Grain Sorghum Yield Components as Influenced by Hybrid, Seeding Date, and Irrigation

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Core Ideas

- Grain sorghum, though not a new crop to the Lower Mississippi River Valley, has received very limited attention in recent years with respect to management research.
- Row-crop irrigation has greatly increased in the Mississippi Delta over the past 20 years to where sub-surface acquifers are being mined at unsustainable rates.
- Grain sorghum appears to benefit very little or not at all from irrigation and may provide a cash crop that will help reduce irrigation water depletion.
- Production practices of grain sorghum that manage around some of the newer pest problems that have recently appeared are in need of development.

ABSTRACT

Grain sorghum [*Sorghum bicolor* (L.) Moench] production retains some interest in the midsouth states as a rotation crop and a drought-tolerant option in limited or non-irrigated cropping systems, thus helping conserve water resources. An experiment was conducted using four grain sorghum hybrids to measure the effects of irrigation vs. no irrigation plus May vs. June seeding dates on yield and yield components of the crop. The May seeding was the normal time of planting while the June seeding simulated double-cropping after wheat (*Triticum asetivum* L.) Furrow irrigation had no impact on seed yield at either seeding date. June seedings were lower (≤4626.4 kg ha^{-1}) than May seedings (≥5168.3 kg ha^{-1}). No differences among hybrids were observed between years of the two May seedings. However, all hybrid yields for June seedings in 2017 were significantly less than the 2016 crop. Heads per hectare basically did not differ between years, but May seedings produced more heads (≥134,167 heads ha^{-1}) than June seedings (≤118,504 heads ha^{-1}). Despite reduced grain yields by June seedings, the lack of having to irrigate double-crop grain sorghum as opposed to having to irrigate double-crop soybean [*Glycine max* (L.) Merr.] makes the former a viable option for water conservation and potential profit.

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Grain sorghum [*Sorghum bicolor* (L.) Moench] production in the combined lower Mississippi River Valley states of Arkansas, Louisiana, and Mississippi was down to ≃40,000 ha in 2016 compared with 133,000 ha in 2013 (USDA-NASS, 2018) due primarily to the invasion of the sugarcane aphid (*Melanaphis saccharia*). Though not considered a major crop for the region, the concentration of this production in the lower Mississippi River Valley exceeds most areas in the United States except for the West Central and Southern Great Plains. Despite the recent invasion by the sugarcane aphid, the crop continues to retain interest for rotational purposes and as a drought-tolerant option to corn (*Zea mays* L.), soybean [*Glycine max* (L.) Merr.], and cotton (*Gossypium hirsutum* L.) in limited or non-irrigated cropping systems.

Extensive irrigation from the Mississippi Alluvia Aquafer, the primary water source for agricultural use for much of the Mississippi Delta, is depleting this water resource at unstainable rates (Pennington, 2007). Bruns (2015) recently reported that furrow irrigation of grain sorghum on a clay soil in the Mississippi Delta did not improve yields over non-irrigated plots. This lack of difference was due in part to the species' ability to compensate among the various yield components to stabilize seed production. These data supported previous work by Heatherly et al. (1990) and Wesley et al. (2001). It also supports the premise of grain sorghum as a partial solution to reducing irrigation demands on limited water resources and maintaining a local feed source for poultry production in the southeastern United States.

Double-cropping of soybean after wheat (*Triticum asetivum* L.) is a common practice in the lower Mississippi River Valley because an appreciable amount of time after wheat harvest (early June) exists for soybean to successfully complete its lifecycle before frost. However, seeding soybean at this time in the growing season risks yield losses and possible crop failure due to drought. Frequent irrigations are almost always essential to produce a successful harvest. Soybean double-cropped after wheat can be risky if not irrigated. Roberson (2009) reported that growers using irrigation to reduce a yield "drag" on double-crop soybean need to realize the crop needs twice as much water during rapid vegetative growth up to full canopy than it needs in the very early growth stages or when nearing maturity. Grain sorghum may be an alternative to soybean in a double crop system with wheat, needing less water to produce a profitable yield.

