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Yield stability and adaptability of sorghum genotypes under water-deficit environments

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Abstract

Unraveling the genetic factors underlying sorghum response to drought stress can speed up the development of drought-tolerant sorghum cultivars. To achieve this goal, we evaluated a collection of sorghum bicolor lines and two local cultivars for yield and yield related traits under three different watering regimes (Well-watered = 0.8 Evapotranspiration (ETp), Mild drought stress = 0.6 ETp and severe drought stress = 0.4 ETp.) in two consecutive growing seasons in Egypt. Analysis of variance showed highly significant variations among the tested sorghum genotypes. As an average of all tested genotypes number of grains/head was the most affected trait by drought followed by grain yield / plant, while head length showed the lowest reduction due to drought stress. According to four models viz., Eberhart and Russell's, Perkins and Jinks, Freeman and Perkins and Tai, beside principal component analysis (PCA), Line No. 22 (34.81 g) and cultivar Dorado (33.51 g) were observed as most stable and widely adapted over environments, surprised mean performance for grain yield/plant than grand mean over environments. According to our results the two genotypes (Line No. 22 and cultivar Dorado) can be recommended to be uses under a wide range of environmental conditions and use in breeding programs for development of high yield stable genotypes across environments for future use.

Keywords:
Sorghum bicolor; drought; grain yield; stability.

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INTRODUCTION

Sorghum is a major staple crop for over half a billion people, mostly in developing countries in the semi-arid and arid tropics. It provides protein, fiber rich, and gluten-free nutrition (McCann *et al.*, 2015 and Impa *et al.*, 2019). In addition to human nutrition, it is being used as a source of feedstock for bioethanol production (Mathur *et al.*, 2017). Grain sorghum (*Sorghum bicolor* L. Moench) is one of the major cereal crops in Egypt, as the cultivated grain sorghum area about 147.961 hectares produced about 727648 tons (FAO 2021). Although sorghum is considered a drought-tolerant crop and can be productive under low-input conditions, drought stress due to water deficiency affects its soil-nutrient uptake capability and nutrient mobilization and transport (Yu *et al.*, 2015 and Sarshad *et al.*, 2021). Drought is a leading cause of yield loss in important cereal crops in addition to adverse climate changes. The development and cultivation of new drought tolerant varieties that can yield adequately under both well water and water stress environments is an important plant breeding goal and the objective of this experiment (Choudhar *et al.*, 2021). Hence, understanding both the effects of the stress and plant response is indispensable for improving drought tolerance of the crop and enhancing our understanding and provide more insights on drought tolerance in sorghum as a contribution to the development of climate resilient sorghum cultivars, it appears possible to develop locally adapted cultivars of sorghum that are drought tolerant and nutrient rich using modern plant breeding techniques (Abreha *et al.*, 2022).

Crop yield stability is an important issue for farmers, breeders, geneticists, and production agronomists. The differential response of cultivars from one environment to another is called a genotype × environment (GE) interaction. GE interactions are an important issue facing plant breeders and agronomists (Heidari *et al.*, 2017). Some physiological traits have the potential to improve crop performance under abiotic stress (Condon *et al.*, 2004 and Richards, 2006). A better understanding of the genetic basis of physiological trait variability will improve the efficiency of crop for drought tolerance. The features of stable genotype are complex due to genotype x environment interactions (GEI) (Alwala, 2010 and Moghaddam *et al.*, 2013). Hence a study of GEI can lead to successful evaluation of sorghum cultivars for stability in yield performance under various environmental conditions. Almost all breeders have used the term ‘‘stability’’ to characterize a genotype that showed a constant yield across environments (Dehghani *et al.*, 2008 and Changizi *et al.*, 2014). Several statistical methods can be used as important measures of crop yield stability, the most widely used is the joint linear regression analysis as proposed by (Eberhart and Russell, 1966; Perkins and Jink, 1968, Freeman and Perkins, 1971 and Tai, 1971). The selection of stable genotypes, based on stability parameters, caused high yield genotypes to be introduced as stable genotypes. The total sorghum production in Egypt does not meet the current demand, and due to the limited area of the agricultural land, there is a need to expand growing sorghum in newly reclaimed areas that suffer from some abiotic stresses, such as drought. Therefore, the present study aimed to find out effected of drought stress on yield and its components on sorghum bicolor genotypes, and to identify stable high-yielding sorghum genotypes in different environments.

MATERIALS AND METHODS

1. Plant material

Twenty-three sorghum bicolor lines were evaluated under different irrigation regimes and released by Plant Genetic Resources Conservation Unit, USDA, ARS, Griffin, Georgia, USD. In addition, two local commercial cultivars were used for agronomic evaluation comparison; those were H306 and Dorado cultivars.

2. Site Description

All plant materials were evaluated in two field experiments during the two summer growing seasons of 2018 and 2019 at the Experimental Farm of Faculty of Agriculture, Sohag University, Egypt.

2.1. Climatic characteristics prevailing

Monthly means of maximum and minimum temperature (C^o), relative humidity (RH) %, wind speed (WS) m/sec, daily sunshine (DS) hours/day and evapotranspiration (ETo) values were computed using ETo_Calculator_V3.2. FAO 2019 (Table 1).

Table 1. Meteorological data and evapotranspiration reference (ETo) during the growing season of 2018 and 2019.

Season	Measurement	Jun.	Jul.	Aug.	Sept.	Oct.	Mean season
2018	Max. Temp. (C°)	39.26	38.97	39.02	36.75	33.43	37.49
	Min. Temp. (C°)	23.48	24.25	24.02	22.02	18.86	22.53
	RH (%)	20.82	24.09	26.84	29.74	32.66	26.83
	WS (m/sec)	5.25	4.87	5.06	5.41	4.19	4.96
	DS (hours/day)	40.57	39.96	37.85	34.36	29.26	36.40
	ETo (mm/day)	13	12.2	11.9	10.9	8	11.20
2019	Max. Temp. (C°)	41.33	41.02	41.07	38.68	35.19	39.46
	Min. Temp. (C°)	24.72	25.53	25.28	23.18	19.85	23.71
	RH (%)	21.92	25.36	28.25	31.31	34.38	28.24
	WS (m/sec)	5.53	5.13	5.33	5.69	4.41	5.22
	DS (hours/day)	42.71	42.06	39.84	36.17	30.80	38.32
	ETo (mm/day)	13.68	12.84	12.53	11.47	8.42	11.79

2.2. Soil characteristics of the experimental site

Basic relevant physical and chemical characteristics of the experimental soil were determined according to Klute (1986) and Page *et al.,* (1982), respectively. The values are presented in Table (2).

3. Experimental Treatments and Design

Twenty-five Sorghum genotypes grown in three experiments each with three replicates in a randomized complete block design (RCBD). Three irrigation experiments, determined as different fractions of calculated potential evapotranspiration (ETp) in the experimental site, namely: Well-watered = 0.8 ETp, Mild drought stress = 0.6 ETp and Severe drought stress = 0.4 ETp. The experimental unit was consisted of one ridge with three meters in length and 60 cm apart. Plants were individually spaced at 20 cm within each ridge. All cultural practices of growing sorghum in the experimental location were followed as recommended. At harvesting, 10 guarded plants from each ridge were chosen at random and the following data were recorded: Head length, 1000-grain weight, no. of grains/plant, biological yield/plant and grain yield/plant.

3.1. Irrigation requirement consumption and water supply

The experimental plots were given volumes of water to raise the moisture of the top 45 cm layer to the field capacity. Water applied to the plots at each irrigation was equal to the difference between moisture at the field capacity and the soil moisture content at irrigation time of each irrigation (for each irrigation treatment) plus 10% of quantity to ensure a good uniform distribution of water through the plots.

