Ogallala Aquifer
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Project Plan from FY2014
(Fiscal Years 2015-2016)

Title: Biomass accumulation and grain yield of sorghum cultivars as influenced by weather variables and initial soil water content

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Research Location: Bushland, TX

Summary/abstract:

Dryland grain sorghum production is well suited to the Southern High Plains. With the right combination of genetic and agronomic management solutions, sorghum grain yield may be optimized to improve the profitability of dryland cropping systems and lessen the impact of groundwater depletion. The yield response of differing sorghum cultivars can be strongly influenced by the environment and the weather associated with each cropping season. Late maturing varieties are generally associated with greater accumulation of carbohydrates and greater yield potential. However, under dryland conditions, water stress at critical periods can strongly influence biomass partitioning and therefore have an overriding effect on grain yield. In addition, early maturing varieties may be planted later in the season to avoid the high evaporative demands typical of the Southern High Plains in late May and early June. Recently developed grain sorghum hybrids with the staygreen trait can exhibit improved post-anthesis drought tolerance compared with senescent varieties. This trait has been linked to greater transpiration efficiency; however, yield advantages of the staygreen trait can be strongly dependent on the environment (Jordan et al., 2011).

The investigators propose to evaluate the accumulation of biomass and associated grain yield of selected sorghum cultivars as influenced by weather variables and initial soil water content. A central question to be evaluated is the degree to which grain yield can be predicted as a function of growing degree accumulation at maturity for each of the varieties and maturity levels. The anticipated outcome of this research is to provide producers with better information regarding the selection of sorghum varieties suited to the planting conditions and environment of the region.

Project Narrative:

Objectives:

1. Compare dryland sorghum [*Sorghum bicolor* (L.) Moench] grain yields, water use efficiencies, and harvest index for different maturity classes (early, medium-early, and medium) of both senescent and staygreen sorghum varieties under two initial (planting) water content regimes.
2. Compare water use prior to and after anthesis, and evaluate how this influences green leaf area, tiller number and biomass accumulation at anthesis and post anthesis for each of the varieties.

3. Evaluate if GDD accumulation during the growth stages is a good predictor of biomass accumulation and grain yield and hence offers a suitable gage for varietal selection for optimal dryland sorghum production in the Texas High Plains environment.

These objectives address OAP Subobjective 2 by developing and evaluating crop management strategies and technologies that could increase the productivity and profitability of dryland cropping systems. The results will provide producers with better information regarding the selection and agronomic management of sorghum varieties suited to the planting conditions and environment of the region.

Rationale/Literature Review/Conceptual framework:

The declining saturated thickness of the Ogallala Aquifer associated reductions in irrigation well capacities throughout the region will decrease irrigated acreage. Although under present market conditions, dryland crop production in the region is less profitable compared with irrigated crop production, trends in demand for agricultural commodities will in many instances, surpass production potential in the next 35 years (Kruse, 2010), which may increase the profitability of these systems. Demand for cereal grains (including sorghum) are expected to increase by 75% by 2050 of which 13% is to be met by an increase in cultivated acreage (Kruse, 2010). With the right combination of genetic and agronomic management solutions, sorghum grain yield may be optimized to improve the profitability of dryland cropping systems and lessen the impact of groundwater depletion. However, further research is required to clarify differences among grain sorghum maturity classes and drought tolerance traits for ideal varietal selection.

Sorghum maturity is an important trait affecting sorghum grain yield. However, the effects of genotypic maturity on yield vary with respect to temperature, water stress and photoperiod (Saeed and Fancis, 1986). Sorghum hybrid maturity is typically rated as the number of days to 50% bloom with early maturing varieties reaching bloom about 5-10 days earlier than medium maturity varieties. In general, late maturing varieties that accumulate more growing degree days (GDD's) prior to bloom have a greater yield potential than early maturing varieties. However, under dryland conditions, water stress at critical periods can strongly influence biomass partitioning and therefore may have an overriding effect on grain yield. In addition, Saeed and Francis (1984) demonstrated that in environments with high night temperatures and high rates of GDD accumulation, sorghum grain yield was positively correlated with days to flowering. In contrast, in environments with low night temperatures and slow accumulation of GDD, yield was correlated with the number of days in grain fill.

Recently developed grain sorghum hybrids also exhibit improved post-anthesis drought tolerance as expressed through the presence of the staygreen trait which is associated with the retention of green leaf area at maturity. Functional stay green phenotypes, associated with extended photosynthetic activity during grain filling, has been linked to greater transpiration efficiency and yield. However, yield can be strongly influenced by environmental factors with yield advantages of the staygreen trait diminishing with decreased water stress (Jordan et al., 2011). Reductions in water use prior to anthesis in favor of greater post anthesis water use may also result in fewer seeds per panicle, a major component influencing sorghum grain yield (Moroke et al., 2011; Bell, 2014). Further plot-scale research is required to clarify the how pre-plant soil moisture and GDD accumulation affect the diverse expressions of the staygreen trait and influence biomass accumulation and grain yield in sorghum.

