SKIP-ROW CONFIGURATION AND PLANT DENSITY EFFECTS ON SORGHUM GRAIN YIELD AND YIELD COMPONENT IN SOUTHERN NEBRASKA

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Abstract

Equal spacing of sorghum rows typically results in the highest grain yield when soil water is adequate throughout the season, but skip-row planting may be a means to reduce water deficits during reproductive growth stages. We evaluated the effect of skip-row planting configuration and plant population density on grain yield, yield components and water use efficiency at five locations in a transect across southern Nebraska where annual mean precipitation ranges from 300 to 900 mm yr^{-1}. Three row configurations including all rows planted (s0), alternate rows planted (s1), and two rows planted alternated with two skipped rows (s2) were evaluated in a complete factorial with two plant population densities. Soil water was measured to 120 cm depth biweekly with a neutron probe. Grain yield was reduced by 20 to 30% with s1 and s2 compared to s0 at the site with greatest precipitation. At a site with moderate precipitation, grain yield was reduced by 18% with s2 and was not affected with s1. At sites with significant soil water deficits, grain yield increases with s1 and s2 ranged between 5 and 123% over s0. Skip row planting significantly increased the harvest index at all five sites while yield per panicle was significantly increased at the medium and low rainfall sites. Water use efficiency was highest with skip-row planting at sites where the mean monthly growing season precipitation ranged between 49 and 63 mm but lowest at sites where the mean monthly precipitation was between 75 and 79 mm.

Introduction

With reoccurring drought conditions in Nebraska, crop producers are seeking profitable alternative production systems. Skip-row planting is one strategy which has been suggested to use soil water more efficiently (McLean et al., 2003; Routley et al., 2003), but has not been evaluated for sorghum production in Nebraska. In seasons with low rainfall, soil water reserves are often depleted by the time of crop flowering and low yields or total crop failure can result. Soil water conserved by skip-row planting in the inter-row area during the early stages of crop growth can be utilized during reproductive stages when there is low in-season precipitation. This may reduce the risk of total crop failure due to soil water deficits, improve harvest index and increase grain yield. Skip-row planting is expected to be most effective where soil water is adequate for the crop to reach the early reproductive stage without significant water deficit stress as the stored soil water will be available for use during flowering and grain fill. Depending on the timing and severity of stress, yield components, include grain size, grains per panicle and panicle number are affected with an ultimate effect on harvest index (Thomas et al 1981).

We hypothesized that changing plant population density and row spacing affects soil water availability, water use efficiency as well as grain yield and yield components. The objectives of this study were to determine planting practices to improve grain sorghum productivity in western Nebraska where inadequate precipitation often severely reduces rainfed crop yield.

Materials and Methods

In 2006, field studies were conducted in five counties across southern Nebraska (Fig. 1). Soil series, rainfall, production practices, and planting densities varied across locations (Table 1). We evaluated three planting row configurations and plant densities in a complete factorial. Row configurations included all rows planted with base 76-cm row spacing (s0) and two skip row configurations: alternate rows planted (s1), and two rows planted alternated with two skipped rows (s2). At Clay County, a relatively high rainfall site, seeding rates were 75,000 and 150,000 seeds ha^{-1}, while at the four other lower rainfall sites seeding rates were 50,000 and 100,000 seeds ha^{-1}. Medium maturing sorghum cv. Dekalb 42-20 was planted at Clay County and Dekalb 23-20 (Monsanto Co., USA) was planted at the Gosper, Frontier, Hayes and Cheyenne County sites. Nitrogen fertilization at each site was based on the University of Nebraska recommendation for the crop. At each of the five sites, a randomized complete block design with four replications was used. Volumetric soil water content was measured beginning two or three weeks after sowing until maturity using neutron probe readings at depths of 30, 60, 90 and 120 cm. Grain yield was determined from 60.8 m^2 of harvested area and standardized at 135 g kg^{-1} water content. Grain weight per panicle and harvest index was determined by threshing heads from 1 m of row. Cumulative water use (CWU, mm) was calculated at maturity as: CWU = SWC (soil water content at the first post sowing measurement) – SWC at maturity + rainfall. Water use efficiency (WUE, kg ha^{-1} mm^{-1}) was calculated as: WUE = CWU/grain yield

