Summary

Optimum seeding rates have been investigated and discussed extensively in the High Plains and Gulf Coast of Texas. Yet, many producers in the central and northern Blacklands of Texas are using plant populations above optimum levels. This can exacerbate soil moisture limitations and result in lower yields, stalk rot diseases and lodging. Selection of optimum seeding rates is further complicated by spatial and temporal variability of pre-season soil moisture and in-season precipitation. We utilized large, replicated strip trials in collaboration with multiple growers throughout the Texas Blacklands to evaluate grain sorghum seeding rates in response to variation climate conditions.

Grain sorghum has the ability to compensate for yield across a wide range of seeding rates and subsequent plant populations and moisture scenarios. Yield compensation with low plant populations under favorable conditions is accomplished through adjustments in grain head numbers per acre (tillering) and increased head size. Grain head size combined with seed size generally had greater influence on yield compared to heads per acre. Grain sorghum populations differ in their sensitivity to variability in precipitation during the growing season. High populations are much more sensitive to less than optimum and greater than optimum precipitation amounts. Under favorable conditions, the optimum seeding rate was between 65,000 and 80,000 seeds/acre. However, lower plant populations, achieved by seeding rates less than 65,000 seeds/acre demonstrated the ability to maintain yield potential across a wide range of precipitation amounts, including below normal precipitation. If precipitation is expected to be below normal (> 10%), seeding rates should be reduced to 50,000-65,000 seeds/acre.

Introduction

Advancements in meteorological and hydrological forecasting create an opportunity for producers to anticipate future growing conditions and decide which management practices are best for expected conditions (Wood, 2002). Yet, uncertainty exists about environmental and hydrologic thresholds that mandate specific changes to agronomic inputs. Crop inputs, such as seed, could be optimized to maximize grain sorghum yields in the Blacklands of Texas.

Within the Blacklands region of Texas, variation in topsoil depth, stored soil moisture and in-season precipitation creates challenges for managing seeding rates for grain crops within the region. Similar challenges exist in other production regions of Texas. While growers recognize grain sorghums ability to withstand heat and drought stress compared to other crops, improper seeding rates often results in poor grain yield due to insufficient soil moisture, disease and lodging issues. Current AgriLife recommendations for grain sorghum seeding rates in the
Blacklands are from 70,000 to 80,000 seeds per acre. However, this could be too high for certain soil and weather conditions. Growers are advised to reduce seeding rates when poor soil moisture conditions are present or when below average rainfall is expected during the current growing season. Yet, decisions about altering seeding rates based on current soil moisture levels and projected weather patterns are largely subjective.

Soil moisture and weather data will be an important component of models used to describe grain sorghum yield response to increasing seeding rates. Knowledge of current soil conditions coupled with seasonal or long-range precipitation outlooks could be used for more precise adjustments to seeding rates. Using advanced models to develop decision-making tools for growers to select seeding rates will be useful for producers in the Blacklands as well as other regions affected by variability in soil and weather conditions.

**Goals and Objectives**

1. Measure grain sorghum yield in response to increasing seeding rates and compare optimum seeding rates to soil and weather conditions in the central and northern Blacklands of Texas.
2. Increase awareness of grain sorghum and sorghum management through Extension and outreach activities.

**Materials and Methods**

Grain sorghum seeding rate trials were imposed at multiple field sites in collaboration with local growers in five areas of the central and northern Blacklands (Thrall, Buckholts, Abbott, Malone, and Farmersville, TX). At each field, treatments were arranged in a randomized complete block design with three replications of five treatments. Treatments comprised five seeding rates (35,284, 51,455, 65,340, 81,675 and 94,090 seeds per acre) planted using a John Deere Max Emerge plus vacuum seeder with grain sorghum hybrid Pioneer 84P80. Plots were four rows wide with 30 inch row spacing at Buckholts (Beckhusen Farm), Abbott (Kaska Farm), Malone (Birdwell Farm), and Farmersville (Wright Farm) and 38 inch spacing at Thrall. Plot length extended the entire length of row for each selected field (from 600-1300 ft). Planting dates were from March 14 through April 11. Prior to planting, deep soil samples (12, 24, 36, 48 inch depth) were collected from each block to quantify soil moisture at planting. Soil moisture sensors and tipping rainfall buckets were connected to a data logger and installed at each site. Due to intermittent disruptions in rainfall data collection, radar estimates for precipitation by month were extracted for each location from NOAA - National Weather Service precipitation website. Following planting, plots were maintained according to AgriLife recommendations for the duration of the project.

