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Study of drought stress correlation on yield and yield components of maize cultivars (*Zea mays* L.)

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SUMMARY

This article was investigated to study the correlation and analysis of drought stress regression on maize cultivars' yield and components. The variance analysis results showed a significant difference between drought stress levels in terms of plant height, total dry weight and number of seeds per row, the total weight of cob, grain yield, harvest index, stem diameter, and cob weight with protective leave. Also, there was a significant difference in ear weight without protective leaves, ear diameter, ear length, plant weight, 100-seed weight, and seed per ear on hybrid treatments. There were statistically significant differences between cultivars in plant height, leaf area, ear diameter, ear length, number of seeds per row, number of seeds per ear, the total weight of cob wood, 100-seed weight, harvest index, plant dry weight. The results of the correlation of traits for the mean levels of drought stress showed a positive and significant correlation between plant yield and plant height, seed per row, ear length and weight of 5 pieces of wood and also with a total weight of cob wood, ear weight with bark showed the highest correlation. There is a significant correlation between leaf area and stem diameter, plant weight, total dry weight at the probability level of 0.05. Correlation coefficients between traits in non-stress conditions showed a positive and significant correlation between grain yield and height, ear length and grain in the row, which was a significant increase compared to stress conditions. The correlation of traits under full stress conditions also showed that the correlation coefficient between cob length trait and positive height was positive and significant. From the study of correlation coefficients between maize traits in non-stress conditions, it can be concluded that the most important components of grain yield are cob length and grain per row. While the correlation coefficients under moisture stress conditions show that the grain trait in the row has a positive and significant correlation with yield, under stress conditions in the cob stage did not show any traits with correlation yield.

Keywords: *maize; drought stress; correlation; regression; grain yield*

INTRODUCTION

Corn (*Zea mays* L.) is one of the most important crops globally, so it plays a major role in providing food to many people around the world (Nagy, 2007). According to forecasts, by 2050, the demand for corn in developing countries will be almost double the current demand (Ort and Long, 2014). Environmental stresses such as water shortage (drought) are one of the main obstacles to the production of crops and horticulture in many parts of the world, especially arid and semi-arid regions such as Iran. The material is transferred back to the seed and reduces the yield due to the reduction of grain weight. Drought limits the photosynthesis of plants, which results in changes in the amount of chlorophyll and damage to the photosynthetic complex. In addition, drought stress limits photochemical activities and reduces the activity of enzymes in the Calvin cycle (Talaat, 2020). Water stress in maize has adverse effects on yield and yield components. Maize yield decreases by about 17% due to drought stress, but depending on the severity and timing of drought stress, this yield reduces to 80% (Hejazi et al., 2013). According to research, dehydration in the vegetative stage affects not only the leaves and stems but also the important developmental events of the corn plant, such as corolla emergence, ear silk, beginning and end of linear growth in grain filling, nitrate reduction and protein synthesis (Shojaei et al., 2016). According to Amini et al. (2014), in the cultivation of four-grain maize hybrids at different irrigation levels, the effect of irrigation levels on grain yield, biological yield, harvest index, 100-grain weight, number of grains per row, ear length and ear diameter was significant. However, irrigation had no significant effect on the number of rows per ear and the percentage of plant water. Differences between hybrids were also significant in grain yield, the number of rows per ear, 100-grain weight, biological yield, ear diameter and water content of the plant. In an experiment, Considering the issue of water scarcity as one of the major concerns of human societies, especially in arid and semi-arid regions including Iran, to complete the studies performed on corn, the present study aims to evaluate the effect of water stress on yield. Yield components of corn plant were done to be used in irrigation planning. If each performance component has a higher heritability than the performance and its correlation with the performance is positive, these components can be selected alone, to improve performance (Mousavi et al., 2019; Mousavi et al., 2020; Mousavi et al., 2021). Dolatabad et al. (2010)