Results and Discussion

From Jan. to Sep. 2006, Clay and Gosper Counties had higher total precipitation than the long-term average precipitation. On the other hand Cheyenne, Hayes and Frontier Counties had lower precipitation than the long-term average (Table 1). As a result of timely rainfall at Clay County, SWC remained consistently high throughout the growing season in both s0 and s1, and SWC in s2 was significantly higher than s0 throughout the growing season (Fig. 2a). At the Cheyenne Co. site, SWC was highest at 23 DAP and was not affected by row configurations at this growth stage (Fig. 2b). The effect of row configuration on soil water availability became evident as the growing season progressed and crop water uptake increased. From 36 DAP to the end of the growing season, conventional planting had significantly lower SWC compared with skip-row planting (Fig. 2b). At Hayes County, there was adequate soil water at 30 DAP due to good rainfall in June. Soil water was less at 55 DAP and later in s0 and s1 compared to s2 (Fig. 3). At Frontier County, s2 had significantly higher SWC than s1 and s0 throughout the growing season (Fig. 3). Though total precipitation during the period was lower than the long-term average, it was well distributed during the growing season (data not presented). Planting pattern did not affect SWC in Gosper County where rainfall was above average and well-distributed (Table 1, Fig. 3).

Sorghum Grain Yield and Yield Components

At Cheyenne, Hayes and Frontier counties, skip row configurations (s1 and s2) had higher grain yield than s0 (Fig. 4). However, differences in grain yield between s1 and s2 were significant only at Hayes County. In these water deficit environments, grain yield increase of skip-row over conventional planting ranged between 5 and 123%. Our results confirm findings of other studies which showed the grain yield advantage of skip-row planting of sorghum and corn over conventional planting under severe water deficit conditions (Holland and McNamara, 1982; Routley et al., 2002; Collins et al. 2006, Klein, 2006). The rationale for skip-row configuration is to improve yield by delaying utilization of soil water in the center of the skip area until the grain filling stage. This may be responsible for the higher grain yield with skip-planting in the drier environments.

Routley et al (2002) found that the soil water extraction front (the limit of the area where roots are extracting soil water) extended from the base of the plant at a rate of approximately 2 cm per day in all directions. Assuming this rate of root extension and a row spacing of 76-cm, roots meet the roots of the other row with s0, s1 and s2 at 38, 76 and 114 cm, respectively. Days of growth required to fully exploit soil water near the soil surface and at 120 cm depth are respectively 19 and 63 for s0, 38 and 71 for s1, and 57 and 82 for s2. With inadequate precipitation, conventional planting is expected to deplete soil water earlier than with skip-row planting. The lower yield with s0 in the drier environments is attributed primarily to less available soil water during the reproductive stages of crop growth.

At the Gosper Co. site with moderate precipitation, grain yield was reduced by 18% with s2 and not affected with s1. At Clay County, grain yield was reduced by 20 to 30% with s1 and s2 compared to s0 (Fig. 3). In high and medium rainfall environments, potential yield can be significantly reduced when using wider rows due to the inability of the plant canopy to completely cover the ground area and efficiently utilize all the available resources (Myers and Foale, 1981).

The effect of different plant population density on sorghum grain yield was not consistent across sites. At Clay, Cheyenne and Hayes Counties, grain yield was greater with the higher plant population, while the reverse was observed at Frontier and Gosper (Fig. 5). Sorghum can produce tillers to compensate for lower population, but the number of productive tillers is influenced by soil water availability. Thus in high rainfall sites the higher population had adequate moisture to out-perform productive tillers in the lower population. On the other hand, in a drier environment, tillers may suffer from water stress as observed at Cheyenne and Hayes Co. sites (Fig. 5).

Considering the effects of planting configuration on yield across locations and rainfall regimes, there is an indication of a crossover at about 4 Mg ha^{-1}, with conventional planting outperforming skip-row planting when average yield was above 4 Mg ha^{-1} (Fig. 6). However, due to limited data in this range it is difficult to precisely determine a yield value below which skip row configuration will be superior to conventional spacing. Similar trends have been observed elsewhere but at lower crossover values (Collins et el., 2006; Routley et al., 2003).

