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Genotype - Environment Interaction for Grain Yield In Wheat

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Abstract

Three field experiments were carried out at the Experimental Farm Station of the Faculty of Agriculture Moshtohor, Benha University, Kalubia Gavernorate, Egypt, during two successive winter seasons of 2017/2018 and 2018/2019 to investigate the effect of some folair application materials: [ascorbic acid (ASA) and potassium (K) on and genetic stability of wheat plants grown under different water stress levels. The treatments included the combination between three water treatments and 4 treatments of folair application spray with control.

The treatments were arranged in split-split plot design with three replicates, the main plots were assigned to water stress levels, while five treatments of folair application spray were located in subplots and six varieties were arranged in sub-sub plot. Stability analysis of the 6 wheat genotypes was carried out for grain yield/plant across all studied environments.

The effect of the interaction becomes more complex with the increase of number of factors with the same magnitude that have impact on genotype. Very often one prevalent environmental factor influences the genotype. In such cases linear regression models can comprise a good part of the sum of squares of the interaction and thus explain the stability of the genotype. With regard to AMMI analysis of grain yield/ m^2, Results showed highly significant due to treatments, genotypes and environments this pointed out that all sources of variance are important in analysis, however genotypes contributed with (5.77%) in treatments variances, the environment contributed with (89.63%) in treatments variance also interaction principal component axis (IPCA) Pc1 and Pc2 accounted for (39.36% and 28.62%) respectively, were found to be highly significant, the (IPCA1 and IPCA2) together with had a total (67.98%) variances of the interaction. The genotype G5 is suitable to E3, E5, E11, E23 and E29. The genotype G6 is suitable to E12, E14 and E26. The polygon reflects that G2, G1 and G3 are high grain yielding and suitable to either of the environments. An important feature of the AMMI was also predicted. In mega-environment identification process, furthest genotypes are connected together to form a polygon, and perpendicular genotypes are drawn to form sectors which will make it easy to visualize the mega-environments.

Keywords: Genotype, Grain Yield, Ascorbic Acid (ASA) -Potassium (K), Stability

Introduction

Wheat (*Triticum aestivum* L.) is the major cereal crop in Egypt as well as several other countries. Wheat is the most important food crop in the world. Hundreds of millions of people around the world depend on food. These made into flour that is used in making, bread, cakes, biscuits and other foods. Wheat follows the grass family, as it belongs to the cereal crop.

Drought is a major limiting factor in the production of wheat in many areas of the world and there is considerable interest in trying to increase drought tolerance in wheat. Irrigation water is not available during drought; the possible mean is to grow cultivars which can produce economic yields under such conditions (*Hsiao, 1973*). Drought is a worldwide, most critical abiotic factor due to which sustainable wheat crop productivity is at risk (*Ahmad, et al 2018.*). Drought severity is predicted to successively increase under climate change scenarios of atmospheric and soil warmings and altered precipitation patterns (*Strack et al, 2019*). Consistent and prolonged warming and drought conditions combined with associated abiotic and biotic changes Preston *et al*,2018. Drought stress reduces nutrient uptake, which can cause poor development of roots, low transpiration and photosynthetic rates. One of the stress defense mechanisms is the folair application defense systems. To reduce the toxicity of ROS, plant cells have developed an folair application system, consisting of low molecular weight folair application (Non-enzymatic) like ascorbate, α-tocopherol, glutathione, carotenoids and phenolic as well as protective enzymes or folair application enzymes like superoxide dismutase (SOD), catalase (CAT) and peroxidase (POD). Superoxide radical are scavenged by superoxide dismutase, while the resulting H_2O_2 is reduced to H_2O by CAT and POD (*Mittler, 2002; Apel and Hirt, 2004 and Waraich et al., 2011).*

On the other hand, folair application is one of new methods to assist the plant to tolerate any environmental conditions and increased plant growth, cell cycle through plant growth and plant protect of any ROS (Reactive Oxygen Spices) and increased Rubisco sub unit, photosynthetic pigments thereby increased chlorophyll contents, increased photosynthetic rate, increased productivity by plants *Chen and Gallie (2006) and Inskbashi and Iwaya (2006).* Therefore, many compounds have been applied to minimize the harmful effects of drought stress, such as ascorbic acid and potassium citrate. Ascorbic acid and K is the major folair application in plant known to increase plant growth and cell cycle, through photosynthetic apparatus and plant protect of any ROS (Reactive Oxygen Species) and increased Rubisco subunit, photosynthetic pigments thereby increased chlorophyll contents, photosynthetic rate and increased productivity of plants *(Chen and Gallie, 2006).*