Within 6 weeks after planting, plant populations were measured by counting the number of plants in 40 ft of row (4, 10 ft subsamples). Sub-plots were harvested by hand for 20 ft of row, heads counted, threshed using a stationary thresher, weighed and seed numbers per pound determined on a sub sample. Hand harvest data was used to estimate yield components, including heads per acre, seeds per head, seed size and seed weight. Yield was measured for each strip-plot by harvesting the center 2-rows using a John Deere 3300 modified plot combine. The plot
combine provided measurements of plot weight, grain moisture and test weight. Plot weights were converted to yield per acre with grain moisture adjusted to 14%.

Data was analyzed using SPSS 20.0. Analysis of variance was used to compare yield, plant populations, emergence, and yield components in response to seeding rates. A significant location by seeding rate interaction was observed for grain yield. Yield was analyzed separately for each location. If treatment differences were significant, means were separated using L.S.D. Non-linear regression was used to model yield response for contrasting seeding rates across locations in response to soil profile moisture at planting and in-season precipitation.

Results and Discussion

Plant Populations and Emergence.

Within six weeks of planting, plant populations and emergence was determined for each location. Percent of planted seed that had emerged ranged from 88-100% (Figure 1). Emergence did not differ (p > 0.10) across locations or seeding rates. Soil moisture was adequate at planting to ensure quick and uniform emergence. Plant populations measured at six weeks after planting did respond (p < 0.01) to increases in seeding rates (Figure 2). While this result was expected, it is necessary to establish differences in plant populations for contrasting seeding rates before tillering or other factors that influence grain yield transpire.

Grain Yield

Despite differences in plant populations, grain yield did not differ (p > 0.05) across seeding rates at three of the five locations. Average grain yield by location ranged from 4,834 lbs/acre (Birdwell Farm) to 7,832 lbs/acre (Kaska Farm). Grain yields for contrasting seeding rates did differ (p = 0.035) at Birdwell Farm ranging from 3,864 lbs/acre to 5,522 lbs/acre. This was primarily due to lodging that resulted from fusarium stalk rot, which is associated with early
season moisture stress. Grain yield significantly (p < 0.05) declined with seeding rates greater than 81,675 (Figure 3). Grain yields were negatively correlated ($r^2 = 0.55$) with lodging (%) scores. In contrast, grain yields at Wright Farm planted at 35,384 seeds/acre were lower (p = 0.015) than yields achieved with greater than 65,340 seeds/acre.

**Figure 3.** Grain yield and lodging (%) for contrasting seeding rates in grain sorghum near Malone, TX.
For three of the five locations, grain yields did not differ across seeding rates. This included Abbott with an average yield of 7,833 lbs/acre, Buckholts averaged 6,756 lbs/acre and Thrall that averaged 6,712 lbs/acre. These three locations along with the Farmersville location all illustrated the ability of grain sorghum to compensate for variations in plant population. The compensation is achieved through adjustments in tillering and head size. Tillering alters the number of heads per plant to reduce differences in the number of heads per acre for contrasting seeding rates (Figure 6). While the number of heads per acre was significantly different ($p < 0.000$) for contrasting seeding rates, the range was from 55,056 heads/acre to 80,192 heads per/acre in contrast to the range in plant populations (Figure 2).
Figure 5. Grain yield by seeding rate for grain sorghum at Abbott, Buckholts and Thrall, TX.
The second component that contributed to yield compensation for lower seeding rates was variation in head size (measured as seeds per head). Grain head size generally increased as seeding rates decreased (Figure 7). Principle component analysis of yield components (heads/acre, head size, seed size, and seed weight) indicated that head size combined with seed size/weight accounted for 60% of yield while heads/acre account for only 38% of yield. The combination of tillering to maintain levels of grain heads per acre and increase in head size resulted in grain yields that did not differ across a broad range of seeding rates and subsequent plant populations.

Figure 6. Impact of seeding rate on the number of grain heads per acre averaged across five locations.
Similar to average yield by location, hydrologic conditions differed at each location when accounting for soil profile moisture to a 4 ft depth at planting and in-season precipitation. Figure 8 shows variation in volumetric water content by depth for each location. Variation was greatest within the 0-12 inch depth although profile moisture was considered to be near field capacity or above at planting for all locations and soil depths. Soil water content (0-12 inch depth) was greatest (p < 0.01) at Farmersville and lowest at Buckholts (p < 0.01) compared to other locations. Given all locations were at field capacity or greater throughout the soil profile, in-season precipitation was expected to have a greater influence on grain yield.