Harvest index (HI) across locations ranged between 0.123 and 0.528. Row configuration significantly influenced HI at all sites. In general skip-row planting had significantly higher HI than conventional planting, suggesting better conversion of accumulated biomass to grain yield. This may be due to improved water availability during the grain filling stage.

Thomas et al. (1981) reported that moisture stress at flowering and grain filling stage significantly affects the yield components of sorghum. With the exception of Clay County, skip row planted sorghum had higher grain yield per panicle than conventional planting (Table 2).

Water Use Efficiency

At physiological maturity, row configuration significantly influenced cumulative water use (CWU) at Cheyenne and Frontier Counties. At Cheyenne County, CWU was in the order of s0>s1>s2, but the order at Gosper and Clay County was s2>s1>s0 and s2>s0, respectively.

Water use efficiency (WUE) was significantly influenced by row configuration at all counties except Gosper. At Cheyenne, Hayes and Frontier Counties, the-skip configuration had significantly higher WUE than the conventional planting. At Clay County, s0 had significantly higher CWU and WUE than s2 (Table 2). The difference in WUE between s1 and s2 were not significant at all sites and the pattern was not consistent (Table 2). The higher water use efficiency in the drier environment in skip planting could be attributed to the availability of the stored water in the skipped area during flowering and grain filling stage (Blum and Naveh, 1976).

References

Blum, A, and Naveh, M. (1976)-Improved water-use efficiency in dry land grain sorghum by promoted plant competition. *Agronomy Journal* 68: 111-116.

Collins, R., Buck, S., Reid D., and Spackman, G. 2006. Manipulating row spacing to improve yield reliability of grain sorghum in central Queensland. Proceedings of the Australian Agronomy Conference, Australian Society of Agronomy.

Holland, J.F. and Mcnamara, D.W. (1982). Weed control and row spacing in dry land sorghum in northern New South Wales. Aust. J. Exp. Agric. Anim. Husb., 22, 310-316.

Klein, R.N., J.A. Golus, D. Baltensperger, R. Elmore, S. Knezevic, D. Lyon, S. Mason, L. Nelson, A. Pavlista, A.J. Schegel, C. Shapiro, and M. Vigil. 2005. Skip-Row Corn for Improved Drought Tolerance in Rainfed Corn. The ASA-CSSA-SSSA International Annual Meetings (November 6-10, 2005)

McLean, G., Whish, J., Routley, R.A., Broad, I., and Hammer, G. 2003. The effect of row configuration on yield reliability in grain sorghum: II. Yield, water use efficiency and soil water extraction. Proceedings of the 11th Australian Agron. Conf. Geelong. Aust. Soc. Agron.

Myers, R.J.K. and Foale, M.A. (1981). Row spacing and population density in grain sorghum – a simple analysis. *Field Crops* Research 4:146 – 154.

Routley, R., Broad, I., McLean, G., Whish, J. and Hammer, G. (2003). The effect of row configuration on yield reliability in grain sorghum: 1. Yield, water use efficiency and soil water extraction. In Proceedings of the 11th Australian Agronomy conference, Geelong, Victoria. (The Australian Society of Agronomy). sorghum – a simple analysis. *Field Crops*

Research 4:146 – 154.
Thomas, G. A., French, A. V., Ladewig, J. H. and Lather, C. J. 1981. Aust. J. Expt. Agric. Anim. Husb., 21, 210 – 217.

Table 1. Soil series, taxonomic classes, agronomic data and rainfall at each study site.

County	Clay	Gosper	Frontier	Hayes	Cheyenne
Soil series	Crete silt loam	Holdrege silt loam	Hall silt loam	Kuma silt loam	Duroc loam
Taxonomic class	fine, smectitic, mesic Pachic Arguistolls	Fine-silty, mixed, superactive, mesic Typic Argiustolls	Fine-silty, mixed, superactive, mesic Pachic Arguisolls	Fine-silty, mixed, superactive, mesic Pachic Arguisolls	Fine-silty, mixed, superactive, mesic Pachic Haplustolls
Variety planted	Dekalb 42-20	Dekalb 23-20	Dekalb 23-20	Dekalb 23-20	Dekalb 23-20
Plant population	75,000/ha 150,000/ha	50,000/ha 100,000/ha	50,000/ha 100,000/ha	50,000/ha 100,000/ha	50,000/ha 100,000/ha
Plant date	June 7, 2006	May 16, 2006	May 23, 2006	May 24, 2006	June 1, 2006
Harvesting date	Oct. 25, 2007	Oct. 31, 2006	Oct. 31, 2006	Nov. 1, 2006	Oct. 17, 2006
Jan-Sept. 2006 rainfall (mm)	596.9	508.0	358.1	394.4	311.7
Jan-Sept long term average rainfall (mm)	591.3	489.5	461.8	450.6	421.9