Genotype-by-environment (G×E) interaction is reflected in inconsistent crop yield across environments. Variations in climate change and soil properties and the inherent potential of genotypes are among the major factors for variable crop yield *(Bornhofen et al. (2017).* Fortunately, the possibility exists to find or develop stable and high-yielding genotypes (fit genotypes) for the mega-environments *(Alam et al. 2017).*

Additive main effect and multiplicative interaction (AMMI) model *(Mohammadi et al. 2016)* and genotype plus genotype-by environment (GGE) biplot model *(Rasul et al 2017)* are frequently applied procedures for genotype, environment and genotype-by-environment analysis based on crop attributes. AMMI separates the genotype and environment main effects and the GEI effects *(Ajay et al. 2017*) and provides much insight into GEI *(Aktas 2016).* The objectives of this study were (i) to identify wheat promising genotypes and folair application treatment that have both high mean yield and stable yield performance across different environments, and (ii) to study the relationships, similarities and dissimilarities among yield – stability statistics.

Materials and methods

Plant materials

This study was conducted on six genotypes bread wheat (*Triticum aestivum*). The code, Name, pedigree of those genotypes are presented in Table 1.

Field experiment

Two field experiments were carried out at the Experimental Farm Station of the Faculty of Agriculture Moshtohor, Benha University, Kalubia Gavernorate, Egypt, during two successive winter seasons of 2016/2017 and 2017/2018 growing seasons. The chemical analysis of soil samples (10-30 cm soil surface) were done according to Jackson (1962) and Piper (1947), Table 2 shows results of analysis.

Table 1. Code, name, origin and pedigree of the six bread wheat genotypes used in the present study.

Code	Name	Origin	Pedigree
G1	Sahel 1	Egypt	NS732/PIMA//Veery"S"#5
G2	Line 137	CIMMYT	MILAN \ S87137 \\ BABAX
G3	Gemiza 11	Egypt	Bow "s"/ Kvz "s"//7C/Seri 82 /3/ Giza 168 / Sakha 61 GM 7892-2GM-1GM-2GM-1GM-0GM
G4	Misr 1	Egypt	OASIS/SKAUZ//4*BCN/3/2*PASTOR CMSSOOYO 1881T-050M-030Y-030M-030WGY-33M-0Y-0S.
G5	Line 125	CIMMYT	MILAN \ S7125 \\ Hall //(Ne700011)
G6	Shandaweel1	Egypt	SITE//MO/4/NAC/TH.AC//3*PVN/3/MIRLO/BUC. CMSS93B00567S-72Y-010M-010Y-010M-0HTY-0SH.

Table 2. Chemical analysis of soil during 2016/2017 and 2017/2018 growing seasons.

Season	OM %	CaCO3 g kg-1	pH	EC (dSm-1)	Soluble anions (mmolcL-1)			Soluble cations (mmolcL-1)			
					Cl-	HCO3-	SO4--	Na+	K+	Ca2+	Mg2+
Soil analysis (0 – 30cm)											
2016/2017	2.1	2.8	8	0.5	9.8	1.1	7.1	8.7	0.4	5.7	3.2
2017/2018	1.9	3.2	8.1	0.8	6.56	2.2	10.7	8.6	1.2	8.2	1.4

Meteorological data from November to May in the seasons of 2016/2017 and 2017/2018 were obtained from the Agro-meteorological Station at Moshtohor, Benha Univ., the maximum temperatures were 19.8, 19.7, 17.7, 20.4, 25.8, 29.1 and 34.5°C, and the minimum temperatures were 9.5, 9.2, 6.1, 7.8, 11.4, 14.4, and 19.0 °C, relative humidity were 52.2, 51.3, 55.9, 47.2, 37.3, 38.9 and 32.1% and the mean precipitation were 0.2, 0.5, 1.6, 0.8, 0.4, 0.3 and 0.00 mm respectively in season 2017/2018. As for the second season the maximum temperatures were 18.9, 18.5, 16.3, 19.6, 24.5, 28.3 and 32.6°C, and the minimum temperatures were 8.9, 8.4, 7.0, 6.7, 10.9, 15.3, and 19.5 °C, relative humidity were 46.8, 50.1, 52.8, 45.2, 34.3, 35.9 and 29.8% and the mean precipitation were 0.1, 0.4, 2.1, 1.5, 0.8, 0.5 and 0.03 mm, respectively.

