Grain Sorghum Fails to Consistently Respond to N-Fertilizer When Grown on a Tunica Clay Soil.

H. Arnold Bruns

USDA-ARS Crop Production Systems Research Unit

Stoneville, MS 38776

Abstract

Nitrogen fertilization of grain sorghum (*Sorghum bicolor* L. Moench) on clay soils in the Mississippi Delta and similar environments has not been extensively researched. Six hybrids grown with 0.0, 112.0, and 224.0 kg N ha^{-1} added fertilizer on a Tunica clay soil (clayey over loamy, montmorillonitic, non-acid, thermic, Vertic Halaquept) in 2014 and 2015 were evaluated for yield and yield components. The 2014 seeding did not require irrigation while three irrigations were applied in 2015. No yield differences occurred between N-treatments in 2014 but added N did increase yields in 2015. No consistent differences in yield or yield components occurred between hybrids. Yields were sub-standard to regional variety trial data probably due in part to the water and nutrient availability inherent to the clay soil. Rates of N-fertilizer at 112.0 kg N ha^{-1} probably will benefit grain sorghum yields from clay soils most years but higher levels most likely are not necessary.

Introduction

During the past six years, grain sorghum production has increased from approximately 124,000 to 629,000 A in the combined lower Mississippi River Valley states of Arkansas, Louisiana, and Mississippi (USDA-NASS, 2016). Though not considered a major crop for the region, the concentration of this production exceeds most areas in the United States except for the West Central and Southern Great Plains. Despite recent invasion by the sugarcane aphid (*Melanaphis saccharia*), the crop continues to retain interest for rotational purposes and as a drought tolerant option for limited- or non-irrigation cropping systems.

Nitrogen fertility recommendations for grain sorghum production in Mississippi are based mainly on previously mentioned information from Arkansas (Bond et al., 2015.). The effects of N-fertility on grain sorghum grown on the heavy textured clay soils of the lower Mississippi River Valley is limited. These soils are often relegated to produce soybean (*Glycine max* L. Merr.) and rice (*Oryza sativa* L.) while lighter textured soils such as clay loams, loams and sandy loams are usually reserved for cotton (*Gossypium hitduyum* L.) and corn (*Zea mays* L.) production. This experiment was conducted to determine the effects of varying N-fertility rates on the yield and yield components of several grain sorghum hybrids grown on a Tunic clay soil that is common to the Mississippi Delta and similar in physical and chemical properties to other clay soils in humid subtropical river deltas.

Materials and Methods

The experiment was conducted during the 2014 and 2015 growing seasons on a Tuncia clay site one mile north of Elizabeth, MS on land leased by the Crop Production Systems Research Unit of the USDA-ARS Jamie Whitten Delta States Research Center in Stoneville, MS. Tunica clay is one of several clay soils found in the lower Mississippi River Valley with a clay content of between 35 to 75% most of which is Montmorillinite. Results from a soil test of the site, conducted by Mississippi State University Soil Testing Laboratory, Mississippi State, MS were as follows; pH=6.5, P=105 kg ha^{-1}, K=500 kg ha^{-1}, Ca=6200 kg ha^{-1}, Mg=117 kg ha^{-1}, S=160 kg ha^{-1}, Zn=2.0 kg ha^{-1}, and a CEC= 20.7 meq 100 g^{-1}. No deficiencies in any of the macro-nutrients were noted and pre-plant applications of P, K, Ca, or Mg were not recommended. Organic matter content for the site was $\leq$1.0%. Tests for available soil N are not conducted by the laboratory because N is considered ephemeral under the environmental conditions of the Lower Mississippi River Valley. By spring, seldom will any previously applied N be present because to the humid sub-tropical environment that allows volatilization during the winter due of waterlogged soils, leaching, and/or continuous biological denitrification as a result of soil temperatures never getting below 4.5° C.

The experimental design used for the study was a split-plot of a randomized complete block replicated four times. Whole plots were one of three N-fertility treatments 0, 112 or 224 kg N ha^{-1} randomly assigned in each block and applied in the form of a urea:NH_4NO_3 solution within 21 d following planting. Split-plots were one of six hybrid grain sorghum cultivars: Pioneer[1] brand 83P17 (Pioneer-DuPont, Johnston, IA), Dekalb brand[1] DKS54-03 (Monsanto, St. Louis, MO), Asgrow A571 (Monsanto, St. Louis, MO), Sorghum Producers brand[1], KS735, NK6638, or SP6929 (Chromatin, Lubbock, TX) randomly assigned within each whole plot. Individual experimental units were eight 102 cm spaced rows, 9 m long. Site preparation for planting began by disking the land level each autumn followed by the forming of 60 cm high ridges, spaced 102 cm apart in late winter. The previous crop on the site prior to initiating the experiment had been corn. Prior to planting the ridges were harrowed to form a 28 cm wide seedbed. A seeding rate of 99,000 kernels ha^{-1} was made using a John Deere[1] model 7100 vacuum planter (John Deere, Inc., Moline IL) and occurred on 27 May, 2014 and 4 June, 2015.

