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Categorization of wheat genotypes during drought stress using principal component analysis

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An experimental design consisting of randomized full blocks with three replications during stress and non-stress circumstances was executed in Khalkhal city during the crop year 2020-21 to assess the genotypes of drought-resistant wheat. A total of 14 genotypes were used in the study. Stress sensitivity index, tolerance index, mean productivity index, tolerance index, stress tolerance index, geometric mean productivity index, and harmonic mean focusing on grain genotype yielding in a stressful setting, Ys and stress-free, Yp were estimated during this research. There was a statistically significant difference in grain output between the genotypes evaluated during standard irrigation, according to an analysis of variance of grain efficiency under drought tension and regular drainage system. Genotypes No. 14 (4458 kg/ha) and 14 (4325 t / ha) exhibited the greatest mean grain yields during standard irrigation and drought stress, respectively. In considerations of grain yield reaction to stress, various genotypes appeared to have varying sensitivity or resistances. The MP, GMP, TOL, STI, and HM indices varied significantly across the genotypes examined during this research. In drought-stressed and non-drought-stressed situations, indices demonstrated a positive and substantial connection with grain genotype yield at the 1% probability level. Consequently, the most resistant genotypes contain a significant proportion of these indicators. There was a positive and substantial link between the TOL index and efficiency during typical irrigation circumstances, for instance. However, it has a negative and substantial association with effectiveness during drought stress circumstances. 98.1% of the overall alterations were attributable to the first and second main components. The primary component featuring 74.22% alteration in yield capacity and drought tolerance and also the secondary component featuring 23.88% variation were designated as drought-tolerance components. During standard irrigation and drought stress, it was determined that mean productivity, stress tolerance, geometric mean productivity, and mean harmonic productivity were the most valuable indicators for selecting genotypes, according to findings of correlation analysis between indices and mean yield. Genotypes containing lower TOL and SSI and high yield during extreme drought tension and vice versa. As a result, the second factor might be referred to as a drought susceptibility factor.

Keywords: Wheat, Drought stress, Stress tolerance indices, Correlation, Principal components analysis

INTRODUCTION

Wheat is a member of the spermatophyte and angiosperm subfamilies and is classified as a monocotyledon. It is categorized as a member of the order Glumiflorea and the genus Triticum. Wheat's origin is believed to be in southwest Asia (Abdi 2021, Alizadeh 2021, Karasakal 2021, Mohammadzadeh 2021, Radmanesh 2021), and it is the world's most significant crop as a result of its distinctive properties. A considerable portion of the world's land is dedicated to the cultivation of wheat, making it the most prominent cereal crop in terms of area under cultivation and yearly output(Gholamin and Khayatnezhad 2020, Bi, Chen et al. 2021, Guo, She et al. 2021, Hou, Li et al. 2021, Huang, Wang et al. 2021, Wang, Shang et al. 2021, Wang, Ma et al. 2022). Agriculture has a huge issue nowadays: meeting global demand for wheat owing to the rising global population (Hamam, 2008). Iran's and the world's wheat harvests are both hampered by drought, which is one of the primary causes (Gholamin and Khayatnezhad 2020, Khayatnezhad and Gholamin 2020, Chen, Khayatnezhad et al. 2021, Shi, Khayatnezhad et al. 2021, Sun and Khayatnezhad 2021, Wang, Ye et al. 2021, Wang, Khayatnezhad et al. 2022). 90% of Iran's territory is dry or semi-arid, according to the World Food Organization (FAO, 2018). Drought stress affects around 33% of the world's wheat area, with 55% of the wheat acreage throughout developing nations, particularly Iran, being impacted in some way (Tousi Mojarad et al., 2005). Drought stress occurs when a crop's genetic capacity is restricted because of insufficient water supply, both in terms of volume and dissemination, during its life span