In each season a split-split-plot design in three replicates was laid out. The planting date was on 23th and 25th Nov. in the first and second season, respectively. The main plots were allotted to three irrigation treatments (1) water stress giving one irrigation after sowing in tillering stage, (2) water stress giving two irrigations after sowing in tillering and heading stage and (2) normal irrigation which giving 5 irrigations. The sub-plot was five treatments (1) spray with tap water (control) (2) the folair application materials ascorbic acid (ASA) at concentration of 100PPm (3) ASA at concentration 200ppm, (4) potassium citrate (k) at concentration of 100 PPm and (5) K at concentration of 200 ppm. The sub-sub-plot was allocated to the twelve wheat genotypes. In order to display the appropriate environments used in the research, the table 4 can be clarified this situation, in each environment the six wheat genotypes were sowing in sub-sub plot. The plot area was $10.5m^2$. All of another practices were done as a recommended till to wheat harvest. After physiological maturity (within 155 days after planting) 1 meter from each plot was harvest then grains were separated and weighted to determine Grain yield m-2

Table 3. The studied treatments combination folair application and irrigation at studied seasons.

	Season 2016/2017			Season 2017/2018		
	Irrigation treatments			Irrigation treatments		
Spray	I1	I2	I3	I1	I2	I3
Control	E1	E6	E11	E16	E21	E26
ASA at 100 ppm	E2	E7	E12	E17	E22	E27
ASA at 200 ppm	E3	E8	E13	E18	E23	E28
K at 100 ppm	E4	E9	E14	E19	E24	E29
K at 200 ppm	E5	E10	E15	E20	E25	E30

Stability analyses:

Stability analysis of the 6 wheat genotypes was carried out for grain yield/plant across all studied environments, representing the combinations of two seasons x 3 irrigation treatments × 4 spray treatments + control) = (30 environment). Two different approaches were adopted for estimating the stability parameters, namely AMMI analysis and GGE biplot method of stability analysis (*Yan et al., 2000).* AMMI and GGE biplot models were computed using the GeneStat-17.1.13780 software program.

Additive means effect and multiplicative interaction (AMMI) model:

The AMMI model is as follows: Yger = μ + αg + βe + Σnλnγgnδen + ε ger + ρge ; where Yger was the observed yield of genotype (g) in environment (e) for replication (r); Additive parameters: μ was the grand mean; αg is the deviation of genotype g from the grand mean, βe is the deviation of the environment e; Multiplicative parameters: λn was the singular value for interaction principal component axis (IPCA) n, γgn was the genotype eigenvector for axis n, and εen is the environment eigenvector; εger is the error term and ρge are PCA residuals. Accordingly, genotypes with low (regardless of the sign) IPCA scores showed general or wider adaptability, while those with high IPCA scores showed specific adaptability *(Gauch and Zobel, 1996).*

AMMI Stability Value (ASV)

The ASV is the distance from the coordinate point to the origin in a two- dim ensional plot of IPCA1 scores against IPCA2 scores in the AMMI model (*Purchase, 1997).* Because the IPCA1 score contributes more to the G×E interaction sum of squares, a weighted value is needed. This was calculated for each genotype and each environment according to the relative contribution of IPCA1 to IPCA2 as follows:

$$ASV = \sqrt{\left[\frac{SS_{IPCA1}}{SS_{IPCA2}}(GIPCA1score)\right]^2 + (GIPCA2score)^2}$$

ASV = {[(SSIPCA1 ÷ SSIPCA2) (IPCA1 score)] 2 + (IPCA2 score) 2} 1/2

Where SSIPCA1 / SSIPCA2 was the weight given to the IPCA1-value by dividing the IPCA1 sum of squares by the IPCA2 sum of squares. The larger the ASV value, either negative or positive, the more specifically adapted a genotype was to certain environments. A smaller ASV value indicated a more stable genotype across environments *(Purchase, 1997).*

The AMMI model was performed using the Genestat-17.1.13780 software.

GGE Biplot analysis *(Yan et al., 2000)*

To evaluate the phenotypic stability and adaptability, the GGE biplot analysis was performed, considering the simplified model for two main components. In this approach, the effects of genotype (G) and genotype by environment (GE) were considered as random in the model. In this case, the best linear unbiased prediction (BLUP) of G and GE effects are calculated. The components of genotypic variance, of the variance of G×E interaction and residual were estimated by the method of restricted maximum likelihood (REML). For analysis of variance the software package SAS 9.2version was used. GGE biplot software was used to explain relationship between genotype and locations graphical *(Yan and Kang, 2003).*

The model for a GGE biplot *(Yan, 2002)* based on singular value decomposition (SVD) of the first two principal components is:

ξν.η

Yij - μ-βj = λ1 ξi1ηj1 + λ2 ξi2ηj2 + ε ij (1)

where Yij is the measured mean (DBH) of genotype i in environment j, μ is the grand mean, βj is the main effect of environment j, μ + βj being the mean yield across all genotypes in environment j, λ1 and λ2 are the singular values (SV) for the first and second principal component (PC1 and PC2), respectively, ξi1 and ξi2 are eigenvectors of genotype i for PC1 and PC2, respectively, ηj1 and ηj2 are eigenvectors of environment j for PC1 and PC2, respectively, εij is the residual associated with genotype i in environment j.

