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Character association and path analysis of soybean (*Glycine max* L.) genotypes under water deficit stress

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Abstract

Knowledge of interrelationships between seed yield and its contributing components will improve the efficiency of breeding programs through the use of appropriate selection indices. The objective of this study was to evaluate of interrelationships among seed yield and related characters in four soybean genotypes. The genotypes were evaluated using a split-plots design based on randomized complete block with three replications. The stress conditions consisted of three different levels of water deficit stress: I1: irrigation during all growth stages as control treatment, I2: omit irrigation at the onset of flowering stage (R1) and I3: omit irrigation at the onset of grain filling stage (R6). Under normal and abnormal irrigations the correlation of seed yield and three characters biological yield, oil yield and protein yield were positive significantly. However, under water deficiency the relation between seed yield and oil percent was positive significantly. Path analysis was used to partition the correlations between seed yield and most related characters. Under normal irrigation condition the most direct effect was obtained from number of pod per plant followed by the protein yield and oil yield. Also, in this condition the highest indirect effect was obtained from number of pod through protein yield, followed oil yield through number of pod per plant. Under water deficiency conditions the most direct effect of characters on seed yield was obtained from number of seed per plant, followed the protein yield and oil yield. The most indirect effect of characters was observed from oil yield through number of seed per plant followed the protein yield through number of seed per plant.

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Introduction

The soybean is one of the most important crops in the world. It is an important source of protein in the human food and has been utilized in the formulation of the animals' rations, besides utilization of the grain oil. The most worldwide yield is belonged USA, followed of Brazil, Argentina and China, they are responsible for about 90% of the world yield (Vendruscolo *et al.,* 2007). It's the most important oil crop after canola as seed production. Abiotic stresses can damage *Glycine max* L. Merrill, extremely. It is more sensitive than other food legumes, as *vigna unguiculata* (Roy-Macauley *et al.,* 1992; Silvieira *et al.,* 2003) and also with other crops as *Gossypium hirsutumand* and sorghum bicolor (Inamullah and El-shahaby, 2005). Water deficit stress is one of the most common environmental stresses that affects growth and development of plants (Sadras and Milroy, 1996; Aslam *et al.,* 2006). Drought stress is a permanent constraint to agricultural production in many countries, and an occasional cause of losses of agricultural production (Ceccarelli and Grando, 1996). Thus, improvement of drought tolerance in crop is a major objective of most crop breeding programs, particularly in arid and semi-arid areas of the world (Moustaf *et al.,* 1996). Environmental conditions and genotype interaction affected the relationships among plant characters. Path coefficient analysis has been widely used in crop breeding to determine the nature of relationships between grain yield and its contributing components, and to identify those components with significant effect on yield for potential use as selection criteria (Puri *et al.,* 1982; Kang et al., 1983; Milligan et al., 1990; Williams *et al.,* 1990; Board *et al.,* 1997; Samonte *et al.,* 1998). Path analysis showed direct and indirect effects of cause variables on effect variables. In this method, the correlation coefficient between two traits is separated into the components which measure the direct and indirect effects (Farshadfar, 2004). Generally, this method provides more information among variables than do correlation coefficients since this analysis provides the direct effects of specific yield components on yield, and indirect effects via other yield components (Garcia Del Moral *et al.,* 2003).

Our objective was to determine the relationship between grain yield and related characters. Also, one of the goals this study was founding the direct and indirect effects of morphological traits and seed contents on grain yield.

Materials and methods

Experimental design and Plant materials

An experiment was conducted at the Agricultural Research Station in Shirvan Chardavul, Ilam province, Iran (longitude 46° 36′E, latitude 33° 47′N, altitude 975 m above sea level) in 2010. The climate is characterized by mean annual precipitation of 616 mm, mean annual temperature of 16.9° C. The experiment was arranged as split plot on the basis of randomized complete block in three replicates, with water deficit stress treatments (I1, I2, and I3 for irrigation during all growth stages as control treatment, omit irrigation at the onset of flowering stage and omit irrigation at the onset of grain filling stage, respectively) in main plots and four genotypes (Sahar, Williams, Hobit and Harcor) in sub plots. Sowing was done by hand in plots with five rows 4 m in length and 60 cm apart. All plots were irrigated after sowing. Supplementary irrigation was implemented in the evaporation of 60 mm from the basin evaporation during the whole growing stage.