Table 2. Effect of row configuration on grain sorghum yield per panicle, harvest index and water use at physiological maturity at the five Counties. Values followed by different letter are significantly different at probability of 0.05 or less.

County	Row Configuration	Grain yield per panicle (g)	Harvest Index	Cumulative water use (mm)	Water use efficiency (kg ha^{-1} mm^{-1})
Cheyenne	s0†	49.84 a	0.478 a	152.56 a	19.49 a
	s1	60.76 b	0.528 b	151.72 b	21.43 b
	s2	55.82 ab	0.518 b	149.56 c	20.82 b
Hayes	s0	18.32 a	0.123 a	211.16 a	5.04 a
	s1	22.64 a	0.180 a	212.63 a	9.48 b
	s2	32.57 b	0.284 b	212.15 a	11.22 b
Frontier	s0	21.11 a	0.293 a	207.68 a	17.36 a
	s1	35.70 b	0.393 b	208.85 ab	22.72 b
	s2	32.70 b	0.395 b	209.91 b	22.89 b
Gosper	s0	28.42 a	0.186 a	271.20 a	13.63 a
	s1	29.16 a	0.269 b	277.52 a	13.27 a
	s2	29.93 a	0.294 b	274.75 a	10.97 a
Clay	s0	56.05 a	0.386 a	400.67 a	27.25 a
	s1	55.62 a	0.408 b	-	-
	s2	56.96 a	0.400 b	371.48 b	16.99 b

† s0, (plant all rows), s1 (plant 1 skip 1) and s2 (plant 2 skip 2)