PCA1 and PCA2 eigenvectors cannot be plotted directly to construct a meaningful biplot before the singular values are partitioned into the genotype and environment eigenvectors. Singular-value partitioning is implemented by,

gi1 = λ1 f1ξi1 and eij = λ1 1-f1 η1j (2)

Where F1 is the partition factor for PC1, theoretically F1 can be a value between 0 and 1, but 0.5 is most commonly used.

To generate the GGE biplot, the formulae (1) was presented as:

Yij - μ - βj = gi1e 1j+gi2e 2j + ε ij (3)

If the data was environment-standardized, the common formula for GGE biplot was reorganized as follows:

Yij - μ - βj /sj = Σgi1e 1j + ε ij (4)

Where, sj is the standard deviation in environment j,

l =1, 2…, k, gi1 and e1j are PC1 scores for genotype i and environment j, respectively. We used environment standardized model (4) to generate biplot of "which-won where". For the analysis of relationship between the trials, genotype and environment evaluation, we used unstandardized model (3). The GGE biplot model was performed using the Genestat-17.1.13780 software.

Results and Discussion

Effect of irrigation treatments

The results of irrigation treatments are presented in table 4. Grain yield/ m2 decreased significantly with decreasing no of irrigation. For grain yield/ m2, the reductions were 9.26, 13.07and 33.81, 27.58 at two and one irrigation, respectively. Generally, the reduction of grain yield/ m2 were increased from the (control) five irrigations and one irrigation, While, the reduction from recommended treatments and two irrigation were low. It's logic, therefore, grain yield/ m2 had applied to minimize the harmful effects of drought stress, such ascorbic acid, and potassium citrate.

Effect of folair application

The mean performance grain yield/ m2 of folair application is presented in table 4. The regarding treatment (control) gave the lowest mean value for grain yield/ m2.However ,The foliar application of 200ppm of ASA had the highest mean value of this trait followed by 200ppm of K and then by K100 ppm. .The results suggested using 200ppmof ASA or K to improve wheat grain yield. The trait of ASA and K of wheat plant s was studied by *Chen and Gallie (2006)* and *Inskbshi and Iwaya (2006)* they reported that grain yield significantly by the application of ASA and K foliar on plant.

The folair application is one of near methods to assist the plant to tolerate any environmental conditions and increased. Plant growth cell cycle through plant growth and plant protect of any ROS (Reactive Oxygen Species) and increased Rubisco sub unit, Photosynthetic pigments there by increased color

Table 4. Mean performance of grain yield/m2 of spray treatment and varieties as affected by irrigation treatments in both seasons

Spray	Var.	Season 2016/2017			mean	Season 2017/2018			mean
		Irrigation treatments				Irrigation treatments			
		I1	I2	I3		I1	I2	I3	
Control	G1	214.12	359.67	410.91	328.23	230.04	408.57	422.96	353.86
	G2	234.77	386.97	403.95	341.90	328.03	389.49	470.69	396.07
	G3	265.53	387.17	419.25	357.32	287.59	393.20	452.87	377.89
	G4	237.33	321.33	389.33	316.00	251.91	338.02	403.30	331.08
	G5	228.40	322.67	398.13	316.40	303.55	335.27	411.13	349.98
	G6	202.67	302.67	402.13	302.49	193.39	299.64	409.86	300.96
Mean		230.47	346.75	403.95	327.06	265.75	360.70	428.47	351.64
ASA at 100 ppm	G1	284.35	390.29	423.28	365.97	292.61	390.79	437.23	373.54
	G2	299.32	390.97	436.43	375.57	330.04	385.85	455.81	390.57
	G3	300.72	394.65	446.64	380.67	331.44	409.84	478.69	406.66
	G4	265.33	367.73	391.47	341.51	270.45	381.40	395.66	349.17
	G5	253.33	360.67	420.80	344.93	278.59	359.89	446.15	361.54

