + 1.0 pt + 0.25 % v/v	81	66	96	100	98	98
AGH 02001 + Ally + Preference	1.0 pt + 0.1 oz + 0.25 % v/v	90	81	100	100	100	100
Teamwork + 2,4-D LV4 + Ally + Preference	0.33 oz + 1.0 pt + 0.1 oz + 0.25 % v/v	85	81	100	100	100	100
Moxy	1 pt	80	78	98	100	99	96
Bison	1 pt	83	73	99	100	99	100
Ally + Starane + Preference	0.1 oz + 0.67 pt + 0.25 % v/v	89	96	99	100	100	100
Ally Extra + Starane + Preference	0.4 oz + 0.67 pt +0.25 % v/v	88	95	98	100	98	98
Untreated	—	—	—	—	—	—	
LSD (0.05)		10	15	6	2	11	6

Table 3. Wheat response to herbicides and broadleaf weed control in wheat, Tribune, Kansas, 2004.

Treatment	Rate	Yield	Test weight	Grain moisture	Wheat injury	Kochia May 5	Kochia Jul 7	Russian thistle May 5	Russian thistle Jul 7
	(product/a)	(bu/a)	(lb/bu)	(%)	(%)	(% control)			
Unison	1.0 pt	48	55	10	0	30	25	51	80
Unison	2.0 pt	42	54	10	0	46	30	64	100
Barrage HF	0.38 pt	45	54	10	0	23	31	50	100
Barrage HF	0.75 pt	43	55	10	0	44	33	63	100
Salvo	0.4 pt	44	54	10	0	24	35	58	91
Salvo	0.8 pt	38	54	10	0	40	33	63	99
Brash	0.5 pt	45	55	10	0	26	41	59	81
Brash	1.0 pt	39	54	10	3	63	60	78	90
Phenoxy 088	0.5 pt	38	54	10	0	23	35	50	98
Phenoxy 088	1.0 pt	33	52	10	0	26	25	55	100
AGH 02001	0.5 pt	40	54	10	5	68	40	78	94
AGH 02001 + Preference	0.5 pt + 0.25 % v/v	48	55	10	5	69	43	83	97
AGH 02001	1.0 pt	39	55	10	8	75	45	86	99
E99	0.33 pt	50	55	10	0	30	35	59	93
E99 + Preference	0.33 pt + 0.25 % v/v	39	54	10	0	46	31	66	98
E99	0.67 pt	45	55	10	0	43	30	60	95
2,4-D LV6	0.33 pt	38	54	10	0	43	31	60	100
2,4-D LV6	0.67 pt	46	54	10	0	51	33	68	100
2,4-D LV4	0.5 pt	42	55	10	0	25	34	48	93
2,4-D LV4	1.0 pt	38	54	10	0	45	26	63	100
AGH 02008	0.5 pt	41	53	10	0	41	33	60	98
AGH 02008	1.0 pt	38	55	10	0	23	30	53	93
AGH 03007	0.5 pt	42	54	10	0	29	33	51	96
AGH 03007	1.0 pt	41	54	10	0	43	34	58	98
Untreated	—	45	53	10	0	—	—	—	—
LSD (0.05)		11	2	NS	1	14	18	11	13

WEED CONTROL IN CLEARFIELD SUNFLOWER

by
Curtis Thompson and Alan Schlegel

SUMMARY

Spartan® herbicide injured sunflower slightly in one of two experiments. Beyond® herbicide caused slight sunflower chlorosis in the 2004 experiment shortly after application, but the chlorosis disappeared within 2 weeks. No herbicide treatment adversely affected sunflower yield.

Spartan alone and all treatments containing Spartan gave excellent control of kochia, Russian thistle, redroot pigweed, and tumble pigweed in the 2003 experiment. Beyond applied alone controlled Russian thistle, redroot and tumble pigweed and puncturevine. Beyond alone did not give adequate control of kochia in either experiment, mostly because ALS-resistant kochia biotypes existed in the experiments.

INTRODUCTION

With few registered herbicides available for sunflower, broadleaf-weed control has been a challenge in past years. With the registration of Clearfield sunflower varieties, Beyond herbicide for post-emergence weed control, and Spartan and Dual Magnum® for pre-emergence weed control, excellent broadleaf-weed control in sunflower may be attainable. These experiments evaluated weed-control options in sunflower.

PROCEDURES

Two experiments were established at the Southwest Research-Extension Center-Tribune during 2003 and 2004 to evaluate herbicides for weed control in sunflower. Clearfield sunflower hybrids were used to allow the use of Beyond. All experiments were planted no-till into wheat stubble and were grown with limited irrigation.

Mycogen 8N429CL was planted at 18,000 seeds/acre and Touchdown at 0.75 lb ae was applied broadcast to the entire experimental area on June 10, 2003. On the same day, pre-emergence (PRE) treatments were applied to the soil surface with a backpack sprayer equipped with Turbo TeeJet 11003 nozzles that delivered 20 gpa at 32 psi pressure. Post-emergence (POST) treatments were applied on June 28, 2003, to 4-leaf sunflower and 1 to 4-inch broadleaf weeds with a backpack sprayer equipped with Turbo TeeJet 11001 nozzles delivering 10 gpa at 40 psi. All sunflower-injury and weed-control evaluations were made visually on the dates reported in data tables. Plots were 10 by 30 ft, and all treatments were replicated four times. Two center rows of each plot were combine harvested on October 15, 2003.

Mycogen 8N429CL was planted at 25,000 seeds/acre on May 27, 2004. PRE herbicides were applied with a backpack sprayer as described in the 2003 experiment. Sunflower was replanted at 25,000 seeds/acre on July 5 because stands of the first planting had been destroyed by wildlife. Roundup UltraMax II® at 22 oz/acre was broadcast applied to the entire experiment area to kill remaining sunflower and existing weed populations. PRE treatments were not reapplied. POST herbicides were applied on July 26 to 6-leaf sunflower and 4- to 6-inch kochia with a backpack sprayer as described in the 2003 experiment. Plots were 10 by 30 ft, and all treatments were replicated four times. Sunflower was harvested on Nov 8, as described in the previous experiment.

RESULTS AND DISCUSSION

Sunflower injury of 1 to 10% was observed from treatments containing Spartan in the 2003 experiment (Table 1). Sunflower yields, moisture, and test weight did not differ among treatments in 2003.

Because of the time separation of the second planting and the PRE treatments, no sunflower injury was observed from any PRE treatments (Table 3). Beyond caused a yellow flash, resulting in injury ratings from 5 to 10%. Sunflower recovered quickly and, by Aug 9, no injury was observed. Sunflower yields, moisture, and test weight did not differ among treatments.

Kochia and Russian thistle were controlled by all treatments containing Spartan, regardless of rate, in

Table 1. Clearfield sunflower response to various herbicide treatments, Southwest Research-Extension Center, Tribune, Kansas, 2003.

Treatment*	Rate	Application timing	Yield**	Test weight	Seed moisture	Sunflower injury 6/26	7/11	9/12
	(Product/acre)		(lb/a)	(lb/bu)	(%)	- - - - - - - (%)		- - - - -
Untreated			1255	31	8.0	-	-	-
Spartan	2 oz	Pre	1150	31	7.5	1	0	0
Spartan + Prowl	2 oz + 2.4 pt	Pre	1051	30	8.7	4	0	0
Spartan +	2 oz +	Pre/	1401	30	8.1	1	0	0
Select + COC+AMS	8 oz + 1% v/v + 2.5 lb	Post						
Spartan +	2 oz +	Pre/	1347	30	7.9	4	0	0
Beyond + NIS + UAN	4 oz + .25% v/v + 1% v/v	Post						
Spartan	3 oz	Pre	1307	30	9.0	4	0	0
Spartan + Prowl	3 oz + 2.4 pt	Pre	1512	30	9.6	8	0	0
Spartan +	3 oz +	Pre/	1437	30	9.1	9	0	0
Select + COC + AMS	8 oz + 1% v/v + 2.5 lb	Post						
Spartan +	3 oz +	Pre/	1236	30	7.8	10	0	0
Beyond + NIS + UAN	4 oz + .25%v/v + 1% v/v	Post						
Prowl	3.6 pt	Pre	1241	30	8.7	0	3	0
Prowl +	3.6 pt +	Pre/	1498	30	8.4	0	0	0
Beyond + NIS + UAN	4 oz + .25%v/v + 1% v/v	Post						
Beyond + NIS + UAN	4 oz + .25%v/v + 1% v/v	Post	1197	30	9.3	-	0	0
Prowl + Spartan	2.4 pt + 2.67 oz	Pre	1411	30	8.9	7	0	0
Untreated			1285	30	8.5	-	-	-
$LSD_{0.05}$			407	NS	NS	4	3	NS

* Spartan 75DF and Prowl 3.3EC were used.
** Seed yield adjusted to 10% moisture.

2003 (Table 2). Prowl® applied alone controlled kochia and Russian thistle 80 to 90%. Beyond applied POST after Prowl did not increase kochia control, but this combination gave complete Russian thistle control. ALS-resistant kochia is present at this location and is not controlled by Beyond. Treatments that included Spartan generally gave excellent control of redroot and tumble pigweed. Prowl alone controlled 90% of the pigweed at the July evaluation, but control declined to 75 to 79% by the September evaluation. Pre-emergence treatments followed by Beyond, or Beyond applied alone, controlled redroot and tumble pigweed. Prowl applied alone controlled puncturevine almost 80%. Spartan applied alone controlled puncturevine 78 to 85%, whereas the tank mixture of Prowl and Spartan gave 92 to 95% control. Treatments containing Beyond controlled puncturevine 98 to 100%.

Weed control rating tended to be lower than expected in the 2004 experiment (Table 3). Inadequate control generally was attained from all PRE treatments, mostly because the PRE treatments had been applied 39 days ahead of the second planting. Treatments had been applied to heavy residue and a very heavy dying kochia population. Treatments were incorporated with irrigation, which facilitated the breakdown process. Dual Magnum or Prowl H_2O® applied alone provided the poorest kochia control, with October ratings of 33 and 34% control. Spartan plus Dual Magnum, or Spartan applied alone, controlled kochia 60 to 75% at the October ratings. Addition of Spartan to Prowl H_20, followed by Beyond, increased control of kochia to 80 to 92% at the October ratings.

Rates and application timing of the herbicides used in this experiment may or may not comply with the herbicide label, and were intended for experimentation only. Use and apply all herbicides according to the guidelines listed in the federal label.

Table 2. Weed control in Clearfield sunflower, Southwest Research-Extension Center, Tribune, Kansas 2003.

Treatment*	Rate	Application timing	Kochia 7/11	Kochia 9/12	Russian thistle 7/11	Russian thistle 9/12	Redroot pigweed 7/11	Redroot pigweed 9/12	Tumble pigweed 7/11	Tumble pigweed 9/12	Puncture vine 7/11
	(Product/acre)		- - - - - -	- - - - - -	- - - - - -	- - - - - -	(% control)	- - - - - -	- - - - - -	- - - - - -	- - - - - -
Untreated			-	-	-	-	-	-	-	-	-
Spartan	2 oz	Pre	95	100	95	98	90	98	86	98	78
Spartan + Prowl	2 oz + 2.4 pt	Pre	98	100	96	100	88	98	93	100	84
Spartan +	2 oz +	Pre/	98	100	95	97	86	97	90	98	78
Select + COC+AMS	8 oz + 1% v/v + 2.5 lb	Post									
Spartan +	2 oz +	Pre/	100	100	100	100	100	100	100	100	98
Beyond + NIS + UAN	4 oz + .25% v/v + 1% v/v	Post									
Spartan	3 oz	Pre	99	100	98	100	92	97	94	97	85
Spartan + Prowl	3 oz + 2.4 pt	Pre	100	100	100	100	98	100	100	100	92
Spartan +	3 oz +	Pre/	100	100	98	100	93	100	91	100	85
Select + COC +AMS	8 oz + 1% v/v + 2.5 lb	Post									
Spartan +	3 oz +	Pre/	100	100	100	100	100	100	100	100	100
Beyond + NIS + UAN	4 oz + .25%v/v + 1% v/v	Post									
Prowl	3.6 pt	Pre	80	87	85	91	75	91	79	93	79
Prowl +	3.6 pt +	Pre/	85	90	100	100	100	99	100	100	100
Beyond + NIS +UAN	4 oz + .25% v/v + 1% v/v	Post									
Beyond + NIS + UAN	4 oz + .25% v/v + 1% v/v	Post	67	77	100	100	100	100	100	100	100
Prowl + Spartan	2.4 pt + 2.67 oz	Pre	100	100	100	100	98	100	99	100	95
Untreated			-	-	-	-	-	-	-	-	-
$LSD_{0.05}$			10	5	5	4	9	4	7	4	9

* Spartan 75 DF and Prowl 3.3EC were used.

