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CORRELATION AND PATH COEFFICIENT ANALYSIS IN WHEAT (*TRITICUM AESTIVUM* L.) UNDER VARIOUS DROUGHT STRESS CONDITIONS

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Abstract

The usefulness of path coefficient analysis for interrelationships among traits determining grain yield in bread and durum wheats in three locations was carried out. Treatments were arranged in a split plot experiment based on RCBD with three replications. Main plots were fully irrigated, two-third irrigated (S_1) and one-third irrigated (S_2) of used water based on crop water requirements at various growing stages and subplots were 43 genotypes. Grain yield had the highest correlation with harvest index under all conditions, indicating importance of harvest index to improve grain yield. Direct effects of harvest index and spikes weight per plant on grain yield were the highest and positive under non-stress, S_1 and S_2 conditions, respectively, indicating that direct selection to improve grain yield with these traits would be effective. The highest positive and negative indirect effects on grain yield were also belonged to spikes weight per plant and harvest index, respectively under S1 and S_2 conditions.

Introduction

Wheat is the most widely grown crop in the world (Baenziger *et al.* 2009). The development of high-yielding genotypes requires a thorough knowledge of genetic variation of yield and its components (Shukla *et al.* 2006). Grain yield is a complex quantitative trait, considerably affected by environment (Khan and Naqvi 2012). It is important to determine the contribution of the traits which has the greatest influence on grain yield (Desheva 2016). Drought is one of the major environmental factors reducing grain production of rainfed wheat in arid and semi-arid regions (Miralles *et al.* 2000). The results of correlation and path analysis for grain yield in wheat showed that the most direct effect on grain yield belonged to harvest index under non-stress condition (Mohammad *et al.* 2006). In another report it was found that grain weight per spike and fertile tillers per plant had strongest direct effect on wheat grain yield (Desheva 2016). Wahidy *et al.* (2016) revealed that harvest index and grains number per spike had positive correlation with wheat grain yield under non-stress condition. Subhani and Chowdhry (2000) reported that plant height and harvest index had direct effect on wheat grain yield under drought stress condition. Khan and Naqvi (2012) indicated that spikes number, spikelets number, spike length and grains number may be used as an effective selection criterion for increasing grain yield of wheat under different irrigation levels. Therefore it is aprised that these traits could be selected for the different stress environments and it would be beneficial for grain yield.

The objectives of this study were to estimate the correlations between grain yield and other traits and determine the direct and indirect effects of traits on grain yield in wheat grown under drought stress and non-stress conditions in order to find out suitable traits that could be used for grain yield improvement under both conditions.

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Material and Methods

Forty three wheat genotypes based on their reported differences in yield performance under stress and non-stress conditions were planted in field at the research station of Agricultural College, Mohaghegh Ardabili University, Ardabil, Iran (38.19ºN, 48.20ºE and 1350 m above sea level) (Table 1).

Table 1. The name and growth type of wheat genotypes.

No.	Name	Growth type	No.	Name	Growth type	No.	Name	Growth type
1	Atila 4	Spring	16	Sistan	Spring	31	Kavir	Spring
2	Line 7	"	17	Sholeh	Facultative	32	Golestan	Facultative
3	Aria (durum)	"	18	Shiroodi	Spring	33	Line A	Facultative
4	Pishtaz	"	19	Tabasi	"	34	Maroon	Spring
5	MS-18-14	"	20	Falat	"	35	Marvdasht	"
6	Veerynak	"	21	Bahar	"	36	Moghan1	Facultative
7	Chamran	"	22	Arta	Facultative	37	Mahdavi	"
8	Chenab	Facultative	23	Arvand	Spring	38	Niknejad	Spring
9	Line 10	Spring	24	Akbari (durum)	"	39	Hirmand	"
10	Darab 2	"	25	Back cross Roshan	"	40	Yavarous (durum)	"
11	Darya	"	26	Ghods	Facultative	41	Line8	"
12	Roshan	Facultative	27	Karaj2	"	42	Azadi	"
13	Zagrus	Spring	28	Karaj3	Spring	43	Alborz	"
14	Sepahan	"	29	Karkheh (durum)	"			
15	Sorkh-tokhm	Winter	30	Koohdasht	"			

Three treatments were arranged in a split plot experiment based on Randomized Complete Block Design (RCBD) with three replications. Three treatments were fully irrigated, two drought stress treatments as two-third irrigated (S_1) and one-third irrigated (S_2) of used water based on crop water requirements at various growing stages and subplots were the genotypes.