(Mitra, 2001). Drought's impact changes with time, length, and intensity (Cheng, Hong et al. 2021, Khayatnezhad and Nasehi 2021, Xu, Ouyang et al. 2021, Yin, Khayatnezhad et al. 2021, Zhang, Khayatnezhad et al. 2021, Zhang, Khayatnezhad et al. 2022). The quantity and dissemination of rainfall in places like Iran, where the volume of rainfall is low, and the dispersion of rainfall fluctuates from year to year, is problematic to anticipate in advance. Selective indicators focused on grain yield during stressful settings, and without drought, circumstances have been suggested to distinguish drought-resistant genotypes in the field. To select for high-yielding genotypes, a selection index must discriminate between genotypes under stress and cases under non-stress (Gholamin and Khayatnezhad 2020, Karasakal, Khayatnezhad et al. 2020, Ma, Ji et al. 2021, Ren and Khayatnezhad 2021, Sun, Lin et al. 2021, Tao, Cui et al. 2022). A study conducted by Fischer and Maurer (1978) found that all drought interventions severely reduced the efficiency of a variety of dwarf and tall spring wheat types in settings with varied drought degrees; Relative to grain abundance, grain weight was reduced more significantly during their investigation with milder drought interventions. While the proportion of seeds was lowered by extreme drought. They suggested that the grain yielding level under drought situations is the criteria for drought tolerance. A beginning step for discovering drought resistance features and choosing genotypes for breeding in dry areas was to look at genotypes' relative output under drought and water restrictions. Rosille and Hambling (1981) introduced the tolerance index (TOL) and the mean productivity index (MP). As a result, the lower the resistance score, the less susceptible and more appealing the genotypes are against dryness (Karasakal, Khayatnezhad et al. 2020, Khayatnezhad and Gholamin 2020, Zheng, Zhao et al. 2021, Zhu, Liu et al. 2021, Zhu, Saadati et al. 2021). As a result, Fernandez (1992) developed the stress tolerance index (STI) to overcome this deficiency, which is capable of recognizing high-efficiency genotypes in both stressful and stress-free conditions. A genotype with a higher STI index is more drought-tolerant and has better possible productivity. The geometric mean productivity (GMP) was presented by Fernandez (1992) and Kristin et al. (1997). Because the GMP index was stronger in genotype distinction than the MP index, it was founded on Fernandez's STI index. Employing multivariate statistics of the primary components, this research was able to identify drought-resistant wheat varieties.

MATERIALS AND METHODS

In Khalkhal, an investigation was carried out in the cropping years 2017-20 to classify wheat genotypes using principal component analysis during drought stress and standard condition. The design was executed as randomized complete blocks involving three replications employing 14 local and foreign wheat genotypes (Table 1) under two scenarios of drought tension and standard irrigation.

The climate at the experimental location is semi-arid and cold. Soil samples were taken from various locations on the experimental area, ranging in depth from 0 to 30 cm, and transported to the laboratory prior to substrate preparation and cultivation. According to traditional procedures used by the Soil and Water Research Institute, Table 1 shows certain soil parameters of the experimental location. Post-harvest ploughing, disc installation, double vertical leveler, fertilizer sprinkling, and furrowing were all incorporated in the land preparation process. Four hundred seeds per square metre and the 1,000-seeds weight for each cultivar were employed to calculate the total number of seeds. Leakage has been used as a method of irrigation. No irrigation was applied twice in case of drought after blooming. Soil test-based chemical fertilizer has been supplied at a frequency of 50-90-120 kg/ha, with the N-P-K formula as the foundation. Weed removal was carried out by hand. Following the investigation was completed and all of the plants had undergone physiological testing, the final product from each plot was collected. As a result, drought resistance and sensitivity indicators were computed considering the yield of genotypes during standard irrigation and drought tension:

$SI = 1 - (Y2/Y1)$

$SSI = (1-(Ysi/Ypi))/SI$

$MP = (YPi + YSi) / 2$

$TOL = (YPi - YSi)$

$STI = (YPi \times YSi)/Yp2$

$GMP = \sqrt{YPi \times Ysi}$

$HM = 2(Ypi \times Ysi)/(Ypi+Ysi)$

The grain yield during stress-free (Yp) and drought stress (Ys) settings has been evaluated utilizing SPSS software after several drought tolerance indicators were determined. Duncan's multiple range test was used to compare mean values. Factor analysis was subsequently conducted using the varimax rotation approach concerning the characteristics evaluated, based on correlation coefficients.

