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Evaluation of some Durum Wheat Genotypes under Different Stress Conditions

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ABSTRACT

Ten promising advanced durum wheat lines derived from National Wheat Program and five cultivars(BaniSweif 1, BaniSweif 5, BaniSweif 6, Sohag 4, and Sohag 5) were evaluated at the Experimental Farm of Sids Agricultural Research Station, Agriculture Research Center (ARC), Egypt, throughout the twogrowing seasons 2018/2019 and 2019/2020. The studied genotypes were grownunder normal conditions and five combinations of heat and water stress conditions. The combined analysis of variance demonstratedsubstantialvariations between thetreatments, genotypes, as well as their interaction for all the studied traits.In addition, resultsrevealed thatchlorophyll content,days to heading, grain yield, and its components were substantiallydiminishedvia delaying the date of sowing as well as water stress conditions. Stressed conditions (T6) reduced the Spikes m^{-2} number, kernelsspike^{-1}number, 1000 kernels weight, and grain yieldby 42.13, 43.75, 21.04, and 48.15% respectively, compared to normal conditions (T1). The mean performance of the genotypes showed thatthe genotypes that exhibited the highest productivity were Sohag 5, Line 1, Sohag 4, and Line 2.GGE biplotillustrated thatthe most stable genotypes with the greatest grain yield were Sohag 5, Line 1, Sohag 4, Line 3, Line 6, and Line 10, while, Line 2 and Bani Suef 5 were the least stable genotypes across the studied environments.

Keywords: Durum wheat, Genotypes, Sowing dates,Heat stress, Water stress.

INTRODUCTION

Wheat is the main cereal crop in Egypt in terms of cultivated area and crop production. The totalcultivated area of wheat(bread and durum wheat) is about 3.4 million faddans (1.42 million hectares), producing 9.34 million tons with an average of 19.19 ardab/faddan (6.85 ton/ha)(Economic Affaira Sector, 2021). Egypt's imports of wheat were about 13 million tons (FAO, 2020). Consequently, improving wheat production byincreasing the productivity per unit area is the most significant objective to reduce the gap between wheat production and annual local demands.

Durum wheat (*Triticumturgedum var. durum* L.) represents about 8-10% of the wheat-grown area and world production(FAO STAT, 2018). Durum wheat significance is attributable to numerous purposes for human use in bread making pasta industry, and it is high in gluten and protein content (Rachon*et al.*, 2002). Durum wheat cultivated areas in Egypt are centered in upper as well as middle Egypt and are utilized in pasta and bread.

Food security is the principal challenge facing human beings in the twenty-first century. Uncertainty in environmental conditions induced a 7% decline in worldwide crop yields. In fact, wheat cultivation faces some abiotic stresses like elevated temperature and diminished water availability, which often inhibit major cereal crops' productivity and growth.Elevated temperature is always associated with a diminished water supply.Consequently, one of the main objectives of crop breeding programs isto developtolerant cultivars against stresses (Tester and Bacic, 2005). Heat and drought stresses are the most abiotic stressesimpacting the crop's physiological traits. Consequently, even if other factors are at optimum levels, wheat yield is limited under stress conditions. They directly affect photosynthesis and respiration, interrupting the metabolic pathways, causing enduring injuries and severe yield reduction(Gol*et al.*, 2017). Terminal drought and heat stresses are more aggressive than early growing stages because they occur at reproductive growth and grain development stages, affecting grain filling rate, grains spike^{-1}number, grain size, as well as 1000 grains weight.Consequently,a significant decline in wheat grain yieldsby up to fort two percentin drought conditions as illustrated by(Mehraban*et al.* 2019), and a 48% decline under terminal heat stress was stated by(Abro*et al.*, 2019).

The change in the relative performance of genotypes across diverse settings is defined as genotype by environment interaction (G×E) (Cooper and Byth, 1996). It is a significant difficulty for plant breeders since it complicates selection as well as high-ranked genotype testing, decreasing genetic progress (Romagosa and Fox, 1993). If G×E is relevant, breeders must be aware of stable genotypes with relative performance in a variety of conditions. Stability may be either dynamic or static (Becker and Leon, 1988). Stability is static if the genotype maintains constant yield across conditions and dynamic if the genotype's performance adjusts to modifications in the settings. Several statistical approaches for estimating GE interaction have been presented. These vary from multivariate models to univariate parametric modelswith genotype (G) main effect + GE interaction, *i.e.*,

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GGE biplot (Yan *et al.*, 2000). GGE biplot approaches provide a comprehensive visual data analysis of data by presenting average stability and performance as well as illustrating mega-environments (Ding *et al.*, 2007; Kang, 1993; Yan, 2001 and Yan and Kang, 2003), which reveals which genotype is high and stable yielding. It also illustrates discrimination and environmental representation (Yan, 2001).