3.2. Time of irrigation:

Daily evaporation data of pan (mm/day) were obtained from a standard Class-A-Pan located in the experimental field and recorded. Cumulative pan evaporation data for each irrigation treatment were calculated by multiplying daily evaporation by the studied evaporation pan coefficient as following:

- Irrigation interval depending upon 0.8 as pan factor (Ef 0.8).
- Irrigation interval depending upon 0.6 as pan factor (Ef 0.6).
- Irrigation interval depending upon 0.4 as pan factor (Ef 0.4).

3.3. Irrigation interval for different treatments could be explained as follows

Upper limit of available water (AW) is field capacity (FC) and the lower edge is wilting point (WP), the difference between them is the theoretical available water. Growing plants can't use water at WP, therefore the term of allowable moisture depletion (AMD) is introduced. Meaningfully, the actual AW or so-called the available water should be extracted by growing plants is the product of theoretical available water by AMD (50% at 45 cm soil depth for sorghum) (Phocaides, 2000).

In this study as shown in Table 2, theoretical AW for 45 cm depth is 83 mm. multiply this result by 50% (AMD for sorghum) to get the actual AW should be used in all treatments calculate will be

Table 2. Physical and Chemical properties of the experimental soil.

Physical properties					
Depth (cm)	**Bulk density (Mg m^{-3})**	**Field capacity (%)**	**Permanent wilting Point (%)**	**Available water (%)**	**Soil texture**
0-15	1.4	25	10	15	Sandy clay loam
15-30	1.4	24	9	15	Sandy clay loam
30-45	1.5	15	6	9	Sandy loam
Chemical properties					
Properties		**Depth (cm)**			
		0-15		**15-30**	**30-45**
Soil pH		7.5		7.85	8.2
ECe (dS/ m at 25^{o}C)		2.1		2.3	2.5
Available nitrogen (ppm)		50		35	20
Available phosphorus		20		21	22
Available potassium (ppm)		69		65.5	62
Ca CO$_3$ %		3.5		3.8	4.1
Organic matter %		1.9		1.65	1.4

approximately 42 mm. Therefore, the available water to be extracted by sorghum plants will be 42 mm. The irrigation interval per each treatment is the number of days in which the cumulative pan evaporation (CPE) should be approximately equals the estimated water amount of the considered treatment as follows:

$$CPE = \frac{A.w * AMD}{Ef}$$

Where:

CPE= cumulative pan evaporation,

Ef= Empirical pan factor (0.6, 0.8, 1.0, 1.2, 1.4&1.6) treatments,

AW= Available water (mm) for the soil for effective root zone depth, and

AMD= Allowable moisture depletion by setting lower limit 30%.

Then the corresponding CPE for each pan factor (Ef) could be computed, which is resulting in identifying the number of days at which irrigation event should be executed. Values of CPE related to different Ef tested values are tabulated in Table 3.

Table. 3. CPE values for each studied empirical pan factors (Ef)

Treatments (Ef)	**CPE (mm)**
0.8	53
0.6	70
0.4	105

Applied water:

The amount of applied irrigation water during the irrigation treatments was according to crop evapotranspiration (ET_c):

$$ET_{\circ} = EP * K_p \quad \text{,and}$$

$$ETc = ET_{\circ} * K_c$$

Where:

ET_O = Reference evapotranspiration in mm/day,
Ep= evaporation from pan evaporation, mm,
K_p =Pan coefficient (0.85) for pan evaporation class A, and
K_c = crop coefficient.

$$IW = \frac{ET_c * A}{Ea}$$

Where:

IW = amount of irrigation water (L),
ETc = crop evapotranspiration, mm,
A = plot area (m^2), and
E_a = application efficiency (85%).

Statistical analyses

The combined analysis was performed on the recorded data of agronomic traits according to Gomez and Gomez (1984). Means were compared by Revised Least Significant Difference (RLSD) at 5% level of significant (Steel and Torrie, 1980). The stability analysis was computed as obtained by Eberhart and Russell model (1966), Perkins and Jinks model (1968), Freeman and Perkins model (1971) and Tai (1971). INDOSTAT software version 9.2. was used to perform the principal component analysis. Eigenvectors generated by PCA were used to rank tested genotypes for the test environments.

RESULTS AND DISCUSSION

Analysis of variance

Agricultural years differed highly significant from each other for all studied traits; head length, 1000-grain weight, no. of grains/plant, biological yield/plant and grain yield/plant. This indicates the influence of climatic conditions on these traits. The evaluated sorghum bicolor lines had highly significant in its performance regarding all studied traits over seasons, indicating that the existence of inherent genetic variability and point to the possibility of selecting a stable sorghum bicolor line. Studied drought stress treatments had highly significant effects on all the studied traits over the two seasons. as it would be expected for normal and drought stress conditions. The interaction between sorghum bicolor lines and drought stress treatments had highly significantly impact on all the studied traits. These results showed that sorghum bicolor lines responded differently when they were grown under drought stress (Table 4).

Irrigation requirements (Applied water)

Irrigation requirements is the total water needed for evapotranspiration, from planting to harvest for a given crop in a specific climate regime, when adequate soil water is maintained by rainfall and/or irrigation so that it does not limit plant growth and crop yield (ICID, 2000). Plants irrigated at 0.8, 0.6 and 0.4 accumulated pan evaporation received 15, 11 and 7 irrigations (including sowing irrigation) respectively. Irrigation requirement (m^3) of sorghum plants irrigated according 0.8, 0.6 and 0.4 accumulated pan evaporation were 3241.46, 3226.09 and 3165.24 m^3 /fed in 2018 and 3165.43, 3031.31 and 2962.80 m^3/fed in 2019, respectively. From previous results, it could be concluded that seasonal irrigation requirement for irrigation treatments was the highest at 0.8, while it was the lowest at 0.4 accumulated pan evaporation (Tables 5, 6 and 7 and Fig. 1).

Table 4. Mean squares of the combined analysis of variance for all studied traits.

S.O.V.	df	Mean squares				
		Head length (cm)	1000 grains weight (g)	Number of grains/head	Biological yield/plant	Grain yield/plant (g)
Years (Y)	1	11.44**	19.05**	32041.8**	2132.02**	5997.42**
Error a	4	4.24	3.86	442.3	8.91	51.12
Drought (D)	2	1065.49**	3586.45**	56472268.7**	274031.52**	281355.28***
Y x D	2	1.034	1.39	57089.8**	729.98**	1710.54**
Error b	8	3	2.99	3339.2	47.13	43.96
Genotypes (G)	24	153.42**	106.58**	1413464.5**	5933.27**	4096.45**
Y x G	24	2.10*	5.09**	13070.9**	88.04**	322.03**
D x G	48	9.14**	15.41**	247862**	1483.67**	1863.00**
Y x D x G	48	2.36**	4.46**	15540.5**	122.69**	337.35**
Pooled error	276	1.33	1.81	1349.7	36.76	37.56

*, **; Significant at 5 and 1% levels of probability, respectively.

Table 5. Irrigation requirements (IR) (m^3 /Fed) using 0.8 pan evaporation coefficient in the two studied seasons.

Date (Day/Month)	2018	Date (Day/Month)	2019	Average
21/06	94.50	21/06	101.31	97.91
27/06	120.76	27/06	107.00	113.88
5/07	101.95	4/07	119.51	110.73
11/07	201.59	13/07	244.95	223.27
17/07	234.95	21/07	217.32	226.14
23/07	247.22	27/07	218.75	232.99
30/07	239.95	3/07	264.13	252.04
6/08	269.61	11/08	307.66	288.64
14/08	316.28	18/08	313.61	314.94
21/08	309.91	25/08	348.10	329.01
28/08	287.25	2/08	301.42	294.33
4/09	295.66	11/09	180.90	238.28
13/09	214.92	18/09	199.02	206.97
23/09	206.99	23/09	140.43	173.71
2/10	99.90	2/10	101.31	100.61
Total	3241.46	Total	3165.43	3203.44

Table 6. Irrigation requirements (IR) (m^3 /Fed) using 0.6 pan evaporation coefficient in the two studied seasons.