The experimental plot was fully irrigated until ten days before pollination stage and from this point onwards, the two levels of drought stress were applied. To estimate the physical characteristics of soil and crop water requirement, the field capacity moisture was measured using plots of 1 m × 1 m without the plant dimensions, saturated with water and covered with plastic black depths of 15, 45 and 75 cm from the soil surface. Before planting, CROPWAT-4 software (Penman-Monteith method, according to the FAO-56) was used to determine the amount and timing of irrigation regimes (Allen *et al.* 1998).

In above method, plant water requirement, which contributes in designing and management of irrigation schedule, was estimated by using CROPWAT model. Then, monthly "ETo", plant's data, pattern of cultivation as well as monthly rainfall data were entered into the model. In addition, soil and meteorological data were entered to compute irrigation schedule at the next stage. Given the fact that the water requirement of plant generally is evaluated during the growth season by crop coefficients of the same plant, the plant coefficient (Kc) and index of yield coefficient (Ky) for wheat in Ardabil, was calibrated. Wheat crop water requirement was calculated from grass reference crop evapotranspiration (ETo) × crop coefficient (Kc) of wheat, based on meteorological parameters affecting evapotranspiration.

Each treatment was planted to a plot area of 12 m^2 consisting of 20 rows of 3 m long with plants spaced of 10 cm apart within row and spaced 0.2 m apart between rows, 1 m between main plots and sub plots and 1.5 m between blocks. At physiological maturity stage, eight plant samples were chosen from the middle of each row and were determined. plant height, awn length, spike length, chlorophyll, peduncle length to plant height ratio, peduncle length difference, tillers per plant, spikes per plant, seeds per main spike, spikes weight per plant, seed weight per main spike, 1000-seed weight, harvest index and grain yield were determined. Grain yield was measured at physiological maturity and yield was adjusted to 10% seed moisture content. Harvest index was calculated using the following formula:

Harvest index (%) = (Grain yield / Biological yield) × 100

Biological yield was determined after placing seedlings in an oven at 50°C for 72 hrs.

Step-wise regression was achieved for determination of the best model, which accounted for variation exists in grain yield as dependent variable. The path analysis technique performed according to the method suggested by Dewey and Lu (1959) using the procedure PROC CALIS of the SAS software.

Results and Discussion

Results of ANOVA revealed that genotype effects were statistically significant for all the traits (data not shown). The results showed that grain yield had the highest correlation with harvest index under non-stress, S_1 and S_2 conditions (r = 0.84, r = 0.54 and r = 0.63, respectively), indicating that simultaneous selection regarding harvest index and grain yield is possible to be done. This result was similar to other researchers (Khayatnezhad *et al.* 2010).

Positive correlations occurred between tillers per plant and grain yield in non-stress, S_1 and S_2 conditions, indicating that grain yield increase can be obtained if tillers per plant is increased. The same results were reported by other researchers (Bhutta *et al.* 2006). Significantly positive correlation was estimated between spikes per plant and grain yield in non-stress and S_2 conditions (r = 0.38 and r = 0.27, respectively), which pointed out that grain yield increase per field area unit can be obtained by target selection of wheat toward increasing spikes per plant. The same result was reported by Khan and Naqvi (2012). A significantly positive correlation was only observed between seed weight per main spike and grain yield in S_1 condition (r = 0.21). Therefore, seed weight per main spike seems to be suitable trait to grain yield improvement. Based on correlation between grain yield and other traits, harvest index, tillers per plant and spikes weight per plant were suitable traits to improve grain yield in non-stress, S_1 and S_2 conditions. Some correlation coefficients in non-stress condition were different from those of S_1 and S_2 conditions, indicating that these traits were influenced by drought stress conditions. Wahidi *et al.* (2016) reported similar result for harvest index and grain yield under non-stress condition.

Stepwise regression was run with grain yield trait as the dependent variable and harvest index, spikes weight per plant and awn length as independent variables. The most major factor affecting grain yield was harvest index (R^2 = 0.70) trait under non-stress condition (Table 2).

Table 2. Stepwise regression of grain yield (dependent variable) and other traits (independent variables) under non-stress condition.