Piggott (2013), demonstrated in North Carolina that a 4566 kg ha^{-1} grain sorghum yield following wheat had a greater net return than 2016 kg ha^{-1} soybean yield based on prices paid for the two crops in 2012. Ciampitti and Shoup (2017) stated that for southern Kansas double cropping grain sorghum after wheat should be done using early maturing hybrids to ensure crop maturity before frost. They also pointed out that late-planted sorghum will tiller less than earlier seedings and thus benefit from higher seeding rates. A 4-yr experiment in Kansas found that May seedings averaged 4578 kg ha^{-1} as opposed to 4264 kg ha^{-1} for June seedings.

Current research on grain sorghum in the lower Mississippi River Valley is limited, due in part to its comparative small hectarage to corn, soybean, and cotton. The objectives of this experiment were to further research the influence of irrigating vs. not irrigating grain sorghum and strengthen previous observations that suggest the crop can be used to conserve irrigation water resources. Also, it was conducted to examine the feasibility of using grain sorghum as an alternative crop to soybean in a double crop production system following wheat. This was done by investigating its response to June seedings that would simulate planting the crop after wheat harvest.

MATERIALS AND METHODS

The experiment was conducted during the growing seasons of 2016 and 2017 on a Dundee fine sandy loam site (fine-silty, mixed, active, thermic Typic Endoaqualfs) 1.5 km north of Elizabeth, MS, leased by the USDA-ARS Crop Production Systems Research Unit in Stoneville, MS. Four commercially available hybrids; Pioneer brand (DuPout-Pioneer Johnston, IA) 83P17, Dekalb brand (Monsanto, St. Louis, MO) DKS-5400, and Sorghum Partners brands (Chromatin, Lubbock, TX) SP6929 and KS735 were selected for the experiment. The experimental design used was a split-split-plot replicated twice. Irrigated and non-irrigated treatments were whole plots, with May or June seedings as sub-plots and hybrids as sub-sub plots sub-replicated three times. Irrigation treatments were applied with a furrow irrigation system with single applications amounting to approximately 25.0 mm. Two irrigation treatments were applied to the designated whole plots on 1 and 21 July 2016 and 19 July and 8 Aug. 2017.

Site preparation began the previous fall with disk harrowing the crop residue of the 2015 corn crop. The field was then ridged-tilled to form ridges 40 cm high and spaced 102 cm apart. Prior to planting, 67 kg K ha^{-1} in the form of murate potash was broadcast over the site, re-hipped, and the ridges of sub-plots for the first seeding date harrowed to form a seed bed 40 cm wide. Seeding was accomplished with an Almaco 4-single row research plot planter set on 102-cm row spacing. Individual experimental units were eight 102-cm rows 12 m long. Seeding rate for all hybrids on both planting dates was 99,000 kernels ha^{-1}. Seeding dates for the May plantings were 11 May 2016 and 11 May 2017 and for June dates 10 June 2016 and 12 June 2017.

Weed control for the experiment was accomplished both years by first with a pre-plant application of Lexar (Syngenta Crop Protection, Greensboro, NC) (S-metolachlor 19%, atrazine 18.6%, atrazine (6-chloro-*N*2-ethyl-*N*4-(propan-2-yl)-1,3,5-triazine-2,4-diamine) related compounds 0.39%, and mesotrione [2-[4-(Methylsulfonyl)-2-nitrobenzoyl]cyclohexane-1,3-dione] 2.44%) at 7 L ha^{-1} 28 d prior to seeding followed by pre-emergence treatments of 1.1 kg a.i. ha^{-1} atrazine and 1.0 kg a.i. ha^{-1} S-metolachlor. In 2016 at anthesis sorghum midge (*Contrainia sorghicola* Coquillett) was controlled with an application of Besiege (Chlorantraniliprole 9.26% and lambda cyhalothrin 4.63%) at recommended labeled rates (Syngenta Crop Protection, Greensboro, NC) with a second application applied 7 d later for continued control. During 2017, sorghum midge was controlled using two applications of Intrepid [methoxyfenozide: Benzoic acid, 3-methoxy 2-methyl-,2-(3,5-dimethylbenzoyl)-2- (1,1-dimethylethyl) hydrazide] at label rates (Dow AgroSciences Indianapolis, IN) at the same growth stages as the previous year. During the second application in 2017 Transform (sulfoxaflor, [[Methyl(oxo){1-[6-(trifluoromethyl)-3-pyridyl]ethyl}-λ6-sulfanylidene]cyanamide]) (Dow AgroSciences Indianapolis, IN) was added as a tank-mix for sugarcane aphid control. A second application of Transform was necessary 28 d later for continued sugarcane aphid control. Sugarcane aphid was not a significant pest in 2016. Head worm complex became a significant pest in 2017 at Growth stage 8 (hard dough) as defined by Vanderlip and Reeves (1972), and necessitated an application of Besiege for their control.