Date (Day/Month)	2018	2019	Mean
23/06	155.19	144.13	149.66
3/07	146.66	137.49	142.07
12/07	280.31	316.73	298.52
20/07	333.53	293.36	313.45
29/07	374.81	305.15	339.98
8/08	379.86	439.90	409.88
18/08	451.01	412.01	431.51
28/08	389.24	403.03	396.13
8/09	320.96	280.80	300.88
22/08	271.85	174.85	223.35
3/10	122.68	123.88	123.28
Total	3226.09	3031.31	3128.70

Table 7. Irrigation requirements (IR) (m^3 /Fed) using 0.4 pan evaporation coefficient in the two studied seasons.

Date (Day/Month)	2018	2019	Mean
27/06	211.71	213.10	212.40
11/07	465.84	475.68	470.76
24/07	454.51	407.74	431.12
7/08	526.43	607.65	567.04
22/08	654.55	647.55	651.05
6/09	501.26	395.69	448.48
26/09	350.94	215.38	283.16
Total	3165.24	2962.80	3064.02

Sorghum Evapotranspiration (ETcrop)

Etc refers to the evapotranspiration from excellently managed, large, well-watered fields that achieve full production under the given climatic conditions. Due to suboptimal crop management and environmental constraints that affect crop growth and limit evapotranspiration, Etc under non-standard conditions generally requires a correction (Allen et al.,1998). Concerning the effect of irrigation treatments, results in Tables (8, 9 and 10 and Fig. 2) of seasonal ET for sorghum in 2018 and 2019 growing seasons showed that the highest consumptive water use were obtained under irrigation with 0.8 pan evaporation coefficient, while the lowest values of such results were obtained under irrigation with 0.4 pan evapotranspiration coefficient. These results indicated that consumptive use decreased as the available soil moisture decreased in the root zone i.e. irrigation with 0.6 and 0.4 pan evaporation coefficient.

Table 8. Seasonal evapotranspiration (ET) in mm using 0.8 pan evaporation coefficient in the two studied seasons.

Date (Day/Month)	2018		2019	
	Periodical	Daily	Periodical	Daily
21/06	56.70	9.45	55.72	9.46
27/06	72.46	9.06	60.79	10.13
5/07	61.17	10.19	64.20	9.17
11/07	120.96	20.16	71.71	7.97
17/07	140.97	23.50	146.97	18.37
23/07	148.33	21.19	130.39	21.73
30/07	143.97	20.57	131.25	18.75
6/08	161.77	20.22	158.48	19.81
14/08	189.77	27.11	184.59	26.37
21/08	185.95	26.56	188.16	26.88
28/08	172.35	24.62	208.86	26.11
4/09	177.40	19.71	180.85	20.09
13/09	128.95	12.90	108.54	15.51
23/09	124.19	13.80	119.41	9.95
2/10	59.94	7.49	84.26	7.66
Seasonal	1944.87		1894.18	

Table 9. Seasonal evapotranspiration (ET) in mm using 0.6 pan evaporation coefficient in the two studied seasons.

Date Day/Month	2018		2019	
	Periodical	Daily	Periodical	Daily
23/06	93.11	9.31	86.48	9.61
3/07	88.00	9.78	82.49	8.25
12/07	168.19	21.02	190.04	17.28
20/07	200.12	22.24	176.02	22.00
29/07	224.88	20.44	183.09	18.31
8/08	227.92	22.79	263.94	26.39
18/08	270.61	27.06	247.21	27.47
28/08	233.54	23.35	241.82	21.98
8/09	192.58	16.05	168.48	15.32
22/08	163.11	13.59	104.91	9.54
3/10	73.61	8.18	74.33	7.43
seasonal	1935.65		1818.79	

Table 10. Seasonal evapotranspiration (ET) in mm using 0.4 pan evaporation coefficient in the two studied seasons.

Date Day/Month	2018		2019	
	Periodical	Daily	Periodical	Daily
27/06	127.02	9.77	127.86	8.52
11/07	279.50	19.96	285.41	19.03
24/07	272.70	20.98	244.64	18.82
7/08	315.86	22.56	364.59	26.04
22/08	392.73	26.18	388.53	24.28
6/09	300.76	16.71	237.42	13.97
26/09	210.56	11.08	129.23	8.08
seasonal	1899.14		1777.68	

Figure 1. Irrigation requirements (IR) (m^3 /Fed) using 0.8. 0.6 and 0.4 pan evaporation coefficient in the two studied seasons.

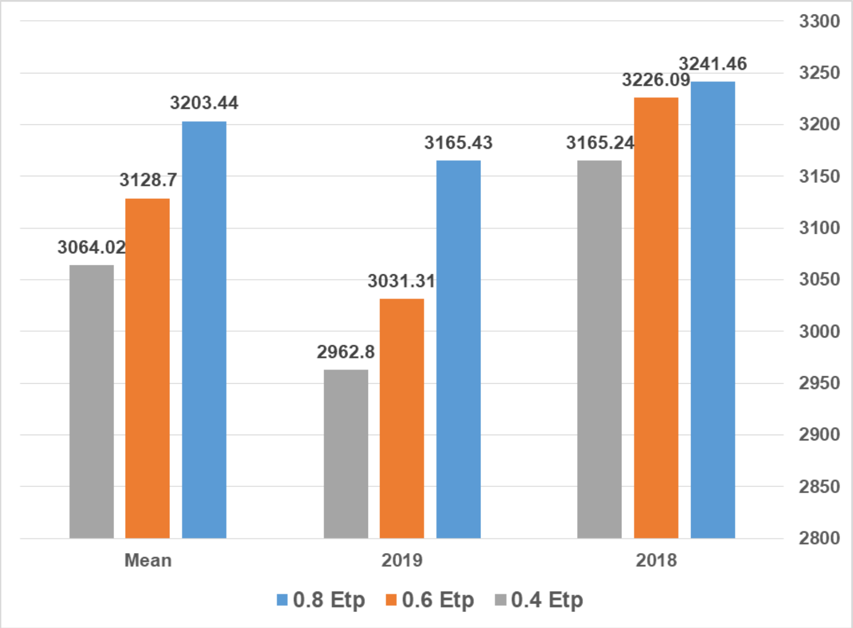
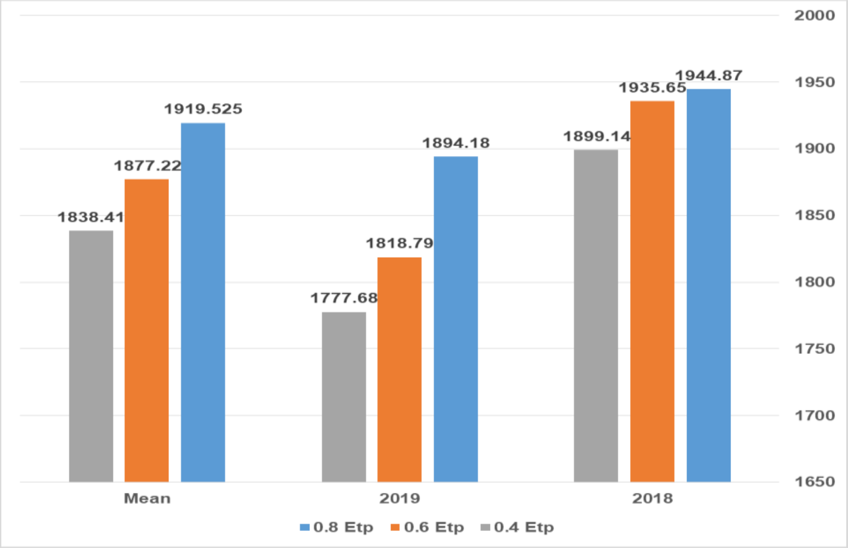


Figure 2. Seasonal evapotranspiration (ET) in mm using 0.8, 0.6 and 0.4 pan evaporation coefficient in the two studied seasons.