Statistical analysis

At physiological ripening data were recorded on five randomly selected plants for number of pod per plant, number of grain per pod, number of grain per plant, 100-grain weight, seed yield, biological yield, oil percent, oil yield, protein percent, protein yield and harvest index. Simple linear correlation coefficients were computed and these coefficients were subjected to path analysis as described by Dewey and Lu (1959) using SPSS v.16 software.

Results and discussion

Correlation analysis

Correlation analysis for normal irrigation and water deficit treatments are shown in Table 2 and 3 respectively. Under normal irrigation a negative significant correlation was found between 100-seed weight and number of seed per pod. Also, under this condition a negative significant correlation was found between protein percent and oil percent. In contrast, under abnormal irrigation a positive significant correlation was showed between 100-seed weight with number of pod per plant, number of seed per plant, seed yield, biological yield, protein percent, oil and protein yield. Under both conditions a positive significant correlation was found between number of seed per plant and four characters including seed yield, biological yield, oil and protein yield. Under abnormal irrigation the correlation coefficient of number of seed per pod and protein percent was negative significantly. Under normal irrigation condition positive significant relation was found number of pod per plant and four other characters comprising seed yield, biological yield, oil percent, oil and protein yield; however, under water deficiency relation between number of pod per plant and oil percent not significant. Thus, these results showed some changes for soybean seed characters relationships due to irrigation conditions. Previous studies indicated positive associations between number of pods per plant, number of seeds per plant and seed yield in soybean (Shinde *et al.,* 1996; Taware *et al.,* 1997; Malik *et al.,* 2006). Under normal and abnormal irrigations the relation of oil percent and protein percent was negative significantly. In contrast, in both conditions relation of oil yield and protein yield was positive significantly. As compare to irrigation condition, under water deficiency an increasing was found for relation of seed yield with oil yield and protein yield. In the work carried out by Ghassemi-Golezani and Farshbaf-Jafari (2012), there was a significant correlation found between the oil yield and protein yield with seed yield. These results illustrated that morphological characters affected some yield components significantly differently depending on the available water. Therefore selection of soybean genotypes for water deficiency conditions must be upon changes of yield components and other morphological character relations especially number of seed per plant, 100-seed weight and number of pod per plant. In soybean, Kobraei *et al.* (2011) reported positive significant correlation between seed yield and many other characters comprising yield components.

Table 1. Correlation coefficients between characters measured in normal irrigation condition.

	100-seed weight (grplant^{-1})	Number of seed per pod	Number pod per plant	Number of seed per plant	Seed yield (kgha^{-1})	Biological yield (kgha^{-1})	Harvest index	Oil percent	Protein percent	Oil yield	Protein yield
100-seed weight (grplant^{-1})	1										
Number of seed per pod	-0.63*	1									
Number pod per plant	-0.06	-0.36	1								
Number of seed per plant	-0.29	-0.04	0.94**	1							
Seed yield (kgha^{-1})	0.14	-0.34	0.95**	0.90**	1						
Biological yield (kgha^{-1})	0.24	-0.20	0.65*	0.63*	0.76**	1					
Harvest index	-0.1	-0.20	0.34	0.29	0.24	-0.44	1				
Oil percent	0.21	-0.50	0.60*	0.47	0.58*	0.24	0.46	1			
Protein percent	0.28	0.03	-0.29	-0.31	-0.19	0.05	-0.37	-0.74**	1		
Oil yield	0.21	-0.48	0.87**	0.76**	0.88**	0.55	0.41	0.89**	-0.53	1	
Protein yield	0.28	-0.33	0.77**	0.71*	0.86**	0.76**	0.03	0.19	0.32	0.58*	1

* and ** Significant at 5% and 1% probability levels, respectively.

Path analysis

Path analysis for normal irrigation and water deficiency conditions were showed in Table 3 and 4, respectively. Under normal irrigation condition the most direct effect of characters on seed yield was obtained from number of pod per plant (0.563) followed by the protein yield (0.553) and oil yield (0.388). The most indirect effect of characters on seed yield was obtained from number of pod through protein yield (0.427) followed oil yield through number of pod per plant (0.490). Under water deficiency conditions the most direct effect of characters on seed yield was obtained from number of seed per plant (0.648) followed the protein yield (0.377) and oil yield (0.313). The most indirect effect of characters on seed yield was observed from oil yield through number of seed per plant (0.575) followed the protein yield through number of seed per plant (0.570). Under water deficiency conditions the direct effect of number of seed per plant on seed yield was increased noteworthy but indirect effect of number of seed pod per plant were decreased. Correlation and path analysis are the two best approach to determine these relations that has been used by many researchers in different crops. In other crops, Khalili *et al.* (2013) showed effects of most important yield components on seed yield by path analysis in safflower. Zarei *et al.* (2012) in corn reported direct and indirect effects of yield components on grain yield.