In 2014 irrigation was unnecessary due to frequent rainfall throughout the season to support crop growth to maturity, but in 2015 three irrigations were applied to reduce drought stress, beginning 5 d after seeding and on 15 July and 4 August (Table 1). Irrigation was accomplished using a furrow system with each irrigation event applying approximately 2.5 mm of water. Weather data were acquired at an official weather reporting station that was approximately 2 km from the experimental site and managed by Mississippi State University's Delta Research and Extension Center at Stoneville, MS.

Both years, weed and insect control, was achieved with applications of approved pesticides at labeled rates. Upon reaching physiological maturity a 0.15% v:v solution of glyphosate herbicide was applied to kill the plants in preparation for harvest 14 d later. Prior to harvest the mean heads per A were determined by counting a 1 m length of row mid-way of each sub-plot. A sample of five randomly selected heads were then harvested from either rows two or seven from each sub-plot, dried at 32° C for 48 h to be later used for determining mean grain weight per head, mean 1000 kernel weight and calculate the kernels per head. Total grain yield and relative moisture content were determined by harvesting the four center rows of each sub-plot with a Kincaid[1] 8XP combine (Kincaid Equipment Heston, KS), equipped with a Juniper[1] HarvestMaster (Juniper Systems, Logan, UT) weigh system. All grain yields were later adjusted to an 11.0% moisture level before data analysis using PROC MIXED of the SAS (SAS Institute, Cary, NC).

Table 1. Precipitation and irrigation events during the growing seasons at a grain sorghum hybrid x N-fertility treatments experiment conducted near Elizabeth, MS in 2014 and 2015.

2014	Precipitation (mm)	2015	Precipitation (mm)
5/28-6/3	114	9-Jun†	25
6/7-6/12	69	3/14-6/15	14
6/24-6/29	69	6/25-7/1	50
7/10-7/11	31	7/4-7/6	52
7/15-7/21	91	15-Jul†	25
7/31-8/2	6	26-Jul	7
8/9-8/12	38	4-Aug†	25
8/30-9/1	31	17-Aug	0.51
Total	449		198

†Signifies and irrigation event.

[1]Disclaimer

Trade names are used solely for the purpose of providing specific information. Mentions of a trade name, propriety product, or specific equipment does not imply approval of the named product to exclusion of other similar products.

Results and Discussion

Added N-fertilizer had no impact on grain yield of sorghum hybrids in 2014, the year in which no supplemental irrigations were applied (Table 2). The only differences in yield that year were among hybrids within the 0 kg N ha^{-1} treatment, where SP6929 yielded more grain that NK6638, A571 and DKS5403. No other differences were observed in the 0 kg N ha^{-1} treatment nor were differences observed among hybrids at the two N-fertilized treatments in 2014.

Table 2: Grain sorghum yields (kg grain per ha at 11.0% H_2O) of six hybrids grown with three levels of supplemental N fertilizer over two years on a Tunica clay soil near Elizabeth, MS.†

	0 kg N ha^{-1}		112 kg N ha^{-1}		224 kg N ha^{-1}	
Hybrid	2014	2015	2014	2015	2014	2015
83P17	3454	1659	2746	3764	3216	4861
A572	2923	1822	2791	3426	2817	3045
DKS54-03	3031	1748	2871	3012	2949	3264
KS735	3117	3682	3365	4394	2940	5007
NK6638	3040	3115	3312	4852	3089	5007
SP6929	3745	2041	3150	4384	3406	4143

†Means of 4 replications; for means with in a column and a row $lsd_{0.005}$ =647

Application of N-fertilizer did increase heads per m^2 especially in 2014 (Table 3). In 2014 each additional 112 kg N ha^{-1} of fertilizer resulted in a significant ($P\leq0.05$) increase in heads per m^2. In 2015 both levels of added N-fertilizer produced a mean of one more head m^{-2} than the 0 kg N ha^{-1} but no difference between 112 and 224 kg N ha^{-1} in heads per m^2 were noted.

Table 3: Mean heads per m^2 of six grain sorghum hybrids grown using three levels of supplemental N fertilizer over two years on a Tunica clay soil near Elizabeth, MS.†

		Heads per m^2	
Hybrid	0 kg N ha^{-1}	112 kg N ha^{-1}	224 kg N ha^{-1}
83P17	11	12	13
A572	10	12	13
DKS5403	10	12	13
KS735	10	13	14
NK6638	11	13	14
SP6929	10	12	12

†Means of 4 replications and two years (2014 and 2015), $lsd_{0.05}$=1 for means within a row and column

Mean seed yield per head in 2014 was greater for the 0 kg N ha^{-1} treatment than for either of the two N-fertilized treatments, while no such differences were observed among the N-fertilized treatments in 2015 (Table 4). However, both N-fertility treatments did produce more grain in 2015 than their comparable treatments in 2014. Seed weight per head among hybrids across the two growing seasons showed no consistency with one or more hybrids being either inferior or superior in seed yield per head (Table 5). Except for 83P17, seed yield per head was greater in 2015 than 2014 for the remaining hybrids. Seed yield per head for 83P17 was significantly ($P\leq0.05$) less in 2015 than 2014. No sound physiological explanation can be given for these results.