From previous results, it could be concluded that seasonal sorghum evapotranspiration (ET crop) for irrigation treatments was the highest at 0.8, while it was the lowest at 0.4 accumulated pan evaporation in the two studied seasons.

Performance of sorghum genotypes

Head length (cm)

Water stress treatments significantly affected head length in the two growing seasons (Table 11). The application of full irrigation produced the longest head length by an average of 18.50 cm over two seasons. Meanwhile, the lowest head length was obtained due to the application of drought stress treatments; mild and severe stress condition with an average over all genotypes of 15.61 and 13.18 cm, respectively. The advantage of full irrigation treatment could be explained that moisture stress decreased head length. The differences among sorghum genotypes in head length were significant in 2018 and 2019 seasons and over both seasons. The highest values of head length over two seasons were recorded with Line No. 9 (28.33 cm), H306 (22.98 cm), 21 (22.08 cm) and 11 (21.66 cm) under full irrigation condition, while under severe stress condition were recorded with line No. 9, Line No. 22, H306 and Dorado by 16.5 cm over two seasons.

1000-grains weight (g)

1000-grains weight was significantly affected by drought stress treatments in the two growing seasons (Table 12). In the two growing seasons, the highest 1000-grains weight was obtained when full irrigation treatment was applied by 22.99 g. Meanwhile, the lowest values were obtained due to the application of drought stress treatments; mild and severe stress conditions with an average over all genotypes of 17.63 and 13.35 g, respectively. This reduction in 1000-kernel weight under drought stress condition could be attributed to the reduction in photosynthetic capacity translocated from different parts of plant to grain especially at grain filling period. Furthermore, the differences in 1000-grains weight among the twenty-five sorghum genotypes were significant in the two growing seasons (2018 and 2019) and over both seasons. Over the two seasons, Line No. 21 had the heaviest kernels by 30.76 g followed by Lines No. 9, 23 and 18 by 29.97, 27.23 and 26.70 g respectively under full irrigation condition, while under severe stress condition were recorded with lines No. 7, 2, 25 and 3 by 18.13, 15.46, 15.06 and 15.02 g respectively in the two seasons (Table 12). This may be due to the genetic behavior in combination with the environmental conditions, which was suitable for some genotypes more than other genotypes.

Table 11. Mean of head length for 25 Sorghum bicolor genotypes under irrigated and drought stress treatments over the two seasons.

Season	**2018**			**2019**			**Mean over the two seasons**		
Genotypes	**I_1**	**I_2**	**I_3**	**I_1**	**I_2**	**I_3**	**I_1**	**I_2**	**I_3**
L2	18.66	16.16	15.5	18.5	16.13	15.16	18.58	16.15	15.33
L3	16.66	14.33	13.33	18	15.16	12.66	17.33	14.75	13
L4	19.33	18.16	16.83	18.66	17.16	15.5	19	17.66	16.16
L5	9.16	7.7	6.76	9.83	8.2	6.83	9.5	7.95	6.8
L6	22.33	17.5	13.83	19.83	15.2	13.5	21.08	16.35	13.66
L7	16	15	12	16.5	13.5	11.16	16.25	14.25	11.58
L8	15.26	14.6	12.06	18.16	13.5	12.5	16.71	14.05	12.28
L9	28.66	22	16.83	28	23.83	16.16	28.33	22.91	16.5
L10	16.83	14.83	12.83	16.16	14.33	12.33	16.5	14.58	12.58
L11	21.16	15.83	12.4	22.16	15.5	13.16	21.66	15.66	12.78
L12	14.83	12.66	10.5	14.16	12.83	9.83	14.5	12.75	10.16
L13	16	13.06	12.66	15.83	12.9	11.33	15.91	12.98	12
L14	17.33	14.76	12.33	16.33	14.16	12.16	16.83	14.46	12.25
L15	12.66	11.16	9.76	13.5	11.23	10.33	13.08	11.2	10.05
L17	21.66	16.5	14.23	20	17.16	14.33	20.83	16.83	14.28
L18	16.33	14.5	13.16	16.7	15.33	13.5	16.51	14.91	13.33
L19	20	15.5	12.66	18.7	14.5	11.83	19.35	15	12.25
L20	15.9	14.3	12.3	17.83	13.66	11.33	16.86	13.98	11.81
L21	22.16	20.16	11.06	22	19.43	13.33	22.08	19.8	12.2
L22	20.16	18.53	16.33	20.16	18.16	16.6	20.16	18.35	16.5
L23	19	14.83	12.83	18	15	13	18.5	14.91	12.91
L25	19.16	13.83	13.33	15.33	15	12.5	17.25	14.41	12.91
L26	21.26	17.83	14.83	21.56	19	15.5	21.41	18.41	15.16
H306	21.13	20.16	16.66	24.83	19.83	16.33	22.98	20	16.5
Dorado	20.6	17.33	18.16	22.16	18.83	14.83	21.38	18.08	16.5
Mean	**18.49**	**15.65**	**13.33**	**18.51**	**15.58**	**13.03**	**18.50**	**15.61**	**13.18**
RLSD 5%									
Treatments (T)	**2.53**			**3.33**			**0.56**		
Genotypes (G)	**1.62**			**1.55**			**0.37**		
T x G	**1.91**			**1.80**			**2.15**		

I_1 = normal irrigation. I_2 = mild stress irrigation. I_3 = severe stress irrigation.

Table 12. Mean of 1000 grains weight for 25 Sorghum bicolor genotypes under irrigated and drought stress treatments over the two seasons.

Season	2018			2019			Mean over the two seasons		
Genotypes	I_1	I_2	I_3	I_1	I_2	I_3	I_1	I_2	I_3
L2	22.58	19.42	15.48	27.40	19.76	15.45	24.99	19.59	15.46
L3	23.60	19.01	15.09	24.70	18.85	14.95	24.15	18.93	15.02
L4	19.99	16.12	12.04	20.08	16.29	12.50	20.03	16.20	12.27
L5	23.29	16.68	13.54	22.68	16.51	12.54	22.98	16.59	13.04
L6	24.41	19.73	14.55	22.31	19.39	14.41	23.36	19.56	14.48
L7	26.22	22.42	17.90	25.57	21.56	18.37	25.89	21.99	18.13
L8	18.10	14.05	9.61	18.82	13.36	9.21	18.46	13.70	9.41
L9	29.91	19.59	14.15	30.03	19.07	14.05	29.97	19.33	14.10
L10	16.64	15.36	12.73	15.82	15.28	13.16	16.23	15.32	12.94
L11	17.59	16.43	12.18	19.34	16.50	12.74	18.46	16.46	12.46
L12	18.94	16.20	13.85	22.25	16.59	14.81	20.59	16.39	14.33
L13	19.74	17.53	13.64	20.29	17.30	14.13	20.01	17.41	13.88
L14	19.53	15.03	10.85	19.45	15.63	11.02	19.49	15.33	10.93
L15	17.70	14.65	11.77	20.74	15.16	12.17	19.22	14.90	11.97
L17	25.38	18.54	14.08	24.59	19.98	13.92	24.98	19.26	14.00
L18	25.96	18.70	13.95	27.45	19.52	14.02	26.70	19.11	13.98
L19	21.76	15.66	7.63	20.20	14.21	10.80	20.98	14.93	9.21
L20	22.69	17.33	11.82	22.91	16.16	13.27	22.8	16.74	12.54
L21	30.42	20.58	13.94	31.10	20.34	15.07	30.76	20.46	14.50
L22	27.65	18.76	15.27	23.67	18.47	14.33	25.66	18.61	14.80
L23	29.25	19.02	11.19	25.21	19.52	14.60	27.23	19.27	12.89
L25	25.13	18.15	15.26	24.32	18.79	14.87	24.72	18.47	15.06
L26	22.92	16.08	11.61	17.91	16.76	10.20	20.41	16.42	10.90
H306	25.58	17.74	14.58	22.87	17.92	14.31	24.22	17.83	14.44
Dorado	24.30	17.74	14.95	20.38	18.51	11.05	22.34	18.12	13
Mean	**23.17**	**17.62**	**13.26**	**22.80**	**17.65**	**13.43**	**22.99**	**17.63**	**13.35**
RLSD 5%									
Treatments (T)	0.46			0.80			0.56		
Genotypes (G)	0.85			1.32			0.43		
T x G	1.54			2.66			2.15		

I_1 = normal irrigation. I_2 = mild stress irrigation. I_3 = severe stress irrigation.

