Agronomic Potential and Grain and Nutritional Quality Attributes in Herbicide Resistant Sorghums

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INTRODUCTION

- Ranked fifth among major cereal grains, sorghum serves as a key feed grain in the developed world and as a primary source of energy and protein in the developing world.
- However, sorghum lags behind several cereals in terms of benefiting from modern production technologies. One of the key areas where technology generation has not kept pace with developments in other crops is the weed control technology. Infestation by grass weeds poses significant threat to sorghum production in mechanized agriculture.
- The discovery of sources of resistance to Acetolactate synthase (ALS) inhibitor herbicides was a positive step towards developing herbicide resistant sorghums. Efforts to that end have generated series of ALS resistant lines. As the technology awaits commercialization, one key concern among both the industry and producers is the interveinal chlorosis commonly observed in ALS resistant lines.
- However, the impact of such phenotype on overall crop performance and agronomic adaptation has not been studied.

OBJECTIVE

- To assess the effect of interveinal chlorosis and reduced seedling vigor associated with ALS resistant sorghum on agronomic potential and grain and nutritional quality of sorghum.

MATERIALS AND METHODS

- Thirty-three ALS resistant inbred lines (parents) expressing different levels of interveinal chlorosis and seedling vigor were selected. Additional thirty hybrids comprising combinations of ALS resistant and regular parents (10 each of ALS × ALS, ALS × Regular, and Regular × ALS hybrids) were also synthesized. Two commercial hybrids were included as checks.
- The hybrids, the ALS resistant lines and the checks were grown in randomized complete block design in three replications during the 2014 cropping season. Plots were 3.5m long paired rows and standard crop management practices were employed.
- Leaf chlorophyll content was measured at five leaf stage and at grain filling stage using the SPAD 502 plus chlorophyll meter (Spectrum Technologies, Inc.).
- At anthesis, days to flowering was recorded and chlorophyll fluorescence was measured using OS30p+ hand held chlorophyll fluorometer (Opti-Sciences, Inc.).

SPAD 502 plus Chlorophyll Meter | OS30p+ Hand Held Chlorophyll Fluorometer | Near Infrared (NIR) System | Single Kernel Characterization System (SKCS)

- At maturity, plant height and yield components were measured. Three panicle samples were collected from each entry and yield components including 1000 kernel weight, kernel number per panicle, panicle weight, panicle length and panicle diameter were determined.
- Physical grain quality parameters were determined using Single Kernel Characterization System (SKCS) (Perten instruments, Inc).
- The entire plots were combine harvested to estimate the overall plot yield.
- Protein, starch, fat and ash content were determined for each entry using the Near Infrared (NIR) spectroscopy (Perten instruments, Inc).
- Analysis of mineral nutrient profiles (P, K, Ca, Mg, Fe, Zn, Cu and Mn) were conducted by local service providers.
- Data were analyzed using SAS 9.4 and XLSTAT version 2015.

RESULTS

Fig.1 ALS resistant sorghum inbred lines and hybrids. a) Resistant progeny families segregating for seedling chlorosis; b) A close-up of interveinal yellowing symptom on leaves; c) Chlorophyll measurements on seedlings; d) Mature panicles of an ALS resistant hybrid (left) and a commercial check (right).

Table1: P-values from the analysis of variance on yield components, phenological and physiological parameters on inbred lines and hybrids.

Measured Parameter	Parental Lines		Hybrids			
	P-value	#	P-value	# AA	# AR	# RA
Seedling Chlorophyll Content	<.001	25*	<.001	00	09	06
Adult Plant Chlorophyll Content	<.001	25*	0.068	10*	10*	10*
Seedling Height	<.001	21*	0.035	10*	10*	10*
Adult Plant Height	<.001	21*	0.229	10*	10*	10*
Days to Flowering	<.001	07*	<.001	10*	10*	10*
Chlorophyll Fluorescence (Fv/Fm)	0.003	17*	0.103	10	10	10*
Thousand Kernel Weight	0.020	13*	<.001	10*	10*	10
Kernel Number per Panicle	<.001	31*	0.175	10*	10*	10*
Panicle Weight	<.001	24*	0.568	10*	10*	10*
Panicle Length	<.001	30*	0.003	10*	10*	10*
Panicle Diameter	<.001	23*	0.077	10*	10*	10*
Grain Yield	0.108	17*	0.885	10*	10*	10*

= number of genotypes with superior or comparable performance as of checks; AA = ALS × ALS hybrids; AR = ALS × Regular hybrids; RA = Regular × ALS hybrids; * Includes genotypes with superior performance as compared to checks.

