The Seybold REPORT

ISSN 1533-9211

DOI 10.5281/zenodo.6786491

DETERMINATION OF YIELD STABILITY IN BREAD WHEAT GENOTYPES UNDER LOW INPUT IRRIGATION AND NITROGEN ENVIRONMENTS

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ABSTRACT

With climate change in the world, changes in temperature and deficiency of irrigation water is considered as a serious threat affecting growth and crop production. Therefore, developing genotypes with existence stable high-yielding and high water use efficiency is a necessary. The purpose of this study was to detect the most yield adaptability/stability of eight bread wheat across 24 environments (combination of three irrigation regimes × four nitrogen levels × two seasons) based on AMMI and GGE methods. A randomized complete block designs with three replicates for each environment was used. AMMI analysis for, wheat grain yield exhibited the highly significant difference of genotypes, environment, GEI and first two interaction principal components (IPCA's). Based on AMMI stability value (ASV) and total rank (ASV and yield) discriminated genotypes Line 3 (G3), Line 1 (G1), Line 4 (G4) and Line 2 (G2) as the most stable and suited for water stress. Using GGE biplot facilitate comparison revealing Line 3 (G3) was the best and ideal genotype with high grain yield potential and stability. Generally, AMMI analysis and GGE biplot methods showed that genotypes Line 3 (G3) was detected to be the most adapted/stable under water deficiency. Thus they should be recommended for release with wider environmental adaptability in Egypt. Moreover, treatment 75 kg nitrogen with medium irrigation regime may be considered as alternative treatment for recommended high irrigation requirements and should be recommended for release with wider environmental adaptability in water deficiency of irrigation requirements.

INTRODUCTION

Wheat (Triticum aestivum L.) is principal cereal food grain not only in Egypt but also all over the world. Wheat is the second most important stable food crops (**Chatrath et al. 2007**) next to rice. Egyptian people depend on wheat for food. Egypt is currently the largest wheat-importing country in the world (**FAO 2020**) total wheat production is not enough for local consumption; the annual wheat consumption is increased as a results to increase growing population by 2.2% annually .Egypt produce only half of the 20 million tons of wheat that consumed annually. Improvement of wheat productivity is the most important way to minimize the gap between production and consumption which can be achieved by vertical and horizontal expansion.

Today and more so in the future, water Shortage and increasing consumption of N fertilizer which has increased more than 75% in the last 20 years is considered as a serious threat affecting wheat production (**Abdel Monem, 1998**). Thus, improving cultivars with field irrigation efficiency practices has been considered as economic and efficient methods. Water

ISSN 1533-9211
DOI 10.5281/zenodo.6786491

deficiency is the most major abiotic stresses, which may be limited plant growth and productivity (**Marulanda et al. 2007; Abdelazim and Abu-hashim, 2018**). Low soil fertility and scarcity of irrigation and wheat genotypes adaptable to environmental stress are the major challenges facing wheat production (**Lopez, et al, 2003; Rashid et al, 2003**). Wheat production varied under different irrigation water amounts and nitrogen supplements (**Abd El-Kreem et al. 2013**). Selection high yielding potentialty genotypes under water stress conditions is the Initiation step to release a new drought tolerance variety (**Baenziger, 2016)**. Selection genotype with high yielding under wide adaptability is the practices that have been considered as economic and efficient methods (**Moustafa et al, 1996; Blum, 2005; Naroui et. al, 2013**).

Breeding for increasing wheat grain yield is the main target in national wheat breeding program. Measuring genotype × environment (GE) interaction under varying environmental condition (soil properties and climate change) is very important, especially under stress environmental in order to determine an optimum treatment/environment for releasing genotypes with adequate adaptation to target environments. Stability analysis used to characterize the great relative performance of evaluated varieties/lines under different environmental conditions (**Rahmatollah et al., 2013**). There are many statistical methods obtained for studying GE interaction to identify genotypes with high yield and adaptation or stability performances. Recently, the multivariate methods can be applied as additive main effect and multiplicative interaction (AMMI) model and genotype by genotype environment interaction (GGE). AMMI model was used to determine the environmental factors responsible for the interaction, revealing the significant of additive main effect (genotype) and multiplicative interaction (analyses these effects by principal components) for yield (**Casanoves et al 2005**). Genotype main effect and genotype- environment interaction (GGE) biplot is a graphically method that allows the user to assess entire two-way data (**Dehghani et al 2006**). GGE biplot method was developed by **Yan (2014)** to use different types of biplot graphs and its application that usefulness in visualizing in genotype evaluation comparison and selection (**Yan and Fregeau-Reid, 2008; Thangavel et al., 2011**). Then, GGE Biplot recently became successfully stability analysis and genotypes selection tool in wheat breeding program.

This research was purposed that detecting high grain yield potential coupled with stability using AMMI method and GGE biplot analysis, evaluating the genetic diversity extent in yield response of eight Egyptian wheat genotypes through controlled field evaluation under low inputs conditions which resembled water shortage types exist in different plant growth stages in Egypt.

MATERIAL AND METHODS

Field experiments were carried out at EL-Gemmiza Agric. Res. Station Farm, El- Gharbia Gov., Egypt, located at center of the Delta (30.97°N, 30° 30.97 E) during two successive winter growing seasons2017/2018and 2018/2019

The Seybold Report
ISSN 1533-9211
DOI 10.5281/zenodo.6786491

Breeding materials

Eight Egyptian wheat genotypes were obtained from wheat Research Department, Field Crops Research Institute, Agricultural Research Center (ARC), Egypt as descript in Table (1).The seed of five advanced lines of bread wheat obtained from Low Input Program at El-Gemmiza and three commercial bread varieties.

