SORGHUM GRAIN YIELD AND YIELD COMPONENT UNDER DIFFERENT SKIP-ROW CONFIGURATION AND PLANT DENSITY IN NEBRASKA

Akwasi Abunyewa[1], Richard Ferguson[1], Charles Wortmann[1], Drew Lyon[2] and Steve Mason[1]
[1]University of Nebraska-Lincoln, Department of Agronomy & Horticulture, South Central Agricultural Laboratory and [2]High Plains Agricultural Laboratory

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. A two year field study was conducted to evaluate the effect of skip-row configuration and plant population density on grain yield and yield components in a transect across 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 1200 mm or 1800 mm depth biweekly with a neutron probe. In both years, loss in grain yield due to skip configuration ranged from 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 significantly affected with s1 in both years. At sites with significant soil water deficits, grain yield increased with s1 and s2 ranging between 5 and 123% over s0 in 2006 but suffered yield loss in 2007 due to adequate soil moisture. Considering yield across all sites in both years, there is an indication of crossover at 4.5 Mg ha^{-1}, with conventional planting outperforming skip row configuration when average yield was above 4.5 Mg ha^{-1}. In both years skip row planting improved the grain yield per panicle and harvest index markedly compared to conventional planting.

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 stored 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 rain fed crop yield.

MATERIALS AND METHODS

A study was conducted in seven counties across southern Nebraska in 2006 and 2007, with a total of nine site/years. Soil series, rainfall, production practices, and two planting densities varied across locations. We evaluated three planting configurations and two plant population densities in a complete factorial design. 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 six other lower rainfall counties 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 28-29 (Monsanto Co., USA) was planted at the McCook, North Platte, Gosper, Frontier, Hayes and Cheyenne County sites. Fertilizer application was based on the University of Nebraska recommendation for the crop and soil nutrient content before planting at each site. A randomized complete block design with four replications was used at each site. Access tubes were installed in the center of each skip treatment and volumetric soil water content was measured beginning two or three weeks after sowing until maturity, using a neutron probe at depths of 300, 600, 900, 1200 mm and to the depth of 1500 mm at McCook and North Platte. 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 hand harvesting panicles and above ground biomass from 1 m row and the panicles were mechanically threshed.

RESULTS AND DISCUSSION

From Jan. to Sept. 2006, Clay and Gosper Counties had higher total precipitation than the long-term average precipitation for the sites. On the other hand Cheyenne, Hayes and Frontier Counties had lower precipitation than the long-term average. In 2007, all the sites had higher total precipitation than the long term mean precipitation over the same period of time (Data not shown).

In 2006 skip row configurations (s1 and s2) had higher grain yield than s0 at Cheyenne, Hayes and Frontier counties (Fig. 1). 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 stored 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. In 2007 due to higher than long term average precipitation (data not shown) at Cheyenne and Lincoln counties, conventional planting significantly out yielded skip row planting (Fig. 2). This is attributed to adequate soil moisture at critical stages of the crop growth period.

At Gosper and Red Willow counties, sites with moderate precipitation, grain yield was reduced by 18% with s2 and not affected significantly with s1 in both years. At Clay County, grain yield was reduced by 20 to 30% with s1 and s2 compared to s0 in 2006 and 2007. In both years s1 significantly out yielded s2 in the high yielding environment (Figs. 1 and 2). In high and medium rainfall environments, yield potential 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 in both years. At Clay, Cheyenne and Hayes Counties, grain yield was greater with the higher plant population in 2006, while the reverse was observed at Frontier and Gosper counties (Fig. 3). In 2007, yield difference between the population densities was significant only at Clay Co. (Fig. 4). 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 in 2006. In 2007 the tillers at low population density would have adequate moisture due to high in season precipitation to produce grains.

Considering the effects of planting configuration on yield across locations and rainfall regimes, there is an indication of a crossover at 4.5 Mg ha^{-1}, with conventional planting outperforming skip-row planting when the average yield was above 4.5 Mg ha^{-1} (Fig. 5). 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).

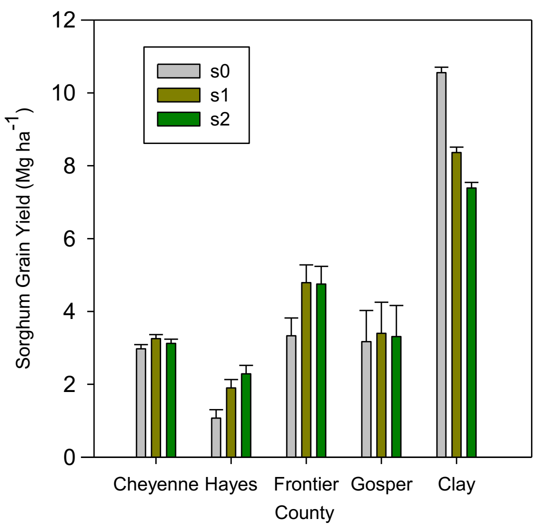

Figure 1. Effect of row configuration on grain sorghum yield at five counties in 2006. LSD bars that do not overlap indicate treatment means that are significantly different at a probability of 0.05 or less