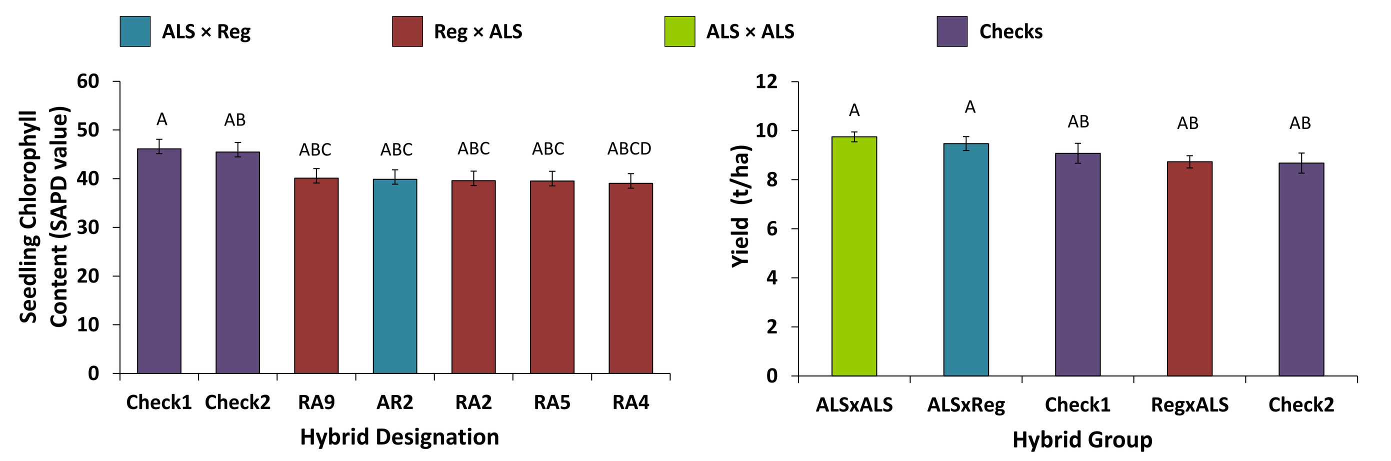

Fig.2 Chlorophyll content and yield among the top hybrid entries representing various cross combinations as compared to commercial checks.

Table2: Grain yield, leaf chlorophyll content and photosynthetic efficiency of ALS resistant hybrids in relation to check hybrids.

Hybrid	Seedling CC*	Seedling Fv/Fm*	Yield (t/ha)
Check1	46.1	0.74	7.95
Check2	45.5	0.74	4.49 ⬇
RA9	40.1	0.73	5.65 ⬇
AR2	39.9	0.74	7.95
RA2	39.6	0.76	8.70
RA5	39.5	0.76	7.66
RA4	39.1	0.73	8.41
AR9	39.0	0.75	7.32 ⬇
AA1	29.5	0.78	10.49 ⬆
AA7	27.2	0.77	9.23 ⬆
AA3	25.6	0.78	9.32 ⬆
AA4	24.7	0.78	8.07
AA10	24.5	0.76	7.95

*CC = chlorophyll content; Fv/Fm = chlorophyll fluorescence; ⬆ highest and ⬇ lowest values

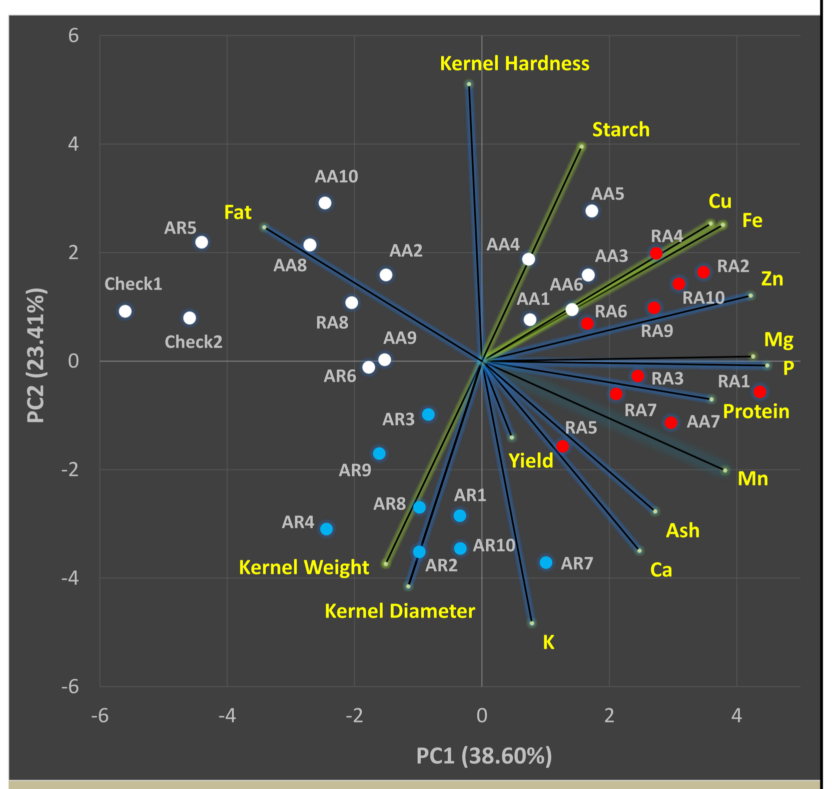

Fig.3 Distribution of ALS resistant hybrids and checks in the principal component space explaining ~62% of the variability observed for nutritional quality parameters and grain yield.