Table 1- Soil physicochemical characteristics

Salinity (ds/m)	pH	Saturation (%)	Lime (%)	Clay (%)	Silt (%)	Sand (%)	Texture
2.05	7.7	52	4.8	38	99	30	Loamy clay
Organic carbon percentage	Nitrogen (ppm)	Absorbable phosphorus (ppm)	Absorbable potassium (ppm)	Zinc (ppm)	Iron (ppm)	Copper (ppm)	Manganese (ppm)
0.865	0.07	2.1	592	2.22	2.48	8.22	4.08

RESULTS AND DISCUSSION

One of the accumulating consequences of wheat's essential components is its grain productivity (frequency of grains per spike, frequency of spikes per unit zone, and grain weight). Environmental and genotypic interactions, as well as management approaches, affect these components. In order to choose high-yielding cultivars, recognizing such components and their correlation with grain yielding might be useful (Gholamin and Khayatnezhad 2020, Jia, Khayatnezhad et al. 2020, Li, Mu et al. 2021, Zhao, Wang et al. 2021, Li, Khayatnezhad et al. 2022). Genotypes under standard irrigation were shown to vary in grain output from those experiencing drought stress during an analysis of variance of grain yielding and resistance indicators. Nevertheless, there was no discernible variation between the genotypes tested when exposed to drought tension (Table 2).

Genotypes No. 14 (4458 kg/ha) and 14 (4325 t / ha) had the greatest mean grain yields during standard irrigation and drought stress, respectively. Nevertheless, examining the mean grain yield in both settings independently demonstrated that genotypic differences were more pronounced during drought stress than regular irrigation. Consequently, it appears that genotypes varied in their susceptibility or tolerance against tension, as measured by grain yield reaction (Figure 1).

Comparable findings have been achieved through other studies (Kordovani, 2000). The MP, GMP, TOL, STI, and HM indices varied significantly across genotypes in this investigation (Table 2).

Most of the indices mentioned above—STI, MP, GMP, and HM—display these traits. A positive and statistically significant association between grain genotype yield and these parameters was found at a probability threshold of 1% in drought tension and regular irrigation settings. Consequently, the most resistant genotypes contain a considerable proportion of these indicators. There was a positive and substantial link between the TOL index and effectiveness under typical irrigation circumstances, for instance. Nevertheless, its connection with drought-stressed effectiveness is negative and substantial (Table 3).

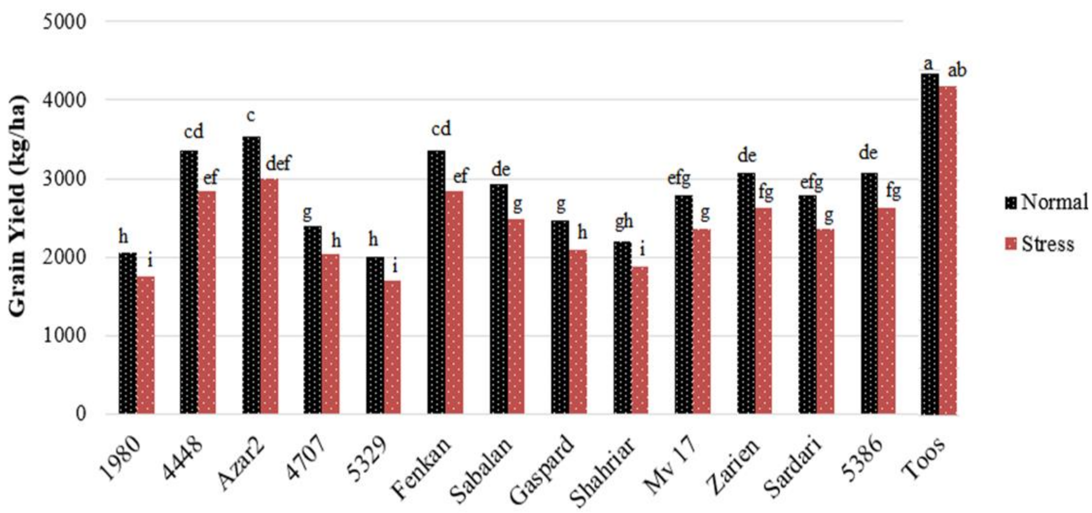

Figure 1: Comparison of mean grain yield during standard settings and drought tension