Table 1: Name and pedigree of studied eight bread wheat genotypes

Code No.	Variety name	Pedigree or selection history
G_1	**Line 1**	KIRITATI/2*WBLL1 CGSS02B00118T-099B-099Y-099M-099Y-099M-18WGY-OB-OGM
G_2	**Line 2**	WBLL1*2/VIVITTSI//AKURI/3/WBLL1*2/BRAMBLING CMSS07Y01066T-099TOPM-099Y-099M-099Y-7M-OWGY-OGM
G_3	**Line 3**	PFAU/SERI.IB//AMAD/3/WAXWING*2/4/TECUE#1 CMSS07B00614T-099TOPY-099M-099Y-099M-49WGY-OB-OGM
G_4	**Line 4**	WHEAR/VIVITIS//WHEAR. CGSS03-B00069T-099Y-099M-34WGY
G_5	**Line 5**	SIDS 1/ATTILA/3/KAUZ//BOW/NKT S.16494-032S-031S-14S-0S
G_6	**Giza 171**	Giza 171
G_7	**Shandaweel 1**	Shandaweel 1
G_8	**Misr 2**	Misr 2

Field experiment

In each season, genotypes were sown in randomized complete blocks design with three replications under 12 treatments combination as environments (E1 to E12 in the 1st season and E13 to E24 in the 2nd season) as shown in Table (2). Each environment was formed as combination level from three irrigation regimes (low, medium and high) water requirements and four levels of nitrogen fertilizer levels (40, 50, 60 and 75 Kg N/fed).Low irrigation (L), where wheat plants were irrigated 3 times at Germination tillering, and at booting with 1275m^3 water. Medium Irrigation (M), where 4 times of irrigation were done at germination, tillering, booting and at heading with 1750 m^3, and recommended irrigation (H) 5 times of irrigation at germination, tillering, booting, heading, and at grain filling stage with 2150 m^3 regime. The amount and time of irrigation depends on weather conditions and plant needs i.e., and four levels of Nitrogen fertilizer levels (40, 50, 60 and the recommended dose 75 Kg N/fed).Factorial treatments were characterized to 12 treatments intwo seasons on the whole

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ISSN 1533-9211
DOI 10.5281/zenodo.6786491

24 environments were described in Table (2). The quantity of water applied was measured in the studied area by using a rectangular sharp crested weir.

The discharge was calculated using the following formula:

Q = CLH3/2 (**Masoud 1967**).

Where Q: The discharge in cubic meters per second.

L: The length of the crest in meters. H: The head in meters.

C: An empirical coefficient that must be determined from discharge measurements

The plot size was 3 m x 3.5 m (10.5m^2). The field experiment was ploughed to a depth of 50 cm, three times, organic manure was incorporated into the ploughed layer at the rate of 40m^3/feddan. Super phosphate (15.5%) at the rate of 15.5 kg P_2O_5/feddan was added and mixed into the upper-15 cm layer of soil during the second ploughing. Sowing dates was November 7th, and 5th Dec. in the first and second season, respectively. Each plot including 15 rows, row was 3.5 m long and the spaces apart rows were 20 cm. All cultural practices for growing wheat were applied as recommended.

Table 2: Description of the studied factorial treatments and their codes

Env.	**Season**	**Treatments**		**Factorial treatments**	**Code**
		Irrigation	**Nitrogen**	**Environment characterization**	
E1	**2017-18 (S1)**	**Low (L)**	40 kg (N_1)	Low irrigation + 40 kg nitrogen under Season1	S_1 L N_1
E2			50 kg (N_2)	Low irrigation + 50 kg nitrogen under Season1	S_1 L N_2
E3			60 kg (N_3)	Low irrigation+ 60 kg nitrogen under Season1	S_1 L N_3
E4			75 kg (N_4)	Low irrigation+ 75 kg nitrogen under Season1	S_1 L N_4
E5		**Medium (M)**	40 kg (N_1)	Medium irrigation+ 40 kg nitrogen under Season1	S_1 M N_1
E6			50 kg (N_2)	Medium irrigation+ 50 kg nitrogen under Season1	S_1 M N_2
E7			60 kg (N_3)	Medium irrigation + 60 kg nitrogen under Season1	S_1 M N_3
E8			75 kg (N_4)	Medium irrigation + 75 kg nitrogen under Season1	S_1 M N_4
E9		**High (H)**	40 kg (N_1)	High irrigation + 40 kg nitrogen under Season1	S_1 H N_1
E10			50 kg (N_2)	High irrigation+ 50 kg nitrogen under Season1	S_1 H N_2
E11			60 kg (N_3)	High irrigation + 60 kg nitrogen under Season1	S_1 H N_3

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ISSN 1533-9211
DOI 10.5281/zenodo.6786491

E12			75 kg (N_4)	High irrigation + 75 kg nitrogen under Season1	S_1 H N_4
E13	**2018-19 (S2)**	**Low (L)**	40 kg (N_1)	Low irrigation + 40 kg nitrogen under Season2	S_2 L N_1
E14			50 kg (N_2)	Low irrigation + 50 kg nitrogen under Season2	S_2 L N_2
E15			60 kg (N_3)	Low irrigation+ 60 kg nitrogen under Season2	S_2 L N_3
E16			75 kg (N_4)	Low irrigation+ 75 kg nitrogen under Season2	S_2 L N_4
E17		**Medium (M)**	40 kg (N_1)	Medium irrigation+ 40 kg nitrogen under Season2	S_2 M N_1
E18			50 kg (N_2)	Medium irrigation+ 50 kg nitrogen under Season2	S_2 M N_2
E19			60 kg (N_3)	Medium irrigation + 60 kg nitrogen under Season2	S_2 M N_3
E20			75 kg (N_4)	Medium irrigation + 75 kg nitrogen under Season2	S_2 M N_4
E21		**High (H)**	40 kg (N_1)	High irrigation + 40 kg nitrogen under Season2	S_2 H N_1
E22			50 kg (N_2)	High irrigation+ 50 kg nitrogen under Season2	S_2 H N_2
E23			60 kg (N_3)	High irrigation + 60 kg nitrogen under Season2	S_2 H N_3
E24			75 kg (N_4)	High irrigation + 75 kg nitrogen under Season2	S_2 H N_4

The main chemical and physical properties of the soil at the initial are presented in Table (3).The Climatic characteristics, relative humidity (RH%), air temperature (TC°), wind speed (Ws, m / sec at 2 m height) and rainfall (mm $month^{-1}$) rainfall during the two seasons are shown in (Table 4).