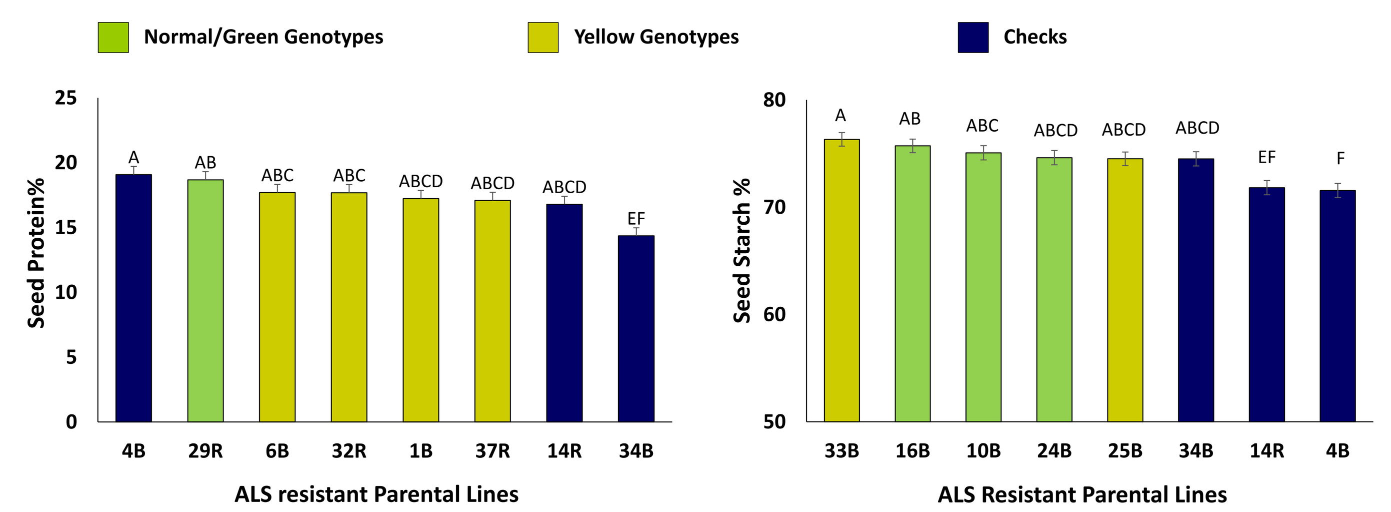

Fig.4 Seed protein and starch content of selected ALS resistant inbreds as compared to the checks.

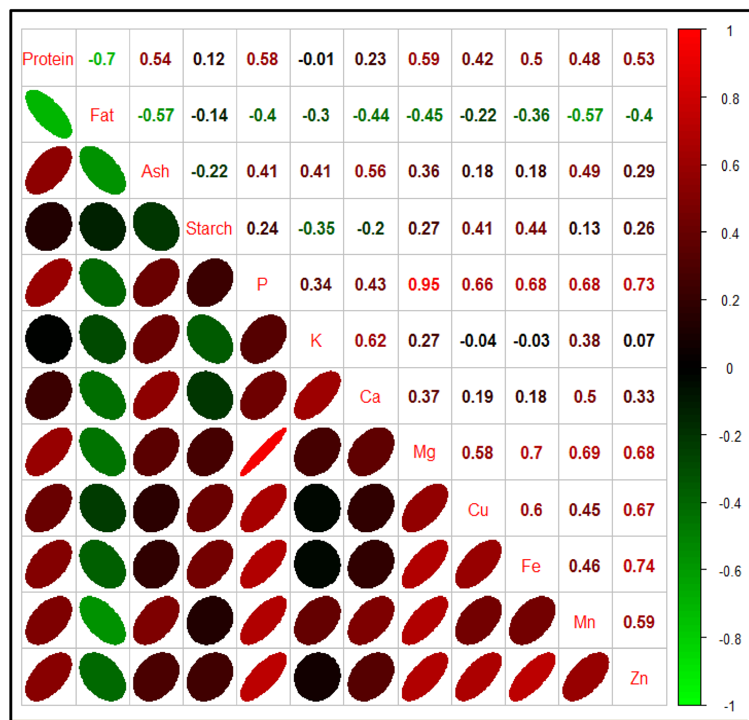

Fig.5 Correlations observed between seed nutrients. Majority of the nutritional parameters showed significant positive correlations among each other except with seed fat content.