Table 2 - Analysis of variance of various indices of drought resistance and grain yield of bread wheat during drought tension and standard irrigation

Source	df	Mean Square							
		YP	YS	SSI	MP	GMP	TOL	STI	HM
Replication	2	16.85**	0.422 ns	0.108ns	6.064**	3.31**	15.3**	0.130**	1.20**
Genotype	13	3.852**	0.842 ns	0.508 ns	2.852**	3.01**	10.7**	0.105**	0.952*
error	26	1.895	0.552	0.468	0.528	0.408	3.22	0.043	0.346
** ,* and ns: indicate significance at the level of 5, 1% probability and no significant difference, respectively									

Table 3: Findings of correlation coefficients between various indices and grain yield during drought tension and standard irrigation

	YP	YS	SSI	MP	GMP	TOL	STI
YS	-0.001	1					
SSI	0.854**	-0.465**	1				
MP	0.905**	0.408*	0.6**	1			
GMP	0.842**	0.564**	0.502**	0.88**	1		
TOL	0.905**	-0.439*	0.941**	0.82**	0.64**	1	
STI	0.751**	0.501**	0.461**	0.95**	0.89**	0.65**	1
HM	0.700**	0.608**	0.280	0.78**	0.93**	0.42*	0.88**

Table 4: Special values and vectors of eight indices for drought resistance of the evaluated cultivars

Component	Total	% of Variance	Yp	Ys	SSI	MP	GMP	TOL	STI	HM
1	7.702	74.22	0.941	0.321	0.673	0.994	0.964	0.755	0.956	0.873
2	3.22	23.88	-0.323	0.944	-0.704	0.049	0.264	-0.648	0.262	0.471

Tolerant genotypes are those with lower scores of this index. Consequently, screening relying on this indicator contributes to collecting genotypes performing well in drought-stressed situations. However, they function poorly in a typical irrigation setting. It is impossible to detect tolerant genotypes using this index or the SSI index. Other investigators' conclusions were in agreement with the results of GMP, MP, and STI in this case study (Gholamin and Khayatnezhad 2021, Khayatnezhad and Gholamin 2021, Ma, Khayatnezhad et al. 2021). Identical results regarding wheat were published by Talebi et al. (2010), Attarbashi et al., and Sobhani and Chowhdry (2000). Based on two components, Table 4 displays the particular scores and vectors of the investigated genotypes. 74.22% of the alterations are represented by the initial vector.

This component demonstrates that the strongest positive coefficients were found in the MP, GMP, TOL, STI, HM indices and effectiveness during standard circumstances. This means that genotypes with higher output are picked during screening relying on the initial component. Accordingly, focusing on the initial component, genotypes exhibiting good yields during standard irrigation circumstances and minimal TOL and SSI are chosen. As a result, this component is capable of distinguishing between cultivars with higher and lower capacities. As a result, it's a factor in terms of both efficiency capacity and drought resistance. Ys, SSI, and TOL were linked to the second component, which described 23.88% of the variations. As a result, this component can discriminate between drought-tolerant and drought-sensitive genotypes. Consequently, genotypes exhibiting lower TOL and SSI and excellent yields during drought tension may be chosen, and conversely (Si, Gao et al. 2020, Khayatnezhad and Gholamin 2021, Liu, Wang et al. 2021, Peng, Khayatnezhad et al. 2021). As a result, the second factor might be referred to as a drought susceptibility factor. Identical findings have been reported by other studies (Bray, 1997) as well. 98.1 percent of the overall difference was due to the first and second main components

CONCLUSION

Mean productivity indices, stress tolerance, geometric mean productivity, and mean harmonic were found to be the most suitable indices for selecting genotypes during drought tension and standard irrigation settings, according to the findings of correlation analysis and mean yielding under two situations. Genotypes exhibiting lower TOL and SSI and effectiveness may be chosen in drought-stressed conditions and vice versa. As a result, the second factor might be referred to as a drought susceptibility factor.

CONFLICT OF INTEREST

The authors declared that present study was performed in absence of any conflict of interest.

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AUTHOR CONTRIBUTIONS

Sina Mohammadzadeh conducted, planned, Analyzed the data, wrote manuscript and interpreted the results and involved in manuscript preparation. All authors read and approved the final version.

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