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ISSN 1533-9211

DOI 10.5281/zenodo.6786491

Table 3: Soil physical and chemical properties for studied area

Season	Soil Depth	PH	EC(ds m^{-1})	Cations (mq/L)				Anions (meq/L)							
				Sand	Silt	Clay	Soil type	Ca2+	Mg 2+	Na	K+	Co3-	HCo3-	Cl-	So4-
Season 1	0-30 cm	8.1	0.9	18.1	17.8	64.1	Clay	4.9	2.0	3.3	0.1	ND	3.2	3.0	2.4
	30-60 cm	8.0	4.6	24.5	39.8	35.7	loamy Clay	9.3	4.3	8.9	1.3	ND	2.1	35.6	5.3
	60-90 cm	7.8	0.8	16.8	24. 6	58.6	Clay	3.3	1.9	1.2	0.1	ND	1.0	2.7	4.0
Season 2	0-30 cm	8.0	0.9	14.1	36.1	49.9	Clay	1.4	3.0	4.4	0.1	ND	4.2	1.9	2.8
	30-60 cm	8.1	1.2	13.9	33.1	53.1	Clay	1.5	4.6	5.2	0.1	ND	3.6	3.0	4.9
	60-90 cm	8.2	1.3	17.3	32.6	50.2	Clay	1.6	3.2	7.8	0.1	ND	3.9	3.6	5.2

PH: was determined in soil water suspension (1:2.5); **EC**: was determined in saturated soil paste extract; CationExchange Anions Exchange.

At harvest, the number of spikes per square meter, kernels per spike, and 1000-kernel weight were recorded. The two external rows from each plot were eliminated to avoid the border effect. Thus, 13 rows were harvested, threshed and their grain yields were weighed and adjusted to Tons per hectare (Ton hec^{-1}).

Table 4: Mean of some meteorological data for the El-Gemmiza area during the two growing seasons

seasons	Month	T Max (C^0)	Tmin (C^0)	RH (%)	Ws m sec^{-1}	Rainfall, mm month
2018/2019	**Dec.**	22.00	11.49	68.06	2.16	0.13
	Jan.	19.73	8.86	67.93	2.79	0.96
	Feb.	23.15	10.26	60.49	1.94	0.20
	Mar.	29.27	12.08	44.19	2.40	0.06
	April.	31.46	14.25	43.39	2.55	0.38
2019/2020	**Dec.**	20.99	10.74	63.87	2.64	0.40
	Jan.	19.26	6.67	52.98	2.88	0.20
	Feb.	21.36	7.79	57.00	2.47	0.24
	Mar.	24.00	9.53	54.84	2.82	0.54
	April.	28.21	12.44	47.26	2.93	0.10

*Effective rainfall was computed as rainfall multiple by 0.7 (**Novica, 1979**).

ISSN 1533-9211

DOI 10.5281/zenodo.6786491

Data Analysis

Collected data was subjected to individual analysis of variance (ANOVA) of randomized complete block design for each treatments combination (environment). **Levene (1960)** was performed to test the homogeneity of individual error before combined analysis. Accordingly, the combined ANOVA over environments and seasons was done using the generalized linear model procedures. ANOVA, appropriate for the specified experimental design and simple correlation coefficients were performed according to **Gomez and Gomez (1984)** for each season with GenStat (version-2017) computer program (**Payne et al., 2015**). Differences among means were tested by Duncan's multiple range test at 5% probability level (**Duncan, 1955**).

The eight genotypes stability was assessed among 24 environments (3 irrigation regimes x 4 nitrogen rates x 2 seasons) by two statistical and graphical approaches.

AMMI model

Additive main effect and multiplicative interaction (AMMI) model as described by **Gauch et al (2008**) used the subjected grain yield data to multivariate analysis to estimate the stability parameters.

AMMI Stability Value of the i^{th} genotype (ASV_i) was calculated for each genotype and each environment according to the relative contribution of IPCA1 to IPCA2 to the interaction SS as follows (Purchase et al., 2000):

$$\text{ASVi} = \sqrt{\{\text{SSIPCA1}/\text{SSIPCA2}(\text{IPCA1 SCORE})\}^2 + (\text{IPCA2 SCORE})^2}$$

Where, SSPCA/SSPCA2 is the weight given to the IPCA1-value by dividing the IPCA1 sum of square by the IPCA2 sum of square.

The ASV values detect the preferences the most stable genotypes across environments (**Purchase, 1997**).

GGE Biplot Model

GGE (genotype + genotype by environments interaction effect) biplot graph are commonly used to display two-way data considering the first two principal components (PC_1 and PC_2). This method was employed to explain relationship between evaluated genotypes and tested environments in the same graph to assess the adaptability or stability range (**Yan and kang, 2003**).

RESULTS AND DISCUSSION

Combined analysis of variance was performed after proving the homogeneity of separate error variances for wheat grain yield and related-traits across the growing seasons.

Table (5) presented pooled analysis of variance for grain yield, number of spikes m^{-2}, number of kernels $spike^{-1}$ and 1000-kernel weight (g) as most important yield-traits of bread wheat

ISSN 1533-9211
DOI 10.5281/zenodo.6786491

genotypes. Results revealed the treatments combination that gathered as environments (E), wheat genotypes (G) and the G x E interaction were highly significant (P < 0.01) which indicated the existence of differential responses of wheat genotypes under different environments. **Moghaddam and Pourdad (2009)** reported the interaction of genotype by environment under abiotic multiple-stress was significant; therefore further proceed can be done to evaluate the stability of genotype across the test environments **(Farshadfar, 2008)**. Significantly G x E interaction suggested availability investigation the genotypes stability, either it is need for the extension analysis of G x E component.

Table 5: Pooled analysis of variance for grain yield and most important yield-traits of 8 bread wheat genotypes combined across 24 environments

Source	d.f.	No. of spikes m^{-2}	No. of kernels $spike^{-1}$	1000-kernel weight	Grain yield (Ton hec^{-1})	
					MS	Explained %
Treatments	191	1610.00**	90.90**	45.39**	1.62**	81.76
Environments (E)	23	6189.00**	218.50**	138.61**	9.57**	71.29
Blocks (Replicate/E)	48	479.00	11.50	6.87*	0.44**	5.54
Genotypes	7	2724.00**	701.10**	353.49**	5.20**	11.78
Interaction	161	907.00**	46.10**	18.68**	0.33**	16.92
IPCA 1	29	1895.00**	87.90**	37.56**	0.64**	35.52
IPCA 2	27	1034.00**	80.20**	25.08**	0.51**	26.37
Residuals	105	602.00*	25.80**	11.81**	0.19*	38.13
Error	336	438.00	12.00	4.59	0.14	12.72
Total	575	831.00	38.10	18.33	0.66	

*** and** significant at 0.05 and 0.01 probability levels, respectively.**

AMMI model is more appropriate in the initial statistical analysis of yield trials, because it provides an analytical tool to clarify the G × E interaction and summarize patterns and relationships of genotypes and environments (**Ilker et al., 2011, Crossa et al. 1990 and Zobel et al., 1988**). Therefore, the sum of squares of G x E interaction was partitioned into the first two principle components (PCAs) that revealed also highly significant for all yield-related traits.

