Evaluation of hybrid sweet sorghum as a biofuel crop for the southeast USA

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Introduction

Sweet sorghum (*Sorghum bicolor* (L.) Moench.) has potential as a multi-purpose biofuel crop in the southeast USA. The sugars from the juice can be easily fermented into ethanol or used to produce other chemicals, while the bagasse could be burned in boilers for energy or used for cellulosic ethanol. The grain and leaf portions could be utilized as livestock feed. The crop is more tolerant of heat and drought than corn (*Zea mays* L.), and requires less N fertilizer. Despite its advantages, all current cultivars are pure lines that produce little seed on very tall plants, which is a major limitation to development of a sweet sorghum-based biofuel industry. There is a need to develop hybrid seed production on short-statured seed parents. Hybrids should also be more productive than pure lines. A test was conducted at Tifton, GA in 2012 to assess the potential for heterosis and combining ability in some of the currently-available sweet sorghum germplasm.

Materials and Methods

A Design II mating design was constructed using three male-sterile (A-line) seed parents as females and 19 males to generate 57 hybrids. The males represent a range of maturities, and include landraces, heirlooms, and improved cultivars. In 2012 all the hybrids, male parents, and the male-fertile (B-line) versions of the females were planted in a randomized complete block design with two replications. Each plot consisted of two rows. One row was used for sampling, while the other was harvested for total biomass at the end of the test. Over the course of the growing season, juice BRIX was sampled at regular intervals to monitor sugar production. BRIX was measured using a hand-held digital refractometer. At harvest, a sample of three stalks was taken from each plot, and these were separated into leaves, stalks, and panicles. The juice was extracted from the stalks with a roller mill and was quantified. Other traits measured included plant height, lodging score, and days to anthesis.

Results

Table 1. Days to anthesis for three females, 19 males, and 57 hybrids. Earlier maturities are shaded green, later maturities are shaded red.

Days to Anthesis		Females		
		N109	N110	N111
Males		65	65	70
COLLIER	62	61	63	62
TRACY	66	57	58	54
LEOTI-PELTIER	66	62	58	64
EARLY FOLGER	67	62	62	61
REX	67	63	61	67
N98	68	64	63	66
N100	68	62	64	60
PI 250898	70	62	59	59
SUGAR DRIP	71	63	60	60
SACCALINE	72	67	59	62
84-5626	75	67	62	61
ATLAS	76	67	65	71
ISIDOMBA	79	70	65	70
RG	92	74	75	72
MER 76-3	93	74	75	74
PI 643017	94	74	74	76
M 81E	100	78	80	80
BRANDES	106	84	78	85
TOP 76-6	108	88	88	92

Hybrids

Table 2. Mature plant height for three females, 19 males, and 57 hybrids. Taller plants are shaded green, shorter plants are shaded red.

Plant Height (cm)		Females		
		N109	N110	N111
Males		105	188	194
COLLIER	189	203	209	235
EARLY FOLGER	190	202	175	188
ATLAS	192	213	230	242
N98	196	168	204	206
N100	205	191	175	182
LEOTI-PELTIER	206	200	177	227
TRACY	217	208	184	210
REX	237	222	216	197
SACCALINE	242	221	189	174
84-5626	244	201	219	218
SUGAR DRIP	269	227	239	224
PI 250898	270	214	214	232
ISIDOMBA	273	262	243	273
BRANDES	274	257	295	300
MER 76-3	301	281	283	278
RG	302	303	296	321
TOP 76-6	316	321	335	349
PI 643017	320	303	279	299
M 81E	357	322	310	330

Hybrids

Table 3. Lodging scores for three females, 19 males, and 57 hybrids. 0 = no lodging, 5 = completely lodged. Better scores are shaded green, worse scores are shaded red.