The purpose of this study was to determine if a genotype has broad or specialized adaptation under heat stress and drought combinations by examining GE interaction for wheat grain production using GGE biplot approaches.

MATERIALS AND METHODS

Ten promising advanced durum wheat linesderived from the National Wheat Program and five cultivars(BaniSweif 1, BaniSweif 6, BaniSweif 5, Sohag 4, and Sohag 5) were evaluated at the Experimental Farm of Sids Agricultural Research Station (Biba28.92001°N, 30.9891° E), Agriculture Research Center (ARC), Egypt, during the twogrowing seasons 2018/2019 and 2019/2020.The pedigree and origin of the studied genotypes are presented in Table 1.The examined genotypes were cultivatedduring the two growing seasons under these conditions:

1- T1: Recommended sowing date (25thNovember) and recommended irrigation: (planting irrigation+ five irrigations with 2520 m^{3}water).
2- T2: Recommended sowing date (25thNovember)as well as water deficit following heading: (planting irrigation +three irrigations with 1710 m^{3}water).
3- T3: Recommended sowing date as well as extreme water stress: (planting irrigation + one irrigation 40 days later with 950 m^{3}water).
4- T4: Late sowing date (25thDecember) as well as recommended irrigation (planting irrigation + five irrigations with 2520 m^3 water).
5- T5:Late sowing date (25thDecember) as well as water deficit following heading (planting irrigation +three irrigations with 1710 m^3 water).
6- T6: Late sowing date (25thDecember) as well as extreme water stress: (planting irrigation and then one irrigation 40 days later with 950 m^3 water).

Table 1. Pedigree, selection history, and origin of the fifteen-durum wheat genotypes used in this study

No.	Genotypes	Pedigree and selection history	Origin
1	Line 1	MINIMUS/COMBDUCK_2//CHAM_3/3/FICHE_6/4/MOJO/AIRON/5/SOMAT_3.1/6/CHEN/ALTAR84/3/HUI/POC//BUB/RUFO/4/FNFOOT/5/TILO_1/LOTUS_4/10/CBC509CHILE//SOOTY_9/RASCON_37/9/USDA595/3/D67.3/RABI//CRA/4/ALO/5/HUI/YAV_1/6/ARDENTE/7/HUI/YAV79/8/POD_9/11/ALTAR 84/S CDSS09Y00795T-099Y-024M-29Y-0M-04Y-0B	CIMMYT
2	Line 2	GUAYACANINIA/GUANAY//PORRON_4/BEJAH_7/3/VANRRIKSE_12/SNITAN/7/MOHAWK/6/RASCON_37/2*TARRO_2/4/ROK/FGO//STIL/3/BISU_1/5/MALMUK_1/SERRATOR_1/8/STOT//ALTAR84/ALD/3/THB/CEP7780//2*MUSK_4/6/ECO/CMH772//BIT/3/ALTAR84/4/AJAIA_2/5/KJOVE_1/7/RASCON_37/2. CDSS10Y00517T-099Y-055M-13Y-4M-06Y-0B.	CIMMYT
3	Line 3	CIRNO C 2008*2/HELLER #1. CMSS09Y01202T-099TOPB-099Y-099B-19Y-0Y.	CIMMYT
4	Line4	ODIN_15/WITNEK_1//ISLOM_1/6/ARMENT/4/2*SKEST//HUI/TUB/3/SILVER/5/TILO_1/LOTUS_4. SDD5100-2SD-1SD -1SD.	Egypt
5	Line 5	ODIN_15/WITNEK_1//ISLOM_1/6/ARMENT/4/2*SKEST//HUI/TUB/3/SILVER/5/TILO_1/LOTUS_4. SDD5100-6SD-2SD -1SD.	Egypt
6	Line 6	SOMAT_4/INTER_8/5/AJAIA_16//HORA/JRO/3/GAN/4/ZAR/6/BaniSuef 5	Egypt
7	Line 7	RCOL/THKNEE_2/9/USDA595/3/D67.3/RABI//CRA/4/ALO/5/HUI/YAV_1/6/ARDENTE/7/HUI/YAV79/8/POD_9/10/Mgnl3/Ainzen-1. SDD5127-3SD-1SD -1SD.	Egypt
8	Line 8	Mgnl3/Aghrass2//Sohag 3. SDD5144-5SD-1SD -1SD.	Egypt
9	Line 9	ODIN_15/WITNEK_1//ISLOM_1/6/ARMENT/4/2*SKEST//HUI/TUB/3/SILVER/5/TILO_1/LOTUS_4. SDD5100-3SD-2SD -1SD.	Egypt
10	Line 10	HESSIAN-F_2/3/STOT//ALTAR 84/ALD/4/BaniSuef 1. SDD5102-2SD-2SD-1SD.	Egypt
11	BaniSuef 1	Jo”S”/AA”S”//FG “S”. CDSS9799-126M-1M-SY-0M-0SD.	Egypt
12	BaniSuef 5	DIPPER-2/BUSHEN-3. CDSS92B128-IM-0Y-0M-0Y-3B-0Y-0SD.	Egypt
13	BaniSuef 6	Boomer-21/Busca-3. CDSS95-Y001158-8Y-0M-0Y-0B-1Y-0B-0SD.	Egypt
14	Sohag 4	Ajaia-16//Hora/Jro/3/Ga/4/Zar/S/Suok 7/6/Stot//Altar84/Aid. CDSSB007785-0T0PY-0M-0Y129Y-0M-0Y-IB-0SH.	Egypt
15	Sohag 5	TRN//21563/AA/3/BD2080/4/BD2339/5/Rascon37//Tarro2//Rascon3/6/Auk/Gull//Green. CDSS00B00364T-0T0PB-0B-2Y-0M-0Y-1B-0Y-0SH.	Egypt