	G6	266.67	361.87	417.47	348.67	282.33	364.61	422.80	356.58
Mean		278.29	377.70	422.68	359.56	297.58	382.06	439.39	373.01
ASA at 200 ppm	G1	320.44	411.86	463.28	398.53	369.10	419.17	497.97	428.75
	G2	330.93	436.35	495.37	420.88	339.85	464.08	523.11	442.35
	G3	346.56	435.90	504.71	429.06	460.48	389.47	527.35	459.10
	G4	274.80	381.87	418.53	358.40	358.96	342.21	460.93	387.37
	G5	275.47	388.13	452.00	371.87	329.91	378.41	476.29	394.87
	G6	276.00	377.47	426.67	360.05	305.50	380.42	440.29	375.40
Mean		304.03	405.26	460.09	389.80	360.63	395.63	487.66	414.64
K at 100 ppm	G1	316.87	403.63	413.05	377.85	391.07	359.13	400.25	383.48
	G2	319.77	396.06	425.68	380.50	385.67	370.75	446.51	400.98
	G3	318.12	407.81	408.97	378.30	372.18	386.25	416.12	391.52
	G4	252.67	382.67	402.00	345.78	322.37	364.63	411.96	366.32
	G5	256.53	382.40	398.27	345.73	275.79	385.67	418.53	360.00
	G6	263.60	378.93	403.07	348.53	315.60	355.09	405.12	358.60
Mean		287.93	391.92	408.51	362.78	343.78	370.25	416.42	376.82
K at 200 ppm	G1	336.91	435.13	440.01	404.02	369.99	426.86	444.74	413.86
	G2	347.20	441.47	455.73	414.80	347.20	441.47	455.73	414.80
	G3	366.91	442.83	461.41	423.72	366.91	442.83	461.41	423.72
	G4	324.27	418.40	450.67	397.78	324.27	418.40	450.67	397.78
	G5	319.07	408.53	448.53	392.04	319.07	408.53	448.53	392.04
	G6	320.93	400.67	440.67	387.42	320.93	400.67	440.67	387.42
Mean		335.88	424.51	449.50	403.30	341.40	423.13	450.29	404.94
Mean of irrgation		287.32	389.23	428.95	368.50	321.83	386.35	444.44	384.21

items	LSD 5%	Items	LSD 5%
Irrigation	1.77	Irrigation	4.16
Spray	2.28	Spray	5.37
Irrigation x Spray	3.95	Irrigation x Spray	9.30
irrigation x Spray x var.	1.77	irrigation x Spray x var.	4.16

contents, increased Photosynthetic rate, increased productivity by plants *chen and Gallie (2006) and Inskbshi* and *I waya (2006)*

Therefore, many compounds have been applied to minimize the harmful effect of drought stress ,such as ascorbic acid, and potassium Citrate . These compounds can decrease the adverse effects of drought in crop plant s under water stress *El-Shayb,(2010);Gille and Tuteija (2010) ; Gadalla(2010);Abd-Ellatif (2012),Ibrahim (2021)*. Also ,These folair application compounds are well known to be involved in plant adaptation to water stress and may play important roles in plant growth and development *(Faroq,etal ,2009) and Gad alla ,2010)*

Effect of interaction between irrigation treatments and folair application .

Table 4 shows the interaction between irrigation treatments and folair application activities for all trait under study.

The highest value for grain yield/ m2 were obtained by five irrigation s with each of foliar application of 200ppm ASA or 200ppm K . On the other hand, the lowest value for all the studied traits were obtained by one irrigation treatments and 0:0 of folair application (table 4). The interaction effect of five irrigation and ASA 200ppm gave significantly higher mean value compared other treatments followed by five irrigation with K200ppm with regard to grain yield

Ascorbic acid is the major folair application in plant known to increase plant growth and all cycle, through Photosynthetic apparatus and plant protect of any ROS (Reactive Oxygen Species) and increased Rubisco subunit ,Photosynthetic pigments there by increased chlorophyll content Photosynthetic rate and increased productivity of plant s (*chen and Gallie, 2006)* . ASA has been showed to play an important role in several physiological processes in plant including growth ,differentiation, and metabolism ASA has a key role in defense against oxidative stress and is particularly abundant in Photosynthetic tissues *(Smirnoff et al 2004)*

Also, (K) play an important role in several plants under environmental stress. This essentially plant nutrient were not only required for better plant growth and development, but also helpful to alleviate different kinds of a biotic stress like drought stress (*Warich et al 2011)* . Potassium is an essential element for many physiological processes such as Photosynthesis, activation of enzymes metabolism, protein synthesis, trans location of Photosynthetic into sink organs , stromal movements (regulates opening and closing for stomata) , water -relation in plant s important of all structure regulates many metabolic processes and increases drought tolerance (*marschner ,1995;waraich et al, 2011 and wang et al, 2013)*

Genotypes performance

The difference among varieties regarding grain yield/m2 reached to be significant Table 5. The results showed that both genotypes line 137 and Gemiza11 exhibited significantly higher grain yield than other genotypes. It could be concluded that the Gamiza11 and Line 137 were considered the best genotypes to be cultivated under Moshtohor conditions .such results is mainly the due to the difference in the genetically constitutes of these genotypes

Table 5. Mean performance of grain yield/ m2 of varieties as affected by irrigation treatments in both seasons.