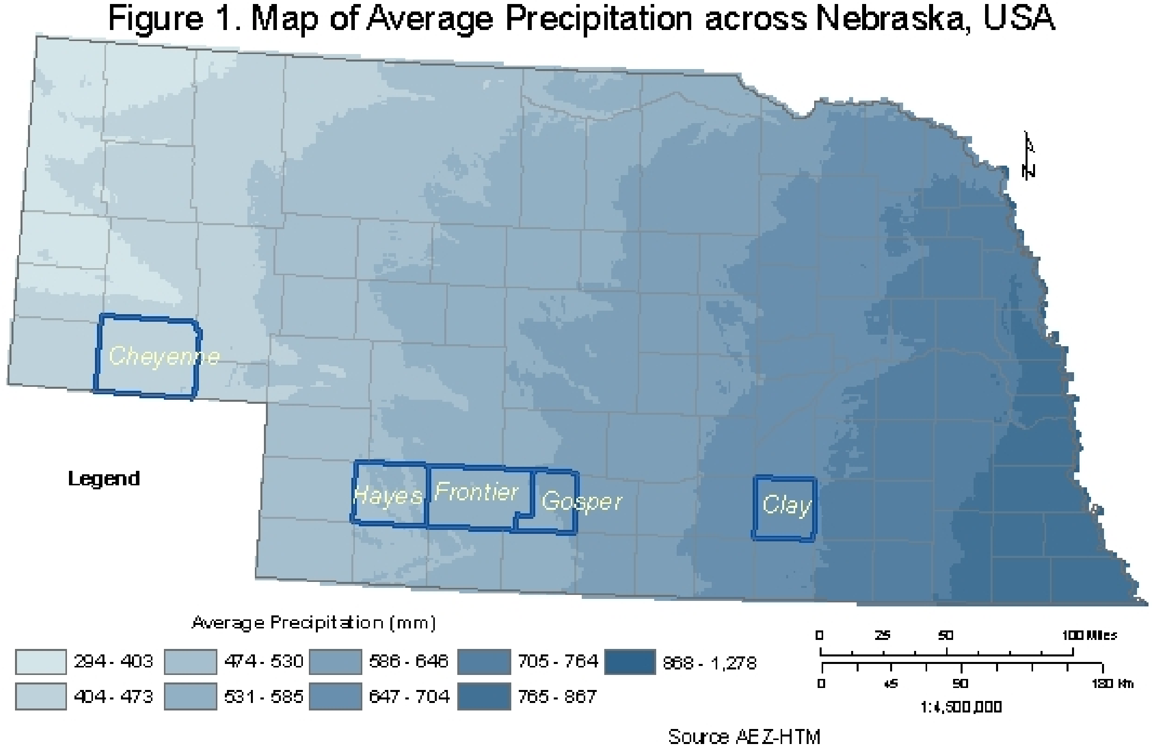

Figure 1. Map of Average Precipitation across Nebraska, USA

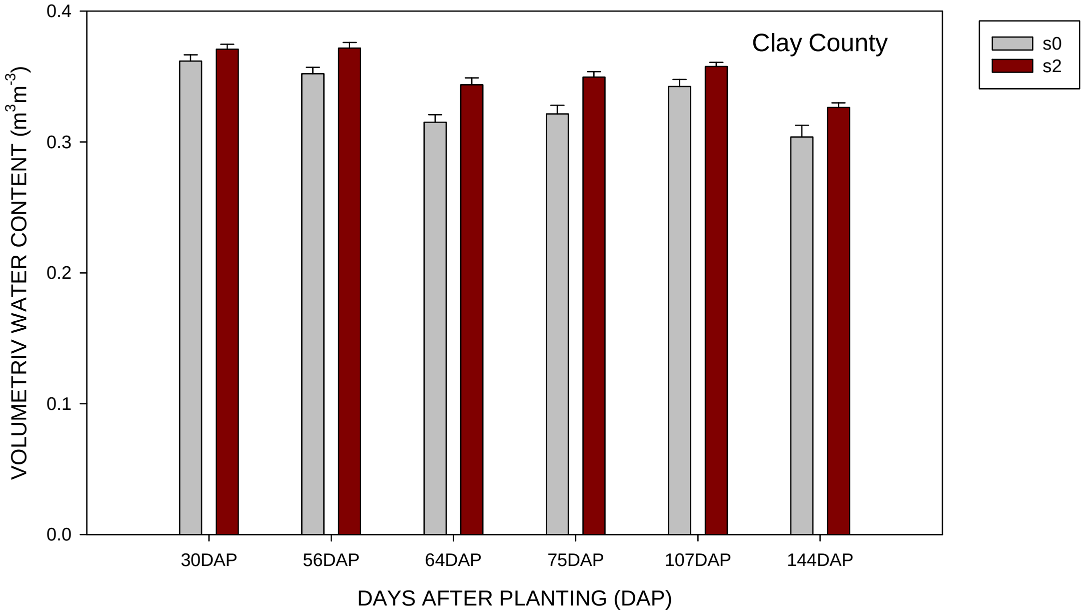

Figure 2a. Effect of row configuration on soil volumetric water content in sorghum production at Clay County. s0 (plant all rows), s1 (plant 1 skip 1) and s2 (plant 2 skip 2). LSD bars that do not overlap indicate treatment means that are significantly different at a probability of 0.05 or less