Number of grains/head

The presented data in Table 13 indicated that number of grains/head was significantly affected by drought stress treatments in the two growing seasons. In the two growing seasons, the highest number of grains/head was obtained when full irrigation treatment was applied by 1697.36. Meanwhile, the lowest values were obtained due to the application of drought stress treatments; mild and severe stress conditions with an average over all genotypes of 952.85 and 480.29, respectively. This reduction in number of grains/head under drought stress condition could be attributed to the reduction in photosynthetic capacity translocated from different parts of plant to grain especially at grain filling period. Furthermore, the differences in number of grains/head among the twenty-five sorghum genotypes were significant in the two growing seasons (2018 and 2019) and over both seasons. Over the two seasons, Line No. 17 had the highest number of grains/head by 2477.29 followed by Lines No. 12, 4, 8 and 11 by 2442.78, 2266.67, 2219.05 and 2070.22 respectively under full irrigation condition, while under severe stress condition were recorded with lines No. 2, 3, 8, 12 and 17 by 738.39, 702.33, 651.75, 684 and 652.98 respectively over the two seasons. This may be due to the genetic behavior in combination with the environmental conditions, which was suitable for some genotypes more than other genotypes.

Biological yield/plant(g)

Results in Table 14 showed that the effect of drought stress treatments on biological yield/plant was highly significant in the first, second and over the two seasons. The plants of all sorghum genotypes in drought stress cases resulted in a progressive decrease in biological yield/plant compared with full irrigation treatment. Whereas the highest biological yield/plant was obtained when full irrigation treatment was applied with an average of 133.94 g over the two seasons. Meanwhile, the application of drought stress treatments; mild and severe stress condition with an average of 83.05 and 49.01 g over two seasons respectively. The response of genotypes differs from year to another; these differences between them in mentioned trait were probably related to differences in climatic and edaphic factors in the two years. These results may be due to the fact that water stress during vegetative growth stage especially at elongation stage reduced moisture observed and nutrient uptake and hence plant height and biological yield. Furthermore, the differences among genotypes of sorghum bicolor in biological yield/plant were significant in 2018 and 2019 seasons and over both seasons. Under well-watered condition, Line No. 18 gave the highest biological yield/plant (193.36 g), followed by Lines No. 6 (175.34 g), 11 (171.50 g), Dorado (169.75 g) and H306 (167.37 g) over the two seasons. Meanwhile, under severe stress condition the highest biological yield/plant was 69.34 g for Line No. 22 followed by Lines 8 by 67.01 g, 2 by 64.99 g, H306 by 59.38 g and 3 by 57.64 g over the two seasons. This may be due to the genetic behavior in combination with the environmental conditions, which was suitable for some genotypes more than other genotypes.

Grain yield/plant (g)

Results in Table 15 showed that drought stress treatments significantly affected grain yield/plant in 2018 and 2019 seasons and over both seasons. Subjecting plants to drought stress conditions due to mild and severe stress conditions resulted in a progressive decrease in grain yield/plant. Whereas the highest grain yield/plant was obtained when full irrigation treatment was applied with an average of 43.58 g over the two seasons. Meanwhile, the application of drought stress treatments; mild and severe stress condition with an average of 27.40 and 15.57 g over two seasons respectively. The advantage of full irrigation treatment could be explained that moisture stress decreased grain yield/plant. The differences among sorghum genotypes in grain yield/plant were significant in 2018 and 2019 seasons and over both seasons. The highest values of grain yield/plant over two seasons were recorded with Lines No. 18 (56.82 g), cultivar H306 (56.29 g) 17 (55.10 g), 26 (53.21 g) and 10 (53.07 g) cultivar H306 (56.29 g) under full irrigation condition, while under severe stress condition were recorded with line No. 2, Line No. 22, H306, line No. 3 and Dorado by 25.13, 22.56, 21.50, 19.51and 19.50 g respectively over the two seasons.

Table 13. Mean of number of grains/head for 25 Sorghum bicolor genotypes under irrigated and drought stress treatments over the two seasons.

Season	**2018**			**2019**			**Mean over the two seasons**		
Genotypes	**I_1**	**I_2**	**I_3**	**I_1**	**I_2**	**I_3**	**I_1**	**I_2**	**I_3**
L2	1684.89	1155.00	777.78	1518.67	1285.30	699.00	1601.78	1220.15	738.39
L3	1735.89	1235.78	728.11	1654.00	1294.67	676.56	1694.94	1265.22	702.33
L4	2339.56	1263.56	633.67	2193.78	1199.67	601.11	2266.67	1231.61	617.39
L5	1560.78	822.89	430.44	1403.11	802.00	470.00	1481.94	812.44	450.22
L6	1560.33	397.89	260.76	1666.56	608.00	329.30	1613.44	502.94	295.03
L7	636.67	378.78	97.44	658.78	320.56	117.63	647.72	349.67	107.53
L8	2187.22	1100.56	679.43	2250.89	1215.00	624.08	2219.05	1157.78	651.75
L9	917.56	638.44	163.67	907.89	570.89	261.50	912.72	604.66	212.58
L10	2178.67	1135.67	669.11	1728.11	1261.89	529.56	1953.39	1198.78	599.33
L11	2080.67	1281.91	699.33	2059.78	1030.97	648.67	2070.22	1156.44	674
L12	2410.89	1271.11	698.56	2474.67	1217.11	669.89	2442.78	1244.11	684.22
L13	1571.11	1269.14	475.89	1601.33	1253.00	404.44	1586.22	1261.07	440.16
L14	1812.67	651.56	166.67	1865.44	735.22	123.89	1839.05	693.39	145.28
L15	1230.59	855.46	288.44	1218.44	809.50	307.44	1224.51	832.48	297.94
L17	2503.11	1228.33	674.11	2451.48	1263.44	631.86	2477.29	1245.88	652.98
L18	1891.22	752.56	555.11	1908.11	801.17	515.39	1899.66	776.86	535.25
L19	2021.78	802.11	516.67	1903.11	867.22	450.78	1962.44	834.66	483.72
L20	1703.22	1041.67	373.22	1866.11	967.67	369.83	1784.66	1004.67	371.52
L21	1378.22	668.78	204.33	1161.22	679.28	205.67	1269.72	674.03	205
L22	1990.67	1032.11	596.11	1852.78	1126.78	599.60	1921.72	1079.44	597.85
L23	977.33	689.78	405.00	1028.33	756.56	373.67	1002.83	723.17	389.33
L25	1481.78	923.33	479.33	1373.00	894.81	612.56	1427.39	909.07	545.94
L26	1614.67	727.22	348.17	1391.67	764.56	392.56	1503.17	745.89	370.36
H306	2018.33	1182.33	614.78	1904.76	1264.78	647.78	1961.54	1223.55	631.28
Dorado	1684.33	1090.83	590.44	1654.14	1055.67	625.17	1669.23	1073.25	607.80
Mean	**1726.88**	**943.87**	**485.06**	**1667.84**	**961.82**	**475.51**	**1697.36**	**952.85**	**480.29**
RLSD 5%									
Treatments (T)	**21.34**			**15.21**			**18.56**		
Genotypes (G)	**32.76**			**26.47**			**11.82**		
T x G	**15.96**			**45.85**			**51.58**		

I_1 = normal irrigation. I_2 = mild stress irrigation. I_3 = severe stress irrigation.