Var.	Season 2016/2017			mean	Season 2017/2018			mean
	Irrigation treatments				Irrigation treatments			
	I1	I2	I3		I1	I2	I3	
G1	294.54	400.12	430.11	374.92	330.56	400.90	440.63	390.70
G2	306.40	410.36	443.43	386.73	346.16	410.33	470.37	408.95
G3	319.57	413.67	448.20	393.81	363.72	404.32	467.29	411.78
G4	270.88	374.40	410.40	351.89	305.59	368.93	424.50	366.34
G5	266.56	372.48	423.55	354.20	301.38	373.55	440.13	371.69
G6	265.97	364.32	418.00	349.43	283.55	360.09	423.75	355.79

items	LSD 5%	Items	LSD 5%
Genotype	2.7	Genotype	6.04
irr. X Genotype	3.99	irr. X Genotype	9.68

Effect of interaction between irrigation treatments and genotypes

The mean performance of interaction effect between irrigation treatments and genotypes in both seasons for all the studied traits is presented in table5

Regarding grain yield, in the first season Gemiza11 with five irrigation had the highest value but without significantly different than line 137 under five irrigation treatment . However , in the second season the highest grain yield/m2 was deterred by line 137 under five irrigation, without significantly surpassed than Sahel1 ,Gemiza11 ,Misr1, line 125 and Shandweel 1 under five irrigation s. Regarding grain yield/ m2 , the lowest mean value was obtained by Shandweel 1 with one irrigation and untreated folair application in both seasons. However, Gemiza11 followed by line 137 expressed significantly with five irrigation and foliar application by ASA200ppm. Followed by both genotypes under five irrigation and foliar application by K200ppm expressed significantly higher grain yield. In both seasons . Ascorbic acid is the major folair application in plant known to increase plant growth and cell cycle through Photosynthetic apparatus and plant protect of any ROS (Reactive Oxygen Species)and Rubisco subunit ,Photosynthetic pigments there by increased chlorophyll contentment, Photosynthetic rate and increased productivity of plants *(Chen and Gallie, 2006).*

Ascorbic acid (ASA) is one of the most important folair application protecting plants from oxidation stress *(Smirnoff, 2005).* it is also involved in regulation Photosynthetic capacity, flowering and senescence *(Davey et al 2000).*

Potassium (k)play an important role. This essential plant nutrient are not only required for better plant growth and development, but also helpful to alleviate different kinds of abiotic stress like drought stress *(Waraich et al, 2011)* .

Potassium is an essential element for many physiological processes such as Photosynthesis activation of enzymes to metabolism, protein synthesis, translocation of Photosynthetic into sink organs stomatal movements (regulates opening and closing stomata),water relation (turgor regulation and osmotic adjustment) in plants important of cell structure, it regulates many metabolic processes and increases drought tolerance *(Marschner,1995,waraich et al, 2011 and Wang et al ,2013)*

AMMI Analysis:

GxE interaction is the source of variation influenced both by genotype and environmental factors. From the statistical point of view GxE interaction appears when two or more genotypes have different responses to the changes of the environmental conditions. Determination of presence and magnitude of interaction is not the only focus of plant breeders, who are even more interested in understanding the impact of GxE interaction on the breeding material.

As numerous environmental factors affect genotype, thereafter GxE interaction could be more or less complex phenomenon. The effect of the interaction becomes more complex with the increase of number of factors with the same magnitude that have impact on genotype. Very often one prevalent environmental factor influences the genotype. In such cases linear regression models can comprise a good part of the sum of squares of the interaction and thus explain the stability of the genotype.

Additive main effects and multiplicative interaction (AMMI) model

AMMI analysis of variance

Combined analysis of variance revealed highly significant (P≤0.01) variances due to environment, genotype, genotype × environment interaction and interaction principle component axes (IPCAs) (Table 6). This result revealed that there was a differential yield performance among the maize genotypes across testing environments and the presence of strong genotype by environment (G×E) interaction. As G×E interaction was significant, further calculation of genotype stability is possible.

The differential ranking of genotypes across different environments has been reported in most multi environment trials in West and Central Africa *(Ifie et al., 2015)*. According to *Moghaddam and Pourdad (2009)*, highly significant GEI for grain yield under the multiple-stress and non-stress environments indicates differential responses of the hybrids and the need to identify high yielding and stable hybrids across the test environments.