Table3: Nutritional profile of selected ALS resistant hybrids in comparison to checks.

Hybrid	Pro+ %	Fat %	Ash %	P*	K*	Fe*	Zn*	Ca*	Cu*	Mg*	Mn*
Check1	13.2	4.6	1.4	0.3	0.3	35.0	19.2	0.01	1.9	0.1	10.5
Check2	13.7	4.9	1.5	0.3	0.3	33.0	20.6	0.01	2.0	0.1	11.5
RA1	16.4	3.8	1.7	0.4	0.3	41.8	28.2	0.02	3.6	0.2	17.0
RA2	15.7	4.1	1.5	0.4	0.3	42.5	29.7	0.02	3.7	0.2	15.9
RA3	17.7	3.7	1.7	0.4	0.3	40.9	26.9	0.02	3.3	0.2	14.1
RA4	15.9	4.0	1.7	0.4	0.3	43.0	25.4	0.02	3.5	0.2	15.0
RA5	16.8	4.1	1.8	0.4	0.3	36.4	23.0	0.02	3.2	0.2	14.0
RA6	15.3	4.1	1.7	0.4	0.3	41.1	23.4	0.02	3.7	0.2	13.8
RA7	17.1	4.1	1.7	0.4	0.3	41.2	26.1	0.02	3.1	0.2	13.9
RA9	15.1	4.4	1.8	0.4	0.3	42.0	29.8	0.02	3.7	0.2	14.4
RA10	14.4	4.4	1.7	0.4	0.3	43.8	28.4	0.02	4.0	0.2	15.4
AA1	15.0	4.2	1.6	0.4	0.3	38.5	25.7	0.02	2.8	0.2	14.9
AA3	15.0	4.4	1.6	0.4	0.3	37.6	25.8	0.02	4.0	0.2	15.2
AA4	15.9	4.4	1.7	0.4	0.2	35.0	25.7	0.02	3.4	0.2	14.3
AA5	15.5	4.1	1.5	0.4	0.3	38.9	24.8	0.02	3.8	0.2	15.0
AA6	16.1	4.2	1.6	0.4	0.3	38.6	23.7	0.02	3.8	0.2	14.7
AA7	16.0	4.3	1.7	0.4	0.3	41.1	28.0	0.02	2.9	0.2	17.0
AR1	14.4	4.2	1.7	0.3	0.4	33.3	21.7	0.02	2.8	0.2	15.4
AR2	15.3	4.1	1.8	0.3	0.4	33.6	19.1	0.02	2.1	0.2	15.1
AR7	14.9	4.2	1.6	0.4	0.4	35.1	25.3	0.02	2.8	0.2	17.2
AR10	14.5	4.2	1.6	0.3	0.3	34.0	23.4	0.02	2.6	0.2	16.3

*ppm; +pro = protein; Color assignment for hybrids was based on hybrid group colors in Fig 4.

DISCUSSION

- ALS resistant hybrids developed from parents of diverse genetic backgrounds expressed different levels of interveinal chlorosis suggesting that background selection can significantly reduce early season yellowing.
- The Regular × ALS and ALS × Regular hybrids had higher seedling chlorophyll content than ALS×ALS hybrids. However, photosynthetic efficiency (Fv/Fm) in ALS×ALS was not affected by the yellowing symptom suggesting that the temporary chlorosis appears to be cosmetic (Table 1 and Table 2).
- While the temporary leaf chlorophyll loss in some ALS resistant lines markedly delayed flowering, adult plant performance and yield in both parental lines and hybrids were not affected by the bizarre seedling phenotype (Table 1,Table 2 and Fig.2).
- Nutritional profile of grains from ALS resistant sorghums (Table 3) were generally similar to those reported for regular sorghums (FAO, 1995; Subramanian and Jambunathan, 1988).
- Both parents and hybrids showed above average (12%<) protein contents (Fig.4 and Table 3). This has not negatively affected starch indicating the potential for simultaneous improvement of protein and starch yield (Fig.3 and Fig 5).
- The ALS resistant hybrids had lower fat content compared to the regular checks. This may not be perceived negatively as low fat sorghum flour is preferred for increased stability and better baking quality (Iva, 2011).

CONCLUSIONS

- The level of interveinal chlorosis among ALS resistant hybrids widely vary for different genetic backgrounds.
- The introduction of ALS resistant gene into cultivated sorghum has no negative impact on agronomic potential and nutritional profile of the grains.

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