Lodging Score (0-5)		Females		
		N109	N110	N111
Males		0.0	3.0	0.5
COLLIER	0.5	1.0	4.0	0.5
ISIDOMBA	0.5	0.0	2.0	1.5
N100	0.5	1.0	0.5	0.5
ATLAS	1.0	1.0	1.0	2.0
BRANDES	1.0	0.0	1.0	1.5
TOP 76-6	1.0	1.0	2.0	1.5
M 81E	1.5	0.0	2.5	2.5
N98	1.5	0.0	1.0	1.0
RG	1.5	1.0	2.0	1.5
MER 76-3	2.0	0.5	2.0	0.0
REX	2.0	1.0	1.5	3.0
84-5626	2.5	2.5	2.5	0.5
EARLY FOLGER	2.5	0.0	2.5	2.5
LEOTI-PELTIER	3.0	2.0	1.0	3.0
PI 250898	3.0	1.5	4.0	3.0
SUGAR DRIP	3.5	3.0	2.0	1.5
SACCALINE	4.0	4.0	2.5	1.0
PI 643017	4.5	3.5	4.5	4.0
TRACY	4.5	1.0	5.0	4.5

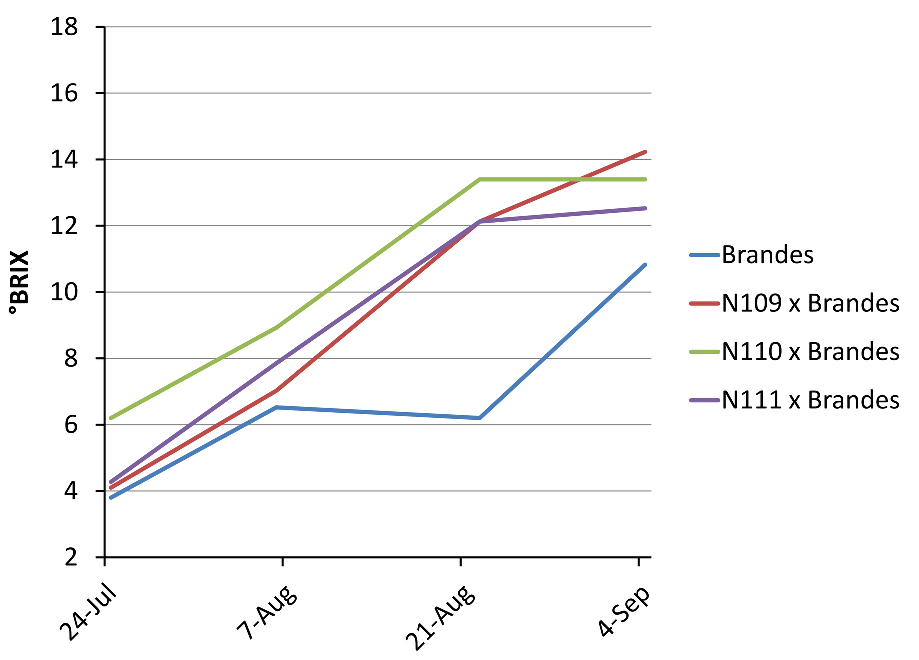
Hybrids

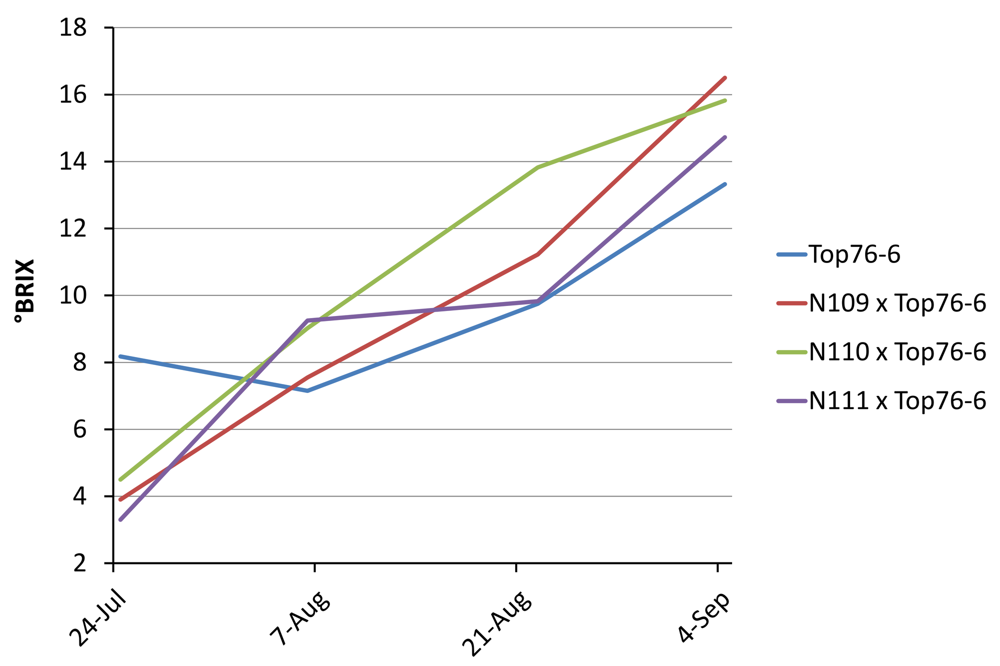
Table 4. Dry biomass yield for three females, 19 males, and 57 hybrids. Higher yields are shaded green, lower yields are shaded red.

