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Proceeding Paper

Investigation of Relationships between Yield and Yield Components in Bread Wheat Using Causality Analysis under Salinity Stress Conditions †

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Abstract: Inanimate stresses, such as salinity, affect plant growth and reduce grain yield. One of the objectives of this study was to identify the agronomic traits related to changes in grain yield of the purified bread wheat under normal conditions and salinity stress. In this study, 111 pure bread wheat lines were examined as an Augmented experiment (When the number of lines is high or the grain density is low, it is not possible to perform duplicate tests, so the design is used without Augmented duplication.) in two research fields of Yazd province, Iran, in the 2020 crop year. In this experiment, after planting 20 genotypes, three wheat cultivars named Narin, Barzegar, and Sistan were planted as the control. During the growth period, yield traits and yield components were evaluated considering morphological traits and compared with the control cultivars. The experimental results showed great diversity in the studied genotypes in terms of most quantitative and qualitative traits. Also, Correlation results showed that in both normal and stress conditions, the grain number, 1000-kernel weight, and spike weight had a positive and significant correlation with grain yield, in stepwise regression, the grain number, 1000-kernel weight, days to heading, plant height, and spike length were included in the model, and even in path analysis, 1000-kernel weight and the grain number per spike had a direct effect on grain yield. Therefore, selection can be done based on 1000-kernel weight and the grain number per spike and reduction of days to heading, in order to achieve salinity-tolerant lines.

Keywords: genetic; cultivar; salinity; correlation; yield

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1. Introduction

Soil salinity is among serious soil problems threatening the stability of the agricultural products in a large area (Flowers, 2004). Grain yield decreases when salinity reaches a threshold and no yield reduction is observed until it reaches this threshold [12]. Some researchers have pointed out higher grain yield under salinity stress conditions, compared to biological yield, as the best criterion for salinity tolerance [9]. The selection of high production genotypes under salinity stress can be the most effective way to increase grain yield and improve salinity tolerance of wheat genotypes [16]. Yield components and agronomic traits have higher heritability than grain yield, which can be used as a criterion for identifying plant salinity tolerance and improving yield of varieties under salinity and drought stress conditions [8,10] Therefore, the aim of this study was the Investigation of

Relationships between yield and yield components in Bread Wheat using causality analysis under salinity stress conditions.

2. Material and Methods

Before starting the experiment, composite sampling was performed on the farm soil and different physical and chemical properties of the soil of the planting site were studied. In the saline conditions, based on soil test (Table 1), 100 kg potassium sulfate and 100 kg ammonium disulfate before planting, and 250 kg urea fertilizer in divided form in 3 stages of tillering, stalking and grain filling were considered.

Table 1. Analysis of soil texture and soil physical and chemical characteristics of the tested site.

Soil Texture	P (mg/Kg)	K (mg/kg)	CO (%)	Silt (%)	Clay (%)	Sand (%)	pH	EC (ds/m)
Sandy Loam	8.10	220	0.33	21	17	62	7.8	4.55

The genetic materials used in this study included 111 wheat lines along with three control cultivars: Narin, Barzegar and Sistan. This population was obtained after 6 generations of self-selection and selection through the modified bulk deformation method. The lines studied in 2020 were planted in a non-repetitive experiment (agglomeration) in two farms: first with saline conditions (electrical conductivity 10 dS/m) and second with normal conditions (electrical conductivity 3 dS/m). Each line was evaluated without repetition, while to check their production capacity, three cultivars Narin, Barzegar and Sistan were repeated as controls at intervals of 20 lines. Each genotype was planted in two lines with a length of 2.5 m, at a distance of 20 cm. The irrigation of the land was of the flood type. Sampling was performed on the soil to a depth of 30 cm during the growing season to determine soil salinity in the root development zone. The average salinity of the soil-saturated extract during the growing season was 10 dS/m. Due to the use of the leaching coefficient during the period, about 25% more water was given to the land in addition to irrigation water, aiming at maintaining soil salinity at about 10 dS/m. Seeds were sown under normal conditions and salinity stress with densities of 400 and 500 seeds per square meter, respectively. During the growing season, genotypes in terms of different traits such as days to heading (DHE), days to maturity (DMA), plant height (PLH), Thousand-kernel weight, spike length (SL), grain number per spike (GNP), grain weight per spike, spikelet number per spike, spike weight and grain yield (GY) were evaluated and compared with the control cultivars. As the genotypes did not have duplication, the statistical analysis of the data was performed based on descriptive statistics including the minimum, the maximum, range, mean, standard deviation and coefficient of variation associated with all quantitative traits. GY in the studied genotypes was compared with the average yield of the controls planted on both sides of the genotype as a percentage of production. To summarize the main aspects of the changes observed in the variables via a smaller number of linear combinations, multivariate analysis by stepwise regression was used. The statistical analysis was performed using SPSS, SAS and Statgraghic software.