A border of 10 meters in width was left between each treatment. In addition, a canal in the middle of this border of a 2 m width and 1 m depth was dug. That to prevent seepage of irrigation water.

The combination of the previously mentioned treatments throughout the two growing seasons resulted in12 environments. Each treatment combined with season number resulted in an environment as follows, *i.e.*, T_1S_1, T_2S_1, T_3S_1, T_4S_1, T_5S_1, T_6S_1, T_1S_2, T_2S_2, T_3S_2, T_4S_2, T_5S_2, and T_6S_2. For each experiment,arandomized complete block design with three replications was used. The plot size was $4.2m^2$, and seeds were drilled and sown in 6 rows, 3.5m long and 20cm apart. The other wheat production agricultural practices were followed. Data recording was performed, includingflag leaf chlorophyll content (SPAD), days to heading, spikes m^{-2}number, 1000 kernels weight (gm),kernels spike^{-1} number,as well as grain yield (ardab fad.$^{-1}$).

Meteorological conditions:

BaniSuef Governorate (Biba 28.92001°N, 30.9891° E) has a hot desert climate (BWh) according to Köppen-Geiger climate classification system(Kottek *et al*., 2006). It has avery hot summer and worm winter with a large difference of temperatures between day and night. Table 2 showed the maximum and minimum temperature during 2018/2019 and 2019/2020 growing seasons.

Table 2. Mean maximum, minimum air temperature© andrangeduring the two growing seasons at SidsAgricultural Research Station.

Months	Air Temperature (°C) 2018/2019			2019/2020		
	Max	Min	Range	Max	Min	Range
November	32.6	11.05	21.55	33.34	10.02	23.32
December	23.23	5.35	17.88	23.9	4.93	18.98
January	25.07	1.47	23.6	24.12	1.58	22.55
February	29.6	4.95	24.65	26.48	3.27	23.2
March	32.05	4.95	27.1	30.58	4.29	26.3
April	36.21	27.24	28.97	35.4	9.3	26.11

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Statistical analysis procedures

Collected data underwent individual analysis of variance (ANOVA) of randomized complete block design for each treatment combination (environment) according to Gomez and Gomez (1984) using GenStat 19th Ed statistical software.Levene (1960) was conducted to verify the individual error's homogeneity prior to combine analysis.

GGE Biplot technique

GGE (genotype + genotype by environments interaction effect) biplot graphs display two-way data considering the first two principal components (PC2 as well as PC1). This technique was employed to explain the interaction between evaluated genotypes as well as tested environments in the same graph to assess the adaptability or stability range (Yan and Tinker, 2006). GGE biplot approaches were subjected using GenStat 19th Ed statistical software.

RESULTS AND DISCUSSION

Mean performance and variability:

Days to the heading:

Results presented in Table3 revealed highly substantial variations between treatments, genotypes, as well as their interaction for days to heading across all treatments. The average performance days to heading differed from treatment to another and genotype to another. The average means for days under the six treatments were 96, 91, 84, 80, 77, and 72 days, respectively. It is noteworthy that stressed conditions (T6) reduced the number of days to heading by about 23.40% compared to normal conditions (T1). Our results are as well as in agreement with those of Chowdhury *et al.*, 2021. The overall means ranged from 82 days (Line 1, Line 2, and Line 3) to 85 days (Line 10) with a grand mean of 83 days. BetweenNovember to March, temperatures are relatively convenient for the wheat crop cultivated in November,whereasdiminishedas well aselevated temperaturesthroughout emergence and phases of grain formation are not convenient for cropscultivated in late December. Significant reduction of days to heading is due to heat stress conditions. These results align with Din and Singh2005 and Mondini*et al.*, 2014. The reduction seems mainly due to the shortage of growth duration where the terminal heat stress is related to late sowing. Similarly, water deficiency substantially decreased the number of days to the heading of bread and durum genotypes. Water stress was proven to accelerate and substantially decrease the number of days to heading. Optimal water delivery throughout the booting, heading, and milking periods increased grain production. The selection of early maturing genotypes has successfully decreased yield loss due to water scarcity, resulting in crop growing periods that are shorter.