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also conducted a study on 14 maize hybrids in nine regions to investigate the genotype-trait interaction and observed a high correlation between traits and grain yield. Choukan and Mosavat, 2005 reported a high and positive correlation between grain yield and number of grains per row, 1000-grain weight and the grain depth. Ramazani et al. (2008) also reported a correlation between grain yield and cob weight. Rafiq et al. (2010) found a positive and significant correlation between ear length, 1000-seed weight and grain weight per ear with grain yield. Alvi et al. (2003) showed that plant height, number of days to emergence, number of days to physiological maturity, ear length, number of seeds per row and 100-grain weight were directly related to grain yield. Phenotypic and genotypic correlation analysis of traits in maize hybrids in another experiment showed that grain yield had a significant correlation with plant height, ear height, the number of grains per row and number of days to emergence and the highest correlation with grain yield was related to the trait of height (Mousavi et al., 2020; Mahrokh et al., 2022). In a study of 12 commercial maize hybrids, Shojaei et al. (2021, 2022 a, b) reported a positive correlation between grain yield and ear length, number of rows per ear, 1000-seed weight and grain length.

MATERIALS AND METHODS

This study was conducted to study the correlation and analysis of drought stress regression on maize cultivars' yield and components. The physical and chemical properties of the test site soil are presented in *Table 1*. The code and name of the studied traits are presented in *Table 2*.

Table 1: **Physical and chemical properties of experiment soil**

EC	Acidity	Clay %	Silt %	Sand %	Organic Carbon %	N (mg kg^{-1})	P (mg kg^{-1})	K (mg kg^{-1})
0.7	7.5	42	42	16	1.2	120000	120000	420000

Table 2: **Code and name of the studied traits in the experiment**

Code	Traits
ERG	Ear row grain
EL.	Ear length
DE.	Diameter of the ear
SPW.	Single plant weight
EPL	Ear weight without protective leaves
NGE.	Number of grains per ear
EW.	Ear weight
WES.	Weight 5 ear stick
WG.	Weight of 1000 grains
YLD.	Grain yield
HI.	Harvest index
PH	Plant height
LA.	Leaf area
SD	Stem diameter
NE.	Number of ears
EWPL.	Ear weight with protective leaves

The experiment was performed under field conditions as a split block with a randomized complete block design with 4 replications. Irrigation as the main factor in three levels including full irrigation, the stress in the emergence stage of tasseling and stress in the emergence stage of the ear and cultivars tested as a sub-factor in 6 levels, including cultivars KSC704, KSC707, SC640, SC647, BC504, KSC260. The field experiment had 18 treatment combinations (6 3) and 4 replications and 72 experimental units. After implementing the plan in the experimental field, cultivation was done by drought (2 to 3 seeds were planted at a depth of 5 to 8 cm) and then irrigation was done. Each plot has 6 rows of planting with a length of 3 meters and a row spacing of 75 cm and between the plots 50 cm, i.e. one row in a row and 1 m spacing between repetitions to prevent water transfer during irrigation treatments considered. Planting was done in the form of ridge planting. The plant distance on the row was considered to be 20 cm. Land preparation operations included autumn plowing, supplementary spring plowing, disc plowing, and stacking. The experiment field was fallow in the year before the study. Planting the was accompanied by applying urea fertilizer and the first level of irrigation stress, i.e. stress in the emergence stage of the first corolla after irrigation for 15 days and in the emergence stage of the second level of irrigation stress began. To eliminate marginal effects from sampling in two side rows of each plot and also 0.5 m at the beginning and end of each row was omitted. A normality test was performed for all data before analysis of variance. Analysis of variance on the studied traits was performed in a field experiment based on strip plot design with randomized complete block design with MSTAT-C software and Duncan test was used to compare the means at 5% probability level. SPSS software was used to calculate simple correlation coefficients and regression analysis in terms of mean stress levels. Stepwise regression was used for this purpose.

RESULTS AND DISCUSSION

Analysis of variance of studied traits

Analysis of variance of traits measured under field conditions (*Table 3*) showed that between drought stress levels in terms of plant height, total dry weight per surface ($p \leq 0.05$) and for number of seeds per row, the total weight of cob, seed yield, harvest index, stem diameter, ear weight with protective leaves, ear weight without protective leaves, ear diameter, ear length, plant weight, 100-grain weight, seed per ear, at the level ($p \leq 0.01$) statistically significant difference. However,