3. Results and Discussion

Under salinity stress conditions, the decrease in mean GY, Thousand-kernel weight, SL, SNP, GNP, spikelet number per spike, and spike weight and PLH were observed compared to control cultivars (Table 2).

Table 2. Mean of studied traits for controls and 111 bread wheat genotypes in control and salt-stress conditions.

Genotype	Environment	GY (kg ha^{-1})	Thousand Kernel Weigh (g)	DHE	DMA	SL (mm)	PLH (cm)	G.W per Spike (g)	G. No per Spike	Spikelet. No per Spike	Spike Weight (g)
1	N	6571.4	36.7	75.1	126.0	100.3	94.3	2.7	51.5	18.8	5.0
	S	3200.0	36.2	77.2	118.8	80.1	66.1	2.4	43.4	13.0	4.2
2	N	7285.7	39.5	77.8	128.1	100.4	91.0	2.6	48.5	17.7	4.9
	S	3014.3	35	82.1	121.3	80.6	57.7	2.3	40.9	13.3	4.3
3	N	7285.7	39.1	78.6	128.3	90.6	92.3	2.7	41.5	17.1	5.0
	S	3100	31.0	82.4	122.3	75.6	54.6	2.3	39.8	15.6	4.3
4	N	5663.1	30.1	78.3	128.7	100.5	99.6	2.3	47.1	18.8	4.7
	S	2100.9	32.1	81.7	122.9	82.6	65.3	1.6	35.3	14.2	3.6

N: normal, S: stress, 1: Narin, 2: Barzegar, 3: Sistan, 4: Lines for abbreviations materials and methods.

2.5 times difference in GY of lines under the normal conditions (5663 kg/ha), compared to stress conditions (2100 kg/ha), indicated that plants had spent most of their growth period in salinity and the amount of toxic chlorine and sodium ions naturally increased in leaves with increasing salinity; therefore, a decrease in yield could be attributed to the high accumulation of ions within the plant. Under salinity stress, a lot of energy was used by the plant to regulate the osmotic conditions to counteract the adverse effects of salinity, reducing the plants' available energy for normal activities and thus weakening and reducing plant growth and efficiency in the inactivated absorption. Furthermore, the reduction of energy in the plant reduced the active absorption of various elements, leading to decreased efficiency of the roots in providing nutrients and water to other organs. Therefore, the growth of shoots was decreased, resulting in the reduction of the dry matter production by salinity stress [7,11].

3.1. Correlation between Traits

Under salinity stress conditions, a positive and high correlation was observed between grain yield with Thousand-Kernel weight, grain weight per spike, grain number per spike and spike weight (Table 3). A significantly negative correlation was observed between grain weight per spike and the number of days to flower, ripen and heighten of the plants under salinity stress (Table 3). In both normal and salinity conditions, a positive and significant correlation was observed between grain weight, grain number per spike and spike weight with grain yield (Table 3). In this study, a significant negative correlation was observed between PLH and spikelet number per spike, the grain number and grain weight per spike and spike weight under stress conditions (Table 3). The relationship between biological yield and grain yield under normal conditions was more positive than stress conditions. In this experiment, the number of grains per spike under normal conditions (0.344) and grain weight per spike under saline conditions (0.497) had the highest positive and significant correlation with grain yield (Table 3).

Table 3. Simple correlation coefficients between traits measured on bread wheat genotypes and controls in control (upper part of diagonal) and salt-stress conditions (beneath part of diagonal).