Table 3. Sunflower response and weed control in Clearfield Sunflower, Southwest Research-Extension Center, Tribune, Kansas, 2004.

Treatment	Rate	Application	Yield	Test weight	Harvest moisture	Sunflower 7/29	Sunflower 8/9	Kochia 8/9	Kochia 10/19
-	(Product/acre)	timing	(bu/a)	(lb/bu)	(%)	- (% injury) -		(% control)	
Untreated			1331	27	11.7	-	-	-	-
Spartan	2.0 oz	Pre	1723	28	10.9	0	0	55	70
Spartan	2.67 oz	Pre	1636	28	10.8	0	0	64	70
Spartan	3 oz	Pre	1640	27	11.8	0	0	54	60
Dual Magnum	1.3 pt	Pre	1672	27	11.3	0	0	20	33
Prowl H_2O	2.67 pt	Pre	1544	27	11.4	0	0	10	34
Spartan + Dual Magnum	2 oz + 1.3 pt	Pre	1749	27	11.4	0	0	49	64
Spartan +	2 oz +	Pre/	1452	27	11.8	0	1	73	75
Dual Magnum	1.3 pt	Post							
Prowl EC +	3 pt	Pre/	1454	27	12.3	6	0	58	78
Beyond + NIS + UAN	4 oz + .25% v/v + 2.5% v/v	Post							
Prowl H_2O +	2.67 pt +	Pre/	1414	27	11.5	6	0	66	79
Beyond + NIS + UAN	4 oz + .25% v/v + 2.5% v/v	Post							
Spartan + Prowl H_2O +	1 oz + 2.67 pt	Pre/	1418	27	11.5	5	0	71	80
Beyond + NIS + UAN	4 oz + .25% v/v +2.5% v/v	Post							
Spartan + Prowl H_2O +	2 oz + 2.67 pt	Pre/	1631	27	11.7	8	0	91	92
Beyond + NIS + UAN	4 oz + .25% v/v + 2.5% v/v	Post							
Spartan + Prowl H_2O +	3 oz + 2.67 pt	Pre/	1377	27	11.8	9	1	85	86
Beyond + NIS + UAN	4 oz + .25% v/v + 2.5% v/v	Post							
Prowl H_2O +	2.67 pt +	Pre/	1591	27	11.5	8	0	54	69
Beyond + COC + UAN	4 oz + 1% v/v + 2.5% v/v	Post							
Spartan + Prowl EC +	2 oz + 3 pt	Pre/	1339	26	12.6	8	1	78	82
Beyond + COC + UAN	4 oz + 1% v/v + 2.5% v/v	Post							
Spartan + Prowl H_2O +	2 oz + 2.67 pt	Pre/	1561	27	11.5	10	1	79	87
Beyond + COC + UAN	4 oz + 1% v/v + 2.5% v/v	Post							
Beyond + NIS + UAN	4 oz + .25% v/v + 2.5% v/v	Post	1710	27	11.3	8	0	58	70
Beyond + COC + UAN	4 oz + 1% v/v + 2.5%	Post	1587	27	11.7	9	0	58	71
$LSD_{0.05}$			NS	NS	1.3	3	1	19	25

EFFICACY OF VIP- AND CRY1AB-EVENT CORN HYBRIDS FOR THE CONTROL OF SOUTHWESTERN CORN BORER AND CORN EARWORM

by

Larry Buschman, Phil Sloderbeck, and Merle Witt

SUMMARY

This trial was conducted to evaluate the efficacy of corn hybrids containing Cry1Ab events, and hybrids containing Cry1Ab events stacked with a VIP event, for controlling southwestern corn borer (SWCB), *Diatraea grandiosella* Dyar, and corn earworm (CEW), *Helicoverpa zea* (Bobbie). The efficacy of the Cry1Ab experimental event (3243M) against SWCB was equal to that of current Bt11 and TC1507 events. The addition of the VIP event stacked with a Cry1Ab event significantly improved efficacy against the corn earworm.

PROCEDURES

Experimental corn seed (supplied by Syngenta) and commercial standard seed (added by the authors) was machine-planted May 28 at the Southwest Research-Extension Center, Garden City, Kansas. The plots were 4 rows wide and 20 ft long. The experimental seed was planted in a single row (row 2) and the other rows were planted to a commercial Bt corn seed. There were 10-ft-wide alleys at each end of the plots. The design was a randomized block design with 4 replicates. Four to 12 rows of Bt and non-Bt corn were planted around the experimental plots as a border and windbreak. One isoline and one TC1507 hybrid were treated for second-generation SWCB and CEW with Warrior T® at 3.84 oz/acre by using a 2-gallon hand sprayer on August 31. The spray was directed at the plants while the nozzle was moved up and down to treat the whole plant. The 10 largest plants in each plot were identified and then infested with 5 SWCB neonates between June 12 and 20 (first generation) and were infested with another 2 to 3 neonates between July 16 and 23 (second generation). The second-generation SWCB infestation seemed to result mostly from free-flying feral moths.

First-generation SWCB leaf-feeding damage was evaluated on August 9 according to the Guthrie scale (1 = no damage, and 10 = dead-heart). Two sets of second-generation SWCB and CEW observations were made. The first observations were made between September 1 and 15 on 10 non-infested plants. The second observations were made on October 18 and 19 on the ten plants that had been infested with first-generation neonates. Tunneling that could be attributed to first-generation SWCB was excluded (first-generation tunneling typically had pupal case remains or very dark tissues around the tunnels). This was particularly important for treatment 6, which was susceptible during first-generation infestation—before the insecticide treatments were made. The ears from both sets of dissected plants were examined for corn earworm damage. Ear tip damage was measured according to the Winstrom scale (cm of feeding penetration, plus 1 for silk feeding). The number of harvestable kernels removed by CEW feeding on the first set of 10 plants was counted (or estimated). The number of CEW traces (tunnels) and the cm for each were estimated. Some SWCB damage in the ear base was present but it was minor and is not reported.

RESULTS AND DISCUSSION

First-generation SWCB feeding damage in infested plants was light, but it still allowed the evaluation of plant resistance to first-generation SWCB. Guthrie ratings averaged 2.05 and 2.88 in the non-Bt isoline treatments (5 and 6)(Table 1). All transgenic hybrids (1 through 4 and 7 through 9) had significantly lower Guthrie ratings than at least one of the isoline hybrids (5 and 6) (Table 1).

Corn earworm damage was moderate, only reaching 4.03 to 4.25 on the Winstrom scale (Table 2). Only the two treatments with stacked Cry1Ab/VIP3a events (1 and 2) had significantly lower Winstrom ratings than did the susceptible isoline. The stacked Cry1Ab/VIP3a event hybrids (1 and 2) had only 0.8 to 1.0 damaged kernels, significantly fewer than the 56 damaged kernels on the susceptible isoline (5 and 6) (Table 2). The other Cry1ab and Cry1F event hybrids (3 through 5 and 7 through 9) had 22 to

28 damaged kernels, a significant reduction in damaged kernels, compared with the 56 damaged kernels on the susceptible isoline (Table 2). The insecticide treatment had 43 damaged kernels, and this was also a significant reduction in damaged kernels. Observations during the first week of September indicated that most CEW were still present in susceptible ears. By the second week, however, many CEW had left the ears of the susceptible isoline. Therefore, the numbers of CEW present probably do not represent CEW activity well (Table 2). The numbers of CEW traces (tunnels) and cm of CEW traces also indicate a significant reduction for the stacked Cry1Ab/VIP3a event hybrids.

The second-generation SWCB population averaged only 0.5 larvae per plant in the untreated non-Bt hybrid (6) (Table 1). During the first two weeks of September, about 25% of the SWCB were found in the ear or shank, but by October all SWCB were found in the stem, and most were found at the base of the plant. All the Cry1Ab and Cry1F hybrids (1 through 4 and 7 through 9) and the insecticide-treated plots (6) had significantly reduced the numbers of SWCB larvae, to very low populations (Table 3). There was an average of 0.9 tunnels and 5.7 cm of tunneling per untreated non-Bt plant (5) (Table 3). All treatments significantly reduced the number of SWCB larvae and the amount of tunneling. A few SWCB were found in the Cry1F plants (8 and 9) (Table 3). The efficacy of the experimental Cry1Ab hybrids was outstanding against SWCB and seemed equal to that of the current commercial Bt11 and Cry1F corn hybrids. The efficacy of the VIP3a event stacked with a Cry1Ab event was also outstanding against the corn earworm.

Table 1. Early-season observations on plant stand, plant maturity, and first-generation corn borer feeding, Southwest Research-Extension Center, Garden City, Kansas, 2004.

Treatment number	Hybrid code (event)	Warrior treatment	Maturity* (% Silking)	Maturity* (% Tasseling)	Infested (/10 Plants)	Guthrie* rating
1	SPS1001L (Bt11 & MIR152V)	—	49 b	66	1.00 c	1.10 c
2	SPS1002L (3243M & MIR152V)	—	51 b	55	2.25 bc	1.25 c
3	SPS1005L (3243M)	—	100 a	95	3.50 bc	1.42 bc
4	SPS1007L (Bt11)	—	46 b	75	1.00 c	1.19 c
5	SPS1008L (none)	—	100 a	95	4.25 b	2.05 b
6	SPS1008L (none)	—	56 b	80	7.50 a	2.88 a
7	N4640 (Bt11)	—	46 b	69	1.25 bc	1.20 c
8	P34N42 (CH351)	—	39 b	63	0.25 c	1.03 c
9	P34N42 (CH351)	—	39 b	68	1.75 bc	1.20 c
	P-value		0.0136	0.5148	0.0015	0.0001
	LSD		40.00	NS	3.05	0.673

Means, within column, followed by the same letter are not significantly different (P ≤ 0.05, LSD).

*Guthrie (1-9 scale) and Maturity Ratings taken 9 Aug. 2004.

Table 2. Observations on corn earworm feeding taken on primary corn ears, Southwest Research-Extension Center, Garden City, Kansas, 2004.