Table 14. Mean of biological yield/plant for 25 Sorghum bicolor genotypes under irrigated and drought stress treatments over the two seasons.

Season	**2018**			**2019**			**Mean over the two seasons**		
Genotypes	**I_1**	**I_2**	**I_3**	**I_1**	**I_2**	**I_3**	**I_1**	**I_2**	**I_3**
L2	133.84	99.63	64.36	134.45	93.85	65.62	134.14	96.74	64.99
L3	125.46	93.38	55.25	119.20	87.61	60.04	122.33	90.49	57.64
L4	160.75	114.92	50.40	147.03	109.65	49.21	153.89	112.28	49.80
L5	90.60	69.31	39.90	85.69	65.85	37.80	88.14	67.58	38.85
L6	181.05	124.40	49.10	169.64	111.03	56.66	175.34	117.71	52.88
L7	83.56	57.03	28.32	82.90	65.20	24.50	83.23	61.11	26.41
L8	146.11	91.59	70.70	138.68	83.66	63.33	142.39	87.62	67.01
L9	75.33	49.68	31.75	73.84	48.33	31.74	74.58	49.00	31.74
L10	176.51	78.79	46.83	125.07	77.47	46.90	150.79	78.13	46.86
L11	175.22	93.63	51.74	167.79	87.35	53.41	171.50	90.49	52.57
L12	133.90	92.01	51.86	143.23	88.33	54.47	138.56	90.17	53.16
L13	99.70	80.35	56.95	100.19	79.23	48.71	99.94	79.79	52.83
L14	139.67	72.88	38.52	133.10	77.38	39.01	136.38	75.13	38.76
L15	103.16	74.82	48.35	94.09	71.81	48.16	98.62	73.31	48.25
L17	160.79	101.65	55.90	160.68	87.49	55.02	160.73	94.57	55.46
L18	213.63	93.63	53.00	173.09	102.09	53.47	193.36	97.86	53.23
L19	84.95	63.74	45.01	87.03	65.63	44.16	85.99	64.68	44.58
L20	121.52	68.78	29.75	104.49	58.88	30.88	113.00	63.83	30.31
L21	104.31	82.01	43.29	102.71	80.06	44.18	103.51	81.03	43.73
L22	158.07	99.75	71.91	146.26	88.19	66.77	152.16	93.97	69.34
L23	131.84	62.74	45.08	108.31	64.24	44.56	120.07	63.49	44.82
L25	160.05	85.14	51.17	155.11	88.12	45.88	157.58	86.63	48.52
L26	157.64	76.38	44.94	152.83	75.72	41.55	155.23	76.05	43.24
H306	176.10	99.88	58.88	158.64	95.12	59.88	167.37	97.5	59.38
Dorado	170.29	90.03	50.50	169.21	84.20	51.52	169.75	87.11	51.01
Mean	**138.56**	**84.64**	**49.33**	**129.33**	**81.45**	**48.69**	**133.94**	**83.05**	**49.01**
RLSD 5%									
Treatments (T)	**21.34**			**15.21**			**10.86**		
Genotypes (G)	**32.76**			**26.47**			**21.84**		
T x G	**15.96**			**45.85**			**40.52**		

I_1 = normal irrigation. I_2 = mild stress irrigation. I_3 = severe stress irrigation.

Table 15. Mean of grain yield/plant for 25 sorghum bicolor genotypes under irrigated and drought stress treatments over the two seasons.

Season	**2018**			**2019**			**Mean over the two seasons**		
Genotypes	**I_1**	**I_2**	**I_3**	**I_1**	**I_2**	**I_3**	**I_1**	**I_2**	**I_3**
L2	44.06	36.65	25.64	45.35	30.84	24.63	44.70	33.74	25.13
L3	38.15	30.89	17.58	36.77	26.20	21.45	37.46	28.54	19.51
L4	30.75	24.97	15.18	28.77	24.48	12.37	29.76	24.72	13.77
L5	32.98	23.90	17.44	31.97	25.02	17.87	32.47	24.46	17.65
L6	45.25	31.73	10.13	42.57	32.10	8.25	43.91	31.91	9.19
L7	36.33	26.19	12.83	37.26	27.91	11.18	36.79	27.05	12.00
L8	51.78	24.66	13.01	41.32	19.10	10.53	46.55	21.88	11.77
L9	24.26	11.21	8.26	24.62	12.37	7.26	24.44	11.79	7.76
L10	67.28	31.56	15.81	38.87	24.79	19.24	53.07	28.17	17.52
L11	37.31	28.06	11.46	33.25	25.20	15.63	35.28	26.63	13.54
L12	50.71	33.37	16.71	49.63	31.30	14.93	50.17	32.33	15.82
L13	32.51	26.07	18.71	32.21	26.82	16.92	32.36	26.44	17.81
L14	51.12	27.09	8.01	48.91	27.43	12.47	50.01	27.26	10.24
L15	42.19	25.75	19.68	36.21	24.94	19.08	39.2	25.34	19.38
L17	53.40	38.02	17.49	56.80	28.29	14.72	55.1	33.15	16.10
L18	60.72	34.37	15.91	52.93	30.87	14.82	56.82	32.62	15.36
L19	32.88	28.27	18.55	31.29	24.73	19.86	32.08	26.5	19.20
L20	53.62	26.18	11.77	38.15	20.56	10.29	45.88	23.37	11.03
L21	36.55	26.29	14.04	33.58	23.24	16.35	35.06	24.76	15.19
L22	52.00	36.10	23.49	46.75	28.89	21.63	49.37	32.49	22.56
L23	61.63	25.19	13.51	41.85	26.24	15.10	51.74	25.71	14.30
L25	47.72	27.38	17.13	48.74	26.21	12.77	48.23	26.79	14.95
L26	52.97	23.08	7.78	53.45	23.38	9.26	53.21	23.23	8.52
H306	57.83	35.38	21.39	54.75	34.18	21.62	56.29	34.78	21.50
Dorado	50.06	33.65	20.05	49.19	29.16	18.95	49.62	31.40	19.50
Mean	**45.76**	**28.76**	**15.66**	**41.41**	**26.05**	**15.49**	**43.58**	**27.40**	**15.57**
RLSD 5% Treatments (T) Genotypes (G) T x G	**2.03** **5.25** **9.10**			**1.26** **4.59** **7.94**			**2.11** **1.96** **8.54**		

I_1 = normal irrigation. I_2 = mild stress irrigation. I_3 = severe stress irrigation.

Table 16. Estimates of stability parameters based on six environments using various models for yield in sorghum.

