Growing Dryland Crops In Clumps To Conserve Water

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Dryland crop production in the semiarid Southern Great Plains is highly dependent on stored soil water to supplement growing season precipitation. Grain sorghum (*Sorghum bicolor* L. Moench) is a major dryland crop in the region. Stored water and precipitation generally support early-season growth but are insufficient to prevent water stress during critical latter growth stages. Several studies have been conducted to test the hypothesis that growing grain sorghum in clumps of four plants spaced 75 cm apart in 75 cm rows will reduce tiller formation and early season vegetative growth to allow more water for use during the grain filling period. Past studies at Bushland, TX and Tribune, KS showed that grain sorghum grown in clumps, compared to the same number of normally spaced plants, increased grain yield as much as 100% when yields were in the 1000 kg ha $^{-1}$ range and 25 to 50% in the 2000 to 3000 kg ha $^{-1}$ range, but there was no increase or even a small decrease at yields above 5000 kg ha $^{-1}$. In 2006, additional grain sorghum trials and a corn (Zea mays) trial were conducted at Bushland, TX.

INTRODUCTION

The southern High Plains is a hostile environment for growing crops without irrigation. Although the region is classified as semiarid, much of it is very close to being arid. The aridity index (Stewart, 1988) is commonly used to classify climates and is determined by dividing the average annual precipitation by the average annual potential evapotranspiration (PET). A location with an index > 0.20 and < 0.50 is considered semiarid. Amarillo, TX has an index of about 0.25. Perhaps even more important, there is not a single month in Amarillo when the average precipitation is as much as 50 percent of the average monthly PET. Therefore, successful dryland cropping in the region depends on plant available water stored in the soil profile at time of planting to supplement the growing season precipitation.

Grain sorghum is a major crop grown under semiarid conditions in the United States and other parts of the world. It is one of the most widely grown dryland crops in the southern Great Plains, but grain yields are generally low and highly variable because of sparse and erratic growing season precipitation. Average yields from 1972 to 2004 were 2530 for southwest Kansas, 2280 for the North Texas High Plains, and 1860 kg ha $^{-1}$ for the South Texas High Plains (National Agricultural Statistics Data Base, 2005). Yields would be considerably lower if based on planted areas because only 90, 79 and 81% of the average planted areas actually were harvested for grain (National Agricultural Statistics Data Base, 2005). The yields and percent of area harvested tend to decrease moving from north to south as drier conditions occur. A lack of water during the reproduction and grain filling stages is common and is the major cause of low grain sorghum yields in the U.S. southern Great Plains. Craufurd et al. (1993) reported that water stress during booting and flowering stages resulted in grain yield reductions of up to 85%. Strategies such as reduced plant populations, different spacing between rows, and skip row configurations have been used with varying degrees of success to enhance soil

Table 1. Long-term average rainfall during various growth stages of grain sorghum seeded on June 1 at Bushland, TX.

Crop stage	Days	PET, mm	Rainfall (mm)	Raifall/ PET (%)*
Day 1 to 3 leaf	23 (9)**	64 (11)	50 (87)	78
3-leaf to flag leaf	30 (7)	151 (9)	64 (65)	42
Flag leaf to flowering	21 (10)	131 (11)	37 (69)	28
Flowering to black layer	37 (11)	191 (8)	57 (71)	30
Total	111 (6)	537 (7)	208 (44)	39

Source: 14 yr potential evapotranspiration (PET) data from Texas A&M University Research and Extension Center (2005)

** Percentage of PET supplied by precipitation for the various growth stages. ** Numbers in parentheses are coefficient of variation values.*

water contents later into the growing season (Blum and Naveh, 1976; Larson and Vanderlip, 1994).

Although dryland grain sorghum yields are low because of sparse and highly variable rainfall, early growth is generally good because it is planted during the time of most favorable rainfall. The data in Table 1 show average rainfall amounts and amounts of PET for various growth stages of grain sorghum. The amounts of PET for the growth stages are also shown and average rainfall during the reproduction and grain filling stages is less than 30 percent of the PET and water stress during these critical stages is common and often severe.

The hypothesis of growing dryland crops, particularly grain sorghum, in clumps is that clumps will increase plant competition so that growing conditions in the vegetative stages will be less favorable than when plants are spaced several cm apart. The increased competition will result in less use of water, nutrients, and sunlight by the clump plants and there will be less vegetative growth, largely because of less tillering. This will leave more water for use by the plants during the reproduction and grain filling stages and result in higher grain yields. Limiting resources early in the season will limit yield potential, but under dryland conditions, early season yield potential is usually not a realistic goal. The reduced tillering of clump plants is likely due to two factors. The first is reduced assimilate because of increased competition, and the second is a change in light quality because of increased shading associated with increased plant density. A decrease in red to far red light at the base of a sorghum plant has been associated with decreased tiller production (Casal et al., 1985; Deregibus et al., 1983).