Prior to harvest, heads per hectare were determined for each experimental unit by counting the number of heads in two linear 1-m row lengths from the two center rows. The four center rows of each unit were sprayed with a 2.0% (v/v) solution of glyphosate [*N*-(phosphonomethyl)glycine] after obtaining growth stage 9 (physiological maturity) and harvested 8 d later with a Kincaid 8X-P (Kincaid Equipment Mfg., Haven, KS) combine equipped with a HarvestMaster weighing, bulk density, and moisture testing system (Juniper Systems, Logan, UT). Harvest dates for the first seedings were 2 Sept. 2016 and 28 Aug. 2017. Second seeding dates were harvested 15 Sept. 2016 and 25 Sept. 2017. Immediately following each harvest, five randomly selected head samples were taken from the inside boarder rows of each harvested experimental unit, dried at 50°C for 48 h, threshed by hand, the grain collected and weighed. A 1000-kernel sample was counted and weighed to determine seed weight. From these data seed weight and number per head were estimated. Grain moisture content was determined during harvest and all grain yield data were adjusted to a standard 110 g H_2O kg^{-1} dry weight. Statistical analyses were conducted using PROC MIXED of the Statistical Analysis System 9.4 (SAS Institute, Cary, NC). Means separation was preformed using the least significant difference (lsd, $\alpha = 0.05$). The analyses of variance are presented in Table 1. Random effects were: whole reps (years), whole reps × irrigation (years), sub-reps (whole reps × irrigation × years), whole reps × hybrids × seeding date (irrigation × year).

RESULTS AND DISCUSSION

Grain yields for May seedings were significantly greater ($P \leq 0.05$) each season for all hybrids than June seedings (Table 2). Yield differences among hybrids within a seeding date were noted for both May plantings and the June 2016 planting, but not for the June 2017 planting. Yields of June seedings for 2016 across hybrids were greater

Table 1. Type III tests of fixed and covariance parameter estimates of an irrigated and non-irrigated grain sorghum hybrid × seeding date experiment conducted near Elizabeth, MS, on a Dundee sandy loam soil† in 2016 and 2017.

Source	df	Heads ha^{-1}	1000 Kernel wt	Kernels head^{-1}	Yield
		P > *F*	*P* > *F*	*P* > *F*	*P* > *F*
Year	1	0.6194	0.0072	<0.0001	<0.0001
Seeding date	1	<0.0001	0.0232	<0.0001	<0.0001
Hybrid	3	0.1071	0.0003	0.0003	0.0003
Irrigation	1	0.4271	0.7528	0.1178	0.8466
Seeding date × hybrid	3	0.002	0.5597	0.0008	0.0917
Year × seeding date	1	0.009	0.2421	<0.0001	<0.0001
Year × hybrid	3	0.0437	0.0074	0.3724	0.0255
Year × seeding date × hybrid	3	0.2845	0.1245	0.8698	0.6365
Hybrid × irrigation	3	0.7852	0.4531	0.1778	0.7883
Year × irrigation	1	0.822	0.9968	0.8908	0.4246
Year × seeding date × irrigation	1	0.1919	0.333	0.4639	0.1127
Year × hybrid × irrigation	3	0.4203	0.291	0.281	0.7261
Seeding date × irrigation	1	0.7186	0.1348	0.1126	0.0395
Year × seeding date × hybrid × irrigation	6	0.0263	0.9233	0.9968	0.9761
		Covariance parameter estimates			
Rep (year)		0	0.1026	0	1.20E–13
Rep × irrigation (year)		0.2848	0	0	0
Sub-rep (year × rep × irrigation)		0.1255	1.3857	3211.33	51,547
Rep × seeding date × hybrid (year × irrigation)		0	0.7052	0	72,412
Residual		3.3155	9.0981	192,923	253,797

† Dundee fine sandy loam, fine-silty, mixed, active, thermic Typic Endoaqualfs.