Table 2. Correlation coefficients between characters measured in water deficiency condition.

	100-seed weight (grplant^{-1})	Number of seed per pod	Number pod per plant	Number of seed per plant	Seed yield (kgha^{-1})	Biological yield (kgha^{-1})	Harvest index	Oil percent	Protein percent	Oil yield	Protein yield
100-seed weight (grplant^{-1})	1										
Number of seed per pod	-0.04	1									
Number pod per plant	0.47*	-0.1	1								
Number of seed per plant	0.44*	0.13	0.97**	1							
Seed yield (kgha^{-1})	0.62**	0.10	0.95**	0.97**	1						
Biological yield (kgha^{-1})	0.63**	0.25	0.77**	0.82**	0.87**	1					
Harvest index	-0.09	-0.35	0.27	0.19	0.13	-0.33	1				
Oil percent	-0.05	-0.16	0.03	0.01	-0.01	0.24	-0.08	1			
Protein percent	0.46*	-0.51*	0.22	0.09	0.19	0.16	0.09	-0.47*	1		
Oil yield	0.51*	0.04	0.87**	0.88**	0.89**	0.77**	0.11	0.43*	-0.06	1	
Protein yield	0.72**	-0.08	0.91**	0.88**	0.94**	.83**	0.14	-0.17	0.50*	0.76**	1

* and ** Significant at 5% and 1% probability levels, respectively.

Table 3. Direct and indirect effects of soybean characters on seed yield under normal irrigation conditions.

	100-seed weight (grplant^{-1})	Number of seed per pod	Number pod per plant	Number of seed per plant	Oil percent	Protein percent	Oil yield	Protein yield	Total correlation with seed yield
100-seed weight (grplant^{-1})	0.088	-0.117	-0.036	0.082	-0.041	-0.074	0.083	0.158	0.143
Number of seed per pod	-0.055	0.187	-0.205	0.011	0.098	-0.009	-0.187	-0.183	-0.345
Number pod per plant	-0.006	-0.068	0.563	-0.258	-0.119	0.078	0.338	0.427	0.956
Number of seed per plant	-0.026	-0.007	0.532	-0.273	-0.093	0.081	0.296	0.391	0.900
Oil percent	0.018	-0.094	0.341	-0.130	-0.196	0.195	0.345	0.107	0.587
Protein percent	0.025	0.007	-0.167	0.084	0.146	-0.262	-0.205	0.178	-0.195
Oil yield	0.019	-0.090	0.490	-0.209	-0.174	0.138	0.388	0.325	0.888
Protein yield	0.025	-0.062	0.435	-0.193	-0.038	-0.084	0.228	0.553	0.865

Table 4. Direct and indirect effects of soybean characters on seed yield under water deficiency conditions.

	100-seed weight (grplant-1)	Number of seed per pod	Number pod per plant	Number of seed per plant	Oil percent	Protein percent	Oil yield	Protein yield	Total correlation with seed yield
100-seed weight (grplant-1)	0.112	0.004	-0.151	0.289	0.007	-0.060	0.159	0.274	0.635
Number of seed per pod	-0.005	-0.084	0.032	0.089	0.022	0.065	0.014	-0.031	0.103
Number pod per plant	0.053	0.004	-0.320	0.629	-0.004	-0.028	0.275	0.343	0.950
Number of seed per plant	0.050	-0.012	-0.310	0.648	-0.001	-0.012	0.278	0.332	0.973
Oil percent	-0.006	0.014	-0.010	0.005	-0.137	0.061	0.135	-0.066	-0.005
Protein percent	0.052	0.043	-0.070	0.058	0.065	-0.128	-0.018	0.190	0.192
Oil yield	0.057	-0.004	-0.281	0.575	-0.059	0.008	0.313	0.286	0.896
Protein yield	0.081	0.007	-0.291	0.570	0.024	-0.064	0.238	0.377	0.942

Conclusion

According to results of this study all characters were affected by water deficit stress. Also, these results revealed that under normal irrigation and water deficiency conditions the most direct effect were obtained from oil yield and protein yield (non-stress condition) and number of pod per plant (stress condition). Thus, the changes of characters relationship in soybean under different irrigation condition should be considered for variety selection and every plant breeding and agronomy program of the plant.

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