Traits	Parameter estimate	Standard error	R^2	T	Probability
Harvest index	0.316	0.010	0.70	31.61	0.000
Spikes weight per plant	0.091	0.006	0.86	14.94	0.000
Awn length	0.092	0.043	0.88	2.16	0.033

When grain yield was considered a dependent variable and harvest index, spikes weight per plant, seed weight per main spike as independent variables, the model determination coefficient was $R^2 = 0.80$. Most of this, $R^2 = 0.38$, was for harvest index trait under S_1 condition (Table 3).

Table 3. Stepwise regression of grain yield (dependent variable) and other traits (independent variables) under S_1 condition.

Traits	Parameter estimate	Standard error	R^2	T	Probability
Harvest index	0.171	0.246	0.38	17.07	0.000
Spikes weight per plant	0.042	0.010	0.67	9.23	0.000
Seed weight per main spike	0.370	0.090	0.76	4.11	0.000
Plant height	0.005	0.003	0.80	1.82	0.071

In S_2 condition, stepwise regression analysis using grain yield as dependent variable indicated that, harvest index, spikes weight per plant and plant height were traits which contributed to gain in grain yield. Particularly, 39% of the variation in grain yield was explained by harvest index, 74% by harvest index and spikes weight per plant altogether and 79% was contributed collectively by harvest index, spikes weight per plant and plant height. This illustrated that the improvement in grain yield was achieved by combination of different factors (Table 4).

Table 4. Stepwise regression of grain yield (dependent variable) and other traits (independent variables) under S_2 condition.

Traits	Parameter estimate	Standar d error	R^2	T	Probability
Harvest index	0.110	0.007	0.39	14.98	0.000
Spikes weight per plant	0.131	0.018	0.74	7.44	0.000
Plant height	0.033	0.012	0.79	2.83	0.006

Since the simple correlation coefficients did not give clear information about the interrelationship between the causal and resultant variables, the correlation coefficient estimates were partitioned into direct and indirect effects to establish the intensity of effects of independent variables on dependent one. The direct and indirect effect values from path analysis are shown in Figs 1, 2 and 3.

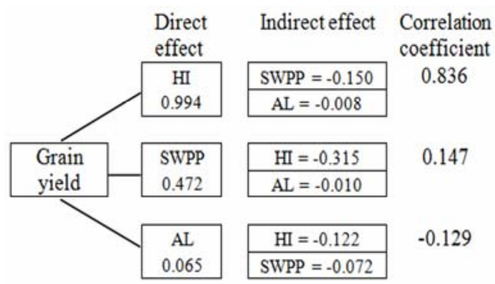

Fig. 1. Path-coefficient values estimated for grain yield and other traits in non-stress condition. Harvest index (HI), spikes weight per plant (SWPP), seed weight per main spike (SWMP), awn length (AL).

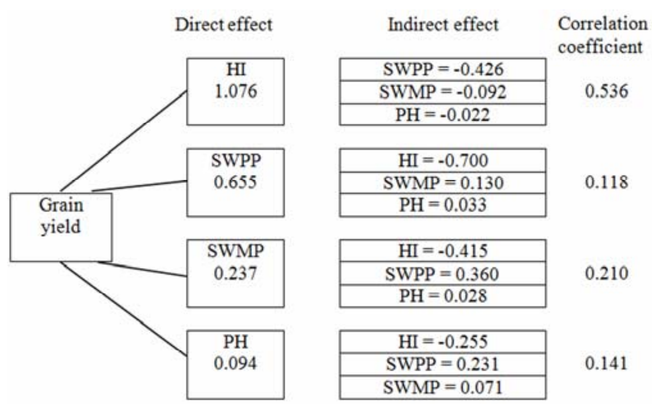

Fig. 2. Path-coefficient values estimated for grain yield and other traits in S_1 condition. Harvest index (HI), spikes weight per plant (SWPP), seed weight per main spike (SWMP), plant height (PH).

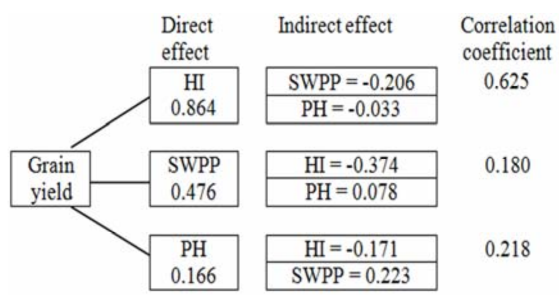

Fig. 3. Path-coefficient values estimated for grain yield and other traits in S_2 condition. Harvest index (HI), spikes weight per plant (SWP), plant height (PH).