Table 2. Grain sorghum yields of four hybrids seeded in May and June of 2016 and 2017 on a Dundee sandy loam soil† near Elizabeth, MS.‡

Hybrid	May seeding		June seeding	
	17 May 2016	11 May 2017	10 June 2016	12 June 2017
	kg ha^{-1}			
DKS-54-00	5615.9bx§	5559.5abx	3984.6by	2276.7z
KS735	5240.4bx	5405.7bx	3352.5cy	2166.7z
P83P17	6229.6ax	5849.1ax	4626.4ay	2163.3z
SP6929	5248.7bx	5168.3cx	4132by	2347.9z

† Dundee fine sandy loam, fine-silty, mixed, active, thermic Typic Endoaqualfs.

‡ Means of 2 whole replications, 3 sub-replications, irrigated, and non-irrigated treatments.

§ Means followed by the same letter or letters within a column (a, b, c) and within a row (x, y, z) are not significantly different by lsd(α0.05) = 354.8.

than those of the succeeding year. The lower grain yields observed in the 2017 June seeding are likely due to the combination of the high amounts of rain during 7 to 11 August (Table 3) that likely caused a loss in available N through denitrification during kernel filling (growth stage 7) along with a probable reduction of available photosynthetic radiation (mean light level = 113 W m^{-2}) during those 5 d (MSUES, 2018). The infestations for both sugarcane aphid and head worm complex in 2017 may have had a more negative impact on yield of the later seeding than the May seeding.

The hybrid Pioneer 83P17 in the formerly mentioned seedings was consistently greater than K735 and SP6929 and only in the May 2017 failed to be significantly greater than DKS-54-00 (Table 2). In the seeding date × irrigation interaction, no statistical differences in yield were noted between irrigated and non-irrigated treatments, with the May seedings (5446.3 vs. 5633.0 kg ha^{-1}) nor the June seedings (3251.2 vs. 3011.2 kg ha^{-1}), respectively. However yields between the two seedings for both the irrigated and non-irrigated treatments differed significantly (lsd(α0.05) = 336.4).

Regarding the yield component, seed heads per hectare, hybrid differences were observed between years and seeding dates (Table 4). Between years there was no consistency in the observed differences among the hybrids, whereas among seeding dates, May seedings

Table 3. Precipitation and irrigation events on an irrigated and non-irrigated grain sorghum hybrid × seeding date experiment conducted near Elizabeth, MS, on a Dundee sandy loam soil† in 2016 and 2017 (MSUES, 2018).

2016		2017	
Event	mm	Event	mm
28–31 May	26.7	12–13 May	38.3
2–6 June	77.4	21–25 May	34.9
13–20 June	36.45	2 June	39.8
1-July‡	22.5	16–20 June	47
5–6 July	25	22–25 June	81
10–12 July	26.1	2–3 July	29
21-July‡	22.5	7–10 July	21.2
25–31 July	89.8	19 July‡	22.5
13–20 Aug.	82.4	23–26 July	42.5
Total	408.85		
		2 Aug.‡	22.5
		7–11 Aug.	140.9
		14–16 Aug.	35.7
		27–31 Aug.	69.3
		Total	624.6

† Dundee fine sandy loam, fine-silty, mixed, active, thermic Typic Endoaqualfs.

‡ Irrigation event.

