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Evaluation of Some Sorghum Cultivars for Drought Tolerance under Gezira Irrigated Conditions

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Abstract **Original Research Article**

This study aimed at to improve drought resilience of sorghum germplasm through development of screening techniques for sustainable food security. Also this study aimed at creating knowledge on the response of farmers' preferred sorghum varieties to water deficit tolerance under Gezira irrigated conditions. Results from this study proved that Tabat showed susceptibility to drought at the four water treatments while Yarwahsa showed resistance to drought at all water treatments especially at 65 days after sowing. Also YR-2 had the best head weight and number of green leaves across all treatments. Future evaluation of the studied cultivars showld be carried on to confirm their tolerance and stability under water deficit conditions would be useful.

Keywords: sorghum germplasm, food security, YR-2, Agricultural Research Corporation (ARC).

INTRODUCTION

Sorghum [*Sorghum bicolor* (L.) Moench] is the fifth most important cereal grain after maize, rice, wheat and barley in the world (FAOSTAT, 2022). Sorghum is a staple food crop in much of sub-Saharan Africa and Asia. It is a staple food crop for millions of African farmers living in the semi-arid tropics (Nikièma *et al.,* 2020). It has wide adaptation and tolerates high temperatures and drought stress. It grows under high radiation, inadequate and erratic rainfall and in soils of poor structure, low fertility and low water holding capacity. Drought events can occur at any stage of sorghum growth but three stages are identified as critical phases sensitive to water deficit (Menezes *et al.,* 2015). The growth stage 1 (GS1) corresponds to the vegetative phase, the growth stage 2 (GS2) corresponds to the pre-flowering phase with panicle initiation at flowering and the growth stage 3 (GS3) corresponds to the post-floral phase with filling and physiological maturity of the grains. Stay-green in sorghum is one of the reliable traits related to drought tolerance. Traits associated with pre- or post-floral water deficit resistance in sorghum also involve relative water content (RWC) and leaf senescence (Nikièma *et al.,* 2020).

Selection and breeding of similar lines with desired traits for specific environments cause a narrowing of the genetic base in breeder's lines. Breeding is dependent on genetic diversity and if the required traits are not present in the primary gene pool the breeder may resort to crossing to more exotic materials including landraces and related wild species relatives. However, the cost of doing so lengthen the breeding process and in addition to the required variation many undesirable traits are also brought in and these need to be eliminated by additional rounds of crossing (Ghanim *et al.,* 2015). An attractive alternative to this situation is mutation breeding. Induced mutation is a heritable change in the genetic material of living organisms, and this has been a major driver in species diversity and evolution. Plant breeding requires genetic

variation in useful traits for crop improvement. The overall objective of this study was to improve drought resilience of sorghum germplasm through development of screening techniques for sustainable food security.

MATERIALS AND METHODS

Genetic Materials

Eight genotypes namely; Gadam elhamam, HD1, Wad Ahmed, Wahi, YR-2, Seredo, AG8 and Butana were planted on 25th July 2018 to adapt screening protocol packages that were used to identify novel sources of drought tolerant generated with gamma irradiation. Yarwasha was used in this experiment as resistant check and it is commonly used in the drought prone areas in Sudan for its good performance under drought stress. Tabat was maintained as the susceptible check to drought in this experiment.

Experimental Sites and Design

A split plot design with three replications was used in this study. The water stress regime was used as main plot and the genotypes were used as sup plots with four main plots. The water stress plots used in this study were; 1: withdrawal of irrigation after 40 DAS; 2: withdrawal of irrigation after 50 DAS; 3: withdrawal of irrigation after 65 DAS and 4: well watered.

Data Collection and Analysis

Moisture contents for the soil were measured in all sites. Phenotypic data were collected included the following traits; plant height (cm), days to 50% flowering (day) and number of green and dry leaves and head weight (g). Data was analyzed using GenStat edition 18th. Means were separated using the least significant difference coefficients (LSD (P≤0.05)).

RESULTS AND DISCUSSION

The experiment was conducted under the farms of the irrigated farm of the Agricultural Research Corporation (ARC) in Gezira during summer season of 2019. Means of squares of morphological traits for ten sorghum cultivars against three water stress treatments were presented in Table 1 and Table 2. Results showed significant ($p<0.01$ and $p<0.001$) effects of the three water stress treatments applied to the ten cultivars. As well, the cultivars showed significant ($p<0.1$) variation, while the interaction between water stress regime and cultivars showed significant ($p<0.1$) response.