Traits	**Grain yield/plant**													
	Environments						**Stability parameters**							
Genotypes	**E_1**	**E_2**	**E_3**	**E_4**	**E_5**	**E_6**	**Mean**	**b_i^E**	**β_i**	**$S_2di^{(E)}$**	**bi^F**	**$S^2d_i^{(F)}$**	**λ**	**α**
L2	44.06	36.65	25.64	45.35	30.84	24.63	34.53	0.69	0.31	-7.60	0.64	144.92	1.58	-0.04
L3	38.15	30.89	17.58	36.77	26.20	21.45	28.51	0.63	0.37	-8.11	0.56	107.95	2.05	-0.05
L4	30.75	24.97	15.18	28.77	24.48	12.37	22.75	0.55**	0.45	-5.46	0.54	118.43	3.13*	-0.06
L5	32.98	23.90	17.44	31.97	25.02	17.87	24.86	0.51	0.49	-11.26	0.50	68.18	3.07*	-0.06
L6	45.25	31.73	10.13	42.57	32.10	8.25	28.34	1.20	-0.20	12.04	1.08	577.65**	2.03	0.02
L7	36.33	26.19	12.83	37.26	27.91	11.18	25.28	0.84	0.16	-0.42	0.82	285.22**	1.17	-0.02
L8	51.78	24.66	13.01	41.32	19.10	10.53	26.73	1.27**	-0.27	-0.65	1.18	602.01**	1.49	0.03
L9	24.26	11.21	8.26	24.62	12.37	7.26	14.66	0.59**	0.41	-7.30	0.56	107.96	2.48	-0.05
L10	67.28	31.56	15.81	38.87	24.79	19.24	32.93	1.35	-0.35	61.89	1.36	1064.39**	6.30**	0.04
L11	37.31	28.06	11.46	33.25	25.20	15.63	25.15	0.76*	0.24	-4.69	0.80	246.88**	1.34	-0.03
L12	50.71	33.37	16.71	49.63	31.30	14.93	32.78	1.20	-0.20	-7.98	1.30	177.18	2.40	0.04
L13	32.51	26.07	18.71	32.21	26.82	16.92	25.54	0.50**	0.50	-8.97	0.49*	75.92	3.46*	-0.06
L14	51.12	27.09	8.01	48.91	27.43	12.47	29.17	1.40	-0.40	-5.36	1.85	1513.05**	8.91**	0.10
L15	42.19	25.75	19.68	36.21	24.94	19.08	27.98	0.72*	0.28	-9.14	0.67	174.42*	1.44	-0.04
L17	53.40	38.02	17.49	56.80	28.29	14.72	34.79	1.37**	-0.37	5.18	1.30	762.06**	2.48	0.04
L18	60.72	34.37	15.91	52.93	30.87	14.82	34.94	1.48**	-0.48	-11.41	1.46	877.60**	2.51	0.03
L19	32.88	28.27	18.55	31.29	24.73	19.86	25.93	0.45**	0.55	-10.21	0.42**	34.31	4.17**	-0.07
L20	53.62	26.18	11.77	38.15	20.56	10.29	26.76	1.28**	-0.28	3.20	1.20	642.44**	1.86	0.03
L21	36.55	26.29	14.04	33.58	23.24	16.35	25.01	0.71*	0.29	-10.84	0.68	158.58*	1.29	-0.04
L22	52.00	36.10	23.49	46.75	28.89	21.63	34.81	0.97	0.03	-7.98	0.98	112.07	0.65	-0.01
L23	61.63	25.19	13.51	41.85	26.24	15.10	30.59	1.38*	-0.38	21.27	1.33	843.52**	3.79**	0.04
L25	47.72	27.38	17.13	48.74	26.21	12.77	29.99	1.17*	-0.17	-3.05	1.11	510.58**	0.65	0.02
L26	52.97	23.08	7.78	53.45	23.38	9.26	28.32	1.58**	-0.58	3.44	1.58	1110.04**	4.57**	0.07
H306	57.83	35.38	21.39	54.75	34.18	21.62	37.53	1.48	-0.48	-53.25	1.37	110.37	0.62	0.03
Dorado	50.06	33.65	20.05	49.19	29.16	18.95	33.51	1.06	-0.06	-9.42	1.03	106.18	0.52	0.02
Mean	**45.76**	**28.76**	**15.66**	**41.41**	**26.05**	**15.49**	**28.86**							

Mean = grain mean yield (ardab/feddan);bi^E = regression coefficient of Eberhart and Russell; β_i = regression coefficient of Perkins and Jinks; b_i^F= regression coefficient of Freeman and Perkins; S^2d_i (E) = deviation from regression Eberhart and Russell; S^2d_i (F) = residual MS of Freeman and Perkins model. **α** and **λ**-Tai's stability parameters. *, ** Significant at the 0.05 and 0.01 probability levels, respectively.

Grain yield stability parameters

According to three models viz., Eberhart and Russell's, Perkins and Jinks and Freeman and Perkins (Table 16 and Fig. 3), two genotypes namely line No. 22 and Dorado were stable performance for grain yield, whereas had grain yield/plant above-grand mean over environments by 34.81 and 33.51 g respectively, the regression coefficient value near 1.0 (b_i^E and b_i^F) and deviation not significantly different from zero ($S^2d_i^E$ and $S^2d_i^F$), β_i equal or near to zero. The genotypes line 12 and H306 exhibited stable performance under favorable environment (above grand mean by 32.78 and 37.53 g respectively, b_i^E and $b_i^F > 1$, $B_i > 0$ and $S^2d_i^E$ and $S^2d_i^F$ non-significant). While the genotype line No. 2 showed stability under unfavorable environment (above grand mean by 34.53 g, b_i^E and $b_i^F < 1$, $B_i < 0$ and $S^2d_i^E$ and $S^2d_i^F$ non-significant). According to three models. Pabale and Pandya (2010) indicated that the genotypes GHB-788, GHB-832 and GHB-840 were observed as most stable and widely adapted over environments in the models of Eberhart and Russell (1966), Perkins and Jinks (1968) and Freeman and Perkins (1971). Changizi *et al.*, (2014) revealed that the selection of stable genotypes, based on these previous methods, caused high yield genotypes to be introduced as stable genotypes. These results are in agreement with those reported by Yahaya *et al.*, (2006), Islam *et al* (2006) Mohammadi *et al.*, (2012), Karimzadeh *et al.*, (2012) and Said *et al.*, (2020). On the other hand, Tai's stability analysis revealed that twenty genotypes namely lines No. 6, 8, 11, 12, 15, 17, 20, 21, 22, 25 and cultivars H306 and Dorado were exhibited average stability (Table 34 and Figure 4), (α, λ) = (0, 1), six of them (Lines No. 12, 17, 22, 25 and cultivars H306 and Dorado) gave high mean over all environments by 32.78, 34.79, 34.81, 29.99, 37.57 and 33.51 g respectively. These results were in accordance with those previously reached by Gomaa *et al.*, (2018) and Said *et al.*, (2020).

Fig. 3. Graphical illustration of the stability parameters ($bi^{Eberhart}$ and $bi^{Freeman}$) and the mean performance of individual genotypes for grain yield/plant.

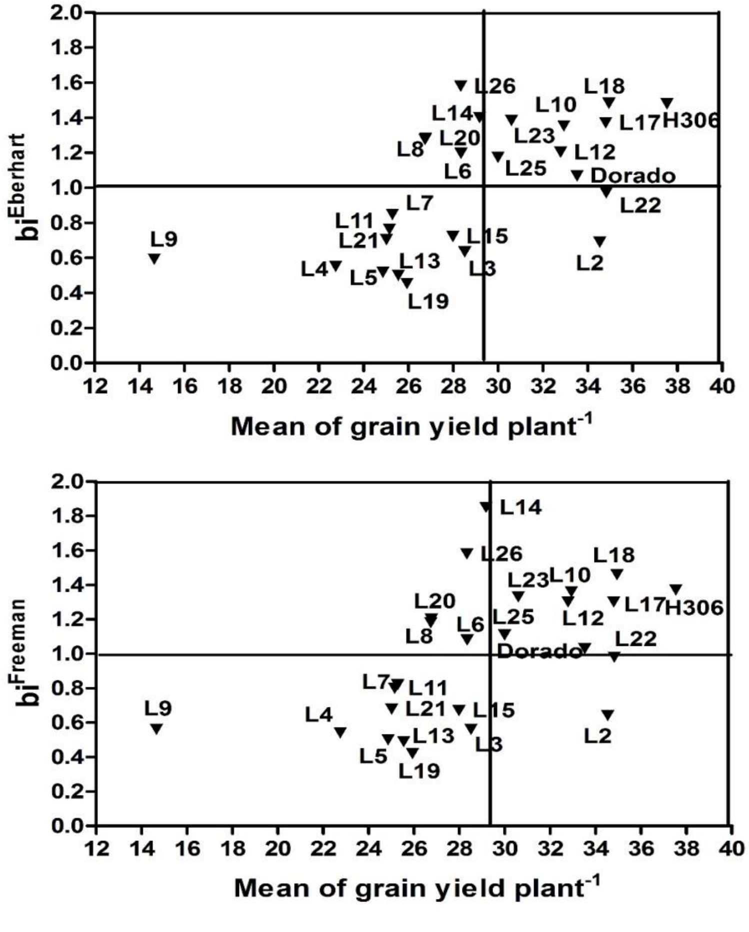
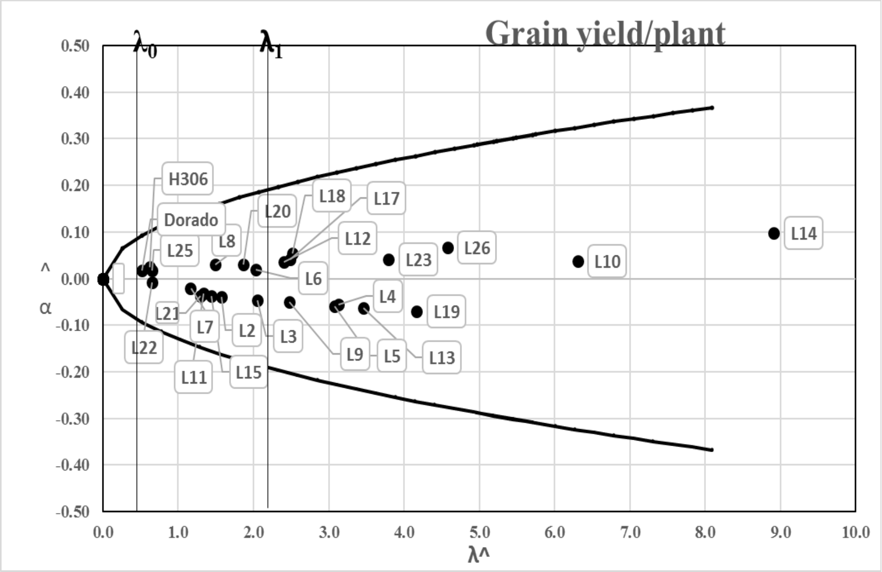