With regard to AMMI analysis of grain yield/ plant data showed highly significant due to treatments, genotypes and environments this pointed out that all sources of variance are important in analysis, however genotypes contributed with (5.77%) in treatments variances, the environment contributed with (89.63%) in treatments variance also interaction principal component axis (IPCA) Pc1 and Pc2 accounted for (39.36% and 28.62%) respectively, were found to be highly significant,

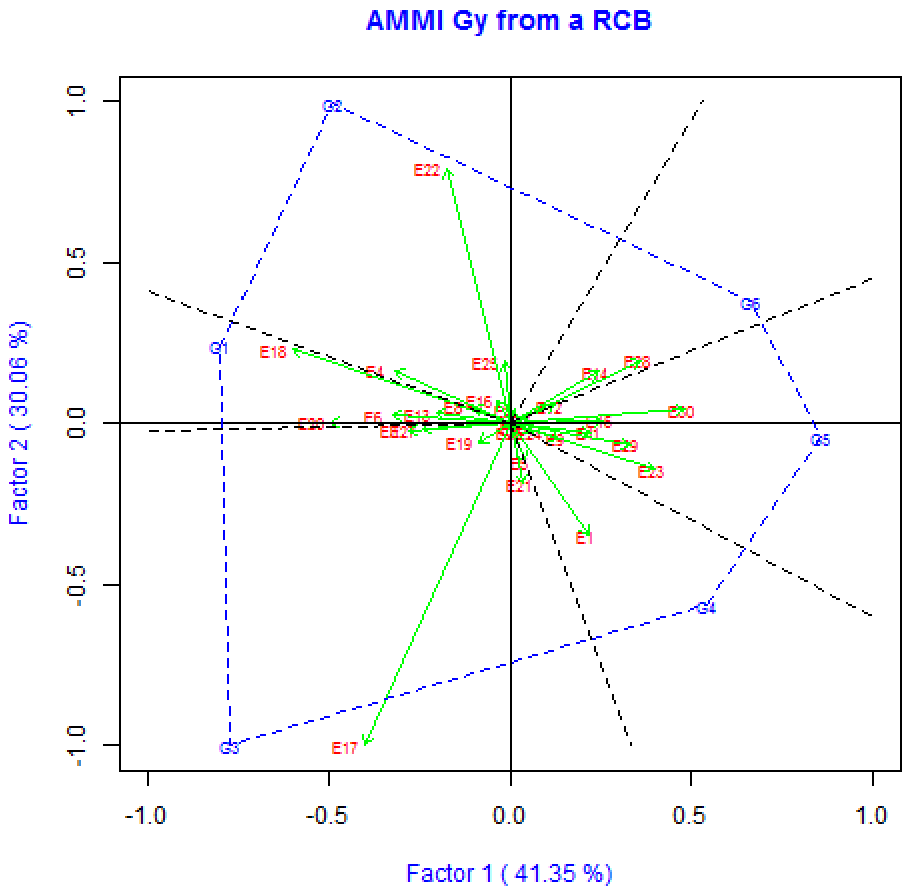
Table 6. Analysis of variance of AMMI model for grain yield/ plant across the studied environments.

	df	Ss	SS%	MS	F	Probf
Env	29	3010896.67	89.63	103824.02	492.42	0.000
Gen	5	193716.29	5.77	38743.26	183.75	0.000
EnvxGen	145	154680.75	4.60	1066.76	5.06	0.000
Pc1	33	60888.77	39.36	1845.11	8.75	0.000
Pc2	31	44267.74	28.62	1427.99	6.77	0.001
Pc3	29	24131.16	15.60	832.11	3.95	0.003
Pc4	27	10889.19	7.04	403.30	1.91	0.999
Pc5	25	7071.36	4.57	282.85	1.34	0.999
Pc6	23	0.00	0.00	0.00	0.00	1.000
residuals	378	79699.25		210.84		

The (IPCA1 and IPCA2) together with had a total (67.98%) variances of the interaction.

AMMI model has been mostly employed to separate the additive variance from the multiplicative of the interaction portion by the use of principal component analysis (PCA) *(Gauch, 2013; Bocianowski et al., 2019)*. This analytic mechanism captured the large portion of the GxE interaction sum of squares *(Zhang et al., 1998; Ajay et al., 2019).*Analysis of Multi Environment trials, irrespective of crops, demand an efficient estimation of main and interaction effects *(Bornhofen et al., 2017)*. More over biased in terpretation regarding the stability of the genotypes had been also reported when low proportion of the variance explained by first interaction principal component IPCA1under AMMI analysis *(Ramburan et al., 2011; Zali et al.,2012; Oyekunle et al., 2017).*

- AMMI graphical analysis
- Fig. 1: Polygon view of AMMI (which–won–where) showing the (G+G×E) interaction effect for grain yield of 6 wheat genotypes across all studied environments.
- (which-won-where) the polygon indicates the best genotype(s) for each environment. The genotypes located on the vertex of a polygon are best or poorest genotypes in some or all environments, except left bottom quadrant. This enables the researcher to have specific and valid justification to recommend genotypes which are good for that particular environment. This also means the genotypes can be tested in those few mega-environments and still good yield data results can be obtained. The GGE biplot also gave information which is important if a researcher has to make decisions and conclusions about specific correlations among environments and genotypes