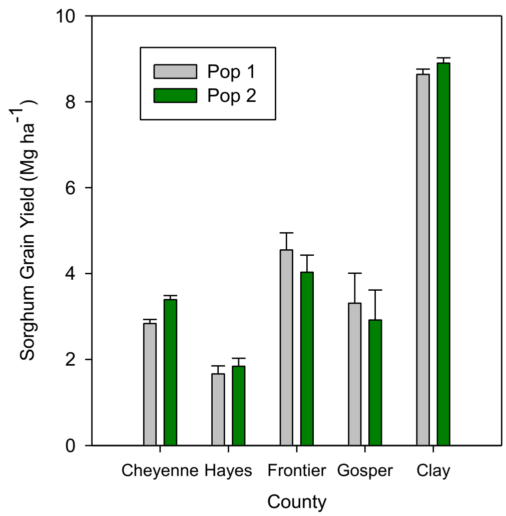

Figure 3. Effect of plant population density on grain sorghum yield in five counties in 2006 . LSD bars that do not overlap indicate treatment means that are significantly different at a probability of 0.05 or less

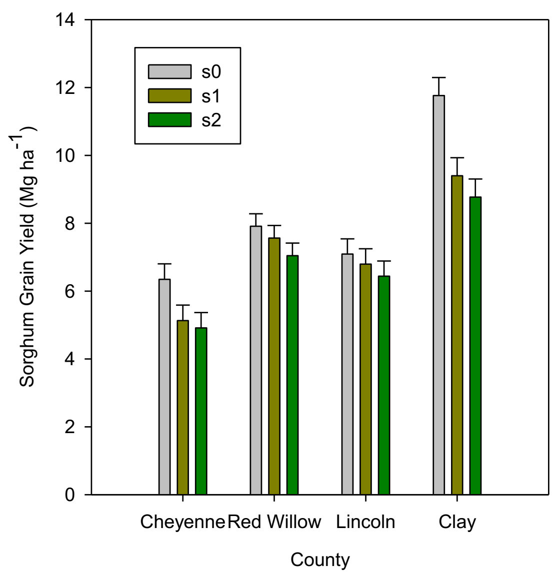

Figure 2. Effect of row configuration on grain sorghum yield at four counties in 2007. LSD bars that do not overlap indicate treatment means that are significantly different at a probability of 0.05 or less

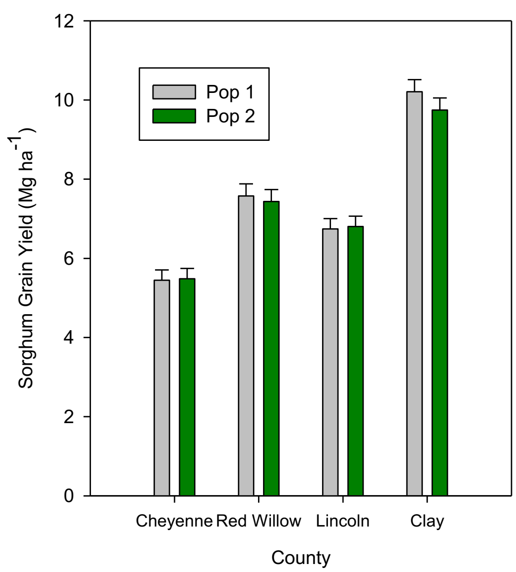

Figure 4. Effect of plant population density on grain sorghum yield at five counties in 2006. LSD bars that do not overlap indicate treatment means that are significantly different at a probability of 0.05 or less

The effect of skip row configuration on grain yield per panicle was more pronounced in the medium and low rainfall sites in 2006 (Table 1). In the high yielding environment and due to the high amount of precipitation at all sites in 2007 during the growing season, skip row configuration had no marked effect on yield in normally drier environments such as Cheyenne Co., North Platte or McCook.