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there was a statistically significant difference in the number of ears per plant. Among cultivars in terms of plant height, leaf area, ear diameter, ear length, number of grains per row, number of grains per ear, total weight of ear wood, 100-grain weight, harvest index, plant dry weight per surface (p≤0.01) and had a statistically significant difference in plant weight at the level (p≤0.05) but in terms of ear weight without protective leaves, ear weight with protective leaves, number of ears, stem diameter and grain yield were statistically significant. Statistically significant differences in traits indicate that the studied cultivars have genetic diversity in the above traits. Interaction of stress levels × cultivar for traits such as number of grains per row, ear weight, harvest index, total dry weight, plant height, stem diameter, ear weight with protective leaf and without protective leaf, plant weight, ear diameter, ear length and grains in the ear row had a statistically significant difference at the probability level (p≤0.01) and in terms of traits such as leaf area, grain yield at the level (p≤0.05) there was a statistically significant difference. Still, in terms of traits such as the number of ears the number of grains per ear and the weight of 100 grains were not statistically significant. The coefficients of variation obtained for all traits in variance analysis were acceptable, indicating good accuracy in the implementation of experimental design, sampling, and measurement of traits such as block, ear weight, harvest index, total dry weight, grain per ear, leaf area, ear diameter, ear length at the surface (p≤0.01) and for plant height, ear weight without protective leaves. There was a statistically significant difference in the level of probability (p≤0.05) but there was no statistically significant difference for grain yield, stem diameter, ear weight with protective leaf, plant weight, number of grains per ear row and 100-grain weight.

Table 3: **Analysis of variance of studied traits in maize cultivars as strip plots based on completely randomized block design**

		MS															
S.O.V	**Df**	**ERG**	**EL**	**DE**	**SPW**	**EPL**	**NGE**	**EW**	**WES**	**WG**	**YLD**	**HI**	**PH**	**LA**	**SD**	**NE**	**EWPL**
Block	3	3.39*	13.82^{ns}	0.02**	0.65**	5.47^{ns}	2182.2**	1475.3**	522.09**	2538.8^{ns}	8**	3.31**	712.8*	2929.9*	0.09^{ns}	41.22*	4.01^{ns}
A	2	41.76**	1.43**	1.43**	81.21**	400.11**	103657.8**	3132.2**	8918.59*	34822.1*	67.16*	1132.2**	1616.2*	1128.1**	0.48**	23.42^{ns}	27.7**
Erro1	6	0.68	5.63	0.07	2.16	2.71	5257.3	5746.14	553.14	850	10.53	7.04	171.56	7703.02	0.02	8.35	2.72
B	5	2.83^{ns}	22.88*	0.23**	35.45**	233.14**	77876.01**	715.53**	746.05**	436.5**	86.18**	798.12**	2573.4*	43223.2**	0.16^{ns}	50.3^{ns}	8.77^{ns}
Erro2	15	2.50	7.97	0.03	1.54	6.74	5393.71	4173.14	122.22	3146.6	5.89	24.52	379.02	6620.9	0.1	50.2*	7.98
AB	15	0.33**	1.21**	0.04**	0.98**	15.53**	7391.29^{ns}	1327**	1004.7**	358.22^{ns}	9.12**	90.35*	102.4**	5074.03*	0.02	12.16^{ns}	0.93**
Erro3	30	0.36	2.11	0.04	1.53	5.50	7243.02	2309.62	261.14	1787.7	3.15	20.4	189.4	2336.9	0.03	12.5	1.44
CV%	--	5.73	6.74	4.62	20.57	16.30	12.88	15.01	14.98	18.01	15.12	11.65	21.75	18.92	7.32	12.15	6.51

**, * and ns: show significant differences in the probability level of 0.01 and 0.05, respectively

Correlation of traits in maize for mean drought stress levels

Traits correlation coefficients for the mean (*Table 4*) showed that a positive and significant correlation between plant yield and plant height, grain per row, ear length and weight of 5 woods per surface (p≤0.05) as well as total weight of ear wood, ear weight with shell at the surface (p≤0.01) showed the highest correlation. There is a significant correlation between leaf area and stem diameter, plant weight, total dry weight at the surface (p≤0.05). The correlation between stem diameter and plant weight and total dry weight was also significant (p≤0.05). The correlation between ear weight with ear weight without shell, grain in ear row, ear wood weight, 5 wood weight and total dry weight at the level (p≤0.05) was positive and significant and between the above traits with length maize and yield were also significant at the level (p≤0.01). The harvest index had no significant correlation in any of the traits. Except for the weight of cob without shell and yield, all traits had a negative and non-significant correlation. Ear length had a positive and significant correlation with plant height and ear weight with the shell, which significantly increased compared to stress conditions (r = 0.93**). In a study of 12 maize hybrids, examined the correlation between agronomic traits with different parameters and traits (Shojaei et al., 2022; Bodnár et al., 2018).