Table 1: Means of squares of morphological traits for ten sorghum cultivars against four water treatments planted at Wad Medani, Gezira Research Station

Source of variation	Df	Dry leaves			Green leaves		
		Number at 50 DAS#	Number at 65 DAS#	Mean	Number at 50 DAS#	Number at 65 DAS#	Mean
Rep	2	11.98	6.9	0.6	5. 0	2.9	0.6
Water treatments	3	11.23**	43.***	1.6**	8.9***	23.1***	50.0***
Residual	6	2.65	2.3	0.4	1.0	1.2	1.7
Cultivar	9	2.48+	1. 9	0.1	1.1	3.0	1.1
Residual	18	0.99	3. 0	0.3	0.7	2.5	4.2
Rep x water treatments x Cultivar	27	2.05	1.1	0.3+	0.8	2.0	3.1
Residual	54	2.20	2.9	0.2	0.9	3.2	4.0
Total	**119**						

DAS is days after sowing.
+ = p<0.1, ** = p<0.01 and *** = p<0.001.

Means of morphological traits for ten sorghum cultivars against four water treatments planted at Wad Medani, Gezira Research Station were presented in Table 2. AG8 showed the highest number of dry leaves at the four water stress treatments while YR-2 showed the lowest number. Besides, Kari showed the highest number of green leaves at the four water stress treatments while HD-1 showed the lowest number. Tabat, susceptible check, showed on average 4.8 dry leaves and 7.8 green leave. Yarwsha, resistant check, showed on average 3.8 dry leaves and 8.5 green leave.

Table 2: Means of number of dry and green leaves for ten sorghum cultivars against four water treatments planted at Wad Medani, Gezira Research Station

Cultivar	Number of dry leaves at 65 days after sowing					Number of green leaves at 65 days after sowing				
	1*	2*	3*	4*	Mean	1*	2*	3*	4*	Mean
AG8	7	4	5	5	5.3	7	9	9	8	8.3
Butana	5	4	4	5	4.5	7	10	8	9	8.5
YR-2	5	2	3	2	3.0	7	9	8	8	8.0
Gadam elhamam	6	4	4	5	4.8	7	8	9	8	8.0
HD-1	6	4	3	4	4.3	5	8	8	8	7.3
Seredo	5	3	4	4	4.0	6	9	8	9	8.0
Wad Ahmed	6	4	3	5	4.5	7	7	9	7	7.5
KARI	4	5	5	5	4.8	7	8	10	9	8.5
Checks:										
Tabat	7	4	4	4	4.8	6	8	8	9	7.8

Cultivar	Number of dry leaves at 65 days after sowing					Number of green leaves at 65 days after sowing				
	1*	2*	3*	4*	Mean	1*	2*	3*	4*	Mean
Yarwasha	6	4	2	3	3.8	8	9	8	9	8.5
Grand mean	5.7	3.8	3.7	4.2	4.4	6.7	8.5	8.5	8.4	8.0
Minimum					0.0					3.2
Maximum					9.6					12
±SE					1.0					0.9
CV%					12					10
LSD (p<0.05)					2.9					2.8
SED (p<0.05)					1.5					1.4

DAS is days after sowing. *1: withdrawal of irrigation after 40 DAS; 2: withdrawal of irrigation after 50 DAS; 3: withdrawal of irrigation after 65 DAS and 4: well watered.

Means of squares of days to 50% flowering, plant height and head weight for ten sorghum cultivars against four water treatments planted at Wad Medani, Gezira Research Station are presented in table 3. There was significant effect at p<0.001 and p<0.01 of water treatments on the plant height and head weight respectively. While there was no effect of the water treatments on the days to 50% flowering.

Table 3: Means of squares of days to 50% flowering, plant height and head weight for ten sorghum cultivars against four water treatments planted at Wad Medani, Gezira Research Station

Source of variation	df	Days to 50% flowering (day)	Plant height (cm)	Head weight (g)
Rep	2	2.6	7.64	104.4
Water treatments	3	30.9	590.95***	3824.3*
Residual	6	32.04	20.01	1010.6
Cultivar	9	11.35	15.33	641.8
Residual	18	118.69	48.25	404.1
Rep x Water treatments x Cultivar	27	81.5	34.41	758
Residual	54	64.56	27.88	871.3
Total	**119**			

* = p<0.05 and *** = p<0.001.