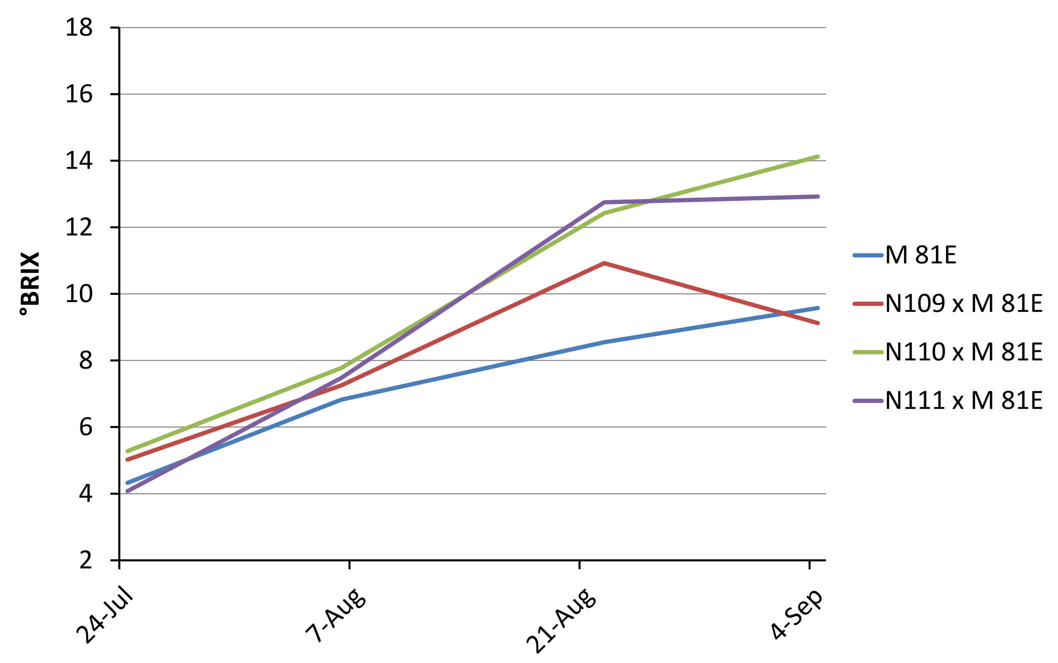
Biomass (kg/ha)		Females		
		N109	N110	N111
Males		3028	6358	8237
COLLIER	3255	6315	8508	6336
TRACY	3998	10673	5285	5412
LEOTI-PELTIER	5386	4575	5252	4896
SUGAR DRIP	5397	7106	6880	5568
PI 643017	5511	10006	10586	7434
SACCALINE	5774	7393	6554	4051
EARLY FOLGER	6509	5687	5344	4587
REX	7082	6722	8331	4924
N100	7433	6736	6564	5073
ATLAS	7505	8058	6816	6471
N98	7773	4595	7181	7721
84-5626	7826	7460	7680	5707
PI 250898	9163	6711	6506	8700
ISIDOMBA	9637	10685	7137	9245
RG	12870	14274	16113	13723
MER 76-3	14821	12362	13281	11904
BRANDES	15002	13849	9740	13756
M 81E	16171	15145	16189	13378
TOP 76-6	20753	14202	13201	15230