Flag leaf chlorophyll content (SPAD):

Chlorophyll content helps to synthesize photosynthesis products in the plant. Therefore, keeping it up is essential for adjusting photosynthesis under drought stress. It considers a vital indicator of drought stress. Elevated content of chlorophyll is preferable since it denotes diminished photo inhibition of the photosynthetic system, decreasing carbohydrate losses for the growth of grains growth (Farquhar and Richarda, 1984).The results of the present study in Table 3 show substantial variations among treatments, genotypes, and their interaction for flag leaf chlorophyll content. Line 2, BaniSuef 1, and Line 1 exhibited a high concentration of chlorophyll content as well as overall treatments with values of 48.18, 46.80, and 46.26 SPAD units, respectively, whereas Line 8 was the lowest one among the studied genotype with the value of 43.56 SPAD units with grand mean 45.29SPAD units. These results indicate that the genotypes differed significantly in retaining high chlorophyll content under different stress conditions. These outcomes are in harmony with Keyvan,2010. The average means for chlorophyll content across the six treatments were 50.03, 47.87, 43.57, 46.92, 42.39, and 38.72 SPAD units, respectively. Notably, chlorophyll content was significantly decreased from 50.03 under recommended sowing date and irrigation conditions T1 to 38.72 SPAD units under late sown and water deficit conditions T6. These findings are compatible with Chowdhury *et al.*, 2021.The results can be attributed to the close connectionbetween air temperature, water, and chlorophyll content (Nagata *et al.*, 2005 and Zhao *et al.*, 2007),

Table 3. Mean performance of days to heading and flag leaf chlorophyll content (SPAD) under normal and stress combinations across the two growing season and overall

Genotypes	Days to heading (days)						Overall	Flag leaf chlorophyll content (SPAD)						Overall
	T1	T2	T3	T4	T5	T6		T1	T2	T3	T4	T5	T6	
Line 1	94	92	79	79	76	71	82	56.13	48.50	43.97	46.78	42.19	40.00	46.26
Line 2	95	91	81	78	76	70	82	53.47	49.57	45.53	47.88	46.29	40.37	47.18
Line 3	95	90	82	80	75	71	82	51.40	47.37	42.50	46.51	43.09	39.00	44.98
Line 4	95	91	84	81	76	73	83	48.33	46.20	43.17	45.34	43.35	40.27	44.44
Line 5	94	88	88	79	74	74	83	52.67	48.67	44.30	47.78	42.42	35.87	45.28
Line 6	97	94	84	78	77	73	84	53.07	47.30	43.00	45.98	42.72	39.50	45.26
Line 7	97	94	87	79	76	73	84	52.62	50.42	45.72	43.24	41.17	40.44	45.60
Line 8	97	93	85	78	76	73	84	52.57	45.77	40.73	43.04	41.15	38.14	43.56
Line 9	99	93	84	79	77	73	84	50.63	48.45	44.42	44.08	40.95	39.97	44.75
Line 10	99	93	86	80	78	74	85	52.57	48.92	44.22	44.51	40.42	38.14	44.79
BaniSuef 1	98	91	86	79	77	73	84	56.03	48.97	44.57	51.42	42.42	37.40	46.80
BaniSuef 5	97	90	85	83	78	73	84	56.03	48.02	45.22	46.44	41.05	36.74	44.71
BaniSuef 6	95	91	83	82	77	71	83	56.03	46.80	42.10	51.83	41.75	35.97	45.14
Sohag 4	93	90	82	80	75	71	82	56.03	45.53	41.15	49.81	43.92	41.54	44.91
Sohag 5	94	90	85	79	78	70	83	56.03	47.62	42.92	49.14	42.95	37.59	45.67
Mean	96	91	84	80	77	72	83	56.03	47.87	43.57	46.92	42.39	38.72	45.29
L.S.D. 0.05														
T							0.88							0.6
G							1.4							1.3
T*G							3.43							2.88

Grain yield and its components:

Grain yield and its components recorded for 15 durum wheat genotypes under stress as well as normal conditions combinations across the two growing seasons are presented in Tables 4 and 5. Results revealed that grain yield as well as its components are substantiallydecreased by postponing the date of sowing as well as water deficiency.Maximum values of wheat grain yield and its components were observed at recommended sowing date, and irrigation, which might be due to those environmental conditions during the recommended sowing date, is more suitable and favorable (Table 2) in most growth periods.Therefore, plants might be more efficient in utilizing the growth factors,*i.e.*, nutrients, water, and light which reflected in better growth with high yielding potential. Stressed conditions (T6) reduced spikes m^{-2} number, kernelsspike^{-1}number, 1000 kernels weight, and grain yield ardab fad.$^{-1}$ by 42.13, 43.75, 21.04, and 48.15%, respectively, compared to normal conditions (T1). Kiliç and Yağbasanlar, 2010reported that days to heading, the number of spikes m^{-2}, 1000 kernels weight, and grain yield were reduced under drought and terminal heat stress conditions.