From the graphic analysis (AMMI), the genotypes G4, G5 and G6 were found to be high yield comparing with the other three genotypes in descending order. The genotypes G4 was higher in grain yield/ plant especially in E1. The genotype G5 is suitable to E3, E5, E11, E23 and E29. The genotype G6 is suitable to E12, E14 and E26. The polygon reflects that G2, G1 and G3 are poor grain yielding and not suitable to either of the environments. An important feature of the AMMI was also predicted. In mega-environment identification process, furthest genotypes are connected together to form a polygon, and perpendicular genotypes are drawn to form sectors which will make it easy to visualize the mega-environments. Environments in one sector having best-performing genotype can be considered as mega-environments for that genotype.

Relationships between genotypes and environments

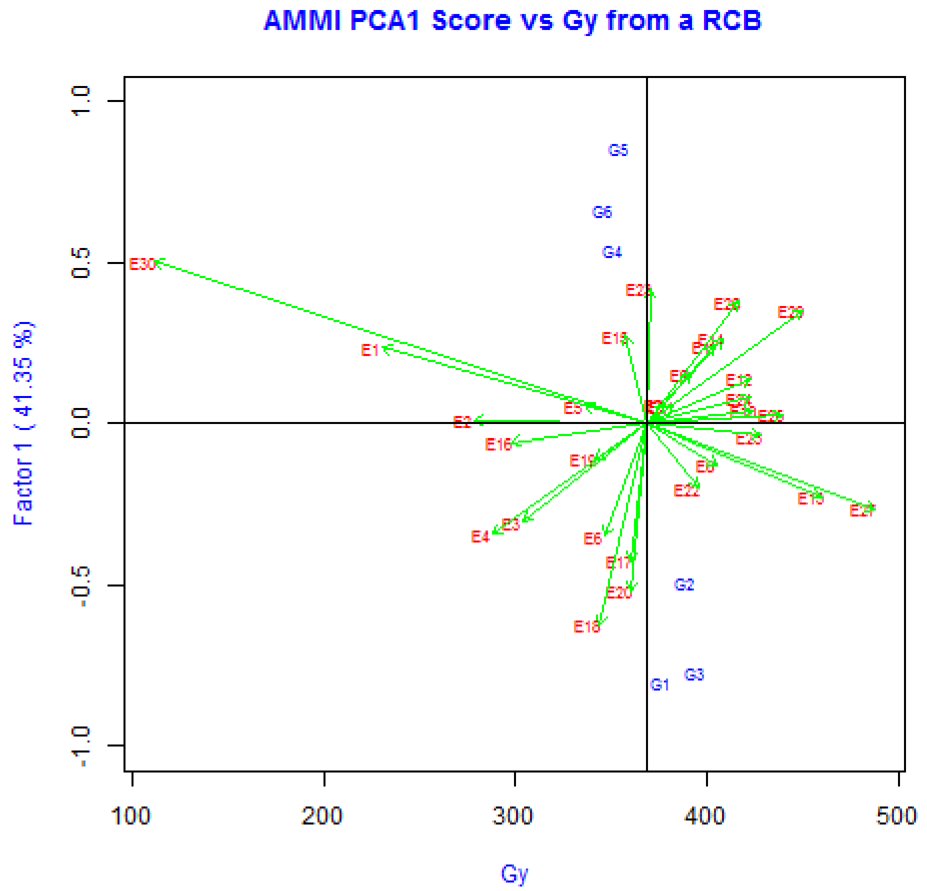


Fig. 2: The AMMI biplot showing relationship between genotypes and mega environments for grain yield.

Environments with a small angle between them are highly positively correlated, and they provide similar information on genotypes. Present investigations showed that E15, E30, E1 and E5 were considered to be similar as they had small angle between them. Also, the environments E22, E6, E23, E13 and E27 are similar; they had small angle between them and they provide similar information on genotypes. The environments E2, E16, E19, E4, E3, E6, E17, E20 and E18 are similar; they had small. Meanwhile, the other environments were closely related. In contrast, the relation between each aforementioned environment groups were dissimilar, since the angle was obtuse, and they provide different information on genotypes.

The greater IPCA-1 shows greater discriminating ability of an environment. This gives the importance of determining the discriminating ability to enhance separation through differences in performances of different genotypes. The results revealed that E30 gave more information on the tested genotypes than the other environments. So this study provides important information on selecting and releasing best and ideal genotypes which are good for production in specific and widely adapted environments as well as determine the most effective and necessary environments which gives more information on varieties in future breeding E7 lied closest to the origin and, therefore, contributed the least to GEI; these environments are the most representative (stable) environments, but with poor discriminating ability as indicated in Fig. (2),

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