Sorghum maturity is dependent on environmental conditions; specifically, daily maximum and minimum temperatures during critical growth stages in addition to available moisture. Maiti et al. (1996) defined optimum growing temperatures for sorghum as 21 to 35°C for germination, 26 to 34° for vegetative growth and development, and 25 to 28°C for reproductive growth. Exposure to extreme high temperatures for periods longer than ten days between vegetative development and growing point differentiation can result in decreased seed set (Prasad, 2008). Water stress between half-bloom and soft dough can inhibit pollen development, pollination of the ovule, and prompt abortion of fertilized ovules (Assefa et al., 2010; Prasad et al., 2008; Gerik et al., 2003). Developmental delay in sorghum often occurs under water stress resulting in increased cumulative GDD (Bell, 2014). As a result, the crop endures a longer period of elevated temperatures during grain fill. Consequently, water availability at critical growth stages is often of greater importance to biomass partitioning compared with cumulative seasonal precipitation (Larfarge et al., 2002) and can offset the positive yield effects of greater cumulative GDD. It is possible that greater water storage deeper in the profile prior to planting may increase yield potential of drought tolerant varieties if roots can access this water during critical growth stages (Evans and Sadler, 2008), and assist the crop in mitigating stress associated with increased GDDs. Consequently, the choice of an appropriate sorghum variety and maturity may depend on pre-plant soil water.

Approach and Research Procedures:

Plots will be established at the USDA-ARS-CPRL (Bushland, Texas) in a wheat- sorghum-fallow rotation to facilitate disease and weed control problems associated with continuous sorghum. Whole plots will consist of two imposed pre-plant soil water levels in a strip plot design. Six grain sorghum varieties will be replicated three times and planted on 0.76-m row spacing at a seeding density of 70,000 seeds ha^{-1} under both pre-plant soil water levels. Varieties will include both pre- and post- flower drought tolerant (non-staygreen and staygreen) lines of three maturity classes (early, medium and medium-long). Soil water content will be determined using a neutron moisture gage (model 503DR, InstroTek, Inc., Raleigh, NC) from 0.1- to 2.3-m depth in 0.2-m at emergence, anthesis, and physiological maturity.

Micrometerological variables will be monitored at 0.25-h intervals and included ambient air temperature and relative humidity, wind velocity, global irradiance, and precipitation. Meteorological variables will be monitored throughout the growing season to calculate GDD and estimate reference ET (Allen et al. 2005) under nonstandard conditions. Above ground biomass and green leaf area index (LAI) will be measured at panicle differentiation and anthesis within each experimental plot using a leaf area meter (model LI-3100, LICOR, Inc., Lincoln, NE). Grain and aboveground biomass will be sampled at physiological maturity from each plot. Harvest index will be calculated as the ratio of grain yield to total aboveground biomass using oven dry equivalent weights. Water use efficiency (kg m^{-3}) will be calculated as the ratio of grain yield (corrected to 0.13 kg kg^{-1} moisture) to total crop water use.

Schedule:

May 2015: Establish field plots. Soil sample for fertility requirements and apply fertilizer. Pre-irrigate half the plots to establish the initial soil water content treatment.

June 2015: Plant sorghum with target planting dates of 27 May, 10 June, and 24 June. Install neutron access tubes, and erect weather station. Begin soil water measurements one week after complete emergence in all plots. Sample plants for green leaf area and aboveground biomass at growing point differentiation and anthesis.

October 2015: Collect yield samples and process yield data.

November 2015-April 2016: Initial analysis and evaluation of first year's data.
May 2016: Establish field plots. Soil sample for fertility requirements and apply fertilizer. Pre-irrigate half the plots to establish the initial soil water content treatment.
June 2016: Plant sorghum with target planting dates of 27 May, 10 June, and 24 June.Install neutron access tubes, and erect weather station. Begin soil water measurements one week after complete emergence in all plots. Sample plants for green leaf area and aboveground biomass at growing point differentiation and anthesis.
October 2016: Collect yield samples and process yield data.
November 2016 – April 2017: Analyze data and prepare a draft of a manuscript detailing results of the two study years.

Expected outcomes:

The results will help delineate how cultivars with differing maturity classes and those containing the staygreen trait respond to water stress and weather variables throughout the growing season. Scientific results of this study will be submitted for publication in a peer-reviewed journal. The practical outcome of this research is to provide producers with better information regarding the selection of sorghum varieties suited to the planting conditions and environment of the region. These results will also be disseminated through regional Texas A&M AgriLife Extension programs to assist local producers with agronomic decisions related to dryland agriculture. Besides established Extension programs, social media will also be used to expand the customer base and influence.

Relevant Publications:

Baumhardt, R.L., J.T. Tolk, and S.R. Winter. 2005. Seeding practices and cultivar maturity effects on simulated dryland grain sorghum yield. Agron. J. 97:935-942.
Baumhardt, R.L. and T.A. Howell. 2006. Seeding practices, cultivar maturity, and irrigation effects on simulated grain sorghum yield. Agron. J. 98:462-470.
Bell, J.M. 2014. Responses of Grain Sorghum to Profile and Temporal Dynamics of Soil Water in a Semi-Arid Environment. Doctoral Dissertation, Texas A&M University. College Station, TX.
Moroke, T.S., **R.C. Schwartz**, K.W. Brown, and A.S.R. Juo. 2005. Soil water depletion and root distribution of three dryland crops. Soil Sci. Soc. Am. J. 69:197-205.
Moroke, T.S., **R.C. Schwartz**, K.W. Brown, and A.S.R. Juo. 2011. Water use efficiency of dryland cowpea, sorghum and sunflower under reduced tillage. Soil Till. Res. 112(1):76-84.

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Saeed, M and C.A. Francis. 1986. Yield-maturity relationship of grain sorghum in diverse environments. Crop Sci. 26:1077-1079.