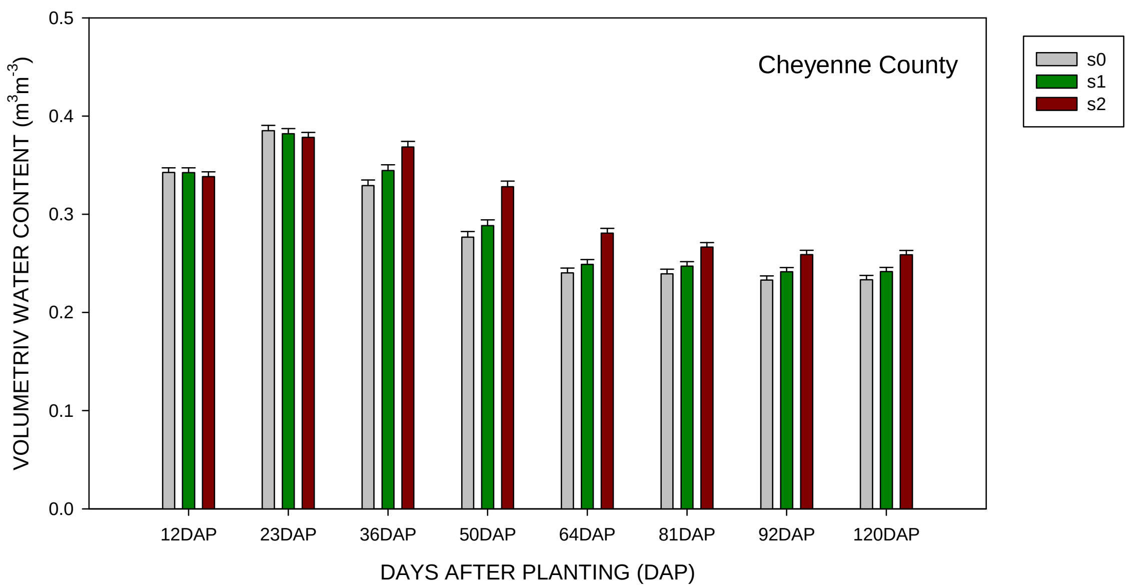

Figure 2b. Effect of row configuration on soil volumetric water content in sorghum production at Cheyenne County. s0 (plant all rows), s1 (plant 1 skip 1) and s2 (plant 2 skip 2). LSD bars that do not overlap indicate treatment means that are significantly different at a probability of 0.05 or less