Correlation matrix

Simple correlation coefficients were estimated to detect the relationship between grain yield and its related-traits evaluated across the two seasons which are presented in **Table (6).** Results cleared that there was a significant positive correlation between grain yield and each of No. of spikes m^{-2} (0.424*) and No. of kernels $spike^{-1}$ (0.405*). It is pointed that grain yield of the tested wheat genotypes may be raised through selection for the plants that had more spikes and kernels $spike^{-1}$. However, it obtained insignificant association with 1000-kernel weight. This may be indicated to independence the genetic behavior of the genotypes under

ISSN 1533-9211
DOI 10.5281/zenodo.6786491

the tested treatments. Highly significant and positive associations between spikes per square meter with each of No. of kernels spike^{-1} (0.560**) and 1000-kernel weight (0.391**), suggesting that genotypes with more spikes m^{-2} produced more kernels spike^{-1} and kernel weight. These obtained results agreed with those reported by **Iqbal et al. (2017).**

Table (6): Correlation coefficients among grain yield and its related traits for studied bread wheat genotypes evaluated across different environments (n=24)

Traits	Grain yield	No. of spikes m^{-2}	No. of kernels spike^{-1}	1000-kernel weight
Grain yield	1			
No. of spikes m^{-2}	0.424*	1		
No. of kernels spike^{-1}	0.405*	0.560**	1	
1000-kernel weight	0.260	0.391**	0.412**	1

*** and ** significant at 0.05 and 0.01 probability levels, respectively.**

Under the nature of magnitude associations among yield components, the wheat breeders prefer selection for the best genotypes with the highest yield performance, because select for high yielding genotypes had the observed expression gain of the important yield-traits values (**Karaman, 2017**). The grain yield is the ultimate expression of many physiological processes that interacted with the environment and weather during growth, especially undergoing different treatments or stresses.

In grain yield trait, G x E interaction mean squares was divided into two first two principle components IPCAs and the residual as a remaining variance. The two IPCAs were highly significant ($P < 0.01$). Total sum of squares attributed to variance components (%) for each partition items. The percentage of variability showed that the impact of genotypes, environments and GE interaction was represented 11.78 %, 71.29 % and 16.92 %, respectively from treatments variance. Meanwhile, IPCA1 and IPCA2 explained 35.52 % and 26.37 %, respectively from the total GE interaction with 38.13 % as residual. Whereas, residual was only significant, indicating being little unexplained interaction part not included in the first IPCAs. Cumulatively IPCAs contributed to 61.89 % of the total variation of GE interaction (Table 5). Then, AMMI with only two IPCAs (> 60 %) is more appropriate in the statistical analysis of bread wheat grain yield data set containing large GE interaction component also AMMI Biplot help in easily comprehension. Similar results were reported in previous studies by **Asnake et al. (2013)** and **Al-Naggar et al., (2020)**.

Grain yield performance across environments

Concerning the grain yield, mean performance of genotypes across 24 environments (treatments combination) is presented in Table (7). A large yield significant variation explained across environments indicated that tested environments were diverse. Data recorded the superiority of twelve environments in grain yield over the grand mean of all environments. They recorded values, ranged from 8.14 ton for E12 to 6.80 ton for E19. Environment E12 (recommended) with 8.14 ton had the highest grain yield while, environment E13 (S2 L N1) had the lowest grain yield over all environments. Seven from the

ISSN 1533-9211
DOI 10.5281/zenodo.6786491

twelve environments (E7, E8, E4, E10, E20, E19, and E16) were used low or medium irrigation regimes (7.91, 7.84, 7.28, 7.09, 7.03, 6.80 and 6.80 ton hec-1). Moreover, E7 (S1 M N3) and E8 (S1 M N4) had insignificant difference from E12, proposing that E7 and E8 (with medium irrigation + 60 and 75 kg N) may be used as alternative treatment without significant decrease in wheat grain yield.

Among the genotypes, Data recorded the superiority of G3 among all genotypes. The grain yield was ranged from 7.16 to 6.43 ton with a grand mean of 6.74 ton hec^{-1}. Four genotypes (G3, G1, G2 and G4) recorded highest yield above grand mean. While the other genotypes (G5, G6, G7 and G8) gave low yield below a grand mean. These results indicated differential performance of genotypes across the tested environments, indicating the existence of genotype-environment interaction. Then, further stability analysis was carried out to identify a stable genotype with high mean yield across environments (**Adu et al., 2019 and Al-Naggar et al., 2020**).

Results in Table (7) and Figure (1) illustrated the differences among 24 environments. These environments including 12 environments per year each environment was formed as a combination level from three irrigation regimes and four levels of nitrogen. Generally, most environments in the 1st season recorded higher mean values compared with environments which had the same combination level in the second season. These results indicating that response of grain yield was different from one season to other. This may due to relatively increase in the average temperature during January in first season (Table 4) which encouraged the vegetative growth and reflected on grain yield Talukder et al. (2014).