*Figure 7. Response of grain head size to increasing seeding rates at 5 locations.*

*Hydrologic Conditions and Grain Yield*
For three of the five locations, soil moisture sensors monitored volumetric water content at two depths, 6 and 18 inches. Rodents destroyed wiring at two locations, limiting data collection and reliability. These two stations are not reported. Figure 9 displays the volumetric water content measured at Malone, Abbott and Buckholts over approximately 110 days. Profile moisture at a 6-inch depth remained relatively unchanged for at least 30 days. Beyond 30 days after planting, plant size and leaf area increased in combination with higher air temperatures increasing crop evapotranspiration. Cycles of depletion of soil moisture and replenishment by rainfall were observed throughout the growing season. For clay soils in this study, volumetric water content of 27% would be near permanent wilting point for plants and cause significant stress. This threshold was surpassed several times throughout the growing season at each location.
Figure 9. Volumetric water content (%) at a 6-inch depth for three locations beginning at planting and recorded through approximately physiological maturity.

The timing and duration of each moisture stress period differed by locations (Figure 10). The Abbott location had the fewest days of moisture stress at 15 total days with all 15 days occurring after flowering. The Buckholts and Malone location each endured significantly longer periods of moisture stress, although at different points during the growing season. At Malone, 50% of the moisture stress days occurred pre-flowering with a total of 40 days. Buckholts sustained 44 days of moisture stress although the majority, 29 days, was post-flowering. The timing and duration of moisture stress is expected to have significant implications on grain yield and could result in other complications such as stalk rot, which was present at Malone. While total stress was greater at Buckholts, early season stress and associated lodging had greater indirect impact on yield (reduced harvest efficiency).
Although ANOVA did not reveal significant differences in grain yield in response to increasing seeding rates, precipitation received during the growing season (April, May, June, July) did influence grain yield. Moreover, response of grain yield to in-season precipitation varied across seeding rates (Figure 11). The optimum, in-season precipitation amount starting with full profile moisture at planting was estimated to be 15 inches. Yields declined significantly with precipitation amounts above or below 15 inches. However, higher plant populations (seeding rates) were much more sensitive to precipitation amounts above or below optimum. This is evident when comparing the coefficient of correlation ($r^2$) across seeding rates for the various quadratic functions. The relationship was strongest ($r^2 = 0.885$) between precipitation and grain yield for the highest seeding rate (94,090 seeds/acre) compared to 35,384 ($r^2 = 0.485$). The reduction in sensitivity of low populations to variation in available moisture provides justification for reduction in seeding rates.

Figure 10. Total, pre-flowering and post-flowering moisture stress in days (volumetric water content < 27%) for three locations.
Figure 11. Regression analysis of grain yield and in-season, cumulative monthly precipitation (April, May, June, July) by seeding rate.

To further illustrate the sensitivity of grain sorghum yield to seeding rates/plant populations and precipitation, grain yields were compared to the cumulative departure from normal precipitation during April, May, June and July (Figure 12). Departures from normal ranged from -1.59 inches at the Birdwell Farm to +2.33 inches at Stiles Farm. A dramatic difference in quadratic response curves was observed for contrasting seeding rates. Seeding rates less than 65,340 seeds/acre demonstrated the ability to maintain yield as precipitation dropped to near or below normal rainfall. Higher seeding rates (>65,340) were sensitive to below normal and above normal precipitation amounts, evident by grain yields that continued to decline as precipitation declined rather than stabilizing as observed in lower seeding rates. A similar trend was observed with greater than normal precipitation amounts.
The optimum seeding rate should be adjusted based on current and anticipated hydrologic conditions. Provided soil profile moisture is adequate at planting and normal precipitation is expected, seeding rates should be between 65,000 and 80,000 seeds per acre (60,000-75,000 plants/acre). This range will enable maximum grain yield and reduce the risk for lodging and other factors that could reduce yield. However, if in-season precipitation is expected to be below normal (>10%), the optimum seeding rate would decrease to 50,000 and 65,000 seeds/acre.

Conclusions

Grain sorghum has the ability to compensate for yield across a wide range of seeding rates and subsequent plant populations. Yield compensation with low plant populations under favorable conditions is accomplished through adjustments in grain head numbers per acre (tillering) and increased head size. Grain sorghum populations differ in their sensitivity to variability in precipitation during the growing season. High populations are much more sensitive to less than optimum and greater than optimum precipitation. In contrast, lower plant populations obtained by seeding rates < 65,000 seeds/acre are much less sensitive to reduced precipitation amounts, yet will adjust and yield well when greater precipitation amounts occur. Moreover, when
precipitation amounts are below normal, lower populations (<51,000) have demonstrated the ability to maintain yield when yield reductions would be expected for higher populations.

Acknowledgments

Appreciation is extended to Chad Kaska and Josh Birdwell for generously donating their time, land, and equipment to conduct these result demonstrations in Hill County.