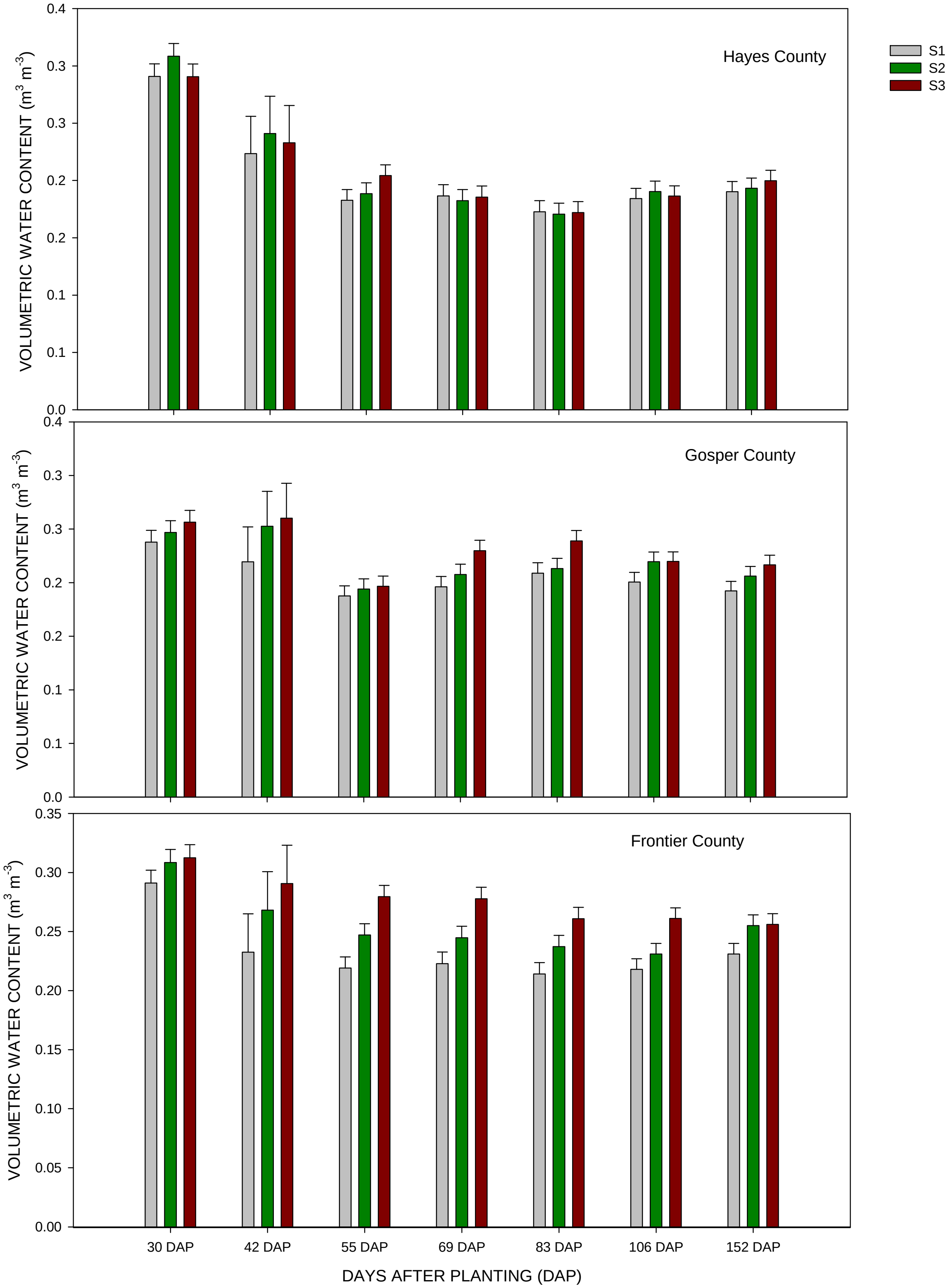

Figure 3. Effect of row configuration on soil volumetric water content in sorghum production at Hayes, Gosper and Frontier Counties. s0 (plant all rows), s1 (plant 1 skip 1) and s2 (plant 2 skip 2). LSD bars that do not overlap indicate treatment means that are significantly different at a probability of 0.05 or less

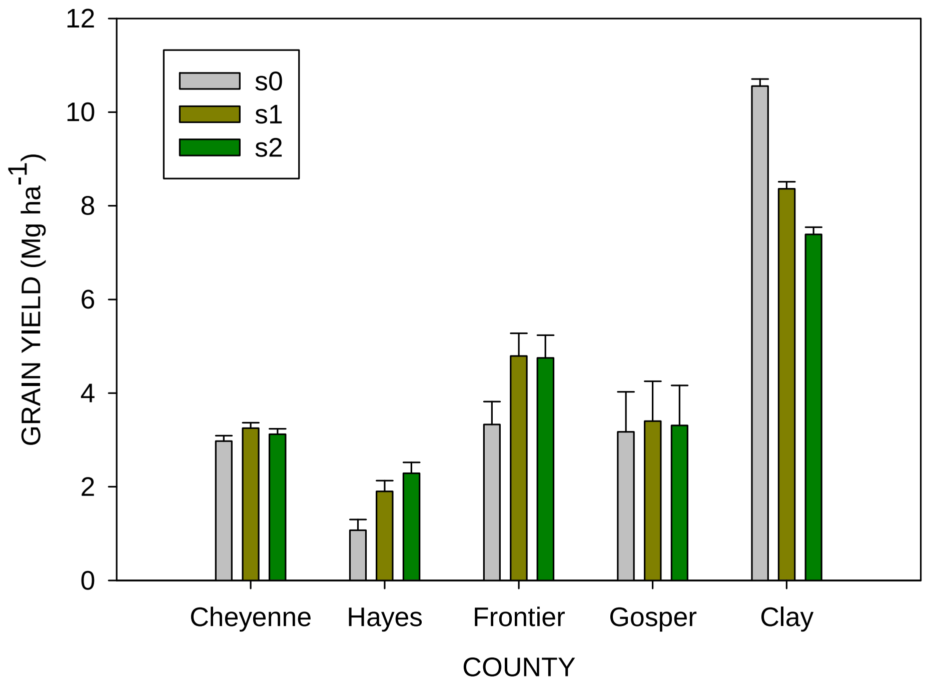

Figure 4. Effect of row configuration at each of the five sites. LSD bars that do not overlap indicate treatment means that are significantly different at a probability of 0.05 or less

