Evaluation of Factors Affecting Extent of Tillering in Dryland Grain Sorghum Clumps

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This photo shows how grain sorghum can be grown in clumps on the Texas High Plains. Growing plants in clumps may decrease tillering, more efficiently use water, and increase yields.

Introduction

Agriculture in Texas High Plains is characterized by limited water supply, high winds and temperatures promoting more evapotranspiration. Average annual rainfall for the region ranges between 400-600 mm. Grain sorghum, with its special characteristics to grow well and produce good yields even in dryland areas, is a major grain crop in the Texas High Plains. Use of stored soil water is critical for development of the crop particularly during the later growth stages. However, much of the stored soil moisture is used during the vegetative growth stages. Under dryland conditions, populations of grain sorghum plants are generally reduced but one to three tillers are commonly formed. Severe stress conditions during later stages of crop growth result in fewer tiller-producing heads that contain less grain. Studies conducted by Stewart and colleagues in Bushland Texas (2002-2004) and Tribune, Kansas (2004) revealed that planting dryland grain sorghum in clumps produced fewer tillers than uniformly spaced rows.

During an exploratory study in 2002, 53,300 grain sorghum plants were maintained per hectare. Four plants were grown per meter in equally-spaced rows and four plants were grown together in clumps. An average of 2.9 tillers per plant was produced in equally-spaced rows compared to only 1.3 tillers per plant in clumps. Plants in the equally-spaced rows showed more visible stress throughout the growing season than plants grown in clumps. Grain sorghum grown in clumps produced less above-ground biomass when compared to equally-spaced plants. Grain yields from plants grown in clumps were 2 times higher than the plants in equally-spaced rows and produced a higher harvest index.

In 2003, a more detailed study was conducted with two grain sorghum varieties grown at a density of about 80,000 plants per ha. About 6 plants per meter were maintained in 75 cm rows, with six plants in a clump every meter. Leaf area, plant biomass, the number of tillers, and leaf temperature were measured at regular intervals. Results showed a dramatic decrease in the number of tillers from grain sorghum plants in clumps (0.6 per plant) compared to the number of tillers per plant (3.0) grown in equally-spaced rows. Leaf area index and plant biomass were lower in grain sorghum plants grown in clumps than in equally-spaced rows. Tillers in grain sorghum plants grown in clumps were more likely to produce heads than plants grown in evenly-spaced rows. The harvest index was higher in plants grown in clumps than those grown in equally-spaced rows. Measurements of the average leaf temperature showed that, during the hottest part of the day, grain sorghum plants grown in equally-spaced plants were 2° C higher than plants grown in clumps. At 60 days after seeding, the difference in temperature was 4° C. which indicates the plants in the equally-spaced rows were under higher water stress.

In 2004, two varieties of grain sorghum were planted in five geometries in no-till and stubble-mulch fields. Three levels of water use were evaluated. Planting geometry had a significant influence on the number of tillers that were produced. Grain sorghum plants grown in rows with spacings of 38 cm and 25 cm produced more tillers compared to plants grown in clumps. Clump treatments consisted of growing four plants in a clump every meter and three plants in a clump every 75 cm. When four plants were grown in a clump, they produced fewer tillers than clumps that consisted of only three plants.

The field had three slope positions that resulted in differing amounts of soil water storage and runoff. Amounts of stored soil water varied across the field for each slope position (upper, middle and bench). The number of tillers produced by grain sorghum plants varied with the different slope levels. Plants grown on upper and middle slopes produced fewer tillers than plants grown on benches. The bench locations collected some runoff water from the upper and middle reaches.

Grain sorghum grown in clumps yielded significantly more grain, indicating plants grown in clumps used water more effectively than plants in equally-spaced rows. It is apparent that plants grown in clumps use less water during the early growth stages so there is more water available during the latter part of the season that can be used for grain filling. Plants grown in clumps showed higher harvest index values than plants grown in equally-spaced rows.

The studies conducted in Tribune, Kansas in 2004 utilized the same planting geometries and grain sorghum varieties used in the studies at Bushland, Texas. Grain yields in Tribune were extremely high for dryland grain sorghum because there was an unusually high amount of precipitation. Because of lack of a water stress, the clumps did not produce more yield than plants grown in equally-spaced rows.