Number of spikes m^{-2}:

The outcomes presented in Table 4 demonstrate highly substantialvariations between treatments, genotypes, and their interactions for spikes m^{-2} number. The average mean values for the six treatments and overall were 553, 492, 382, 439, 381, 320, and 428 spikes m^{-2}, respectively.The average spikes m^{-2} number significantly reduced from 553 spikes m^{-2} under recommended sowing date and irrigation (T1) to 320 spikes m^{-2} under late sown date and water deficit conditions (T6). The highest numbers of spikes m^{-2} were recorded by Line 10, Line9 and Line 6, overall treatments, with values of 443, 439, and 437, respectively, whereas, Sohag 5 and Sohag 4 were the most diminished among the investigated genotypes with values of 416 and 413 spikes m^{-2} and grand mean of 428 spikes m^{-2}. Similar results were reported by Kiliç and Yağbasanlar, 2010 and Guendouz*et al.*, 2012. Spikes m^{-2} number decreases under heat stress conditions. The delayed seedling emergence induced by early maturity as well as diminished temperature as a result of elevated temperatures throughout the reproductive phase, especially the grain-filling period, induced diminished spike m^{-2}number (Tripathi, 2003). The strongest negative impact of water deficiency was detected throughout the floral initiation as well as anthesis phases Ping Li *et al.*, 2012. Water deficiencymay induceintensecompetition between the multiple plant organs for photosynthesis propagules throughout the stem elongation. Consequently, the spike m^{-2}numberis influential since drought stress was diminished in the reproductive phase (Richards *et al.*,2001).

Number of kernels spike^{-1}:

Kernel spike^{-1} number is a significant grain yield element. Calderini*et al.*,1999 reported that high-yielding durum wheat types are related to the high kernel spike^{-1} number. The results presented in Table 4revealed highly substantialvariationsbetweentreatments, genotypes,as well as interactions. The average mean values for the six treatments and overall were 64, 56, 48, 54, 45, 36, and 50 kernels spike^{-1}, respectively. Line 6, BaniSuef 5, and Sohag 5 produced the most significant number of kernels spike^{-1} across all treatments with values of 58, 55, and 54 kernels spike^{-1}, whereas BaniSuef 1 and BaniSuef 6 were the most diminished ones among the investigated fifteen durum wheat genotypes with value 46 kernels spike^{-1}. Kernel spike^{-1} number was substantially decreased from 50 kernels spike^{-1} under recommended sowing date and irrigation conditions of T1 to 36 kernelss spike^{-1} under late sown and water stress conditions (T6). Feltaous and Koubisy, 2020 and Poudel*et al.*, 2020, detected similar trends.The decreased kernel spike-1 number under late sowing conditions can be attributable to the decreased photosynthesis production in a short growing periodBaloch *et al.*, 2012.Water deficiencyprior to flower initiation can also reduce spikelet primordia number throughout this phaseOosterhuis and Cartwright (1983).

Table 4. Mean performance of a number of spikes m^{-2} and number of kernels spike^{-1} under normal and stress combinations across the two growing seasons and overall

Genotypes	Number of spikes m^{-2}						Overall	Number of kernels spike^{-1}						Overall
	T1	T2	T3	T4	T5	T6		T1	T2	T3	T4	T5	T6	
Line 1	557	499	384	441	368	324	429	57	49	41	54	45	40	48
Line 2	553	481	372	443	374	317	423	61	49	42	57	48	29	48
Line 3	542	494	396	432	379	318	427	63	51	41	53	40	35	47
Line 4	581	495	374	412	348	311	420	64	58	50	50	42	36	50
Line 5	557	490	388	446	362	324	428	66	61	56	53	47	42	54
Line 6	553	494	404	453	379	337	437	70	68	57	61	52	43	58
Line 7	551	510	411	434	393	317	436	60	54	46	52	42	40	49
Line 8	560	497	366	451	392	313	430	59	53	48	54	47	27	48
Line 9	568	521	364	450	399	335	439	62	56	49	64	52	40	54
Line 10	587	500	390	464	413	303	443	60	58	51	51	42	35	49
BaniSuef 1	557	483	376	448	393	304	427	62	56	45	46	36	34	46
BaniSuef 5	532	477	395	441	397	322	427	72	66	55	56	46	37	55
BaniSuef 6	557	480	370	420	377	333	423	58	51	43	47	42	32	46
Sohag 4	514	469	365	425	378	326	413	69	57	48	50	44	32	50
Sohag 5	527	490	371	425	360	322	416	72	59	48	57	47	40	54
Mean	553	492	382	439	381	320	428	64	56	48	54	45	36	50
L.S.D 0.05														
T							4.5							1.6
G							4.6							1.7
T*G							11.8							3.7