Note: We did not use subscript because the type gets very small. We used parentheses instead -- lsd(α0.05)

Table 4. Estimated heads per hectare of four grain sorghum hybrids grow in 2016 and 2017 on a Dundee sandy loam soil near Elizabeth, MS.†

	Heads ha^{-1}‡		Heads ha^{-1}§	
Hybrid	2016	2017	May seeding	June seeding
DKS-54–00	124,754by	133,750aby§	140,000by	118,504az
KS735	131,667aby	137,917ay	156,667ay	112,917az
P83P17	122,917by	128,333bcy	134,167by	117,083az
SP6929	134,461ay	124,167cz	140,417by	118,211az

† Means of 2 replications, 3 sub-replications, irrigated and non-irrigated treatments.

‡ Means of 2 seeding dates (May and June). Means followed by the same letter or letters within a column (a, b, c) or a row (y, z) are not significantly different lsd(α0.05) = 9376.

§ Means of 2 growing seasons (2016 and 2017). Means followed by the same letter or letters within a column (a, b) or a row (y, z) are not significantly different lsd(α0.05) = 8460.

Table 5. Grain weight per head, 1000 kernel weight, and kernels per head of four grain sorghum hybrids grow in 2016 and 2017 on a Dundee sandy loam soil† near Elizabeth, MS.‡

	Grain wt. (g) head^{-1}§		1000 kernel wt (g)¶		kernels head^{-1}#	
Hybrid	2016	2017	2016	2017	2016	2017
DKS-54–00	59.0ay	43.6az	19.2ay	26.0bz	2686ay	2133az
KS735	48.7cy	38.1bz	18.9ay	26.1bz	2275by	1824bz
P83P17	58.8ay	46.8az	19.9ay	30.1az	2621ay	1951bz
SP6929	53.6by	43.7az	19.5ay	30.6az	2095cy	2124ay

† Dundee fine sandy loam, fine-silty, mixed, active, thermic Typic Endoaqualfs.

‡ Means of 5 randomly selected seed heads, 2 replications, 3 sub-replications, irrigated or non-irrigated treatments.

§ Means within a column (a, b) or a row (y, z) followed by the same letter or letters are not significantly different lsd(α0.5) = 4.0.

¶ Means within a column (a, b) or a row (y, z) followed by the same letter or letters are not significantly different lsd(α0.5) = 1.6.

Means within a column (a, b, c) or a row (y, z) followed by the same letter or letters are not significantly different lsd(α0.5) = 135.

were consistently greater in heads per hectare over June seedings. The hybrid KS735 produced more heads per hectare (156,667) in May seedings than all other hybrids, and no differences in heads per hectare were observed in the June seedings.

Grain weight per head among hybrids was greater in 2016 than 2017 (Table 5). Hybrid difference for this yield component were observed in 2016 but not in 2017. Weights of 1000 kernel samples though were greater for all hybrids in 2017 than 2016, an example of compensatory effects among yield components that has been reported in the past (Bruns, 2015). Differences among hybrids in 1000 kernel weights were observed in 2017 with SP6929 and P83P17 having 1000 kernel weights >31.0 g whereas DKS-54-00 and KS735 had 1000 kernel weights of $\simeq$26.0 g. No differences in this component were observed among hybrids in 2016. More kernels per head were produced in 2016 than 2017, except for SP6929, which were not significantly different between 2016 and 2017.

These data are similar to previous findings that irrigation does not seem to benefit seed yields of grain sorghum in the lower Mississippi River Valley (Bruns, 2015; Wesley et al., 2001; Heatherly et al., 1990). As such, it strengthens the premise that grain sorghum may well have a place as a crop that can help reduce depletion of underground water resources used for crop irrigation. Grain sorghum yields of June seedings in this experiment did not yield as well as those made in May, similar to findings reported from Kansas (Ciampitti and Shoup, 2017). Higher seeding rates as suggested in Kansas data along with soil water conservation practices, such as no-tilling into stubble immediately after wheat harvest and pre-emergence weed control, will likely aid in stand establishment of the sorghum crop. The excessive rainfall during 7 to 11 Aug. 2017, when kernel filling of the June seeding was occurring, appear to have had a very negative impact on grain yield. Such a rain event during mid-summer is very rare for the region (MSUES, 2018). Yield data from the June 2016 seeding as a result is probably more realistic and suggest that profitable grain sorghum yields from June seedings are possible based on findings by Piggott (2013).

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