Growing grain sorghum plants in clumps was effective in producing fewer tillers and higher yields under water-stress conditions. It was concluded that growing grain sorghum plants in clumps might be beneficial in dryland farming areas of the Texas High Plains. However, the optimal spacing and geometry needed to grow grain sorghum plants clumps in order to decrease tillers was unclear. The mechanisms that lead to a decrease in the number of tillers formed when grain sorghum was grown in clumps were also not well-understood.

2005 Research at Bushland, Texas

As a result, a detailed study was initiated in 2005 at Bushland Texas to gather additional information.

The objectives were to:

1. Evaluate factors affecting the extent of tillering when dryland agriculture methods are used to grow grain sorghum in clumps, and
2. Evaluate the optimal spacing needed to plant grain sorghum in clumps to decrease tillering.

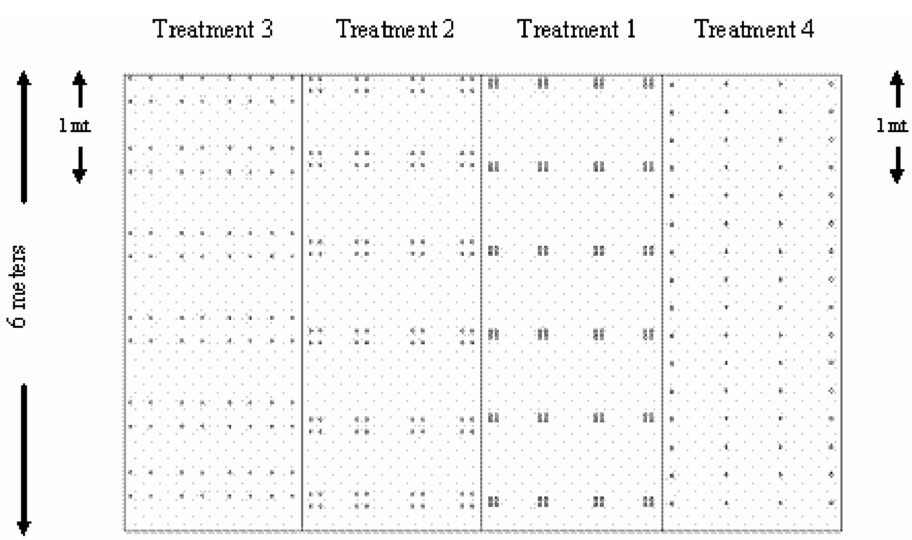
Researchers and graduate students at WTAMU monitored conditions in this grain sorghum plot on the High Plains.

Past studies showed that the red to far-red (R: FR) light ratio may serve as a signal in the production of tillers. Reduced tillers are observed as the R: FR ratio decreases. Gautier et al. (1999) stated that the R: FR ratio is clearly involved in the regulation of tiller production in perennial grasses, and a reduction in the R:FR ratio decreases tillering. Some studies indicate that mutual shading reduced light interception per plant and a lower R: FR ratio at the bases of plants was linked to a reduced number of tillers. Derigibus et al. (1985) showed that “the R: FR ratio could serve as a signal to indicate canopy cover or leaf density. This signal then interacts with others related to the availability of various resources (water, assimilates, nutrients, etc.) to determine the rate of tiller formation or death.” Jones (1985) reported that “environmental conditions favoring main stem also favor tillering. Thus, reduced competition for light, nutrients, and water favors tiller production.”

With this information, we designed two experiments for the 2005 study at Bushland, Texas.

Experiment 1
We used four treatments with different spacing between plants: 1) a close clump with all plants close to each other, 2) a clump with seeds 1 inch apart from each other in a square, 3) a clump with seeds spread 4 inches apart in a square pattern, and 4) row plants spaced every 25 cm. For every meter, there were four plants in equally-spaced rows as well as plants in clumps in every 75 cm rows.

Experiment 2
Single plants or groups of two, four or six plants were grown together in clumps every 75 cm in rows that were 75 cm apart. Thus, there were one, two, four or six plants in every 0.5625 meter^2. Tiller counts, the stage of plant growth, leaf count, and plant height were determined 4 times during the vegetative growth period. Light measurements (red to far-red ratio) were taken using a Skye 660/730 sensor. On 2 days, measurements were taken every hour from 9 a.m. to 6 p.m.