1000kernels weight (gm):

As shown in Table 5, the values denote highly substantial variations among treatments, genotypes, and their interactions for 1000 kernels weight. The average of 1000 kernels weight significantly reduced from 55.47 gm under recommended sowing date and irrigation of T1 to 43.80 gm under the late sown date and water stress conditions (T6). These results are in accordance with Feltaous and Koubisy, 2020 and Poudel *et al.*, 2020. Line 8, Line 2, and Line 3 overall treatments with values of 54.35, 53.88, and 53.17, respectively, showed the highest 1000 kernels weight, whereas BaniSuef 6 was the lowest one among the studied 15 genotypes with 45.45 gm with grand mean 49.29 gm. Heat stress occurs during the anthesis stage of wheat cultivated under late seeded conditions, reducing weight per kernelMohammadi, 2012.The reduction of the grain-filling phase in late planting also contributes to a decline in 1000 kernels weight(Spink *et al.*,2000).

Table 5. Mean performance of 1000 kernels weight (gm) and grain yield ardabfad.$^{-1}$ under normal and stress combinations across the two growing seasons and overall

Genotypes	1000 Kernels weight (gm)						Overall	Grain yield ardab fad.$^{-1}$						Overall
	T1	T2	T3	T4	T5	T6		T1	T2	T3	T4	T5	T6	
Line 1	53.99	49.40	45.18	48.02	46.46	43.15	47.70	27.662	25.432	22.392	19.418	16.757	14.267	20.99
Line 2	59.51	55.46	49.14	56.69	53.67	48.79	53.88	29.542	24.323	20.278	17.172	15.473	12.780	19.93
Line 3	59.05	55.31	50.66	54.52	52.01	47.45	53.17	26.538	23.572	19.987	19.473	16.337	13.522	19.90
Line 4	51.73	46.28	43.27	48.69	47.41	43.13	46.75	23.745	21.025	18.012	17.417	15.040	12.817	18.01
Line 5	54.40	50.11	47.49	47.17	44.93	41.08	47.53	25.737	22.753	17.963	17.070	14.490	13.278	18.55
Line 6	50.96	48.21	45.82	47.65	45.29	41.54	46.58	24.788	23.335	20.422	17.012	16.793	13.763	19.35
Line 7	55.60	50.31	45.41	50.40	46.72	41.83	48.38	21.922	20.615	17.465	15.623	13.618	9.865	16.52
Line 8	63.45	58.82	53.18	57.37	50.56	42.69	54.35	22.793	20.827	18.168	15.750	14.558	12.613	17.45
Line 9	57.39	50.22	46.69	51.31	49.58	44.87	50.01	23.353	21.720	18.292	16.653	13.128	12.643	17.63
Line 10	54.46	51.15	47.20	50.47	46.63	42.26	48.69	24.688	22.708	19.210	16.153	15.772	14.267	18.80
BaniSuef 1	53.57	48.63	45.52	52.13	48.46	45.48	48.96	21.825	20.027	17.038	15.732	14.233	12.412	16.88
BaniSuef 5	54.86	48.85	46.12	51.51	49.05	45.16	49.26	26.313	21.460	18.270	15.178	14.105	12.653	18.00
BaniSuef 6	53.07	44.60	40.28	49.68	44.09	41.00	45.45	22.220	19.890	17.197	14.055	12.747	11.620	16.29
Sohag 4	54.20	48.95	45.48	52.23	48.82	44.95	49.10	28.680	24.178	20.425	17.978	17.235	13.518	20.34
Sohag 5	55.87	50.07	46.30	52.66	48.40	43.64	49.49	27.725	25.283	23.028	18.568	16.872	15.657	21.19
Mean	55.47	50.42	46.51	51.37	48.14	43.80	49.29	25.17	22.48	19.21	16.88	15.14	13.05	18.65
L.S.D 0.05														
T							1.32							0.26
G							1.60							0.58
T*G							3.35							1.51

Grain yield ardab fad.$^{-1}$:

As shown in Table 5, the results showed that stress and non-stress conditions induced highly substantial impacts on grain yield ardab fad.$^{-1}$. The average mean values of grain yield ardab fad.$^{-1}$ under the six treatments and overall were 25.17, 22.48, 19.21, 16.88, 15.14, 13.05, and 18.65 ardab fad.$^{-1}$, respectively. It is evident that the average mean of grain yield ardab fad.$^{-1}$ was significantly reduced from 25.17 ardab fad.$^{-1}$ under recommended sowing date and irrigation (T1) to 13.05 ardab fad.$^{-1}$ under late sown date and water stress conditions (T6).These findings align with those of (Guendouz*et al.*, 2012; Feltaous and Koubisy, 2020; Poudel*et al.*, 2020 and Chowdhury *et al.*, 2021). The values of the overall mean average revealed that the genotypes that exhibited higher productivity were Sohag 5, Line 1, Sohag 4, and Line 2, with values of 21.19, 20.99, 20.34, and 19.93 ardab fads.$^{-1}$, respectively. These genotypes might be considered high yielding and well adapted across various environments. While Banisuef 1, Line 7, and Banisuef 6 gave the lowest productivity values, 16.88, 16.52, and 16.29 ardab fad.$^{-1}$, in the same respective. Delayed sowing than the optimum time reduces any crop's maturity duration. The timely sowing of wheat elevates kernels spike^{-1}number, spike m^{-2}number,and 1000 kernels weight, which finally increases grain yield (Qasim*et al.*,2008). Delay sowing reduces the yield due to a decrease in yield components Mohammadi, 2012. Heat stress affects the wheat yield by reducing tiller number, grain filling period, kernel size, and biomass. Furthermore, grain yield was greater under irrigated conditions than water deficit and heat stress due to increased yield components. One thousandgrains weight and grain yield were remarkably reduced when water stress was imposed at booting, pre-anthesis, anthesis, and post-anthesis with a reduced grain-filling period Serragoa*et al.*, 2013 and Mehraban*et al.*, 2019.Significant reduction in grain yield due to post-anthesis water stress may result from a reduction of photo-assimilates production, power of the sink to absorb photo-assimilates, and the grain filling period. Water stress at post-anthesis severely reduced grain yield (98%), depending on the severity of stress and growth stage in which the drought condition was imposed Maralian*et al.*, 2010

Genotype by genotype-environment biplot (GGE biplot)

In plant breeding multi, environments are conducted to evaluate the performance of multi-plant breeding environments and assess the performance of the genotype in various conditions. The GGE biplot is a valuable visualization instrument for tracking the performance of the genotype in various contexts. Yan and Tinker (2006) proposed GGE as an efficient and informative graphical tool for detecting stable as well as high-ranking genotypes in a given environment. It may be utilized in multi-environment trials to determine genotype main impact (G) as well as genotype by environment interaction effect (GE). GGE biplot based on singular value decomposition (SVD) of a three-way table into several two-way tables. The GGE biplot is created using principal component analysis's first and second components (PC1 and PC2). PC1 and PC 2 explained 91.40 percent of the overall variance in our research. GGE may be used for (1) identifying the connection between the tested environments, (2) evaluating environments, (3) determining which genotype performed better in each environment (Which – Won – Where), and (4) ordering genotypes in the testing environments utilizing average test coordination (ATC).

Scatter plot:

GGE biplotswere created using grain yield characteristics from fifteen durum wheat genotypes in six settings. Each environment is represented by a vector, and the cosine of the angle between environment vectors offers information about their correlation coefficients. A positive correlation is shown by an acute angle, a right angle by no correlation, and a negative correlation by an obtuse angle. The starting point in the scatter plot Fig. 1represents a virtual genotype with an average performance in each setting. Genotypes close to the origin perform well in all contexts (extensively adapted), but genotypes farther away from the origin exhibit a substantial genotype plus interaction impact. The Scatter plot shows a significant positive relationship between the six environments.

Which-Won-Where polygon:

The Which-Won-Where view of the GGE biplot helps the breeders identify which genotypes performed best in each environment and mega-environment. A convex hull has been drawn by connecting the farthest genotypes to form a polygon that encompasses all the genotypes. Sectors have also been added by drawing lines from the origin perpendicular to each side of the convex hull. Finally, ellipses have been drawn around the environments within the same sector to form a mega-environment.

The Which-Won-Where polygon revealed that there are two mega environments. The first mega environment (ME1) contains T1 "normal conditions," while the second mega environment (ME2) contains T2, T3, T4, T5, and T6 "stress conditions." The best performing genotypes under the first one are Line 2, Line 5, Banisuef 5, and Sohag 4, whereas the best genotypes under the second one are Line 1, Line 3, Line 6, Line 10, and Sohag 5. In contrast, durum wheat genotypes Line 4, Line 7, Line 8, Line 9, BaniSuef, 1, and BaniSuef 6 are located in separate sectors, which were not belonging any sector because their performance was lower than the average performance of any the six environments.