Table (7): Average grain yield (tons hec^{-1}) of eight bread wheat genotypes tested across twenty-four environments

Genotype	G1	G2	G3	G4	G5	G6	G7	G8	Mean
E1	6.60	6.32	6.74	6.47	5.97	6.24	6.25	5.73	**6.29^{g-j}**
E2	6.77	6.39	7.53	6.04	6.02	6.46	5.99	5.84	**6.38 $^{f-i}$**
E3	6.71	6.70	6.83	6.21	6.75	5.96	6.56	5.93	**6.46^{e-i}**
E4	7.90	7.19	7.90	7.33	6.69	7.07	7.48	6.74	**7.28^{b-d}**
E5	6.75	6.42	7.05	6.15	6.03	5.63	6.53	6.60	**6.39^{f-i}**
E6	6.76	7.20	6.09	6.07	6.13	5.57	5.93	6.19	**6.24^{h-j}**
E7	7.97	8.23	8.49	7.87	7.80	7.78	7.43	7.76	**7.91^{ab}**
E8	8.21	8.02	8.64	7.90	7.31	7.29	7.68	7.67	**7.84^{a-c}**
E9	6.93	6.85	7.30	6.73	6.80	6.67	7.00	6.40	**6.84^{d-h}**
E10	7.21	7.21	7.73	7.39	7.01	6.79	6.45	6.91	**7.09^{c-f}**
E11	6.75	6.99	6.50	7.14	6.93	6.86	6.97	7.26	**6.93^{d-h}**
E12	8.71	8.72	8.67	7.66	8.24	7.32	8.49	7.39	**8.15^{a}**
E13	5.40	5.54	5.61	5.81	5.29	4.99	5.19	6.34	**5.52^{j}**
E14	6.15	6.02	6.12	6.17	5.47	5.03	5.90	6.37	**5.90^{ij}**
E15	6.12	6.21	6.15	6.20	5.98	6.32	6.04	6.78	**6.22^{h-j}**
E16	6.89	6.53	7.36	6.90	6.94	6.30	6.17	7.31	**6.80^{d-h}**

ISSN 1533-9211

DOI 10.5281/zenodo.6786491

E17	6.67	6.72	6.44	6.14	5.81	5.96	5.89	6.14	**6.22^{h-j}**
E18	6.72	6.18	6.86	6.64	5.92	6.36	5.95	6.49	**6.39^{f-i}**
E19	7.15	6.92	7.18	7.20	6.11	6.62	6.37	6.86	**6.80^{d-h}**
E20	7.50	7.38	7.60	7.22	6.18	6.67	6.72	7.00	**7.03^{d-g}**
E21	6.64	6.76	6.56	6.67	5.71	6.31	5.94	6.25	**6.35^{f-i}**
E22	6.77	6.80	7.26	6.76	6.22	6.54	5.98	6.80	**6.64^{d-i}**
E23	7.11	6.84	7.51	7.17	6.44	7.24	6.09	7.01	**6.93^{d-h}**
E24	7.61	7.39	7.75	7.71	6.77	7.32	6.79	6.32	**7.21^{b-e}**
Mean	**7.00^{ab}**	**6.901**	**7.16a**	**6.82b**	**6.44**	**6.47**	**6.49^{de}**	**6.67**	**6.74**

Means of the same column (environment) or row (genotypes) followed by the same letter (s) are not significantly different.

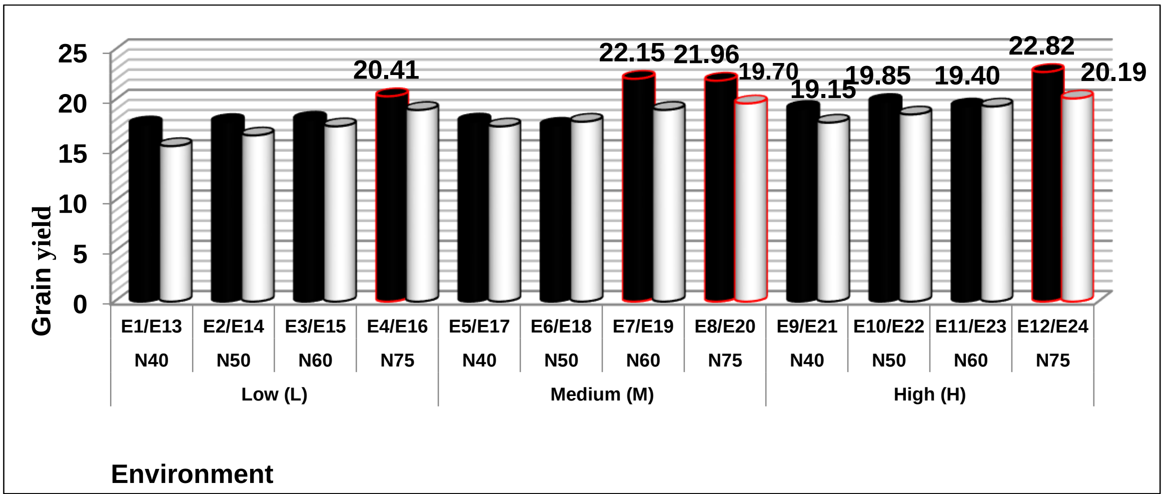

Figure 1: Differences in grain yield of 24 environments during 2017/18 and 2018/19.

Results obtained that E12 (S_1 H N_4) had the highest grain yield, followed by E7 (S_1 M N_3), E8 (S_1 M N_4), E4 (S_1 L N_4), E24 (S_2 H N_4) and E20 (S_2 M N_4).Generally, results showed that using 75 kg N increased the grain yield under different irrigation regimes. That revealed the important of N fertilizer in yield development. This may be suggested the roll of nitrogen application fertilizer in wheat enzyme activities under water deficiency (~~drought~~ water deficiency stress), providing better conditions for the uptake of water and nutrients; enhancing grain filling (**Amiri et al., 2017; Wu et al 2017 and Kiran 2018**). These results are in harmony with those obtained by (**Ali 2017 and El-Hawary et al 2019**).

AMMI Stability analysis for grain yield

Looking for the differential of genotypes performances across different tested environments (treatments/seasons), there is need to identify the most stable and adapted wheat genotype in different environments. Thus, stability methods (AMMI and GGE biplot) could be used to

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DOI 10.5281/zenodo.6786491

discriminate high-yielding and stable genotypes for using them in general cultivation and identify special genotypes to special low input environments.

Scores of IPCA1, IPCA2 and AMMI stability values (ASV) for 24 environments and 8 bread wheat genotypes are shown in Tables (8 and 9). Least ASV and IPCA scores support selection of relatively most stable genotypes or environments (Purchase et al., 2000). Mean and ASV ranking revealed rank differences of genotypes across environments. Results Show genotypes G3, G1, G4 and G2 demonstrated the least ASV values and IPCAs scores (ignoring ± signs). Furthermore, genotypes G3, G1, G2 and G4 had the highest yield. These results revealed that those genotypes were showing relatively better stability than other ones. However, genotypes G8 and G7 were less adaptable and unstable (high ASV) recording low yield across environments.