Means of days to 50% flowering, plant height and head weight morphological traits for ten sorghum cultivars against four water treatments planted at Gezira Research Station were presented in Table 4. Seredo had the least days to 50% flowering and was early maturing cultivar while Butana had the most days to 50% flowering and was the late maturing genotyping at all water treatments. Tabat the susceptible check was the early maturing cultivar and Yarwasha was late maturing across the four water treatments. Butana followed by YR-2 were the longest cultivars while Kari and Wad ahmed were the shortest cultivars across all water treatments. Tabat flowered at 43.7 days on average while Yarwasha flowered at 42.9 days on average across the four treatments. YR-2 had the heaviest head amongst all cultivars with 120.3g while HD-1 had the lightest head with 96.8g. Tabat showed less head weight (120g) compared to Yarwasha (109.9g).

Table 4: Means of days to 50% flowering, plant height and head weight morphological traits for ten sorghum cultivars against four water treatments planted at Wad Medani, Gezira Research Station

Cultivar	Days to 50% flowering (day)					Plant height (cm)					Head weight (g)				
	1*	2*	3*	4*	Mean	1*	2*	3*	4*	Mean	1*	2*	3*	4*	Mean
AG8	34.7	40.4	44.2	46.1	41.3	31.9	43.6	46.8	48.4	42.7	98.5	108.3	125.4	141.4	118.4
Butana	45.4	34.9	41.8	46.6	42.9	43.2	42.1	45.9	49.3	44.7	119.7	121.2	116.4	101.4	114.7
YR-2	38.6	44.9	37.0	44.1	41.9	41.6	48.7	41.9	48.4	44.8	103.5	120.8	124.6	132.3	120.3
Gadam elhamam	41.2	39.1	39.4	39.3	40.5	39.3	45.7	47.3	37.7	42.1	118.5	120.0	121.0	107.5	116.8
HD-1	35.3	38.8	48.5	45.2	42.7	39.7	41.3	49.1	47.7	44.1	94.5	83.0	101.9	107.8	96.80
Seredo	43.7	35.1	43.8	36.8	40.6	35.8	43.2	49.5	42.6	42.4	112.1	100.7	127.5	108.0	112.1
Wad ahmed	33.7	46.8	40.3	41.4	41.3	35.0	41.8	46.6	45.8	41.9	120.6	98.4	132.6	123.2	118.7
KARI	40.7	49.2	37.6	32.0	40.6	34.7	46.5	46.2	41.5	41.9	62.3	108.4	127.4	131.8	107.5
Checks:															
Tabat	44.7	43.4	32.8	39.3	40.8	40.8	48.0	41.6	46.0	43.7	98.8	112.9	122.6	105.4	109.9
Yarwasha	36.4	43.6	43.4	41.4	42.0	36.8	45.8	48.0	42.4	42.9	68.2	120.8	151.8	139.1	120.0
Grand mean	39.4	41.6	41	41.4	41.6	38.9	44.7	46.3	45	43.1	99.7	109.4	125.1	119.8	113.5
Minimum					26.9					27.3					44.90
Maximum					59.0					58.0					182.9
±SE					4.90					2.99					15.90
CV%					12.9					11.8					8.700
LSD (p<0.05)					13.8					8.87					45.15
SED (p<0.05)					6.89					3.98					22.63

*1: withdrawal of irrigation after 40 DAS; 2: withdrawal of irrigation after 50 DAS; 3: withdrawal of irrigation after 65 DAS and 4: well watered.

Results from this study proved that Tabat showed susceptibility to drought at the four water treatments while Yarwahsa showed resistance to drought at all water treatments especially at 65 days after sowing. Also YR-2 had the best head weight and number of green leaves across all treatments. Also this study concluded that late drought is the most limiting factor in sorghum production in Sudan. The results showed that plant height, days to 50% flowering and number of green and dry leaves could be used as suitable phenotypic characters and criteria to characterize the response of sorghum cultivars towards resistance or susceptibility to drought. Further evaluation of those cultivars to confirm their tolerance and stability under water deficit conditions would be useful. So, multilocal tests on other experimental sites will be conducted in the coming years to evaluate the agronomic performance of the best lines, taking into account genotype- environment interaction. In addition to leaf senescence and relative water content already recommended in phenotyping for drought tolerance, the chlorophyll content at days after water stress application should also be considered as phenotypic trait in similar studies.

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