Ranking biplot:

An excellent genotype should have high mean performance as well as excellent stability over many mega settings. The GGE biplot's "Ranking biplot" mode is helpful for visually analyzing both areas' genotypes. According to Fig. 3, the genotypes on the left side of the ordinate line had lower yields than the mean yield (Line 5, Line 4, Bani Suef 5, Line 9, Line 8, Bani Suef 1, Line 7, and Bani Suef 6), whereas the genotypes on the right side of the ordinate line (Sohag 5, Line 1, Sohag 4, Line 2, Line 3, Line 6, and Line 10) had higher yields than the mean yield across environments. The genotype stability is measured by the line length between the genotypes and their orthogonal projection onto the biolot axis. Long lines indicate poor stability, whereas short lines suggest strong stability. Sohag 5, Line 1, Sohag 4, Line 3, Line 6, and Line 10 were the most stable durum wheat genotypes with yields more than the mean yield, whereas Line 2 and Bani Suef 5 were the least stable.

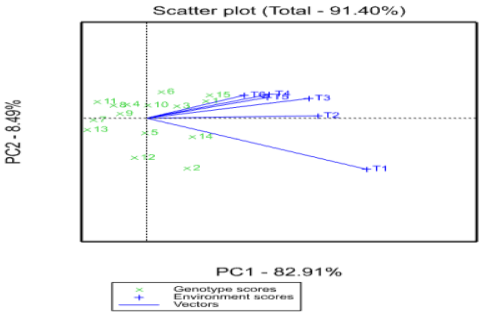

Fig. 1. GGE scatter biplot viewing the interaction between the six environments and the studied genotypes.

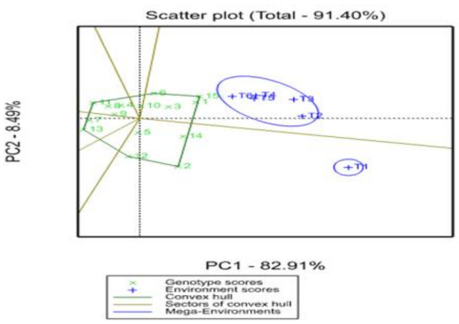

Fig. 2. Which-Won-Where polygon of GGE biplot viewing mega environments and genotypes for the six environments.

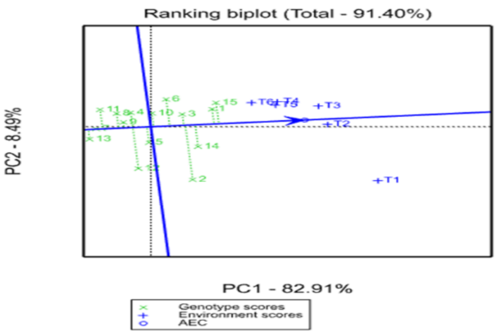

Fig. 3. The AEC view of GGE biplot to rank the genotypes based on grain yield data across all environments.

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تقييم بعض التراكيب الوراثية من قمح الديورم تحت ظروف مختلفة من الاجهاد

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الملخص

أجريت هذه الدراسه بمحطه البحوث الزراعيه سدس – مركز البحوث الزراعيه – مصر. إشتملت الدراسه على ١٥ تركيب وراثى تم زراعتها وتقييمها تحت ست معاملات للإجهاد الحرارى والمائى خلال موسمين زراعيين ٢٠١٩/٢٠١٨ و ٢٠٢٠/٢٠١٩. أظهر تحليل التباين وجود إختلافات معنوية بين التراكيب الوراثيه وبين االمعاملات والتفاعل بين التراكيب الوراثيه مع المعاملات. أشارت النتائج إلى وجود نقص معنوي في عدد الأيام حتى طرد السنابل، محتوى الكلوروفيل ومحصول الحبوب ومكوناته مع تأخير ميعاد الزراعة والإجهاد المائي. أدت ظروف الإجهاد إلى نقص في عدد السنابل/م٢، عدد حبوب السنبلة، وزن الألف حبة ومحصول الحبوب/فدان بمقدار ٤٢,١٣، ٤٣,٧٥، ٢١,٠٤ و ٤٨,١٥ على التوالي مقارنة بالظروف المثلى. أشارت نتائج متوسط أداء التراكيب الوراثية إلى تفوق صنف سوهاج ٥، سلالة ١، سوهاج٤ و سلالة ٢ لمحصول الحبوب/فدان. أظهرت نتائج GGE biplotأن التراكيب الوراثية سوهاج٥، سلالة ١، سوهاج ٤، سلالة ٣، سلالة ٦ وسلالة ١٠ كانت الأعلى محصولاً والأكثر ثباتاً بينما كانا التركيبان الوراثيان السلالة ٢ والصنف بني سويف٥ الأقل ثباتاً.