Table 8: Means, IPCA-1 and IPCA-2 scores and AMMI stability value (ASV) of 8 bread wheat genotypes for grain tons hec.$^{-1}$

Genotype	Mean	Yield Rank	IPCAg1	IPCA g2	ASV	ASV Rank	Total Rank
G1	**7.00^{ab}**	2	0.79	0.05	1.07	3	**5**
G2	**6.90^{b}**	3	0.44	-0.64	0.88	1	**4**
G3	7.16^{a}	1	0.91	0.96	1.55	7	**8**
G4	**6.82^{bc}**	4	-0.64	0.72	1.13	4	**8**
G5	6.44^{e}	8	0.08	-0.88	0.89	2	10
G6	6.47^{e}	7	-0.17	1.37	1.39	5	12
G7	6.49d^{e}	6	0.68	-1.14	1.47	6	12
G8	6.67^{cd}	5	-2.10	-0.44	2.86	8	13

IPCA1 and 2= principal components 1 and 2.

Total rank of genotypes yield mean and ASV were gathered both to detect the lowest value pointing to the most stable one. Based on the total rank, genotypes G2, G1, G3 and G4 were the most favorable genotypes for both high grain yield and stability.

Similarity, total rank for environments in Table (9) showed that E7 (S_1 M N_3), E8 (S_1 M N_4), E10 (S_1 H N_2) and E20 (S_2 M N_4) environments recorded the highest yield values coupled with least ASV and IPCAs scores. Meanwhile, E13 (S_2 L N_1) was no-adaptable and unstable that recorded high ASV score with low yield across environments.

DOI 10.5281/zenodo.6786491

Table 9: Means, IPCAe-1, IPCAe-2 scores and AMMI stability value (ASV) of tested environments for bread wheat grain yield ton hec^{-1}

Environment	Mean	Rank	IPCAe1	IPCAe2	ASV	ASV Rank	Total Rank
E1	**6.29[g-j]**	19	0.43	0.23	0.63	12	31
E2	**6.38[f-i]**	17	0.72	0.65	1.17	21	38
E3	**6.46[e-i]**	14	0.60	-0.64	1.03	17	31
E4	**7.28[b-d]**	4	0.66	0.18	0.90	16	20
E5	**6.39[f-i]**	15	0.08	-0.51	0.52	8	23
E6	**6.24[h-j]**	20	0.08	-0.88	0.89	15	35
E7	**7.91[ab]**	2	0.06	0.12	0.14	1	3
E8	**7.84[a-c]**	3	0.30	0.05	0.41	6	9
E9	**6.82[d-h]**	10	0.41	-0.19	0.58	9	19
E10	**6.73[c-f]**	6	-0.04	0.31	0.31	4	10
E11	**6.93[d-h]**	8	-0.77	-0.55	1.18	22	30
E12	**8.15[a]**	1	1.15	-0.96	1.82	24	25
E13	**5.52[j]**	24	-1.08	-0.38	1.50	23	47
E14	**5.90[ij]**	23	-0.49	-0.59	0.88	14	37
E15	**6.22[h-j]**	21	-0.83	-0.17	1.13	20	41
E16	**6.80[d-h]**	12	-0.65	-0.04	0.87	13	25
E17	**6.22[h-j]**	22	0.07	-0.15	0.17	2	24
E18	**6.39[f-i]**	16	-0.29	0.48	0.62	11	27
E19	**6.80[d-h]**	11	-0.26	0.39	0.52	7	18
E20	**6.32[d-g]**	7	0.07	0.24	0.26	3	10
E21	**6.35[f-i]**	18	-0.13	0.29	0.34	5	23
E22	**6.64[d-i]**	13	-0.31	0.42	0.59	10	23
E23	**6.93[d-h]**	9	-0.38	0.93	1.07	18	27
E24	**7.21[b-e]**	5	0.60	0.75	1.10	19	24

Means of the same column (environment) or row (genotypes) followed by the same letter (s) are not significantly different.

AMMI Biplot

AMMI models illustrated interaction effects of both genotype and environments in biplot graph to facilitate identification the best genotypes adapted or suited for specific environments. In AMMI biplot, genotype and environments mean effects were located against IPCAs scores. The positive right side of graph concludes the higher yields (genotype or environments) than those located on the left side. Genotypes with low IPCAs scores near origin (zero mid-point) of the axis have small interactions, whereas others with large scores have high interactions.

ISSN 1533-9211
DOI 10.5281/zenodo.6786491

Figure (2) showed the AMMI biplot model mean effects vs. IPCA1. Genotypes G3, G1, G2 and G4 that located in right side of graph had the highest yield and have low and medium interactions. Whereas, G3, G1 and G2 with the positive IPCA1scores fall in the right and higher quadrant, but G4 that had negative IPCA1scores fall in the right and lower quadrant. Meanwhile, G5 and G6 that had lowest yield placed in the left side of graph (near zero mid-point) with closest IPCA1 score to zero having small interactions and most stable (unfavorable genotypes).

The genotypes G3, G1, G2 and G4 exhibited relative low IPCAg1 scores and ASV coupled with highest yield, indicating to less influence by the treatments and having adaptability part over tested environments. Meanwhile, stable genotypes G5 and G6 were poor yielding, butG6 and G8 with relatively high value of IPCAg1 scores were unstable or miss-adaptability.

The best performing environments (treatments/seasons) wereE12 (S_1 H N_4), E7(S_1 M N_3),E24(S2 H N_4), E4(S_1 L N_4),E20(S_2 M N_4)and E9(S_1 H N_1)were ranked the highest yielding. On the other side, environment E13 (S_2 L N_1) was the poorest yield followed by E14 (S_2 L N_2) andE15 (S_2 L N_3). The closest environments E10 (S_1 H N_2),E8 (S_1 M N_4) E20 (S_2 M N_4) and E7 (S_1 M N_3) to the origin were the least interaction especially, being had smallest IPCA1 value (-0.04, 0.07 and 0.06) and little interaction and most stable. Meanwhile, E12 (S_1 H N_4), E8 (S_1 M N_4), E4(S_1 L N_4)andE24 (S_2 H N_4)displaying farthest from the origin revealed high performances with relatively medium interaction. Then, these environments were good ability to discriminate wheat genotypes. However, E8 (S_1 M N_4) and E20 (S_2 M N_4) were medium irrigation regime in the both seasons; meanwhile, E12 (S_1 H N_4) and E24 (S_2 H N_4) were recommended environments in the both seasons. Then, it was observed that environments E20 (S_1 M N_4), E7 (S_1 M N_3) and E8 (S_1 M N_4) environments may nominated as ideal and best environments for testing these evaluated wheat genotypes. These results are in agreed with **Mesfin et al (2020), Roseane et al (2012) and Akçura et al (2011)**.