Treatment number	Hybrid code (event)	Warrior treatment	Winstrom ratings mean 9/1-14	Winstrom ratings mean 10/18-19	Kernels damaged (mean/ear)	CEW larvae (/10 ears)	CEW mean instar	CEW traces (/10 ears)	CEW mean (cm/ear)
1	SPS1001L (Bt11 & MIR152V)	—	0.32 c	1.50 c	0.8 d	0.15	2.68	0.23 d	0.10 c
2	SPS1002L (3243M & MIR152V)	—	0.70 c	0.78 c	1.0 d	0.20	3.08	0.47 d	0.23 c
3	SPS1005L (3243M)	—	3.20 ab	3.20 b	23.2 c	1.00	3.15	1.78 ab	3.23 b
4	SPS1007L (Bt11)	—	3.10 ab	3.80 ab	28.3 c	0.78	3.33	1.63 b	3.28 ab
5	SPS1008L (none)	—	4.03 a	3.93 ab	56.2 a	0.65	4.03	2.10 ab	4.95 ab
6	SPS1008L (none)	8/31	3.90 ab	4.25 a	43.3 b	0.48	3.85	1.70 b	5.30 ab
7	N4640 (Bt11)	—	3.05 b	3.83 ab	19.7 c	1.05	3.55	1.53 c	3.43 ab
8	P34N42 (CH351)	—	3.33 ab	2.83 ab	23.9 c	1.28	3.60	2.30 a	5.43 a
9	P34N42 (CH351)	8/31	3.50 ab	3.45 ab	21.6 c	1.18	3.70	2.15 ab	5.23 ab
	P-value		>0.0001	>0.0001	>0.0001	0.0899	0.2188	>0.0001	>0.0001
	LSD		0.949	0.994	13.029	NS	NS	0.546	2.178

Means, within column, followed by the same letter are not significantly different ($P \leq 0.05$, LSD).

Table 3. Observations on second- generation southwestern corn borer feeding on corn plants, Southwest Research-Extension Center, Garden City, Kansas, 2004.

Treatment number	Hybrid code (event)	Warrior treatment	2nd gen.* SWCB (/20 plants)	Tunnels (/20 plants)* Stalk	Tunnels (/20 plants)* Shank	Tunnels (/20 plants)* Total	Tunnels (cm/20 plants)* Stalk	Tunnels (cm/20 plants)* Shank	Tunnels (cm/20 plants)* Total
1	SPS1001L (Bt11 & MIR152V)	—	0.00 c	0.0 c	0.0 b	0.0 c	0.0 c	0.0 c	0.0 c
2	SPS1002L (3243M & MIR152V)	—	0.00 c	0.0 c	0.0 b	0.0 c	0.0 c	0.0 c	0.0 c
3	SPS1005L (3243M)	—	0.00 c	0.0 c	0.0 b	0.0 c	0.0 c	0.0 c	0.0 c
4	SPS1007L (Bt11)	—	0.00 c	0.0 c	0.0 b	0.0 c	0.0 c	0.0 c	0.0 c
5	SPS1008L (none)	—	9.75 a	11.8 a	5.5 a	17.3 a	99.0 a	13.5 a	113.5 a
6	SPS1008L (none)	8/31	4.50 b	7.3 b	4.0 a	9.8 b	50.4 b	8.3 b	57.4 b
7	N4640 (Bt11)	—	0.00 c	0.0 c	0.0 b	0.0 c	0.0 c	0.0 c	0.0 c
8	P34N42 (CH351)	—	0.00 c	0.1 c	0.3 b	0.5 c	0.1 c	0.1 c	0.3 c
9	P34N42 (CH351)	8/31	0.25 c	0.5 c	0.0 b	0.5 c	4.0 c	4.0 c	4.0 c
	P-value		>0.0001	>0.0001	>0.0001	>0.0001	>0.0001	0.0001	>0.0001
	LSD		1.775	1.982	1.283	3.696	15.442	0.160	17.715

Means, within column, followed by the same letter are not significantly different (P ≤ 0.05, LSD).

*Plants dissected Sept. 1-14 and Oct. 18-19.

EFFICACY OF IN-SEASON APPLICATIONS OF SYSTEMIC INSECTICIDE TO CONTROL DECTES STEM BORERS IN SOYBEAN

by
Larry Buschman, Merle Witt, and Phil Sloderbeck

SUMMARY

Eight systemic insecticides were applied to the soil and 7 systemic insecticides were applied to the foliage and tested for their effectiveness in reducing Dectes stem borers (*Dectes texanus texanus*) in soybean. The insecticides were applied during the beetle flight to target the first two instars of the insect developing inside the plants. Of the soil insecticides tested, only the late application (August 3) of fipronil and imidacloprid seemed to reduce Dectes stem borer infestations, and there were no significant differences for grain yield. Fipronil and clothianidin were found to be the most effective foliar treatments tested for reducing Dectes stem borer infestations. There was a significant increase in yield (5.6 bu/acre average for two treatments) associated with the fipronil treatments; this implies a 8.9% physiological yield loss due to Dectes stem borers when approximately 50% of the plants showed tunneling.

PROCEDURES

This trial was conducted in soybean, DSS3772 RR (maturity group 3.8), planted May 29, 2004 on the Ramsey Brothers Farm 3 miles north of Garden City, Kansas. Two sets of plots were established, one for soil-applied insecticides and one for foliar-applied insecticides. In each experiment, 15 treatments were assigned in a randomized complete-block design with five replications. Plots were four rows (10 ft) wide and 20 ft long, with a 5-ft alley across the ends of the plots. Treatments were 8 systemic insecticides applied to the soil and 7 systemic insecticides applied to the foliage. The insecticides were applied during the beetle flight to target the first two instars of the insect developing inside the plants. The soil-applied treatments were applied July 19 and August 3, when the soybeans were 18 and 30 inches high, respectively. The granular soil treatments were measured out into small containers for each row and hand scattered beside the soybean plants. (This did not work as well as planned, and the insecticide often ran out before reaching the end of the row. Therefore, insect samples were taken from the treated end of the rows, where the actual dose would have been higher than stated). The liquid soil treatments were applied with a back-pack sprayer with a hand-held wand with a single nozzle (fan LF3 80^{o}) that was held close to the ground to apply a 6-inch band 6 inches from the base of the plants. All soil-applied insecticides were incorporated by hand raking the soil. The foliar treatments were applied July 22 and August 13 or 17 with the back–pack sprayer and a hand-held boom with two nozzles (Conejet TXVS 6), each directed at a single row from 12 inches to each side. In all treatments, the sprayer was calibrated to deliver 20 gal/acre (7.5 sec per 20-ft row at 30 psi). A timer was used to maintain appropriate speed.

Dectes stem borer infestations were recorded for 20 plants in each plot from three of the replicates at the end of the season (Sept. 28 to Oct. 27). The plants were pulled and inspected for entry nodes where the larvae had tunneled from the leaf petiole into the stem. The plants were then dissected to record tunneling at the base of the plant, and the presence or absence of the larvae.

Grain yield was determined by machine harvesting all 4 rows from each plot from all five replicates and converting to bu/acre at 12% moisture.

RESULTS AND DISCUSSION

None of the granular insecticides applied to the soil seemed to reduce Dectes stem borer infestations (Table 1). Of the liquid insecticides applied to the soil, only the August 3 applications of fipronil and imidacloprid significantly reduced Dectes stem borer infestations, and there were no significant differences for grain yield (Table 1).

Of the liquid insecticides applied to the foliage, only fipronil and clothianidin seemed effective in reducing Dectes stem borer infestations (Table 1). For clothianidin, it seems that the first application was a little more effective than the second application. There was a significant increase in yield (4.6 to 6.6 bu/acre) for the fipronil treatments. This implies a 7 to 11% physiological yield loss due to Dectes stem borer infestations. The early clothianidin treatment had the third-highest yield in the test, but was not statistically different from the untreated check.

This is one of the first studies to document physiological yield losses to Dectes stem borer. Fipronil, imidacloprid, and clothianidin are not currently labeled on soybeans, but their use in future research trials will be important in establishing yield losses associated with Dectes stem borer and may stimulate additional research that could lead to these or other products eventually gaining registration for use by producers for the management of Dectes stem borer infestations.

Figure 1. Treatment application dates relative to Dectes stem borers in 100 sweeps from July 8 to August 17, 2004, at Garden City, Kansas. Plants grew from 6-leaf stage to 36 inches tall during this time.

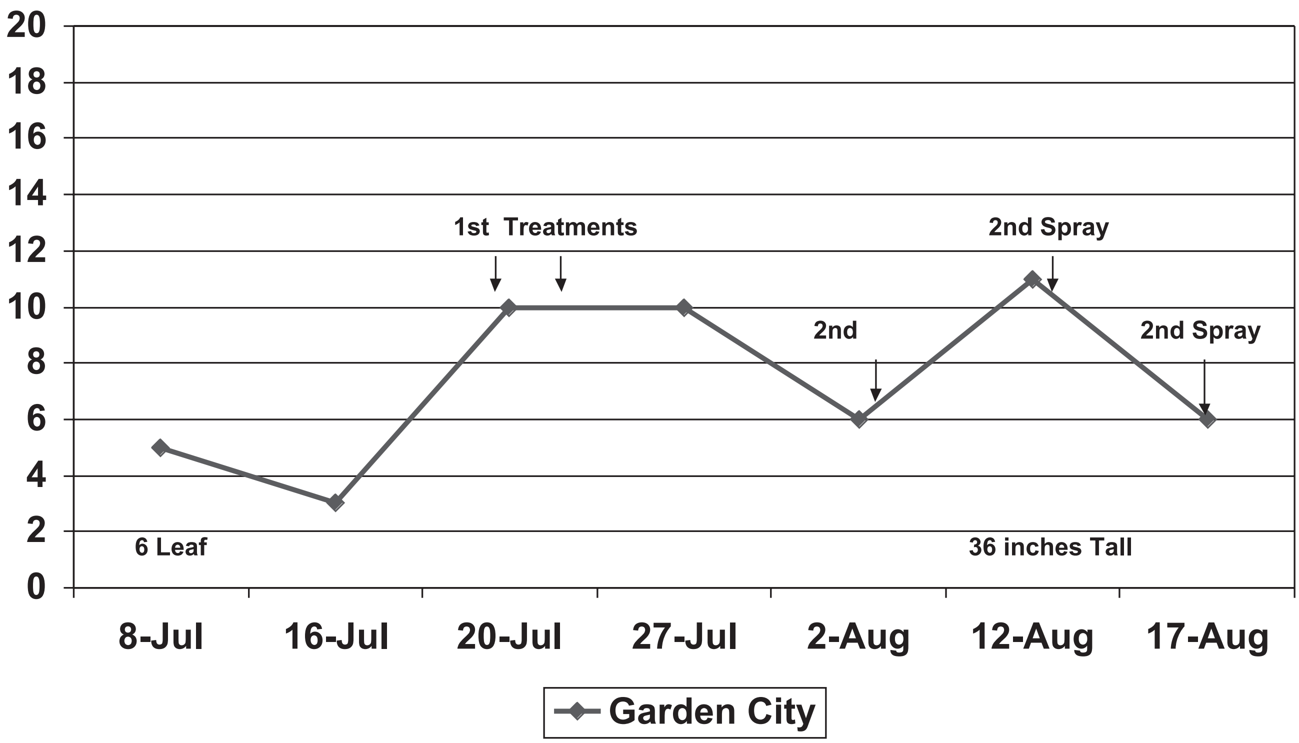


Table 1. Efficacy of soil-applied systemic insecticides against the Dectes stem borers in soybean, Southwest Research-Extension Center, Garden City, Kansas, 2004.