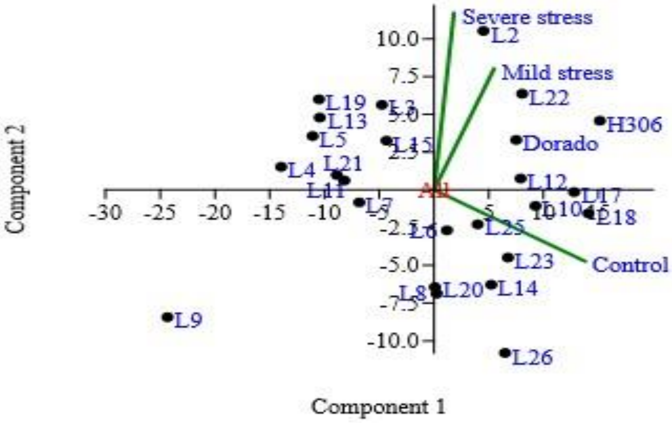
Fig. 4. Genotypic stability parameters of 25 sorghum genotypes for grain yield/plant.



Principle components analysis

Principal component analysis (PCA) simplifies the complex data by transforming the number of correlated variables into a smaller number of variables called principal components. In Figure 5, PCA gives two important views of association among irrigation treatments and classification of tested sorghum genotypes. Sorghum genotypes were classified into four groups based on biplots of PC1 vs. PC2 (Figures 5). According to biplot analysis, the correlation coefficients between irrigation treatments were positive and highly significant with twenty-five genotypes for grain yield/plant, whereas Lines No. 10, 12, 17, 18, 22 and cultivars H306 and Dorado were located near all environments (normal irrigation and drought stress treatments) for this trait (stable genotypes over environments). Meanwhile, Line No. 2 was located near mild and severe stress treatments (drought stress) for this trait (stable genotypes under this condition). Abdolshahi *et al.*, (2010); Dadbakhsh *et al.*, (2011); Shivramakrishnan *et al.*, (2016) were able to reveal that the genotypes with larger PCA1 and lower PCA2 scores gave high yields (stable genotypes). Moreover, Chahal and Gosal (2002) cleared those characters with largest absolute value closer to unity within the first principal component influence the clustering more than those with lower absolute value closer to zero.

Figures 5. A biplot of grain yield/plant for twenty-five sorghum genotypes under normal irrigation and drought stress treatments.



CONCLUSION

Our data revealed that both mean performance of a sorghum genotypes and its stability parameters should be taken together into consideration to identify new genotypes to be used in various environments. Whereas, according to four models viz., Eberhart and Russell's, Perkins and Jinks, Freeman and Perkins and Tai, line No. 22 (34.81 g) beside cultivar Dorado (33.51 g) were observed as most stable and widely adapted over environments, surprised mean performance for grain yield/plant than grand mean over environments, b_i^E and b_i^F equal or near to one, B_i equal or near to zero and $S^2d_i^E$ and $S^2d_i^F$non-significant and with average stability has (α ، λ) = (0 ، 1) beside principal component analysis (PCA) also showed that two genotypes were located near all environments (Normal irrigation and drought stress treatments). While the genotype line No. 2 showed stability under unfavorable environment (Above grand mean by 34.53 g, b_i^E and $b_i^F< 1$, $B_i < 0$ and $S^2d_i^E$ and $S^2d_i^F$ non-significant and with average stability), beside PCA showed that it was located near mild and severe stress treatments (Stable under this condition).

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الملخص العربي

أقلمه وثبات المحصول في تراكيب وراثية للذرة الرفيعة تحت بيئات نقص المياه

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تم إجراء تجربتين ميدانيتين في المزرعة التجريبية بالكوثر بكلية الزراعة، جامعة سوهاج، مصر، خلال موسمي الزراعة الصيفيين 2018 و2019 لتقييم إنتاجية وثبات عدد 23 سلالة من الذرة الرفيعة تحت ظروف الاجهاد المائي، بالإضافة الي صنفين محليين (H306 وDorado) في ثلاث تجارب لكل منها ثلاث مكررات في تصميم القطاعات كاملة العشوائية. ثلاث تجارب ري، وهي: الري بدون اجهاد = 0.8 من النتح بخر وجفاف متوسط = 0.6 من النتح بخر وجفاف قاسى = 0.4 من النتح بخر. وتم تقييم 5 صفات محصولية وهم طول النورة ووزن الـ 1000 حبة وعدد حبوب النورة ووزن المحصول البيولوجي للنبات ومحصول النبات الفردي في كل من الري العادي وظروف الاجهاد المائي. تم استخدام أربعة نماذج لتقدير ثبات محصول الحبوب للتراكيب الوراثية للذرة الرفيعة عبر البيئات المختلفة وهي إيبرهارت ورسل، بيركنز وجينكس ، فريمان وبيركنز ، وتاي، بالإضافة الي استخدام تحليل المكونات الاساسية.

أظهر تحليل التباين للصفات المدروسة تباينًا كبيرًا بين التراكيب الوراثية والبيئات وتفاعلاتها، مما يشير إلى أنها تباينت في استجاباتها للبيئات المتنوعة. كما اظهرت النتائج تفوق السلالة رقم 22 وصنف Dorado تحت الظروف البيئية المختلفة، وذلك لإظهارهما أداءً عاليًا لمحصول الحبوب عبر هذه البيئات عند مقارنتها بالمتوسط العام للتراكيب الوراثية المدروسة بجانب معايير الثبات المقبولة. بينما أظهر التركيبين الوراثيين، سلالة رقم 12 والصنف المحلي H306 أداءً ثابتا تحت ظروف الري العادي مع متوسط عالي لمحصول الحبوب. في نفس الوقت، أظهر التركيب الوراثي رقم 2 ثباتًا تحت ظروف بيئة الاجهاد المائي بمتوسط محصول عالي. هذه التراكيب الوراثية يمكن استخدامها في برامج التربية على نطاق واسع تحت هذه الظروف.