ISSN 1533-9211

DOI 10.5281/zenodo.6786491

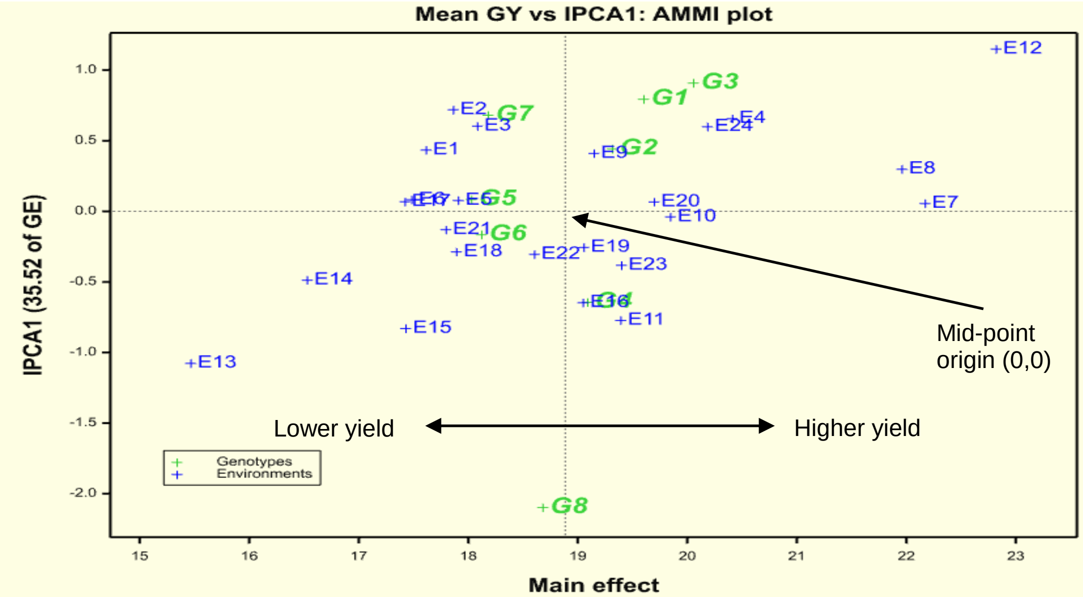

Fig. 2: The relationship between wheat grain yield means and IPCA-1 of 8 genotypes (G) evaluated over twenty-four environments (E).

From obvious results, E20 (S_2 M N_4), 8 (S_1 M N_4) and E7 (S_1 M N_3) which are water stressed environment (medium and low water) across both provides characteristics information helped in discriminating and selecting best genotypes having widely adapted environments. Generally**,** Line3 (G3), Line1 (G1), Line2 (G2) and Line4 (G4) genotypes were insensitive to environmental stress and have adapted to the poor environments, suggesting being effective releasing in Low Input breeding program.

GGE bi-plotof the best genotypes based on multiple environments

GGE biplot is the two-dimensional graphical tool to determine the effects of the evaluated genotypes on the multi-environments in the same graph (**Akcura and Kokten 2017**). GGE model may be the most accurate model than AMMI which can be predicted by using the first two IPCAs. Many researches reveal the main environmental effect is the major magnitude in stability analysis, while the explained variations by the main genotype effect and GEI, which can be interpretable, is low. Since the environment is not a factor that can be controlled, hence GGE biplot graphically virtualizes G plus GE of a MET in a way that facilitates visual genotypes evaluation and mega environment identification (**Gauch and Zobel 1996 and Yan and Kang 2003**). Graphically, genotypes holder positive PC1 scores on the right side were identified as higher yielding and those that had negative PC1 scores were identified as lower yielding. The GGE graph illustrated the eight wheat genotypes tested across at twenty-four environments are shown in Figure (3). Graph summarized interrelationships among evaluated genotypes toward tested environments (irrigated-fertilizer treatments), interpreting amount obtained of the total variation. Principal components, PC1 and PC2 explained 51.04% and 19.39% of the total variation, respectively. Thus, both of them together accounted for 70.43% of the total variation for the wheat genotypes across environments. This total variation was an

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DOI 10.5281/zenodo.6786491

expected result due to existence a great variation of climate conditions and environmental soil and genotype x environment interaction. Both PC's reflected more than 60% of the total variation, therefore, GGE biplot model acquired the good visual assessment (**Yan and kang 2003**).

GGE-biplot can be used to compare genotypes on the basis of multiple environments (irrigations and nitrogen fertilizer) and to identify genotypes that are particularly good in certain part or side and therefore can be nominee for high yielding and less water (high water use efficiency) selection and development in wheat breeding program (**Yan and Rajcan, 2002 and Yan and Tinker, 2006**).In addition to, the genotype and environments comparison help to determinate the most consistent (ideal) environment for wheat mean grain yield and IPCA scores during 2018 and 2019. The instability which obtained may have been due to the variation in weather conditions, soil and other unknown factors.

Biplot graphs were used to evaluate the response of 8 bread wheat genotypes under different environments (treatment levels) in both seasons. There are many types of GGE biplot differed based on the study objective. Concerning the GGE-biplot based on genotype and environment focused scaling for comparison genotype and environments. Figure (3) illustrated the relative ranking of the environments or genotypes relative to the ideal ones. The concentric circles on the drawn line passing through the biplot origin and the average environment coordination or axis (AEC) assist in discriminating and relative ranking for the genotypes. The central (concentric) circle with an arrow pointing to the ideal genotype is defined as having the highest grain yield in all environments and is absolutely stable (Yan, 2002).