In non-stress condition, the estimated correlation coefficient between harvest index and grain yield was 0.836. The direct effect of harvest index was highest, 0.994. Direct selection through harvest index would be effective to improve grain yield. Indirect effect of harvest index via spikes weight per plant was relatively high and negative (–0.150). The indirect effect to the harvest index via awn length was low and negative (–0.008) (Fig. 1). Similar result was found in wheat reporting highest direct effect of harvest index on grain yield (Mohammad *et al.* 2006).

Estimated correlation coefficient at phenotypic level between spikes weight per plant and grain yield was 0.147. The direct effect of spikes weight per plant on grain yield was positive (0.472). Therefore, direct selection through spikes weight per plant would be effective. Indirect effect of spikes weight per plant via harvest index was high and negative (–0.315). The indirect effect to the spikes weight per plant via awn length was low and negative (–0.082) (Fig. 1). Similar results were found in wheat reporting high direct effect of spikes weight per plant on grain yield (Saed-Moucheshi *et al.* 2013). The relationship between awn length and grain yield was –0.129. The direct effect of awn length on grain yield was 0.065. Indirect effect of awn length via harvest index was relatively high and negative (–0.122). The indirect effects to the awn length via spikes weight per plant was low negative (–0.072) (Fig. 1).

In S_1 condition, estimated phenotypic coefficient of correlation between harvest index and grain yield was 0.536. Partial analysis of correlation coefficients showed the highest direct effect of harvest index on grain yield (1.076). Harvest index had relatively high and moderate indirect negative effects on grain yield via spikes weight per plant (–0.426) and seed weight per main spike (–0.092). While, harvest index had low indirect negative effect on grain yield via plant height (–0.022) and caused that correlation decrease between harvest index and grain yield (Fig. 2). Similar result was also reported for harvest index (Gashaw *et al.* 2007, Subhani and Chowdhry 2000) and plant height (Subhani and Chowdhry 2000).

The relationship between spikes weight per plant and grain yield was 0.118. Strong positive direct effect on grain yield was exhibited by spikes weight per plant (0.655). It was ascribed due to strong negative indirect effect of harvest index (–0.700) and positive indirect effect of seed weight per main spike and plant height (0.130 and 0.033, respectively) (Fig. 2). The positive direct effect of spikes weight per plant on grain yield was also reported by other workers (Saed-Moucheshi *et al.* 2013). Positive direct effect on grain yield was occurred due to seed weight per main spike (0.237). The correlation coefficient between this trait and grain yield was positive, 0.210. This was likely due to negative indirect effect of harvest index (–0.415) and positive indirect effect of spikes weight per plant and plant height (0.360 and 0.028, respectively) (Fig. 2). The positive direct effect of seed weight per main spike on grain yield was also reported by other researchers (Dokuyucu and Akkaya 1999).

Estimated phenotypic coefficient of correlation between plant height and grain yield was 0.141, but partial analysis of correlation coefficients indicated low direct effects of plant height on grain yield (0.094). The plant height had relatively high indirect negative effect on grain yield via harvest index (–0.255) and had relatively high and moderate indirect positive effects on grain yield via spikes weight per plant and seed weight per main spike (0.231 and 0.071, respectively) and causes to increase the correlation between plant height and grain yield (Fig. 2). Similar result was also reported for plant height (Jahanbin *et al.* 2011). In S_2 condition, the relationship between harvest index and grain yield was 0.625. However, its direct effect was very high (0.864). Harvest index had moderate and low indirect negative effects on grain yield via spikes weight per plant (–0.206) and plant height (–0.033) and caused that correlation decrease between harvest index and grain yield (Fig. 3). The result was in agreement with (Mollasadeghi *et al.* 2011) for harvest index.

Path analysis under drought conditions indicated that the total positive effect of spikes weight per plant on grain yield (0.180) was the result of positive direct effects of spikes weight per plant (0.476) and negative and positive indirect effects of harvest index and plant height (–0.374 and 0.078, respectively) (Fig. 3). The total positive effect of plant height on grain yield (0.218) seemed to be due to the positive direct effect of plant height (0.166) and negative and positive indirect effects of harvest index and spikes weight per plant (–0.171 and 0.223, respectively) (Fig. 3).