MATERIALS AND METHODS

Several studies have been conducted in recent years with dryland grain sorghum and limited work has been done with dryland corn. Much of the grain sorghum work has been published by Bandaru et al. (2006). This paper will summarize a portion of that work but readers should refer to the publication for additional details.

Studies were conducted at the USDA Conservation and Production Laboratory at Bushland, TX in 2002, 2003, and 2004, and at Tribune, KS in 2004. The objective of the studies was to compare the growth and grain yields of dryland grain sorghum of equal populations of uniformly spaced plants with clumps containing three or more plants.

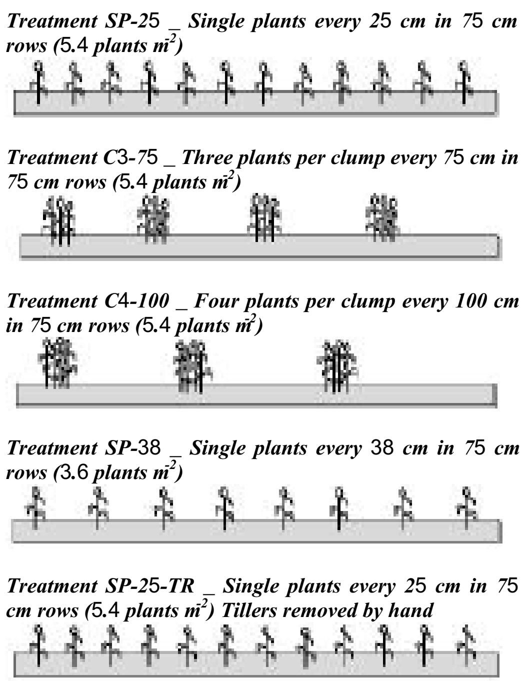

Figure 1. Schematic showing plant geometries for the treatments in the 2004 study at Bushland, TX and Tribune, KS.

Treatments for the 2004 study at Bushland, TX and Tribune, KS are shown in Figure 1. The treatments were placed on both stubble-mulched and no-tilled areas. At Bushland, the plots were placed on a bench-terraced watershed with a 1 to 2% slope. Runoff from the upper two-thirds of the watershed collected on the level bench. Some of the runoff from the upper one-third of the watershed infiltrated into the soil while moving over the middle-third and never reached the level bench. Soil water contents were variable across the watershed with the

Table 2. Mean values of measurements for grain sorghum as affected by five planting geometries in 75-cm rows in experiments located on the upper (Upper), middle (Middle), and bench (Bench) positions of a stubble-mulched bench-terraced field at Bushland, TX in 2004.

Planting geometry	Tillers per plant 28 DAP[†]	Biomass 42 DAP (kg ha^{-1})	Heads m^{-2}	Grain yield (kg ha^{-1})
Upper				
SP-25	1.8a[‡]	2080a	8.1a	2385c
C3-75	0.7b	1900c	7.7a	2976b
C4-100	0.3b	1617d	6.2b	3563a
SP-38	3.1a	2284b	8.0a	2702bc
SP-25-TR	Removed	1518d	5.4c	2964b
Middle				
SP-25	2.0a	2758a	10.6a	3180c
C3-75	1.1b	1919c	9.5b	4013a
C4-100	0.5c	1732d	8.1b	3952a
SP-38	2.6a	2303b	10.0a	3610ab
SP-25-TR	Removed	1609c	5.4c	3563bc
Bench				
SP-25	2.3a	3015a	12.0a	4743a
C3-75	1.2b	2150c	9.9bc	4902a
C4-100	0..8c	1806d	8.8c	4810a
SP-38	2.9b	2408b	10.8b	4911a
SP-25-TR	removed	1694c	5.4d	4274b

[†]Days after planting (DAP); [‡]Means in columns for Upper, Middle, and Bench positions on the watershed followed by the same letter are not significantly different.

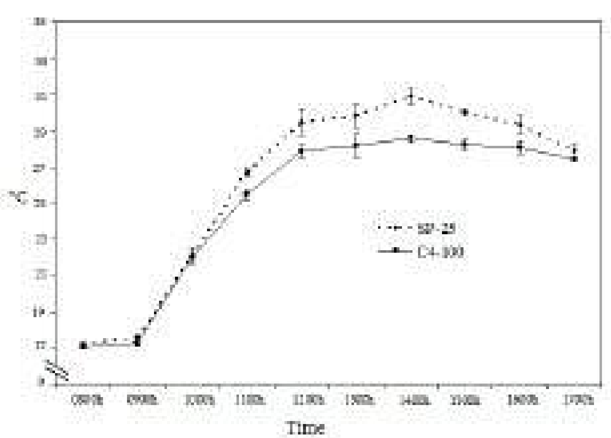

Figure 2. Comparison of hourly grain sorghum leaf temperatures on 8 Aug. 2004 at Bushland, TX for selected treatment in the middle position experiment on the stubble mulch area.

upper-third having the least water, the lower-third (level benched area) having the most, and the middle-third having intermediate levels. This allowed establishing plots on areas containing three different amounts of stored soil water on both the stubble-mulched and no-tilled areas at Bushland. Only the materials and methods for the 2004 study are presented in this paper, but the information for the other studies can be found in Bandaru et al. (2006).