	Insecticide	Rate oz/1000 ft 7/19	Rate oz/1000 ft 8/3	Entry nodes /20 plants	Stem tunneling /20 plants	Live larvae /20 plants	Grain yield bu/acre
1	Check	—	—	20.3 a	10.7 a	9.3 a	61.5
2	disulfoton (Di-Syston 15G)	8	—	16.7 ab	8.0 a	6.3 a	62.8
3	aldicarb (Temik 15G)	9.2	—	21.0 a	10.0 a	8.7 a	61.8
4	terbufos (Counter 20CR)	6	—	27.0 a	11.7 a	10.0 a	62.5
5	phorate (Thimet 15G)	12	—	23.3 a	11.3 a	10.0 a	60.7
6	clothianidin (TM-44401 50WP)	0.17	—	23.0 a	11.7 a	10.7 a	62.8
7	carbofuran (Furadan 4F)	5	—	17.3 ab	9.0 a	9.0 a	65.4
8	fipronil (Regent 4SC)	0.24	—	13.7 ab	6.7 ab	5.3 a	62.8
9	imidacloprid (Provado 1.6F)	1.44	—	17.3 ab	9.0 a	8.3 a	62.5
10	disulfoton (Di-Syston 15G)	—	8	22.3 a	11.3 a	10.3 a	63.2
11	aldicarb (Temik 15G)	—	9.2	25.7 a	10.7 a	7.7 a	64.2
12	clothianidin (TM-44401 50WP)	—	0.17	28.3 a	11.3 a	8.0 a	59.9
13	carbofuran (Furadan 4F)	—	5	19.7 ab	9.7 a	8.7 a	63.1
14	fipronil (Regent 4SC)	—	0.24	7.7 b	2.3 b	1.0 b	63.2
15	imidacloprid (Provado 1.6F)	—	1.44	9.7 ab	4.7 b	4.0 b	63.4
	P-value	—	—	0.0409	0.0127	0.0077	0.8275
	LSD	—	—	11.779	4.880	4.505	—

Table 2. Efficacy of systemic insecticides applied to foliage against the Dectes stem borers in soybean, Southwest Research-Extension Center, Garden City, Kansas, 2004.

	Insecticide	Rate oz/acre 7/22	Rate oz/acre 8/13 & 8/17	Entry nodes /20 plants	Stem tunneling /20 plants	Live larvae /20 plants	Grain yield bu/acre
1	Check	—	—	19.0 a	10.3 ab	10.0 ab	62.3 cde
2	carbofuran (Furadan 4F)	8	—	21.3 a	10.0 ab	9.7 ab	60.6 de
3	disulfoton (Disyston 8EC)	9.2	—	19.0 a	9.3 b	9.3 ab	63.3 bcde
4	fipronil (Regent 4SC)	6	—	0.0 c	0.0 d	0.0 d	66.9 ab
5	imidacloprid (Provado 1.6F)	12	—	18.7 a	11.0 ab	11.0 ab	61.9 cde
6	abamectin (Agri-Mek 0.15 EC)	0.17	—	18.0 a	10.7 ab	10.7 ab	61.2 cde
7	dimethoate (Dimethoate 400)	5	—	16.0 ab	9.3 b	9.3 ab	61.9 cde
8	clothianidin (TM-44401 50WP)	0.24	—	8.7 bc	4.3 c	4.3 c	64.7 bc
9	carbofuran (Furadan 4F)	1.44	—	13.3 ab	8.0 b	8.0 b	59.8 e
10	disulfoton (Disyston 8EC)	—	8	17.7 a	10.3 ab	9.7 ab	60.8 cd
11	fipronil (Regent 4SC)	—	9.2	3.3 c	0.3 d	0.3 d	68.9 a
12	imidacloprid (Provado 1.6F)	—	0.17	18.3 a	10.7 ab	10.3 ab	63.8 bcd
13	abamectin (Agri-Mek 0.15 EC)	—	5	15.3 ab	10.3 ab	9.7 ab	62.6 cde
14	dimethoate (Dimethoate 400)	—	0.24	21.0 a	13.0 a	12.0 a	61.5 cde
15	clothianidin (TM-44401 50WP)	—	1.44	15.3 ab	9.7 b	9.0 ab	62.4 cde
	P-value	—	—	0.0005	>0.0001	>0.0001	0.0018
	LSD	—	—	8.793	3.231	3.048	3.983

YIELD OF IRRIGATED WARM-SEASON GRASSES IN SOUTHWESTERN KANSAS

by

Ron Hale, Curtis. Thompson, Troy Dumler, Darl Henson[1] , and Garrett Gold[2]

SUMMARY

Seventeen annual and perennial warm-season grasses of different species and varieties were planted in two southwestern Kansas counties to evaluate yield and adaptability when grasses are produced under irrigation. The varieties included switchgrass, eastern gamagrass, crabgrass, buffalograss, seeded bermudagrass, and sprigged bermudagrass. Grasses were planted in four replicated plots during the late spring and early summer of 2002. Hand weeding, mowing, livestock grazing, and herbicides were used in 2002 and 2003 to control weeds. Forage samples were collected in the summer of 2004 to measure dry matter content and yield. Although the bermudagrasses in Grant County were harvested three times, variety yield differences occurred only at the first cutting. Total annual yield did not differ between varieties. In Stevens County, the bermudagrasses were compared with the other warm-season grasses. Early bermudagrass and eastern gamagrass growth was killed by a mid-April freeze, so they were harvested only twice. Buffalograss was harvested on the same days as the bermudagrasses and eastern gamagrass. Switchgrass and the crabgrasses were harvested once. The crabgrasses were planted late in 2004, after efforts that year and in 2003 to eliminate native crabgrass. Switchgrass; eastern gamagrass; and ‘Vaquero,’ ‘CD-90160,’ ‘Midland 99,’ ‘Quickstand,’ and ‘Wrangler’ bermudagrasses were the highest producers. The crabgrasses and buffalograss had the lowest yields. It is expected that the crabgrasses will be harvested more frequently, and have higher yields, in coming years. Bermudagrass stands were generally best for the seeded varieties. The sprigged exceptions included Quickstand, known for its rapid growth, in Stevens County and ‘World Feeder’ in Grant County, which was planted immediately after being harvested rather than 2 or 3 days later, as the other varieties were. Careful consideration should be given these results because only one year’s data is presented, and because the growing season was unusually cool.

INTRODUCTION

Interest in irrigated grass production has increased in southwestern Kansas in recent years. In 2001, producers were surveyed for grasses used, management practices, and reasons for converting from traditional cash crops. Reasons given were related to existing corn and cattle prices, effluent use, reduced irrigation-well production, and importance in a cattle-production program. The advantages warm-season grasses have over cool-season grasses include higher forage yields during the summer heat and more efficient use of water. Disadvantages of warm-season grasses include establishment difficulty because of weed competition and soil moisture maintenance, reduction in annual income due to longer establishment time, and shorter growing season. Although several warm-season grasses are being used in southwestern Kansas, there has been limited research comparing different species and varieties. This project was initiated to evaluate the adaptability and yield of several warm-season grasses raised under irrigation.

PROCEDURES

Seventeen annual and perennial warm-season grasses of different species and varieties were planted in two southwestern Kansas counties. Eastern gamagrass (‘PMK-24’), switchgrass (‘Blackwell’), crabgrass (‘variety-not-stated’ and ‘Red River®’), buffalograss (‘Sharp’s Improved Prime®’), three seeded bermudagrasses (‘Wrangler’®, ‘Vaquero’®, and ‘CD-90160’®), and seven sprigged

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bermudagrasses (‘Hardie’®, ‘Midland 99’®, ‘Ozark’®, ‘Quickstand’®, ‘Tifton 44’®, ‘LCB84x19-16’ and ‘LCB84x16-66’) were planted in Stevens County. Eight bermudagrasses (CD-90160, Hardie, Midland 99, Ozark, LCB84x16-66, LCB84x19-16, Wrangler and ‘World Feeder’®) were planted in Grant County. The different bermudagrasses were selected because of reported differences in winter hardiness, and to compare seeded and sprigged varieties. LCB84x16-66 and LCB84x19-16 are two experimental varieties being evaluated by Kansas State University and Oklahoma State University. Vaquero is a bermudagrass blend of CD-90160, ‘Mirage’®, and ‘Pyramid’®.

Each grass was planted at each location in four randomly assigned plots measuring 16 by 25 ft between May 31 and July 2 of 2002. The Grant County plots were under a quarter-section center-pivot sprinkler on a Ulysses silt loam soil. The Stevens County plots were under a 15-acre pivot on a Vona-Tivoli loamy fine sand. The ground had been tilled for weed control and seedbed preparation. Fifty pounds of nitrogen (N) and 50 lbs of phosphorus per acre were broadcast and incorporated into the soil at the last tillage operation. Seed, except for the eastern gamagrass, was broadcast manually onto the plots and then lightly raked into the soil. The eastern gamagrass had been stratified by soaking it in a fungicide solution and then storing it at 35°F for 10 weeks. Three days after removal from refrigeration, it was planted in 28-inch rows with a single-row garden planter. Seeding rates per acre were: crabgrass at 4 lb pure-live-seed (PLS), switchgrass and eastern gamagrass at 8 lb PLS, and seeded bermudagrasses at 12 lb bulk seed. The sprigged bermudagrasses were planted at an estimated 20 bushels of sprigs per acre. The sprigs, except World Feeder, were planted 2 or 3 days after having been dug. World Feeder was planted immediately after digging. The sprigs were kept moist and cool until planting. The soil was closely monitored to ensure it remained moist throughout the summer. A large amount of native crabgrass seed prevented the establishment of the desired crabgrass varieties. From 2002 until early summer of 2004, the crabgrass plots were routinely tilled after the preexisting seed had sprouted to eliminate the native seed. On June 22, 2004, the Red River and VNS crabgrasses were replanted.

Extensive hand weeding, mowing, livestock grazing, and herbicides were used to control weeds to develop pure research stands. Dual Magnum® (1.5 pint/acre), Treflan® (10 lb/acre), Paramount® (8 oz/acre) with crop oil, 2,4-D (1 pint/acre), and glyphosate (1.5 pint or 1 quart/acre) were applied after the stands were established or when grasses were dormant. Common weeds were crabgrass, grassy sandbur, henbit, bindweed, buckwheat, pigweed, kochia, and matuagrass. Although no samples were collected until 2004, the plots were managed to eliminate weeds during 2002 to ensure grass establishment, and were managed during 2003 as if under production.

Nitrogen applications, of urea or cattle manure, differed by grass species and location. In Grant County, approximately 20 tons of manure was applied per acre in the early spring of 2003. In the spring of 2004, 80 lb N/acre was applied. In Stevens County, the crabgrass plots were fertilized once each spring with 100 lb N/acre. The other plots received 100 lb N/acre before spring green-up, with additional applications of 100 lb/acre after the first and second bermudagrass harvests. Phosphorus and potassium were applied during the fall, according to recommendations based on testing of soil samples collected at each location. Plots were irrigated when necessary to provide a minimum of 22 inches total water during the growing season.

Forage samples were collected by cutting 20 square feet of each plot. Bermudagrass samples were harvested from the best-covered area of those plots with less than full coverage. Switchgrass was harvested to a height of 8 inches, eastern gamagrass was cut to 10 inches, and all other grasses were cut to 3 inches. In 2004, plots were harvested on June 14, July 16, and August 27 in Grant County. Unseasonably early bermudagrass and eastern gamagrass growth was killed by freezing mid-April temperatures in Stevens County. Because of slow regrowth, the bermudagrasses were harvested only twice, on June 30 and August 23. Buffalograss and eastern gamagrass were harvested on the same days as the bermudagrasses. Switchgrass was cut once on June 30. The crabgrasses were also harvested once, on August 30, because of the late 2004 planting. The bermudagrass plots in both counties were scored before each harvest to evaluate plot cover.