Direct effects of harvest index and spikes weight per plant on grain yield were the highest and positive under non-stress, S_1 and S_2 conditions, respectively, indicating that direct selection to improve grain yield with these traits would be effective. Harvest index had the highest negative indirect effects on grain yield under non-stress condition. The highest positive and negative indirect effects on grain yield were also belonged to spikes weight per plant and harvest index, respectively under S_1 and S_2 conditions.

References

Allen RG, Pereia LS, Raes D and Smith M 1998. Crop evapotranspiration-guidelines for computing crop water requirements-FAO Irrigation and Drainage Paper 56, Food and Agriculture Organization of the United Nations, Rome, Italy.

Baenziger P, Graybosch R, Van Sanford D, Berzonsky W 2009. Winter and specialty wheat. *In:* Handbook of plant breeding, Cereals, Carena MJ (Eds), pp. 251-265. Spinger, New York.

Bhutta WM, Ibrahim M and Tahira 2006. Association analysis of some morphological traits of wheat (*Triticum aestivum* L.) under field stress conditions. Plant Soil Environ. **52**(4): 171-177.

Desheva G 2016. Correlation and path-coefficient analysis of quantitative characters in winter bread wheat varieties. Trakia J. Sci. **1**: 24-29.

Dewey DR and Lu KH 1959. A correlation and path-coefficient analysis of components of crested wheatgrass seed reduction. Agron. J. **51**: 515-518.

Dokuyucu T and Akkaya A 1999. Path coefficient analysis and correlation of grain yield and yield components of wheat genotypes. Rachis Newsletters **18**(2): 17-20.

Gashaw A, Mohammed H and Singh H 2007. Selection criterion for improved grain yields in Ethiopian durum wheat genotypes. Afr. Crop Sci. J. **15**(1): 25-31.

Jahabbin MA, Roshdi M and Zaefizadeh M 2011. Effect of end season drought stress on yield and its components in synthetic wheat. Middle East J. Sci. Res. **9**(3): 330-333.

Khan N and Naqvi FN 2012. Correlation and path coefficient analysis in wheat genotypes under irrigated and non-irrigated conditions. Asian J. Agric. Sci. **4**(5): 346-351.

Khayatnezhad M, Zaefizadeh M, Gholamin R and Jamaati-E-Somarin S 2010. Study of genetic diversity and path analysis for yield in durum wheat genotypes under water and dry conditions. World Appl. Sci. J. **9**(6): 655-665.

Miralles DJ, Richards RA and Slafer GA 2000. Duration of the stem elongation period influences the number of fertile florets in wheat and barley. Aust. J. Plant Physiol. **27**: 931-940.

Mohammad T, Haider S, Amin M, Khan MI and Zamir R 2006. Path coefficient and correlation studies of yield and yield associated traits in candidate bread wheat (*Triticum aestivum* L.) lines. Suranaree J. Sci. Technol. **13**(2): 175-180.

Mollasadeghi V, Imani AA, Shahryari R and Khayatnezhad M 2011. Correlation and path analysis of morphological traits in different wheat genotypes under end drought stress condition. Middle East J. Sci. Res. **7**(2): 221-224.

Saed-Moucheshi A, Pessarakli M and Heidari B 2013. Comparing relationships among yield and its related traits in mycorrhizal and nonmycorrhizal inoculated wheat cultivars under different water regimes using multivariate statistics. Int. J. Agron. **2013**: 1-14.

Shukla S, Bhargava A, Chatterjee A, Srivastava A and Singh SP 2006. Genotypic variability in vegetable amaranth (*Amaranthus tricolor* L) for foliage yield and its contributing traits over successive cuttings and years. Euphytica **151**: 103-110.

Subhani GM and Chowdhry MA 2000. Correlation and path coefficient analysis in bread wheat under drought stress and normal conditions. Pak. J. Biol. Sci. **3**: 72-77.

Wahidy S, Suresh BG and Lavanya GR 2016. Genetic variability, correlation and path analysis in wheat germplasm (*Triticum aestivum* L.). Int. J. Multidiscip. Res. Dev. **3**(7): 24-27.

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