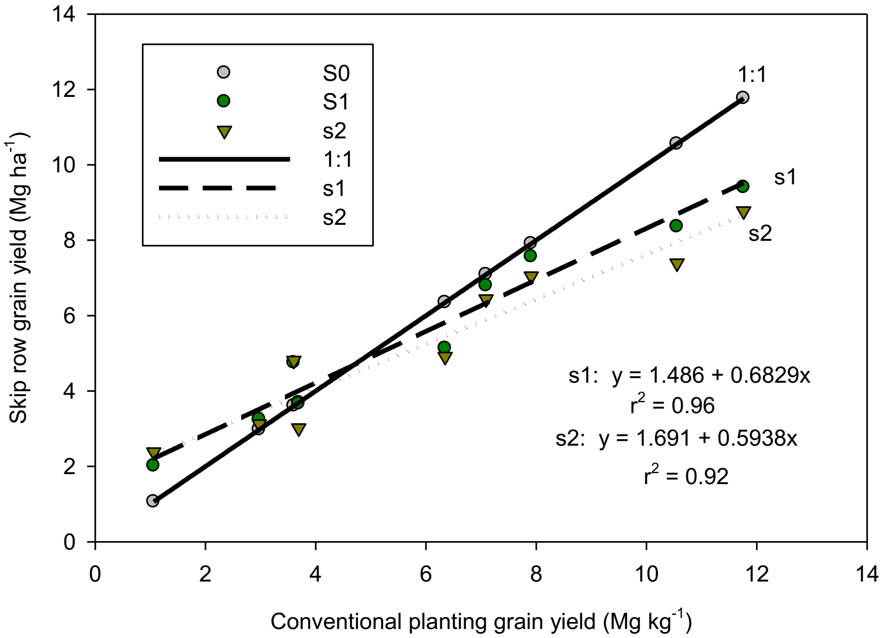

Figure 5. Relationship between grain yield on conventional and skip row planting in a 9-site year study in Nebraska

Harvest index (HI) across locations ranged between 0.123 and 0.615. Row configuration significantly influenced HI at all sites (Table 1). In general skip-row planting had significantly higher HI than conventional planting, suggesting more efficient partitioning of synthesized carbohydrate to the grain. 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 1).

Table 1. Effect of row configuration on sorghum grain yield per panicle, harvest index and kernel weight in nine-site years in transect across Nebraska. Values followed by different letter are significantly different at probability of 0.05 or less.

County	Row Configuration	Grain yield per panicle (g) 2006	2007	HI‡ 2006	2007	100 kernel weight (g) 2006	2007
Cheyenne	s0†	49.84 b	45.51 a	0.478 b	0.615 a	1.948 a	2.779 a
	s1	60.76 a	51.35 a	0.528 a	0.611 a	2.088 a	2.799 a
	s2	55.82 ab	49.13a	0.518 b	0.581 a	2.043 a	2.786 a
Hayes	s0	18.32 b	-	0.123 b	-	2.698 a	-
	s1	22.64 b	-	0.180 b	-	2.830 a	-
	s2	32.57 a	-	0.284 a	-	2.720 a	-
Frontier	s0	21.11 b	-	0.293 b	-	2.947 a	-
	s1	35.70 a	-	0.393 a	-	3.032 a	-
	s2	32.70 a	-	0.395 a	-	3.063 a	-
Gosper	s0	28.42 a	-	0.186 b	-	2.669 a	-
	s1	29.16 a	-	0.269 a	-	2.801 a	-
	s2	29.93 a	-	0.294 a	-	2.876 a	-
Clay	s0	39.41 a	37.06 b	0.386 b	0.481 b	3.060 b	2.552 b
	s1	40.15 a	44.81 a	0.408 a	0.486 b	3.178 a	2.722 a
	s2	40.84 a	41.080 a	0.400 a	0.541 a	3.077 b	2.734 a
McCook	s0	-	54..20 a	-	0.398 a	-	2.923 a
	s1	-	60.61 a	-	0.401 a	-	2.821 a
	s2	-	56.21 a	-	0.400 a	-	2.780 a
North	s0	-	32.06 b	-	0.403 a	-	2.575 b
Platte	s1	-	60.69 a	-	0.398 a	-	2.605 ab
	s2	-	63.03 a	-	0.418 a	-	2.772 a

† s0, (plant all rows), s1 (plant 1 skip 1) and s2 (plant 2 skip 2). ‡ HI, (Harvest index),

CONCLUSION

This study was conducted across southern Nebraska to evaluate the effect of skip row configuration and plant population density on grain sorghum yield. At highest rainfall site, yield loss between 20 and 30% over conventional was observed with skip-row planting. At the lowest rainfall sites, skip-row out-yielded conventional planting by 5 to more than 100% in 2006. However, in the second year of the study, with higher than average precipitation at the various study sites, there were yield losses due to skip row planting, especially with the plant 2/skip 2 configuration. Skip-row significantly improved harvest index and grain yield per panicle at medium and low rainfall sites. Below the average yield level of 4.5 Mg ha^{-1}, skip-row planting out-yielded conventional planting, while conventional planting outperformed skip-row planting when the average yield was above 4.5 Mg ha^{-1}.

ACKNOWLEDGEMENT

The authors wish to gratefully acknowledge the partial financial support from the International Sorghum/Millet Collaborative Research Support Program (INTSORMIL).

REFERENCES

Blum, A, and Naveh, M. (1976). Improved water-use efficiency in dry land grain sorghum by promoted plant competition. Agron. J. 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**.,** Golus, J. A., Baltensperger, D., Elmore, R., Knezevic, S., Lyon, D., Mason, S, Nelson, L., Pavlista, A Schegel, J. Shapiro, C and Vigil. M. (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.