Correlation of traits in maize under drought stress conditions

Correlation coefficients between traits under stress conditions (*Table 5*) showed that there was a positive and significant correlation between grain yield and height, ear length and grain per row at the level (p≤0.01), which increased compared to stress conditions. It was impressive. The correlation coefficient of harvest index with leaf area at the level (p≤0.01) was negative and significant (r = -0.91**). The correlation coefficient of number of grains per ear was positive and significant with plant height. Also, the number of grains in the ear row showed a positive and significant correlation with ear height and length at the surface (p≤0.05). Leaf area had a significant correlation with stem diameter and plant weight at the surface (p≤0.05). The number of ears had a significant correlation with the weight of ear wood and the weight of 5 sticks at the level (p≤0.05). Total dry weight had a positive and significant correlation with cob weight with shell, plant weight, ear length and grain per row (p≤0.01). The height traits and the ear and grain length traits in the row, which were as yield components and as an important feature showed a high positive correlation at the level (p≤0.01) to be considered to improve plant yield. The observed changes in the relationships of plant traits in different environmental conditions justify the diversity of the results of various

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studies and confirm the importance of paying attention to the experimental environment. The correlation between yield and plant height, ear length and grain in the row is positive and significant, which shows that the above traits affect increasing grain yield. In breeding selection, grain yield can be increased by increasing plant height, ear length and grain in the ear row, grain yield will also increase.

Table 4: **Simple correlation for the mean of traits in studied maize cultivars under stress and non-stress conditions**

	PH	LA	SD	NE	EPL	EWPL	SPW	DE	EL	ERG	NGE	EW	WG	YLD	HI
LA	0.64														
SD	0.59	0.84*													
NE	-0.05	-0.45	-0.74												
EPL	0.91*	0.60	0.45	-0.01											
EWPL	0.65	0.33	0.36	-0.16	0.82*										
SPW	0.56	0.89*	0.83*	-0.23	0.62	0.26									
DE	0.54	0.42	0.68	-0.24	0.47	0.06	0.57								
EL	0.83*	0.63	0.44	0.07	0.93**	0.65	0.77	0.47							
ERG	0.98**	0.71	0.54	-0.11	0.90*	0.66	0.63	0.72	0.85*						
NGE	0.92**	0.38	0.41	0.01	0.73	0.48	0.29	0.75	0.60	0.89*					
EW	0.71	0.38	0.33	0.33	0.89*	0.55	0.6	0.49	0.91*	0.74	0.60				
WG	0.55	0.66	0.58	-0.68	0.17	0.1	0.41	0.46	0.78	0.55	0.59	-0.09			
YLD	0.88*	0.41	0.29	0.30	0.94*	0.71	0.45	0.56	0.89*	0.83*	0.79	0.95*	0.04		
HI	-0.08	-0.74	-0.79	0.54	-0.1	0.11	-0.8	-0.30	-0.64	-0.34	0.15	-0.01	-0.37	0.16	
WES	0.80	0.86*	0.82*	-0.29	0.82*	0.73	0.81*	0.39	0.82*	0.81	0.34	0.63	0.52	0.41	0.51

**, * and ns: show significant differences in the probability level of 0.01 and 0.05, respectively

Table 5: **Simple correlation of traits in the studied maize cultivars under normal experimental conditions**