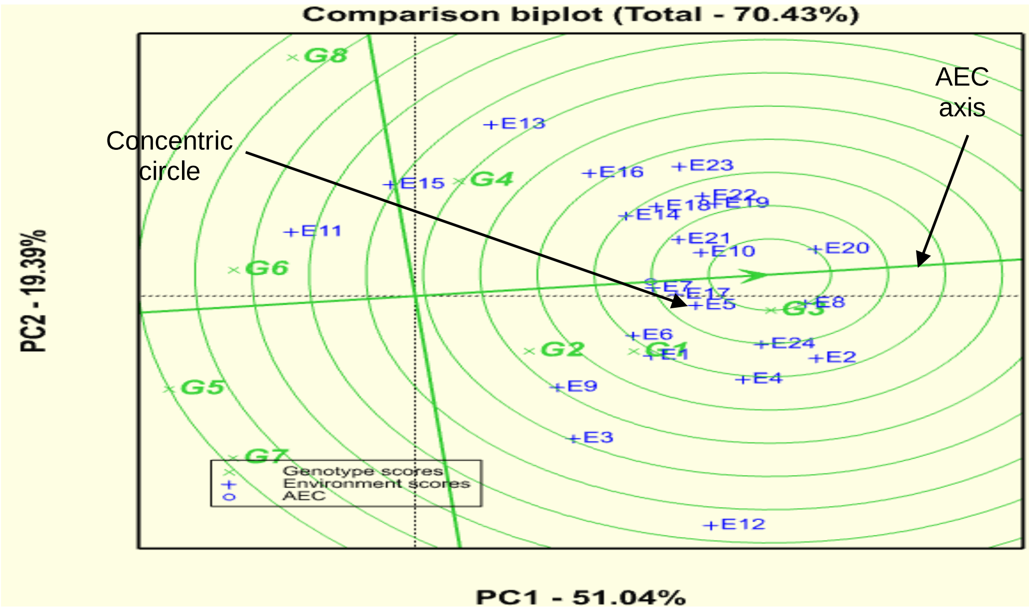

Figure 3: Ideal wheat genotype of GGE biplot, showing the ranking of 24 environments for grain yield trait.

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ISSN 1533-9211
DOI 10.5281/zenodo.6786491

Accordingly, the represented environment closest to the concentric with an arrow pointing to the ideal environment is the most discriminating of genotypes and yet representative of the other test environment (**Asnake et al., 2013 and Naroui et al., 2013**).

The biplot in Figure (3) illustrated both the genotypes and environments ranking relative to the ideal. This graph showed that Line3 (G3) situated closest to the concentric circle above-average mean, demonstrating that this genotype has high grain yield potential and relative stability compared to the rest of genotypes tested in this study. The good genotypes ranked, Line1 (G1), Line2 (G2) and Line4 (G4) placed closer to the ideal genotype or around the concentric circle, proposing their specific adaptability with better performing grain yield. Meanwhile, genotypes Line5 (G5) was the poorest genotypes of adaptability and performance in tested environments.

An ideal test genotype or environment that had small PC1 scores (discriminative power) and PC2 scores (more representative overall genotype or environment), this according to **Yan and Rajcan (2002)** definition. In the present investigation, E20 (S_2 M N_4) and E8 (S_1 M N_4) were the ideal environments for evaluated genotypes, especially G3. However, these environments were the same treatments in both seasons, confirming the result of being to the most discriminating environment. The good environment followed by E10 (S1 H N2), E24 (S2 H N4), E17 (S2 M N1), E7 (S1 M N3), E5 (S1 M N1) and E21 (S2 H N1) were the closest to the ideal. Meanwhile, G4 was good adaptive to E11 (S1 H N3), 15 (S2 L N3) and E13 (S2 L N1) that were non-discriminating and less representative (Fig. 3). This implied that, varietal stability could be challenged not only due to the change in the tested environment but also due to change in growing season per environment. Similarly, **Kendal et al (2019)** investigated the stable environments (representative and discriminating) for the evaluated wheat performance and **Al-Nagar et al. (2020)** in maize genotypes.

Generally, Line3 (G3), Line1 (G1) and Line2 (G2) had adaptive to ideal (favorable) environments while Line4 (G4) was good adaptive to poor (unfavorable) environments (Figure 3). Many previous studies conducted to reported that the best wheat genotypes for general adaptability (high yielding and stable). They are recommended for further verification and possible release. In many of previous studies conducted in multi-environments, stable and unstable bread wheat genotypes were identified (**Asnake, et al 2013; Kadir et al 2018, and Kendal et al 2018**).

CONCLUSION

From the obvious results, combined analysis of variance revealed highly significant variation in the all studied traits for genotype, environments and GEI. Application of N was useful in enhancement wheat production under water deficiency.

In this study, AMMI and GGE analysis was the best predictive model to present the maximum GE interaction for grain yield. These graphical methods facilitated the visual comparisons and selection the best environment for growing superior high yielding

DOI 10.5281/zenodo.6786491

genotypes, thereby supporting decisions on wheat genotypes recommendation for different environments.

In addition to the purpose of test-environment (treatment) evaluation is to identify test environments that can be used to effectively select superior genotypes. An "ideal" test environment should be both discriminating of the wheat genotypes and representative of the target environment. Environments (irrigations and nitrogen fertilizer) and to identify genotypes that are particularly good in certain part or side and therefore can be nominee for high yielding and less water (high water use efficiency) selection and development in wheat breeding program

The comparison view of GGE bi-plot model drew an overall picture and summarized both the all tested treatments and genotypes knowledge, ranking and determining the best environments (treatments). Therefore, the ideal environment (E20 and E8) under both seasons recorded best performance, pointing to adding (75 kg nitrogen) with 4 times of irrigation regime (at germination, tillering, booting and at heading with 1750 m^3) had no significant difference from recommended irrigation with 5 times of irrigation at germination, tillering, booting, heading and at grain filling stage (with 2150 m^3). Then, treatment 75 kg nitrogen with medium regime of 4 times irrigation may be considered as alternative treatment for recommended high irrigation requirements under water deficiency.

Moreover, Line 3 (G3) was detected as the most adapted/stable wheat genotype under water deficiency types exist in different plant growth stages. Then, it should be recommended for releasing with wider environmental adaptability in water deficiency of irrigation requirements.

Acknowledgements

The authors would like to acknowledge the financial support of Applied Research and Extension Campaigns Support Component, Agricultural Development Program (ADP), for funding this study through A Varietal Map for Wheat Varieties Growing under Low Input Stress Project

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