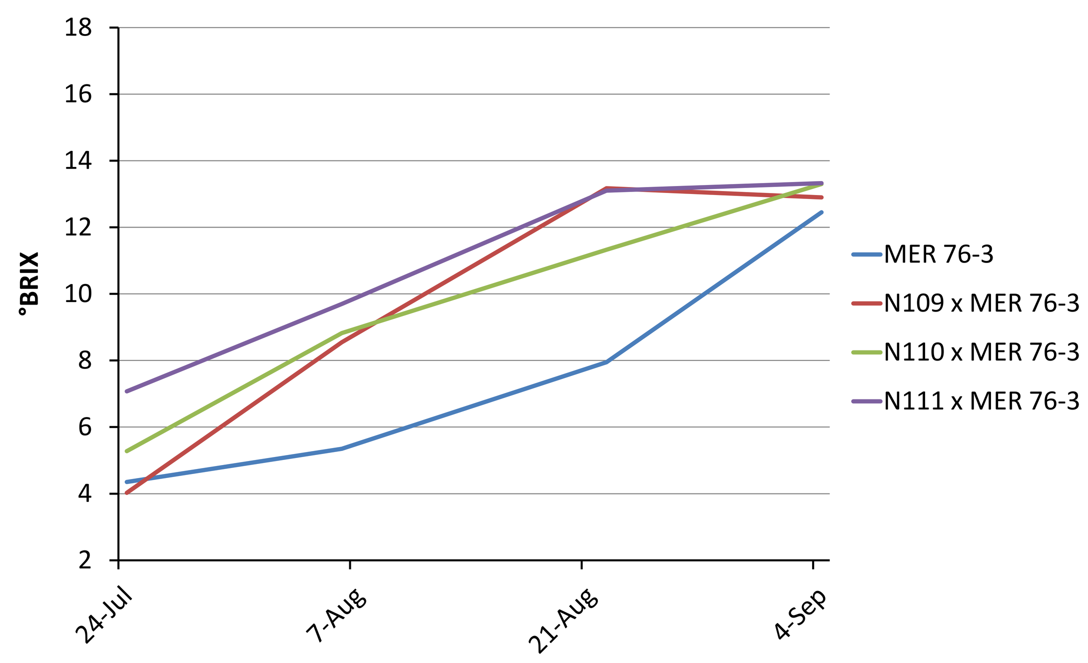
Hybrids

Figure 1. BRIX curves for selected males and their hybrids with N109, N110, and N111.









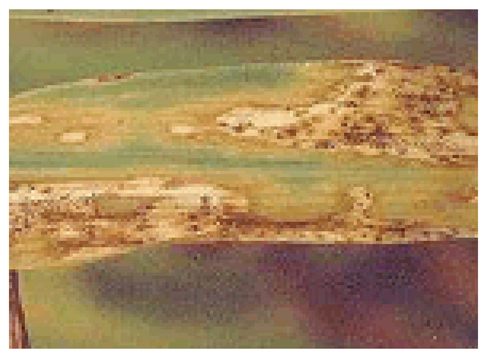


Figure 2. Symptoms of leaf anthracnose on sorghum.

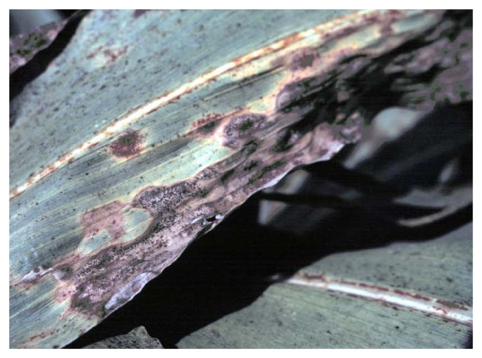


Figure 3. Symptoms of rough leaf spot on sorghum.

Figure 4. Fall armyworm damage on sorghum.

Conclusions

In this study plant height and biomass of hybrids were generally similar to that of their male parents. However, most hybrids matured earlier than their male parent, and some showed better resistance to lodging. Female parent N109 A appears to have good general combining ability for lodging resistance. Earlier maturity, resistance to lodging, and ease of harvesting seed are clear advantages of producing hybrid sweet sorghum seed, and this seed could be produced on short seed parents, such as N109 A, using currently-available cultivars as pollen parents. In this test, the best entries produced sugar yields around 2,000 kg ha^{-1}. This could be converted to around 1,100 L ha^{-1} of ethanol. Improvements in resistance to diseases, such as anthracnose (*Colletotrichum sublineolum*, Fig. 2) and rough leaf spot (*Ascochyta sorghina*, Fig. 3), and resistance to insects such as fall armyworm (*Spodoptera frugiperda*, Fig. 4) are still needed in this crop.