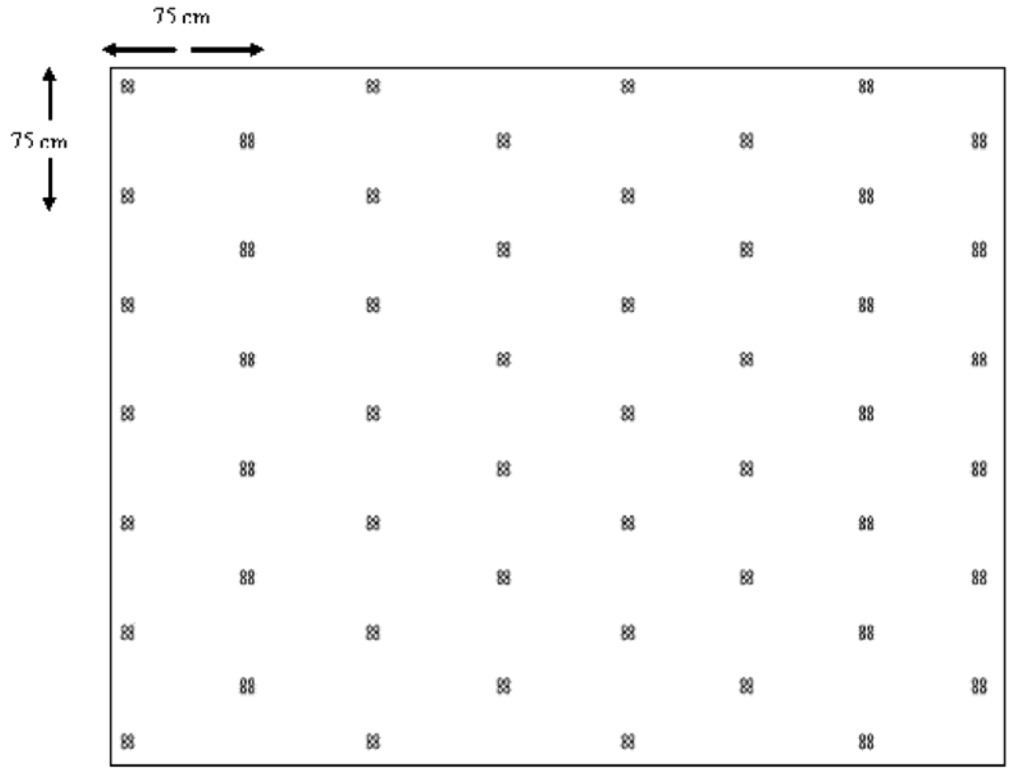


1. Treatment 1 – Four Plants in Clump (close clump)
2. Treatment 2 – Four Plants in Clump (1 inch apart)
3. Treatment 3 – Four Plants in Clump (4 inches apart)
4. Treatment 4 – Four Plants in Row (25 cm apart)

Thus, in all the treatments for every meter, there were four plants in equally-spaced rows as well as plants in clumps in every 75 cm rows.

Funds obtained for this grant was used to purchase a Skye 660/730 sensor. Light was measured in shade and sunlight sides of the plant base to estimate the ratio of R: FR light. Temperature measurements were taken at the plant base and at canopy height using a thermal infrared gun. This information was correlated to the development of tillers. Two grain sorghum varieties were evaluated in both experiments: Pioneer 8699 (variety 1) and NC + 5C35 (variety 2).

In this report, only data about tiller formation on September 2 and light measurements for 1:00 pm on August 19 are interpreted.



Vernon, TX farmer Terry McAlister used this arrangement to plant grain sorghum in clumps in 2005. Four plants were in each clump. The clumps were spaced 75 cm away from each other in 75 cm rows.

Effect of Plant Density on Tillering

Experiment 1:

The number of tillers produced per plant decreased as the plants were located closer to one another. For example, when four plants were adjacent to one another or spaced only 1 inch apart, only about 1.5 tillers were formed for each plant. In contrast, when plants were uniformly spaced several inches apart within rows, 2.3 tillers were formed for each plant. The number of tillers produced per plant in equally-spaced rows was significantly greater than for plants grown in close clumps and 1- and 4-inch clumps.

Treatment	Variety 1	Variety 2
Close clump	1.6 a*	0.9 a
1 inch clump	1.3 a	0.9 a
4 inches clump	1.8 a	1.2 a
Row plants	2.3 b	2.2 b

* Means with the same letter in columns are not significantly different (α = 0.05).

Experiment 2:
The number of tillers decreased as the number of plants in the clumps increased. For example, one plant by itself produced 2.7 tillers, while two plants in a clump each produced 1.5 tillers. In contrast, four and six plants in a clump produced less than 1 tiller for each plant (0.6 and 0.8 respectively). Clumps with four or six plants always had significantly fewer tillers per plant clumps with only one or two plants.