	PH	LA	SD	NE	EPL	EWPL	SPW	DE	EL	ERG	NGE	EW	WG	YLD	HI
LA	0.22														
SD	0.14	0.81*													
NE	-0.16	-0.40	-0.44												
EPL	0.60	-0.68	-0.31	0.11											
EWPL	0.31	-0.25	-0.33	-0.02	0.76										
SPW	0.58	0.90*	0.67	-0.11	0.88**	0.42									
DE	0.28	0.13	0.56	-0.73	0.21	-0.32	0.08								
EL	0.67	0.49	0.34	-0.06	0.64**	0.71	0.83*	-0.17							
ERG	0.89*	0.51	0.40	-0.40	0.73	0.49	0.63	0.42	0.86**						
NGE	0.81	0.05	0.34	-0.53	0.16	0.10	0.12	0.64	0.42	0.64					
EW	0.21	0.64	0.35	0.46	0.85	0.27	0.66	-0.33	0.69	0.28	-0.01				
WG	0.52	0.41	0.54	-0.85*	-0.28	0.24	0.43	0.83*	0.44	0.66	0.65	-0.12			
YLD	0.93**	0.41	0.29	-0.28	0.76	0.60	0.66	0.23	0.92*	0.95**	0.54	0.40	0.74		
HI	0.02	-0.91**	-0.71	0.50	0.53	-0.36	-0.80	-0.29	-0.42	-0.45	0.09	-0.16	0.55	-0.26	
WES	0.45	0.64	0.38	-0.19	0.94**	0.76	0.91**	0.07	0.96**	0.84**	0.33	0.64	0.43	0.85**	-0.54

**, * and ns: show significant differences in the probability level of 0.01 and 0.05, respectively.

Correlation of traits in maize under crest stress conditions

Correlation coefficients between grain yield and the studied traits were not significant under stress conditions (*Table 6*). The correlation coefficient between ear length and height was positive and significant. Grain traits in the row also had a positive and significant correlation with height, ear weight with shell at the surface ($p \leq 0.01$) and for ear length at the surface ($p \leq 0.05$). The correlation coefficient of a number of grains per ear was also significant with height and weight of cob with and without shell. The weight of 5 ear sticks showed a significant correlation with height, ear weight with husk, seeds in ear row at the level ($p \leq 0.05$) and with ear length at the surface ($p \leq 0.01$). Harvest index showed a significant negative correlation with plant weight at the level ($p \leq 0.05$). Total dry weight showed the highest correlation with leaf area, stem diameter at ($p \leq 0.01$) and for plant weight at surface ($p \leq 0.05$).

Correlation of traits in maize under cob stress conditions

Correlation coefficients between yield and none of the traits were significant under the stress conditions in the maize stage (*Table 7*). The correlation coefficient between ear diameter and height was significant at the level of 0.05. Also, the traits grain in row with plant height, leaf area, at the level of 0.01 and with ear diameter at the level of 0.05 had a positive and significant correlation. The trait grain in ear had a high correlation with ear height and weight with shell at the

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level of 0.05. Ear weight showed a significant correlation coefficient with height traits, ear weight with shell at 0.01 level, and ear weight without shell, grain in row at 0.05 level. Total dry weight also showed a significant correlation with ear weight without shell. By comparing the simple correlation coefficients of traits in maize cultivars, it can be concluded that height, row per row, and ear length traits can be considered important traits in increasing grain yield. These traits can be used in breeding selection. The lack of correlation between traits and grain yield under stress can be explained because corn is very sensitive to stress in the reproductive development stages. This significantly reduces the yield and components and consequently affects the correlation of traits. Also, due to different late, medium and early cultivars in this experiment, their correlations may be different and affect grain yield.

Table 6: **Simple correlation of traits in studied corn cultivars under crest stress conditions**

	PH	LA	SD	NE	EPL	EWPL	SPW	DE	EL	ERG	NGE	EW	WG	YLD	HI
LA	0.61														
SD	0.54	0.74													
NE	0.23	0.16	-0.35												
EPL	0.92**	0.51	0.43	0.01											
EWPL	0.32	-0.03	0.20	-0.34	0.80										
SPW	0.42	0.79	0.83*	0.16	0.36	-0.04									
DE	0.57	0.56	0.71	0.1	0.56	0.32	0.77								
EL	0.86*	0.50	0.57	0.46	0.77	0.52	0.63	0.51							
ERG	0.93**	0.56	0.33	0.20	0.94**	0.63	0.42	0.48	0.86*						
NGE	0.84*	0.15	0.27	0.06	0.88*	0.83*	0.21	0.67	0.56	0.88					
EW	0.71	0.31	-0.04	0.79	0.57	0.24	0.36	0.38	0.73	0.34	0.44				
WG	0.21	0.78	0.23	0.16	0.34	-0.08	0.32	0.25	-0.07	0.54	0.34	0.11			
YLD	0.43	-0.12	-0.20	0.001	0.53	0.55	-0.27	-0.23	0.38	0.48	0.27	0.47	-0.47		
HI	-0.21	-0.45	-0.77	-0.01	0.06	0.37	-0.87*	-0.63	-0.18	0.05	0.16	0.13	-0.17	0.44	
WES	0.54	0.93**	0.91**	-0.07	0.64	0.19	0.85*	0.72	0.62	0.61	0.37	0.31	0.30	-0.04	-0.36