Trait	*GY (kg ha^{-1})*	*Thousand Kernel Weight (g)*	*DHE*	*DMA*	*SL (mm)*	*PLH (cm)*	*GW per SPIKE (g)*	*G. No per Spike*	*Spikelet. No per Spike*	*Spike Weight (g)*
GY	1	0.155	0.179	0.251 **	0.273 **	−0.281 **	0.219 *	0.344 **	0.118	0.314 **
Thousand Kernel weight	0.376 **	1	−0.082	0.026	−0.057	0.147	0.161	−0.022	0.124	0.197 *
DHE	−0.085	0.257 **	1	0.685 **	0.351 **	0.283 **	−0.161	0.176	0.136	−0.002
DMA	−0.091	0.115	0.611 **	1	0.361 **	0.155	−0.096	0.202 *	0.039	0.094
SL	−0.151	0.184-	0.154	0.117	1	0.125	0.001	0.200 *	0.262 **	0.161
PLH	0.024	0.086	0.142	0.167	0.368 **	1	−0.137	−0.192 *	0.119	−0.09
G.w per spike	0.497 **	0.088	−0.347 **	−0.315 **	−0.18	−0.259 **	1	0.571 **	0.247 **	0.877 **
G. No per Spike	0.278 **	−0.087	−0.225 *	−0.143	−0.172	−0.32 **	0.753 **	1	0.374 **	0.676 **
spikelet. No per spike	0.16	−0.035	0.001	0.067	−0.024	−0.125	0.411 **	0.490 **	1	0.331 **
Spike weight	0.481 **	0.065	0.308 **-	−0.231 *	−0.117	−0.280 **	0.933 **	0.759 **		

* $p < 0.05$, ** $p < 0.01$.

The most suitable trait for selecting the salinity-tolerant genotypes is a trait having a high correlation with grain yield under both normal and stress conditions. Therefore, the evaluation of correlations between the salinity-tolerant traits, especially the correlation of traits with grain yield in both normal and salinity environments, can lead to the identification of the most suitable traits for the selection of the salinity-tolerant lines in breeding programs for new cultivars. In previous studies, a positive and high correlation between grain yield and the mentioned traits under drought and salinity stress conditions has been reported [13]. A positive and significant correlation between grain yield, Thousand-Kernel weight and grain number per spike was reported [2,3,15]. In dwarf wheat cultivars, the effect of salinity stress on yield reduction through spikelet number per spike was reported [13].

3.2. Analysis of Causality

Under stress conditions, grain number per spike and Thousand-Kernel weight had the most direct positive effect on grain yield, respectively (Tables 4 and 5). The most indirect positive effect was related to the spikelet number through the grain number per spike. Besides, the high correlation between spikelet number and GY per plant could be due to its indirect effect through the grain number per spike. Under normal conditions, grain number per spike and spikelet number per spike had the most direct impact on grain yield. Nonetheless, the most indirect positive effect on the grain number per spike was associated with the spikelet number per spike and DHE.

Table 4. causality analysis between grain yield and other agronomic traits in terms of salinity.

Traits	Direct Effect	Thousand Kernel Weigh	G. No per Spike	Spikelet. No per Spike	Spike Weight	Total Amount	Correlation with Grain Yield
Thousand Kernel weigh	0.056	****	0.394	0.019	0.020	0.481	0.376 **
G.No per spike	0.379	0.027	****	0.530	0.530	0.933	0.278 **
spikelet.No per spike	0.007	0.015	0.597	****	0.064	0.759	0.160
Spike weight	0.131	0.008	0.326	0.034	****	0.510	0.481 **
Residual effect	0.331						

** $p < 0.01$.

Table 5. causality analysis between grain yield and other agronomic traits in normal conditions.

Traits	Direct Effect	DHE	G. No per Spike	Spikelet. No per Spike	SL	Total Amount	Correlation with Grain Yield
DHE	0.067	****	0.119	−0.005	0.002	0.198	0.1798
G. No per spike	0.742	0.004	****	0.116	0.004	0.876	0.344 **
Spikelet. No per spike	0.203	−0.002	0.424	****	0.019	0.675	0.118
SL	0.098	0.001	−0.072	0.041	****	0.093	0.273 **
Residual effect	0.395						

** $p < 0.01$.

In one study, researchers found that the number of grain per spike and the number of spikes per square meter had the most direct effect on grain yield per plant [5,6]. It has also been reported that the number of grain per spike and the weight of 100 grains had a direct and positive effect on grain yield [1,14]. However, if the number of spikelets and days to flowering do not directly affect grain yield, but indirectly by increasing the number of spikelets per spike and day to flowering and finally the day to ripening increase the number of grain per spike and increase grain yield.

4. Conclusions

The selection based on grain yield was not sufficient due to low heritability, particularly in salinity stress conditions; therefore, it was necessary to prioritize traits having a high and significant correlation with grain yield under salinity stress in breeding programs. In causality analysis, 1000-kernel weight and the grain number per spike had a direct effect on GY. Therefore, selection can be done based on Thousand-kernel weight and the grain number per spike and reduction of DHE, in order to achieve salinity-tolerant lines.

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