RESULTS AND DISCUSSION

Only selected data are presented in this paper to illustrate the benefits of growing dryland grain sorghum in clumps. Additional results can be found in Bandaru et al. (2006). Results presented in Table 2 clearly show that grain sorghum plants grown in clumps produced fewer tillers, less early season biomass, and higher grain yields under limited water conditions. On the bench position, more water was available and the grain yields were substantially higher. The clumped geometries, C3-75 and C4100, did not produce higher grain yields at this yield level. The SP-25 treatment yielded significantly less grain at this yield level because there were not enough heads produced at the low seeding rate used with all tillers removed.

The results presented in Table 2 for the upper, middle, and bench positions were analyzed as three separate but identical experiments. They were considered separate experiments because the plant geometry treatments were randomized within each position, but not across positions. The results were vastly different for the experiment on the upper slope position where water was much more limited than on the other positions. The bench position had the highest amount of water stored in the soil at planting time, and also received some runoff from the other positions during the growing season. The yield levels increased substantially from the upper position to the middle position and to the bench position. The differences in the positions affected all the measurements in a marked way with the exception of tiller production. The number of tillers per plant was greatly affected by planting geometry, but they were similar for all the positions. This is because there was ample water available for plant growth early in the season on all the watershed positions. Water became increasingly more limited as the season progressed. The SP-38 treatment had the highest number of tillers in all cases and this was undoubtedly due to the individually spaced plants being further apart from one another. The plant population for this treatment was only 3.6 plants m^{-2} compared to 5.4 plants m^{-2} for the other treatments. The clumped plants had many fewer tillers, and the clumps with four plants per clump had fewer tillers than clumps with three plants. Again, this could be due to more competition resulting in less assimilate or from increased shading of the base of the plants resulting in a change in the ratio of red to far red light. Both of these factors have been shown to affect tiller production of grain sorghum plants.

Although the effect of increased number of tillers on the amount of early season vegetative growth has been clearly established, there are other apparent benefits of growing grain sorghum plants in clumps. The architecture of the plants is markedly changed. Single plants, when spaced several cm apart, tend to grow outward so that all leaves, including leaves on the tillers, are almost totally exposed to the sun and wind. In contrast, plants in clumps grow upward and the leaves of one plant shade the leaves of another plant. The clump plants also protect each other from wind. These factors result in less transpiration of water by the clumped plants. The clumped plants showed less visual water stress and leaf canopy temperature measurements showed significant differences during the hottest part of the day. This suggested that more soil water was available later in the season for the clump treatments. Many studies have shown that leaf temperatures increase during the day as a function of increasing water deficits (Gates, 1964; Wiegand and Namken, 1966; Pallas et al., 1967; Van Bavel and Ehrler, 1968; Slatyer, 1969; Stevenson and Shaw, 1971; Jackson et al., 1977). Canopy temperatures determined on 8 Aug. 2004 for the SP-25 treatment were considerably higher during the hottest part of the day when compared to clump plants (Figure 2).

Although only limited results for the 2004 studies at Bushland are reported in this paper, the 2002 and 2003 studies at Bushland and the 2004 study at Tribune, KS showed similar findings (Bandaru et al., 2006). The exception was for Tribune where there was a slight reduction in grain yield for one of the clump treatments. However, the seasonal precipitation was much above average and grain yields were in excess of 6000 kg ha^{-1} that is more than two times the expected dryland grain sorghum yields in the area. The clumped plants did not produce many tillers and because the plant population was relatively low, there was an insufficient number of heads for the achieved yield level.

CONCLUSIONS

In the southern Great Plains, dryland grain sorghum is commonly seeded during the wettest period of the year when plant available water is abundant in the soil profile. Our results indicate that growing plants in clumps compared to uniformly spaced plants reduces the number of tillers and vegetative growth. This preserves soil water until reproductive and grain filling growth stages, which increases grain yield. There are marked differences in plant architecture of uniformly spaced plants compared to clumped plants. Uniformly spaced plants produce more tillers and the leaves on both the main stalk and tillers grow outward, exposing essentially all of the leaf area to sunlight and wind. In contrast, clumped plants grow upward with the leaves partially shading one another and reducing the effect of wind, thereby reducing water use. The benefit of clumps decreased as grain yields increased, and there was even a slight decrease when yields exceeded 6000 kg ha $^{-1}$. However, dryland grain sorghum yields seldom reach this level in semiarid regions so growing grain sorghum in clumps appears to be a useful strategy with little downside risk.

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