RESULTS AND DISCUSSION

Yields and dry matter content were compared for the Grant County bermudagrasses in Table 1. Significant variety differences for forage yield were observed at the first cutting. Wrangler yield was the lowest, but did not differ from LCB84x16-66. World Feeder and LCB84x19-16 yields were the highest, but they did not differ significantly from Hardie, Ozark, CD-9160, or Midland 99. There were no statistical

Table 1. Forage yield and dry matter content of Bermuda grassesin Grant County, 2004.							
	Type	Cutting Date					
Variety		6/14		7/16		8/27	Total
		Forage yield, lb DM/acre					
CD-90160	Seed	1,907	bc	5,279		3,105	10,291
Hardie	Sprig	2,034	bc	5,929		2,978	10,940
LCB84x16-66	Sprig	1,556	ab	5,120		3,216	9,891
LCB84x19-16	Sprig	2,331	c	5,970		3,206	11,506
Midland 99	Sprig	1,733	bc	5,637		4,660	12,030
Ozark	Sprig	1,995	bc	5,111		2,791	9,896
World Feeder	Sprig	2,396	c	5,608		2,672	10,676
Wrangler	Seed	876	a	6,280		2,373	9,529
		DM content, %					
CD-90160	Seed	28.4	a	26.0	bc	29.2	-
Hardie	Sprig	31.5	bc	27.8	cde	31.2	-
LCB84x16-66	Sprig	31.1	abc	26.9	bcd	30.0	-
LCB84x19-16	Sprig	32.4	bc	25.8	b	29.8	-
Midland 99	Sprig	32.6	c	28.9	e	32.1	-
Ozark	Sprig	29.9	abc	28.4	de	29.4	-
World Feeder	Sprig	28.7	a	22.4	a	29.9	-
Wrangler	Seed	31.6	bc	26.9	bcd	33.9	-

[abcde] Means, within cutting or for total annual yield, that are followed by different superscripts are significantly different (P<.05).

differences in variety yield at the second or third cutting, or in total annual yields. The average yields of the three cuttings differed (P<.05) from each other at 1853, 5617 and 3125 lb, respectively. Variety dry matter content differences were observed for the first and second cuttings only.

Stevens County yields and dry matter contents are shown in Table 2, which compares the bermudagrasses and other warm-season grasses. Dry matter differences occurred between varieties at both cuttings. Statistical differences were found for the forage yields at each of the two cuttings and for total forage production. Buffalograss and both crabgrasses had the lowest yields at each cutting and the least total forage production. Crabgrass, however, was harvested only once because of a late planting. It is anticipated that yields will be higher in the coming years. Although switchgrass was harvested only once, it was still one of the highest-yielding grasses. As the result of two good harvests, eastern gamagrass was also one of the best producers. Switchgrass and eastern gamagrass did not differ statistically from each other, nor from CD-90160, Midland 99, or Quickstand, or Vaquero bermudagrasses. There were no significant differences between the Stevens County bermudagrasses at the first cutting. CD-90169 was the highest yielding bermudagrass at the second cutting, but it did not differ statistically from Quickstand or Vaquero.

Table 3 illustrates that the seeded varieties of bermudagrass generally had better stands than the sprigged varieties did. This can be attributed to the large number of potential plants from seed, compared with the limited number of sprigs planted. The sprigged exceptions were Quickstand in Stevens County and World Feeder in Grant County. Quickstand is known for its rapid growth. World Feeder sprigs, having been dug and planted in the same afternoon, were not subjected to the same amount of stress that the other varieties experienced by being planted 2 or 3 days after having been harvested. This may have resulted in quicker growth for World Feeder. It is clear that some varieties, such as Midland 99, have good yield potential despite being slow to fully establish.

Table 2. Forage yield and dry matter content of warm-season grasses in Stevens County, 2004.

Variety	Type	Cutting 6/30	Cutting 8/23	Total
		Forage yield, lb DM/acre		
Buffalograss	-	2,060 [a]	1,427 [a]	3,486 [ab]
Crabgrass, common	-	-	1,654 [a]	1,654 [a]
Crabgrass, Red River	-	-	2,379 [ab]	2,379 [a]
Eastern gamagrass	-	6,95 [c]	5,223 [de]	12,174 [de]
Switchgrass	-	12,259 [d]	-	12,259 [e]
Bermudagrass				
CD-90160	Seed	4,832 [abc]	6,923 [f]	11,754 [de]
Hardie	Sprig	3,719 [ab]	4,081 [cd]	7,800 [c]
LCB84x16-66	Sprig	3,858 [ab]	4,513 [cde]	8,370 [c]
LCB84x19-16	Sprig	2,553 [ab]	3,473 [bc]	6,026 [bc]
Midland 99	Sprig	5,463 [bc]	4,837 [cde]	10,301 [cde]
Ozark	Sprig	3,813 [ab]	4,842 [cde]	8,654 [c]
Quickstand	Sprig	3,801 [ab]	5,897 [ef]	9,698 [cde]
Tifton 44	Sprig	3,079 [ab]	4,470 [cde]	7,549 [c]
Vaquero	Seed	5,996 [bc]	5,866 [ef]	11,862 [de]
Wrangler	Seed	4,920 [abc]	4,328 [cd]	9,248 [cd]
		DM content, %		
Buffalograss	-	39.4 [c]	35.2 [e]	-
Crabgrass, common	-	-	19.1 [a]	-
Crabgrass, Red River	-	-	18.0 [a]	-
Eastern gamagrass	-	27.4 [ab]	25.5 [bcd]	-
Switchgrass	-	25.2 [a]	-	-
Bermudagrass				
CD-90160	Seed	28.5 [ab]	28.7 [d]	-
Hardie	Sprig	27.9 [ab]	26.1 [bcd]	-
LCB84x16-66	Sprig	27.0 [ab]	26.6 [bcd]	-
LCB84x19-16	Sprig	25.3 [ab]	25.1 [bc]	-
Midland 99	Sprig	27.1 [ab]	26.5 [bcd]	-
Ozark	Sprig	28.8 [b]	27.2 [cd]	-
Quickstand	Sprig	27.8 [ab]	25.0 [bc]	-
Tifton 44	Sprig	27.6 [ab]	26.7 [bcd]	-
Vaquero	Seed	29.1 [b]	27.1 [cd]	-
Wrangler	Seed	28.2 [ab]	23.3 [b]	-

[abcdef] Means, within cutting or for total annual yield, that are followed by different superscripts are significantly different ($P<.05$).

Table 3. Bermudagrass stand evaluation scores,* 2004.			
Variety	Type	Grant County	Stevens County
CD-90160	Seed	1.5[ab]	1.9[a]
Hardie	Sprig	3.3[cde]	2.9[b]
LCB84x16-66	Sprig	2.3[bc]	3.1[b]
LCB84x19-16	Sprig	3.8[de]	4.2[c]
Midland 99	Sprig	4.0[e]	3.2[b]
Ozark	Sprig	2.8[cd]	2.6[ab]
Quickstand	Sprig	-	1.9[a]
Tifton 44	Sprig	-	3.1[b]
Vaquero	Seed	-	1.9[a]
World Feeder	Sprig	1.0[a]	-
Wrangler	Seed	1.0[a]	2.1[a]

* Plot cover: 1=Excellent, 2=Very good, 3=Good, 4=Fair.
abcde Means, within county, that are followed by different superscripts are significantly different (P<.05).

The results reported in this paper represent only one year's data. It was also a year of atypical weather, with an unseasonably cool and wet summer. It is likely that growth patterns of these warm-season grasses will differ in coming years. Choosing a grass variety for irrigated production should not be based on annual yield only. Important agronomic factors that should be considered include soil and climate adaptation, fertility and water requirements, and winter hardiness. Animal-related factors include the nutritional requirements of the species and class of animals consuming the forage, forage nutritional quality, grazing tolerance, and desired grazing season. Other factors to consider include primary use (haying or grazing) and the producer's management style. These factors have an important place in determining what species and variety is best adapted to environmental conditions, intended use, and management practices.

FORAGE YIELD AND QUALITY AT THREE CUTTINGS FOR TWELVE HARD RED AND WHITE WINTER WHEAT VARIETIES

by

Ron Hale, Curtis Thompson, Troy Dumler, Alan Schlegel, and Charles MacKown[1]

SUMMARY

Six hard red winter wheat varieties (2137, Jagalene, Jagger, OK101, Stanton, and Thunderbolt) and six hard white winter wheat varieties (Burchett, Lakin, NuFrontier, NuHills, NuHorizon, and Trego) were planted in two southwestern Kansas counties to evaluate forage yield and quality. Four replicated plots were planted in September 2003 for each variety at each location. Forage samples were collected from each plot during December 2003, March 2004, and April or May 2004. Dry matter content, dry matter yield/acre, crude protein, acid detergent fiber, neutral detergent fiber, relative feed value, total digestible nutrients, net energy for maintenance, net energy for gain, and nitrate nitrogen were determined. Forage yields differed among the cuttings, depending on the county. The highest yields in Clark and Stanton Counties occurred at the December and May harvests, respectively. Forage quality was higher at the first two cuttings in each county. Crude protein and energy content of the third cutting at Clark County may not support maximum gain, depending on animal age and weight. Forage traits measured in this experiment seem related to individual varieties rather than to wheat color.

INTRODUCTION

Wheat pasture provides economical, high-quality forage for livestock during a time of year that few other comparable forages are available. Dual-purpose forage and grain programs permit producers to more effectively and profitably utilize their land. Producers may also forgo a grain harvest and graze out the wheat to maximize profitability. Although hard red winter wheat varieties dominate, it is anticipated that the use of hard white winter wheats will increase because of potential incentives associated with its marketing, milling, and end use. This experiment examined the forage yield and quality of six hard white and six hard red winter wheat varieties. Forage harvest simulated grazing for a dual-purpose program, as well as for wheat graze-out.

PROCEDURES

Six hard white (Burchett, Lakin, NuFrontier, NuHills, NuHorizon, and Trego) and six hard red (2137, Jagalene, Jagger, OK101, Stanton, and Thunderbolt) winter wheats were planted in Clark and Stanton Counties. Sixty-five lb/a of nitrogen (N) was applied at Clark County, and 80 lb N/a was applied at Stanton County, before planting. On September 16, 2003, each variety was planted in four replicated plots at each location, in 10-inch rows at a depth of approximately 1.75 inches. Planting rates were 90 lb seed/a at the dryland Clark County plots and 120 lb/a at the limit-irrigated Stanton County plots. Applied with the seed was 11 lb N/a and 52 lb P_2O_5/a. Soil type at both locations was a silt loam.

Wheat forage was harvested on December 31, 2003, and March 19 and April 29, 2004, at Clark County, and on December 30, 2003, and March 25 and May 4, 2004, at Stanton County. The March cuttings were taken before jointing occurred. Cuttings were collected from the same six feet of closely clipped row length in each plot. Samples were immediately dried, weighed, and sent to a commercial laboratory for crude protein (CP), acid detergent fiber (ADF), and neutral detergent fiber (NDF) determination. Relative feed value (RFV), total digestible nutrients (TDN), net energy for maintenance (NEm), and net energy for gain (NEg) were calculated from the laboratory analysis by using the formulas in Table 1. Nitrate-nitrogen (NO_3-N) assays were performed at the USDA-ARS laboratory in El Reno, OK.

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[1]USDA ARS El Reno, Oklahoma.

Table 1. Formulas used to calculated TDN, NEm, NEg, and RFV from ADF and NDF.

Item	Formula
TDN, %	95.88 – (0.911 x ADF%)
NEm, mcal/lb	0.995 – (0.0121 x ADF%)
NEg, mcal/lb	0.786 – (0.0132 x ADF%)
RFV	[(88.9 – (.779 x ADF%)) x (120 ÷ NDF%)] ÷ 1.29

RESULTS AND DISCUSSION

Forage yield (Table 2) differed among varieties at all Stanton County cuttings, but only at the April cutting in Clark County. The only yield difference related to wheat color occurred at the March cutting in Clark County. Forage yields in Clark County appeared to be highest in December, whereas Stanton County yields were generally highest in May. Differences in variety dry matter (DM) content (Table 3) occurred only at the December Clark County cutting. Crude protein (Table 4) differed among varieties at all cuttings except in March at Clark County. The differences were not color dependent. Early spring growth (March) appeared to have the greatest CP content at both locations. December and March protein values were well in excess of the requirement for stocker calves. The simulated April/May graze-out cuttings had less CP, with Clark County having a somewhat marginal CP content for stockers, depending on animal weight and rate of gain.