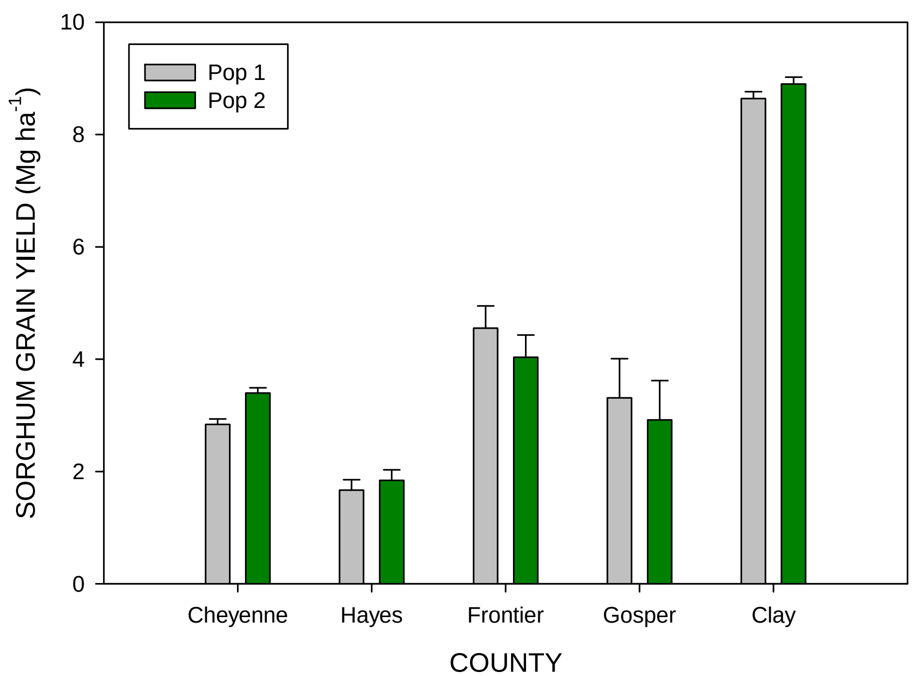

Figure 5. Effect of row configuration at each of the five sites on sorghum grain yield. LSD bars that do not overlap indicate treatment means that are significantly different at a probability of 0.05 or less

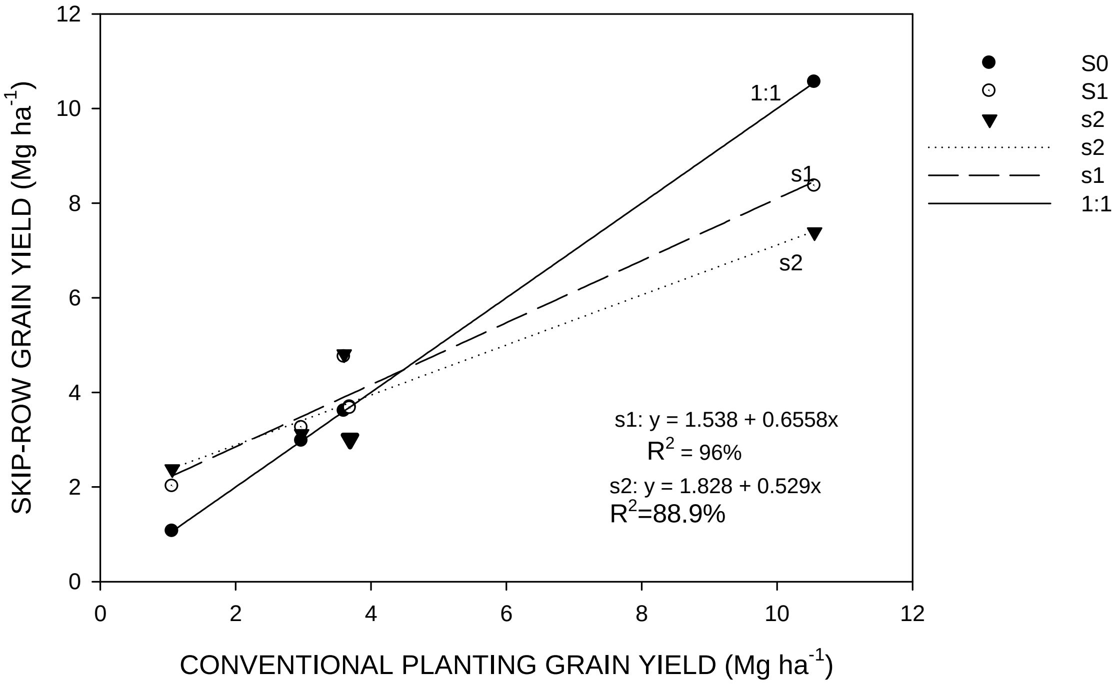

Figure 6. Relationship between conventional and skip-row planted grain yield in five counties across southern Nebraska

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