**, * and ns: show significant differences in the probability level of 0.01 and 0.05, respectively

Table 7: **Simple correlation of traits in studied corn cultivars under cob stress conditions**

	PH	LA	SD	NE	EPL	EWPL	SPW	DE	EL	ERG	NGE	EW	WG	YLD	HI
LA	0.85*														
SD	0.74	0.82*													
NE	-0.19	-0.17	-0.74												
EPL	0.89*	0.60	0.44	0.16											
EWPL	0.46	0.47	0.72	-0.45	0.81										
SPW	0.52	0.86*	0.66	-0.64	0.41	0.28									
DE	0.85*	0.67	0.47	0.14	0.73	0.12	0.45								
EL	0.75	0.77	0.24	-0.26	0.71	0.40	0.54	0.60							
ERG	0.96**	0.95**	0.79	-0.08	0.75	0.49	0.43	0.84*	0.76						
NGE	0.84*	0.67	0.44	0.12	0.85*	0.60	0.52	0.73	0.72	0.80					
EW	0.93**	0.73	0.72	-0.14	0.92**	0.83*	0.60	0.67	0.70	0.83*	0.71				
WG	0.46	0.43	0.44	-0.35	0.02	0.04	0.02	0.20	0.04	0.40	0.49	0.02			
YLD	0.60	0.55	0.06	0.37	0.72	0.38	0.44	0.70	0.61	0.47	0.42	0.63	-0.50		
H.I.	0.36	-0.21	-0.07	0.65	0.47	0.42	-0.42	0.43	-0.09	0.08	0.34	0.33	-0.14	0.55	
WES	0.48	0.53	0.58	-0.44	0.58	0.84*	0.56	-0.02	0.53	0.42	0.34	0.67	0.05	0.17	-0.13

**, * and ns: show significant differences in the probability level of 0.01 and 0.05, respectively

Regression analysis for the mean of traits in different maize cultivars

The regression analysis results for the mean of the traits showed that the trait of total cob weight had a higher beta coefficient and this indicates that the above trait has a greater effect on grain yield (*Table 8*). The obtained coefficient of explanation (0.902) showed that the high justification of performance by the attribute entered into the model at this level.

Table 8: **Regression coefficients for the mean of performance-related traits in the studied cultivars of maize**

Model	Standard regression coefficients	Non-standard regression coefficients	Non-standard standard deviation	Significant level
WES	0.950	2.902	0.477	0.004
E.W.	---	1020.40	199.71	0.007
				R^2=0.902

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The regression analysis results obtained from Jalali et al. (2020) showed that 1000-grain weight, leaf area and cob percentage had a negative effect on grain yield, which showed that with increasing these traits, yield increased, while increasing the percentage of ears will reduce yield.

CONCLUSIONS

The analysis of variance of data in field conditions showed a significant difference between cultivars in terms of some studied traits, which indicates the existence of genetic differences between cultivars. From the study of correlation coefficients between maize traits in non-stress conditions, it can be concluded that the most important components of grain yield are ear length and grain per row. Correlation coefficients in water stress conditions show that the seed trait in the row has a positive and significant correlation with yield, but in the stress stage in the ear stage did not show any correlation with yield, so the grain trait in the row can be the most important plant characteristic to improve yield in conditions tensions should be noted. Regression analysis for mean stress levels showed that ear weight trait with high coefficient of determination with grain yield has a greater effect on grain yield and this shows that this trait has done high justification of yield.

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