Table 4: Mean seed yield per head of six grain sorghum hybrids grown with three levels of supplemental N fertilizer on a Tunica clay soil near Elizabeth, MS for two years.†

		grain yield per head (g)	
Year	0 kg N ha^{-1}	112 kg N ha^{-1}	224 kg N ha^{-1}
2014	52	44.2	41
2015	53.2	57.9	55.5

†Means of 6 hybrids (83P17, A572, DKS5403, KS735, NK6638, or SP6929) and 4 replications: $lsd_{0.05}$=5.4 for means within a row or a column.

Table 5: Mean seed yield per head of six grain sorghum hybrids grown in 2014 and 2015 using three levels of supplemental N fertilizer on a Tunica clay soil near Elizabeth, MS†

	grain yield per head (g)	
Hybrid	2014	2015
83P17	63	52.4
A572	33.8	48
DKS5403	40.6	60.3
KS735	45.3	53
NK6638	48.3	53.2
SP6929	43.4	66.3

†Means of 3 N-fertilizer treatments (0, 112 and 224 kg N ha^{-1}) and 4 replications; $lsd_{0.05}$=6.8 for means within a row or a column.

Mean 1000 kernel weights were greater in 2015 (21.3 g) than 2014 (18.4 g), the hybrid x N-fertilizer rate interaction was statistically significant ($P\leq0.05$). However, no trends of inferiority or superiority in 1000 kernel weight for any hybrid or group of hybrids across the different levels of N-fertilizer rates were evident, much like what was observed for seed yield per head (Table 6).

Table 6: Mean 1000 kernel weight of six grain sorghum hybrids, grown for two years with three supplemental N fertilizer treatments on a Tunica clay soil near Elizabeth, MS.†

	grain yield per head (g)	
Hybrid	2014	2015
83P17	63	52.4
A572	33.8	48
DKS5403	40.6	60.3
KS735	45.3	53
NK6638	48.3	53.2
SP6929	43.4	66.3

†Means of 3 N-fertilizer treatments (0, 112 and 224 kg N ha^{-1}) and 4 replications; $lsd_{0.05}$=6.8 for means within a row or a column.

Several factors may have resulted in the less than stellar yields in this experiment as well as a lack of consistent differences between years, hybrids and N-fertility treatments. Because of the high amount of montmorillonite the heavy clay soils such as Tunica, can develop, large, deep cracks in the upper 12" to 18" of the soil profile as they dry during droughty conditions. Such soils can readily cause root pruning with this cracking, especially for crops with fibrous root systems such as grain sorghum, thus lowering potential yields. However, this was not the case during the first year of this experiment where the several heavy rains that occurred likely caused a loss of the applied N fertilizer.

The large differences in rainfall between the two growing seasons (17.5" for 2014 vs. 5.36" + 3.0" irrigations in 2015) (Table 1), seem to have resulted in the lower grain yields in 2014 compared to 2015. Several of the rain events in 2014 resulted in waterlogged soil conditions for extended periods of several days throughout the season and likely resulted in extensive denitrification of the fertilized treatments. This would have in turn had an adverse effect on yields. Leaching was probably not a big factor in the reduced yields of 2014 due to the very slow permeability of the Tunica soil. Other factors such as insect pressures were similar both years and was effectively controlled.

Differences in mean daily solar radiation between the two seasons may also have contributed to the reduced yields observed in 2014. Average daily solar radiation levels recorded at the weather station near the experimental site during August, 2014 was 1.9 M J m^{-2} d^{-1} compared to 2.2 M J m^{-2} d^{-1} during the same time in 2015 (MSUES, 2016). This event coincides with the period of kernel filling (Growth Stages 7 and 8) (Vanderlip and Reeves, 1972). The lower mean solar radiation in 2014 during these growth stages would have likely resulted in lower photosynthetic photon flux density levels and thus less photosynthate produced for kernel filling, partially explaining the lower yields observed in the N-fertilized treatments in 2014.

Data from this study along with the previously reported experiment (Bruns, 2015) does point to a need of applying at least 200.0 lbs. N A^{-1} supplemental fertilizer, especially if the crop is to be irrigated. These findings are similar to those reported by Roy and Wright (1972) and Mahama et al. (2014). The sub-standard yields observed in most of this experiment though do suggest that soils such a Tunica or other soil of high clay content in an alluvial river delta may not be best suited to grain sorghum production, especially during rainy seasons.

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