Treatment	Variety 1	Variety 2
1 plant per clump	2.7 a*	4.0 a
2 plants per clump	1.5 a	1.7 a
4 plants per clump	0.6 b	0.6 b
6 plants per clump	0.8 b	0.3 b

* Means with the same letter in columns are not significantly different (α = 0.05).

Light: Effect of Plant Density on Red to Far-red Light Ratio

Sensor in shade *(Experiment 1)*
The ratio of red to far-red light is measured in micromol/sq.m./sec per microamp ($\mu molm^{-2}s^{-1}/\mu A$) (Skye Instruments, 2005). The sensor output shows that the R: FR ratio in close clumps and 1-inch clumps is about 0.20 μmol. In contrast, the clumps with plants 4 inches apart and plants in equally-spaced plants had R: FR ratios of 0.26 μmol, which were statistically higher. This indicates that the R: FR ratio decreases as plants grow in closer proximity to one another, and fewer tillers are produced when plants are close to one another. These findings are in agreement with Deregibus et al. (1985).

Treatment	Variety 1	Variety 2	Mean
Close clump	0.21	0.23	0.22 a*
1 inch clump	0.18	0.20	0.19 a
4 inch clump	0.27	0.25	0.26 b
Row plants	0.28	0.24	0.26 b

* Means with the same letter in columns are not significantly different (α = 0.05).

Sensor in shade *(Experiment 2)*
The R: FR ratios for a single plant (0.33μmol) and for two-plant clumps (0.27 μmol) were significantly higher than those for four-plant clumps (0.21 μmol) and six-plant clumps (0.19 μmol). The R: FR ratio becomes smaller with the increase in plant density.

Treatment	Variety 1	Variety 2	Mean
One plant clump	0.33	0.33	0.33 a*
2 plants per clump	0.25	0.29	0.27 a
4 plants per clump	0.25	0.17	0.21 b
6 plants per clump	0.17	0.20	0.19 b

* Means with the same letter in columns are not significantly different ($\alpha = 0.05$).

Sensors in sunlight (*Experiment 1*)

Treatment	Variety 1	Variety 2
Close clump	1.12	1.03
1 inch clump	1.01	1.04
4 inches clump	1.04	1.04
Row plants	1.03	1.01

Sensors in sunlight (*Experiment 2*)

Treatment	Variety 1	Variety 2
Close clump	1.08	1.04
1 inch clump	1.03	1.04
4 inches clump	1.03	1.05
Row plants	1.02	1.03

There were no statistically significant differences between the sensor measurements for any of the treatments or varieties, and all ratios were close to 1.0. This finding was not surprising because the sensors were placed in positions that received full sunlight, regardless to how close the plants were growing to one another.

Conclusion

It is a common practice to seed dryland grain sorghum in the Texas High Plains during the wetter part of the year. The stored soil moisture supported by seeding during the wetter part of the year produces two to three tillers per plant and large amount of above ground biomass. Because water often becomes a limiting factor during the latter part of the growing season, a larger number of tillers fail to produce head.

However, it appears that growing grain sorghum in clumps may offer a promising strategy to increase the beneficial use of water in a way that decreases tillering and encourages grain filling. Results from 3 years of study at Bushland, Texas and one year at Tribune, Kansas show that growing dryland grain sorghum in clumps produce fewer tillers and increase grain yields and the harvest index. The results from studies at Bushland, Texas in 2005 show that the number of tillers decreased as the plants are placed closer to one another in clumps. The number of tillers produced per plant decreased significantly when there were four plants (0.6) in a clump rather than just one plant by itself (2.7). The R: FR ratio (measured in the shade at the base of a grain sorghum plant) was 0.33 µmol for one plant and 0.19 µmol for six plants in a clump. The R:FR ratio decreased when plants were grown in greater densities. The number of tillers produced per plant decreased when larger numbers of plants were grown in clumps.

As a result of this project, there is increased interest among several agricultural producers throughout the High Plains and the Rolling Plains of Texas in growing grain sorghum plants in clumps. Several of the farmers who have tried this method are satisfied with the yields and water savings that can be accomplished using this strategy.

If the practice of growing grain sorghum in clumps becomes more widespread, it could encourage several growers to consider dryland agriculture, thus reducing irrigation and protecting valuable groundwater resources in the region.

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