Acid detergent fiber, a measure of cellulose and lignin, increases as a plant matures. The increase is associated with decreased nutrient digestibility and energy availability. Neutral detergent fiber measures hemicellulose, cellulose, and lignin. As NDF increases feed intake tends to decrease. Higher ADF (Table 5) and NDF (Table 6) values result in lower energy and feed values. Although variety differences occurred for ADF and NDF at four of the six cuttings, the only significant color difference was observed for ADF at the May Stanton County cutting. This resulted in color differences for TDN (Table 7), NEm (Table 8), and NEg (Table 9) at the same cutting. A wheat color difference was also seen for NEg at the March cutting in Clark County. There were no color differences for RFV (Table 10), although five of the six cuttings showed variety differences. The ADF, NDF, TDN, NEm, NEg, and RFV differences in this study were due to individual varieties and do not seem strongly related to wheat color. The April Clark County cuttings had marginal energy values for calf gain, similar to the CP results. Forage energy content of the other five cuttings was well in excess of stocker requirements.

In Stanton County, NO_3-N (Table 11) differed among varieties at the December and March cuttings, and between red and white wheat varieties at the December cutting. Although two means at the March cutting were in the “low-moderately safe” range of 701-1400 ppm, the majority of the observed values were in K-State’s “very low-virtually safe” range of 0-700 ppm.

Although Stanton County had limited irrigation and Clark County was dryland, other factors, such as higher elevation and fewer growing-degree units would have suppressed forage growth in Stanton County. The data suggest that the Stanton County forage may have been somewhat less mature and, therefore, might have had slightly better nutritional quality. It is expected that cattle performance would be the same when grazing any single variety at either location. The data also suggest that seasonal differences may exist, especially in a graze-out program.

The varieties chosen are among the more popular wheats planted, but they do not necessarily represent all wheat varieties, wheat colors, growing conditions, or cultural practices. Forage traits measured in this experiment seem related to individual varieties rather than to wheat color.

Table 2. Forage dry matter yield (lb DM/a) by county and variety.

Variety	Color	Clark County 12/31/03	Clark County 3/19/04	Clark County 4/29/04	Stanton County 12/30/03	Stanton County 3/25/04	Stanton County 5/4/04
2137	Red	2,461	1,129	1,692	1,163	1,156	1,811
Burchett	White	2,511	934	1,365	1,672	1,348	1,594
Jagalene	Red	2,640	1,186	1,844	1,468	1,436	1,681
Jagger	Red	2,638	1,209	1,410	1,176	1,127	1,250
Lakin	White	2,592	1,194	1,885	1,418	1,313	1,744
NuFrontier	White	2,879	1,166	1,267	1,478	1,288	1,536
NuHills	White	2,099	999	949	1,146	1,247	1,269
NuHorizon	White	2,492	968	1,282	1,804	1,561	1,499
OK101	Red	2,228	1,099	1,333	1,206	1,033	1,563
Stanton	Red	2,421	1,281	1,244	1,194	1,302	1,624
Thunderbolt	Red	2,213	1,166	1,762	1,246	1,284	1,951
Trego	White	2,809	1,181	1,666	1,538	1,528	2,091
LSD (.05)		NS	NS	307	396	288	328
	Red	2,433	1,178	1,547	1,242	1,223	1,647
	White	2,561	1,074	1,402	1,509	1,381	1,622
	LSD (.05)	NS	83	NS	NS	NS	NS

Table 3. Dry matter content (%) by county and variety.

Variety	Color	Clark County 12/31/03	Clark County 3/19/04	Clark County 4/29/04	Stanton County 12/30/03	Stanton County 3/25/04	Stanton County 5/4/04
2137	Red	29.7	22.8	29.0	35.4	21.6	22.3
Burchett	White	30.5	26.5	28.8	35.8	21.1	21.5
Jagalene	Red	32.0	23.8	30.0	36.4	21.2	22.5
Jagger	Red	29.2	24.0	30.5	37.8	22.9	23.5
Lakin	White	30.4	25.0	31.8	36.5	22.9	21.8
NuFrontier	White	29.5	23.0	26.3	36.7	22.2	21.3
NuHills	White	30.0	22.8	29.8	34.7	21.3	22.8
Nu Horizon	White	31.7	24.0	27.8	35.5	21.1	21.8
OK101	Red	30.1	23.5	30.5	37.4	22.0	22.0
Stanton	Red	30.3	23.5	31.8	36.1	22.7	21.0
Thunderbolt	Red	30.5	23.8	28.3	35.2	22.2	22.3
Trego	White	32.0	25.0	29.8	34.3	22.2	21.0
LSD (.05)		1.8	NS	NS	NS	NS	NS
	Red	30.3	23.5	30.0	36.4	22.1	22.3
	White	30.7	24.4	29.0	35.6	21.8	21.7
	LSD (.05)	NS	NS	NS	NS	NS	NS

Table 4. Crude protein (% of DM) by county and variety.

Variety	Color	Clark County 12/31/03	Clark County 3/19/04	Clark County 4/29/04	Stanton County 12/30/03	Stanton County 3/25/04	Stanton County 5/4/04
2137	Red	21.7	25.5	11.7	22.7	24.0	15.2
Burchett	White	22.4	25.0	12.5	23.9	26.8	18.6
Jagalene	Red	21.1	25.3	13.0	24.6	28.8	19.6
Jagger	Red	22.7	24.6	12.7	22.9	26.4	18.2
Lakin	White	21.2	22.2	10.9	22.5	25.0	17.0
NuFrontier	White	21.2	23.9	13.7	21.8	25.0	18.2
NuHills	White	23.5	26.4	13.7	25.7	27.2	18.7
NuHorizon	White	20.9	24.5	14.6	22.0	24.6	19.5
OK101	Red	21.5	24.1	11.4	22.4	24.4	16.5
Stanton	Red	21.4	24.1	13.2	21.9	25.0	17.3
Thunderbolt	Red	23.0	27.0	13.5	24.3	28.7	18.3
Trego	White	20.4	23.5	11.3	22.0	25.5	17.1
LSD (.05)		1.3	NS	2.2	1.3	1.4	1.7
	Red	21.9	25.1	12.6	23.1	26.2	17.5
	White	21.6	24.2	12.8	23.0	25.7	18.2
	LSD (.05)	NS	NS	NS	NS	NS	NS

Table 5. Acid detergent fiber (% of DM) by county and variety.

Variety	Color	Clark County 12/31/03	Clark County 3/19/04	Clark County 4/29/04	Stanton County 12/30/03	Stanton County 3/25/04	Stanton County 5/4/04
2137	Red	18.6	26.1	33.5	18.4	25.4	29.1
Burchett	White	20.3	25.2	34.0	20.2	24.7	29.4
Jagalene	Red	17.3	25.7	32.8	17.0	24.6	27.9
Jagger	Red	20.6	27.6	34.1	19.0	25.4	28.6
Lakin	White	18.7	24.3	33.8	18.2	24.7	29.2
NuFrontier	White	20.3	26.6	31.2	18.6	25.6	29.0
NuHills	White	18.8	26.6	32.6	18.3	25.6	28.7
NuHorizon	White	19.1	26.4	30.7	18.6	25.5	29.5
OK101	Red	19.2	27.0	33.5	19.3	25.3	29.0
Stanton	Red	20.0	26.8	32.0	19.0	24.6	28.9
Thunderbolt	Red	19.4	25.5	32.1	18.4	24.0	28.4
Trego	White	18.3	26.2	33.0	18.9	25.6	30.1
LSD (.05)		1.4	1.1	1.6	1.4	NS	NS
	Red	19.2	26.4	33.0	18.5	24.9	28.6
	White	19.2	25.9	32.5	18.8	25.3	29.3
	LSD (.05)	NS	NS	NS	NS	NS	0.5

Table 6. Neutral detergent fiber (% of DM) by county and variety.							
		Clark County			Stanton County		
Variety	Color	12/31/03	3/19/04	4/29/04	12/30/03	3/25/04	5/4/04
2137	Red	41.1	42.9	58.5	42.9	39.5	50.2
Burchett	White	42.5	43.0	58.9	45.0	40.7	49.6
Jagalene	Red	38.8	42.5	56.1	40.3	40.2	49.1
Jagger	Red	43.2	45.5	59.2	45.1	41.8	50.4
Lakin	White	43.2	42.5	58.8	43.0	41.3	52.5
NuFrontier	White	44.1	44.6	55.2	43.2	42.6	51.3
NuHills	White	41.7	44.2	56.5	43.5	41.4	48.4
NuHorizon	White	41.1	43.8	54.9	41.6	42.7	51.2
OK101	Red	42.6	45.9	59.3	43.4	42.4	52.2
Stanton	Red	44.1	45.5	56.1	43.5	42.5	50.4
Thunderbolt	Red	44.7	43.7	57.0	43.2	40.9	50.3
Trego	White	40.8	43.6	58.0	42.8	42.3	52.1
LSD (.05)		1.8	1.8	2.0	2.1	NS	NS
	Red	42.4	44.3	57.7	43.0	41.2	50.4
	White	42.2	43.6	56.9	43.2	41.8	50.9
	LSD (.05)	NS	NS	NS	NS	NS	NS

Table 7. Total digestible nutrients (% of DM) by county and variety.							
		Clark County			Stanton County		
Variety	Color	12/31/03	3/19/04	4/29/04	12/30/03	3/25/04	5/4/04
2137	Red	79.0	72.1	65.5	79.2	72.8	69.4
Burchett	White	77.5	72.9	65.0	77.5	73.4	69.1
Jagalene	Red	80.1	72.5	66.0	80.4	73.5	70.5
Jagger	Red	77.1	70.7	64.9	78.6	72.8	69.9
Lakin	White	78.9	73.8	65.1	79.4	73.4	69.3
NuFrontier	White	77.4	71.7	67.5	79.0	72.6	69.5
NuHills	White	78.8	71.6	66.2	79.3	72.6	69.8
NuHorizon	White	78.5	71.9	67.9	78.9	72.7	69.0
OK101	Red	78.4	71.3	65.4	78.3	72.9	69.4
Stanton	Red	77.7	71.5	66.7	78.6	73.5	69.6
Thunderbolt	Red	78.2	72.7	66.7	79.1	74.0	70.1
Trego	White	79.3	72.0	65.9	78.7	72.6	68.5
LSD (.05)		1.3	1.0	1.5	1.3	NS	NS
	Red	78.4	71.8	65.8	79.0	73.2	69.8
	White	78.4	72.3	66.2	78.8	72.9	69.2
	LSD (.05)	NS	NS	NS	NS	NS	0.5

Table 8. Net energy for maintenance (Mcals per 100 lb of DM) by county and variety.							
		Clark County			Stanton County		
Variety	Color	12/31/03	3/19/04	4/29/04	12/30/03	3/25/04	5/4/04
2137	Red	77.3	68.0	59.0	77.3	69.0	64.5
Burchett	White	75.3	69.0	58.3	75.3	69.5	63.8
Jagalene	Red	78.5	68.5	59.8	79.0	69.8	65.8
Jagger	Red	74.8	66.0	58.3	76.8	68.8	64.8
Lakin	White	77.3	70.0	58.5	77.8	69.5	64.3
NuFrontier	White	75.0	67.3	61.8	77.0	68.5	64.3
NuHills	White	77.0	67.3	60.0	77.5	68.8	64.8
NuHorizon	White	76.5	67.8	62.5	77.0	68.8	63.8
OK101	Red	76.3	66.8	59.0	76.3	68.8	64.5
Stanton	Red	75.3	67.0	60.5	76.5	69.5	64.5
Thunderbolt	Red	76.0	68.5	60.5	77.5	70.5	65.0
Trego	White	77.5	67.8	59.5	76.5	68.5	63.3
LSD (.05)		1.7	1.3	2.0	1.5	NS	NS
	Red	76.3	67.5	59.5	77.2	69.4	64.8
	White	76.4	68.2	60.1	76.8	68.9	64.0
	LSD (.05)	NS	NS	NS	NS	NS	0.6

Table 9. Net energy for gain (Mcals per 100 lb of DM) by county and variety.							
		Clark County			Stanton County		
Variety	Color	12/31/03	3/19/04	4/29/04	12/30/03	3/25/04	5/4/04
2137	Red	54.3	44.0	34.3	54.5	45.0	40.3
Burchett	White	52.0	45.3	33.8	52.0	46.3	39.8
Jagalene	Red	55.8	44.8	35.3	56.3	46.3	41.5
Jagger	Red	51.3	42.3	33.8	53.8	45.0	40.8
Lakin	White	54.3	46.5	34.0	54.8	46.0	40.3
NuFrontier	White	52.0	43.8	37.8	54.0	44.8	40.3
NuHills	White	53.8	43.8	35.5	54.5	44.8	40.8
NuHorizon	White	53.3	43.8	38.3	54.3	45.0	39.8
OK101	Red	53.3	43.0	34.3	53.0	45.3	40.5
Stanton	Red	52.3	43.0	36.5	53.5	46.3	40.5
Thunderbolt	Red	53.0	44.8	36.3	54.5	47.0	41.3
Trego	White	54.5	44.0	34.8	53.5	44.8	38.8
LSD (.05)		2.0	1.5	2.1	1.8	NS	NS
	Red	53.3	43.6	35.0	54.4	45.8	40.8
	White	53.3	44.5	35.7	53.8	45.3	39.9
	LSD (.05)	NS	0.8	NS	NS	NS	0.7

Table 10. Relative feed value by county and variety.

Variety	Color	Clark County 12/31/03	Clark County 3/19/04	Clark County 4/29/04	Stanton County 12/30/03	Stanton County 3/25/04	Stanton County 5/4/04
2137	Red	169	149	100	162	163	123
Burchett	White	160	150	100	152	159	124
Jagalene	Red	181	151	105	175	162	127
Jagger	Red	157	138	98	153	154	123
Lakin	White	161	153	99	162	157	118
NuFrontier	White	154	143	109	160	151	121
NuHills	White	166	143	105	160	155	128
NuHorizon	White	167	146	111	167	151	120
OK101	Red	162	138	99	159	152	118
Stanton	Red	155	140	106	159	153	123
Thunderbolt	Red	154	147	104	161	160	124
Trego	White	171	147	101	162	152	117
LSD (.05)		8	7	6	9	NS	5
	Red	163	144	102	161	157	123
	White	163	147	104	160	154	121
	LSD (.05)	NS	NS	NS	NS	NS	NS

Table 11. Nitrate-nitrogen (ppm, 100% DM basis) by county and variety.

Variety	Color	Clark County 12/31/03	Clark County 3/19/04	Clark County 4/29/04	Stanton County 12/30/03	Stanton County 3/25/04	Stanton County 5/4/04
2137	Red	195	479	124	84	262	146
Burchett	White	202	347	105	122	502	357
Jagalene	Red	112	251	84	74	1,031	473
Jagger	Red	190	261	159	79	499	327
Lakin	White	152	83	44	83	436	315
NuFrontier	White	179	333	114	81	374	331
NuHills	White	154	526	141	87	432	377
NuHorizon	White	128	242	103	94	455	368
OK101	Red	174	298	85	75	442	220
Stanton	Red	135	353	147	74	496	423
Thunderbolt	Red	170	305	113	85	717	343
Trego	White	151	310	106	83	536	366
LSD (.05)		NS	NS	NS	21	232	NS
	Red	162	324	119	78	575	322
	White	161	307	102	91	456	352
	LSD (.05)	NS	NS	NS	10	NS	NS

EFFECT OF GRAZING ON GRAIN YIELD AND QUALITY OF TWELVE HARD RED AND WHITE WINTER WHEAT VARIETIES

by

Ron Hale, Curtis Thompson, Troy Dumler, Alan Schlegel, and Tim Herrman[1]

SUMMARY

Six hard red (2137, Jagalene, Jagger, OK101, Stanton, and Thunderbolt) and six hard white (Burchett, Lakin, NuFrontier, NuHills, NuHorizon, and Trego) winter wheat varieties were planted in two southwestern Kansas counties to evaluate grain yield and quality. A split-plot design was used with four grazed and four ungrazed plots of each variety in each county. Cattle were allowed to graze the wheat after it was well established and were removed before wheat began jointing. Grain was harvested from the grazed and ungrazed plots. Grazing did not influence grain yields in Stanton County. In Clark County, the yield of two varieties was improved with grazing, whereas the yield of two other varieties decreased. Test weight differed for grazing by variety in Clark County, but was not affected by grazing in Stanton County. Grazing reduced crude protein content in Clark County, but did not affect protein content in Stanton County. Grazing appeared to more significantly affect grain quality in Clark County than in Stanton County. Although variety differences occurred, they did not seem related to wheat color.

INTRODUCTION

The use of winter wheat as a source of forage for cattle can allow producers to more effectively and profitably utilize their land. Wheat provides economical, high-quality forage at a time of the year when few other comparable forages are available. Wheat can be used just as a forage source, or in a dual forage and grain program. Research has shown that grazing winter wheat can occur up to wheat jointing without reducing grain yield. An estimated 6 million acres of Kansas winter wheat may be grazed during a good forage-producing year. Although hard red winter wheat varieties dominate, it is anticipated that the use of hard white winter wheat will increase because of potential incentives associated with marketing, milling, and end use. This experiment examined the effect of grazing on grain yield and quality of six hard red and six hard white winter wheats.

PROCEDURES

Six hard white (Burchett, Lakin, NuFrontier, NuHills, NuHorizon, and Trego) and six hard red (2137, Jagalene, Jagger, OK101, Stanton, and Thunderbolt) winter wheats were planted in Clark and Stanton Counties. Sixty-five lb/a of nitrogen (N) was applied at Clark County and 80 lb N/a was applied at Stanton County before planting. On September 16, 2003, each variety was planted in 10-inch rows at a depth of approximately 1.75 inches. Planting rates were 90 lb seed/a at the dryland Clark County plots and 120 lb/a at the limit-irrigated Stanton County plots. Fertilizer (11 lb N and 52 lb P_2O_5 per acre) was applied with the seed. Soil type at both locations was a silt loam. A split-plot design used four ungrazed and four grazed plots for each variety at each location. The plots were located within the producers' wheat fields, where stocker cattle were allowed to graze after wheat was well rooted and had sufficient tillering. Cattle were removed from the plots before wheat jointing began. On March 26, 2004, liquid UAN was applied to the grazed wheat plots at 30 lb N/a. Grain was harvested in Clark County on June 4 and in Stanton County on July 3, 2004. Grain yield, moisture, and test weight were determined on the day of harvest. Stanton County samples were evaluated for sprouting because of the precipitation received prior to harvest (7.40 inches in June). The 200-kernel weight was also determined. Samples were sent to the KSU grain laboratory for measurement of kernel diameter, hardness, moisture, and 1000-kernel weight. These traits are part of the single kernel characterization system (SKCS) used to determine grain quality. Samples were also analyzed at the KSU soil laboratory for crude protein (CP) content.

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RESULTS AND DISCUSSION

In Clark County, statistical differences were seen among varieties for 200- and 1000-kernel weights (Table 4 and 5), and for CP content (Table 9). Grazing also affected these grain traits. The 200- and 1000-kernel weights were highly correlated (r^2 = .84, P<.0001). Crude protein was greatest for Jagger (17.4%), with the CP of other varieties ranging from 14.8 to 15.9%. Grain from grazed forage had less CP. Several interactions between grazing and wheat variety occurred in Clark County (Table 1). Grain yield of Jagger and Lakin increased with grazing, whereas yields for NuFrontier and NuHorizon decreased. The other eight varieties were unaffected by grazing. Greater moisture content was seen for six grazed varieties at harvest (Table 2) and for three grazed varieties when the SKCS characteristics (Table 8) were measured. Less variation was seen for the SKCS moisture than for the harvest moisture because the grain samples had time to equilibrate before testing. Clark County test weights (Table 3) were lighter when 2137, Jagalene, Jagger NuFrontier, NuHorizon, and OK101 were grazed. Although there was a tendency for kernel diameter (Table 6) of all varieties to be smaller when grazed, six varieties were significantly affected. Grazing increased kernel hardness (Table 7) of 2137 and Trego, reduced hardness of NuHorizon, but did not affect the other nine varieties in Clark County.

There were no interactions between grazing and wheat variety in Stanton County, but grazing did reduce 200- and 1000-kernel weights and kernel diameter. Although grain yield, test weight, and moisture were unaffected by grazing, variety differences did occur. Jagalene had the highest grain yield (45 bu/a), with the yield of other varieties ranging from 31 to 39 bu/a. Jagalene test weight (53.6 lb/bu) was also greater than that of the other varieties (47.7 to 52.8 lb/bu). Although harvest and SKCS moistures differed among varieties, SKCS moisture again had less variation because of equilibration. The 200- and 1000-kernel weights differed among the varieties and were closely related (r^2 = .67, P<.0001). Variety differences were seen for SKCS kernel hardness and diameter. Jagalene was harder than all other varieties and it had the largest kernel, although diameter did not differ from those of Burchett, Stanton, or Thunderbolt. Crude protein content of Stanton County wheat also differed among varieties, ranging from 15.9 to 17.7%, with no apparent differences between wheat colors.

Grain sprouting occurred in Stanton County because of continuous, heavy rainfall before harvest (Table 10). There was an interaction between grazing and wheat variety wherein grazing significantly reduced sprouting for NuFrontier, NuHills, and NuHorizon, but did not affect the other varieties. The white wheats were 3.5 times more susceptible to sprouting than were the red wheats.

Because of the rainfall before harvest, the quality of wheat from Stanton County was lower than the quality of Clark County grain, as indicated by test weight, 200-kernel weight, and the single-kernel characteristics. But CP was greater in Stanton County than in Clark County Grazing seemed to have more impact on grain, both positive and negative, in Clark County than in Stanton County Visual observation suggested that the forage in Clark County was more heavily grazed than forage in Stanton County was. Although there were equal numbers of white and red varieties in this study, they are not representative of all wheats, but were selected for their popularity or potential in southwestern Kansas. Other than sprouting, there do not seem to be any grain traits strongly related to wheat color.

Table 1. The effect of grazing on wheat variety grain yields (bu/a at 13% moisture).

		Clark County			Stanton County		
	Color	Not grazed	Grazed	Variety mean	Not grazed	Grazed	Variety mean
2137	Red	38	39	39	34	35	34
Burchett	White	33	35	34	40	35	38
Jagalene	Red	36	37	37	44	46	45
Jagger	Red	28	37	33	32	34	33
Lakin	White	35	42	39	36	32	34
NuFrontier	White	40	33	36	34	33	34
NuHills	White	35	41	38	36	35	36
NuHorizon	White	39	28	33	33	29	31
OK101	Red	31	35	33	32	30	31
Stanton	Red	32	38	35	43	35	39
Thunderbolt	Red	49	46	47	33	34	33
Trego	White	37	42	40	38	39	39
Grazing Means		36	38		36	35	
Grazing LSD (.05)		NS			NS		
Variety LSD (.05)				NS			5
Grazing x Variety LSD (.05)		6			NS		

Table 2. The effect of grazing on wheat variety grain moisture (%).

		Clark County			Stanton County		
	Color	Not grazed	Grazed	Variety mean	Not grazed	Grazed	Variety mean
2137	Red	9.6	10.0	9.8	9.4	9.5	9.4
Burchett	White	10.9	10.9	10.9	9.8	9.5	9.7
Jagalene	Red	9.9	10.5	10.2	9.7	9.8	9.7
Jagger	Red	9.4	9.6	9.5	9.2	9.3	9.2
Lakin	White	10.0	10.2	10.1	9.3	9.6	9.5
NuFrontier	White	10.2	10.8	10.5	8.7	8.9	8.8
NuHills	White	9.9	10.5	10.2	9.3	9.4	9.3
NuHorizon	White	10.4	11.2	10.8	8.5	8.9	8.7
OK101	Red	9.7	9.8	9.8	8.9	9.3	9.1
Stanton	Red	9.3	9.9	9.6	9.2	9.3	9.2
Thunderbolt	Red	10.0	10.2	10.1	9.6	10.1	9.8
Trego	White	10.2	10.4	10.3	9.5	9.2	9.3
Grazing Means		10.0	10.3		9.2	9.4	
Grazing LSD (.05)		NS			NS		
Variety LSD (.05)				NS			0.3
Grazing x Variety LSD (.05)		0.3			NS		

Table 3. The effect of grazing on wheat variety grain test weight (lb/bu).							
		Clark County			Stanton County		
	Color	Not grazed	Grazed	Variety mean	Not grazed	Grazed	Variety mean
2137	Red	60.3	59.7	60.0	49.5	50.6	50.0
Burchett	White	62.1	61.9	62.0	52.4	52.6	52.5
Jagalene	Red	62.9	62.1	62.5	53.5	53.8	53.6
Jagger	Red	61.7	61.0	61.3	49.1	49.2	49.2
Lakin	White	61.3	60.9	61.1	50.6	51.1	50.8
NuFrontier	White	60.8	59.5	60.2	47.7	48.1	47.9
NuHills	White	62.1	62.2	62.1	50.5	50.6	50.5
NuHorizon	White	61.3	58.4	59.8	47.2	48.1	47.7
OK101	Red	61.3	60.5	60.9	48.2	48.8	48.5
Stanton	Red	60.4	60.2	60.3	50.3	49.7	50.0
Thunderbolt	Red	61.8	61.5	61.7	52.6	53.0	52.8
Trego	White	61.8	61.4	61.6	51.3	50.5	50.9
Grazing Means		61.5	60.8		50.2	50.5	
Grazing LSD (.05)		NS			NS		
Variety LSD (.05)				NS			0.6
Grazing x Variety LSD (.05)		0.5			NS		

Table 4. The effect of grazing on wheat variety 200-kernel weight (gm).							
		Clark County			Stanton County		
	Color	Not grazed	Grazed	Variety mean	Not grazed	Grazed	Variety mean
2137	Red	5.93	5.50	5.71	4.53	4.75	4.64
Burchett	White	5.58	5.58	5.58	4.93	4.77	4.86
Jagalene	Red	6.15	5.78	5.96	5.23	5.35	5.29
Jagger	Red	5.88	5.70	5.79	4.50	4.38	4.44
Lakin	White	6.25	5.88	6.06	5.08	4.75	4.91
NuFrontier	White	5.15	4.60	4.88	4.03	3.90	3.96
NuHills	White	5.83	5.68	5.75	4.73	4.33	4.53
NuHorizon	White	4.65	4.20	4.43	4.08	3.98	4.03
OK101	Red	6.13	5.63	5.88	4.60	4.45	4.53
Stanton	Red	6.38	6.18	6.28	5.15	4.60	4.88
Thunderbolt	Red	5.88	5.63	5.75	4.83	4.75	4.79
Trego	White	6.45	5.85	6.15	5.05	4.63	4.84
Grazing Means		5.85	5.51		4.73	4.55	
Grazing LSD (.05)		0.12			0.09		
Variety LSD (.05)				0.29			0.24
Grazing x Variety LSD (.05)		NS			NS		

Table 5. The effect of grazing on wheat variety SKCS 1000-kernel weight (gm).							
		Clark County			Stanton County		
	Color	Not grazed	Grazed	Variety mean	Not grazed	Grazed	Variety mean
2137	Red	30.1	28.4	29.3	23.8	24.3	24.1
Burchett	White	28.9	27.8	28.3	25.6	24.7	25.3
Jagalene	Red	31.0	29.2	30.1	26.7	24.9	25.8
Jagger	Red	30.2	29.1	29.6	24.4	23.1	23.7
Lakin	White	30.9	29.4	30.1	25.2	25.1	25.2
NuFrontier	White	26.1	24.2	25.1	22.0	21.5	21.7
NuHills	White	30.1	28.4	29.3	24.9	23.5	24.2
NuHorizon	White	25.3	23.0	24.1	21.9	21.3	21.6
OK101	Red	31.0	29.1	30.1	24.5	23.4	24.0
Stanton	Red	31.9	31.3	31.6	26.5	23.4	25.0
Thunderbolt	Red	29.1	28.0	28.6	25.5	25.0	25.3
Trego	White	32.4	29.8	31.1	25.6	23.7	24.7
Grazing Means		29.7	28.1		24.7	23.7	
Grazing LSD (.05)		0.3			0.4		
Variety LSD (.05)				0.8			1.0
Grazing x Variety LSD (.05)		NS			NS		

Table 6. The effect of grazing on wheat variety SKCS kernel diameter* (mm).							
		Clark County			Stanton County		
	Color	Not grazed	Grazed	Variety mean	Not grazed	Grazed	Variety mean
2137	Red	2.35	2.27	2.31	2.06	2.07	2.06
Burchett	White	2.37	2.32	2.34	2.22	2.17	2.20
Jagalene	Red	2.49	2.42	2.45	2.31	2.22	2.27
Jagger	Red	2.41	2.38	2.40	2.16	2.08	2.12
Lakin	White	2.42	2.35	2.38	2.15	2.13	2.14
NuFrontier	White	2.19	2.07	2.13	1.99	1.97	1.98
NuHills	White	2.44	2.37	2.40	2.22	2.11	2.17
NuHorizon	White	2.21	1.99	2.10	2.01	1.98	1.99
OK101	Red	2.47	2.37	2.42	2.08	2.04	2.06
Stanton	Red	2.53	2.50	2.52	2.25	2.12	2.18
Thunderbolt	Red	2.39	2.31	2.35	2.22	2.20	2.21
Trego	White	2.53	2.38	2.45	2.15	2.08	2.11
Grazing Means		2.40	2.31		2.15	2.10	
Grazing LSD (.05)		NS			0.03		
Variety LSD (.05)				NS			0.09
Grazing x Variety LSD (.05)		0.07			NS		

* SKCS kernel diameter: <2.24 mm, small; ≥2.24 mm - ≤2.92 mm, medium; >2.92 mm, large.

Table 7. The effect of grazing on wheat variety SKCS kernel hardness index*.							
		Clark County			Stanton County		
	Color	Not grazed	Grazed	Variety mean	Not grazed	Grazed	Variety mean
2137	Red	65	68	66	49	50	50
Burchett	White	75	77	76	59	57	58
Jagalene	Red	79	81	80	67	66	67
Jagger	Red	80	79	80	62	60	61
Lakin	White	72	73	73	51	50	51
NuFrontier	White	73	73	73	50	50	50
NuHills	White	83	85	84	66	62	64
NuHorizon	White	81	73	77	52	53	52
OK101	Red	67	68	67	45	45	45
Stanton	Red	65	67	66	53	53	53
Thunderbolt	Red	72	72	72	54	53	54
Trego	White	70	73	72	55	55	55
Grazing Means		73	74		55	55	
Grazing LSD (.05)		NS			NS		
Variety LSD (.05)				NS			2
Grazing x Variety LSD (.05)		2			NS		

* SCKS hardness index: 40-49, medium soft; 50-64, medium hard; 65-79, hard; 80-89, very hard.

Table 8. The effect of grazing on wheat variety SKCS kernel moisture (%).							
		Clark County			Stanton County		
	Color	Not grazed	Grazed	Variety mean	Not grazed	Grazed	Variety mean
2137	Red	11.0	11.3	11.2	10.6	10.6	10.6
Burchett	White	11.0	11.1	11.0	10.8	10.7	10.7
Jagalene	Red	10.9	11.3	11.1	10.4	10.6	10.5
Jagger	Red	10.8	11.0	10.9	10.2	10.3	10.2
Lakin	White	11.3	11.3	11.3	10.5	10.7	10.6
NuFrontier	White	11.4	11.2	11.3	9.9	9.9	9.9
NuHills	White	10.9	11.4	11.1	10.2	10.2	10.2
NuHorizon	White	11.6	11.5	11.6	10.0	10.1	10.0
OK101	Red	11.0	11.1	11.1	10.4	10.5	10.5
Stanton	Red	10.7	11.3	11.0	10.7	10.5	10.6
Thunderbolt	Red	11.0	11.2	11.1	10.5	10.5	10.5
Trego	White	11.2	11.5	11.4	10.1	10.1	10.1
Grazing Means		11.1	11.3		10.3	10.4	
Grazing LSD (.05)		NS			NS		
Variety LSD (.05)				NS			0.3
Grazing x Variety LSD (.05)		0.3			NS		

Table 9. The effect of grazing on wheat variety grain crude protein content (% of DM).							
		Clark County			Stanton County		
	Color	Not grazed	Grazed	Variety mean	Not grazed	Grazed	Variety mean
2137	Red	15.6	14.8	15.2	16.8	15.7	16.2
Burchett	White	15.9	15.4	15.6	16.6	17.4	16.9
Jagalene	Red	15.2	14.4	14.8	17.2	16.6	16.9
Jagger	Red	17.9	16.9	17.4	17.8	17.6	17.7
Lakin	White	15.3	14.4	14.8	15.6	15.8	15.7
NuFrontier	White	15.0	15.1	15.1	16.7	16.8	16.7
NuHills	White	16.2	15.7	15.9	17.7	17.3	17.5
NuHorizon	White	14.9	15.7	15.3	16.7	16.9	16.8
OK101	Red	15.4	14.4	14.9	16.1	16.2	16.2
Stanton	Red	16.2	14.8	15.5	16.1	16.1	16.1
Thunderbolt	Red	16.0	14.7	15.4	18.3	17.2	17.7
Trego	White	15.7	14.7	15.2	16.4	15.3	15.9
Grazing Means		15.8	15.1		16.8	16.6	
Grazing LSD (.05)		0.3			NS		
Variety LSD (.05)				0.7			1.0
Grazing x Variety LSD (.05)		NS			NS		

Table 10. The effect of grazing and wheat color variety on sprouted kernels (%) in Stanton County.				
	Color	Not grazed	Grazed	Variety mean
2137	Red	8	10	9
Burchett	White	21	21	21
Jagalene	Red	7	9	8
Jagger	Red	18	15	17
Lakin	White	52	50	51
NuFrontier	White	62	58	60
NuHills	White	38	31	35
NuHorizon	White	78	64	71
OK101	Red	18	18	18
Stanton	Red	28	24	26
Thunderbolt	Red	9	8	9
Trego	White	51	50	50
Grazing Means		33	30	
Grazing LSD (.05)			NS	
Variety LSD (.05)				NS
Grazing x Variety LSD (.05)			5	
Color Means	Red	14	White	49
Color LSD (.05)		2		

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