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Character association and path analysis in common bean (*Phaseolus vulgaris* L.)

Asteraki Hossein[1], Mokhtar Dashadi[2], Rouhollah Radjabi[3*]

[1]*Broujerd Agricultural and Natural Resource Research Station, Lorestan, Iran*

[2]*Department of Soil Sciences, Dezful Branch, Islamic Azad University, Dezful, Iran*

[3]*Plant Protection Department, Islamic Azad University, Dezful Branch, Dezful, Iran*

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Abstract

The objective of this study was to estimate the correlation coefficients and carry out path analysis between seed yield, morphological traits and yield components. The experiments, in randomized complete blocks with three replications, were carried out in the counties of Iran (Broujerd agriculture and natural resources station, Lorestan province) in the 2008-2009 growing seasons. Ten common bean genotypes were assessed including advanced lines and commercial varieties. Results of combined analysis of variance revealed that the studied genotypes differed significantly for all of the traits. It could be concluded that environmental effects significantly affected the performance of the present bean genotypes. The results of path analysis indicated the number of pods per plant (Np) and 100 seed weight (Hs) were considered as the first-order variables among the various seed yield traits under in 2008. Hs and Lp were positively related with seed yield. The direct effect of these predictor variables on seed yield were 0.29 and 0.41, respectively. Seed yield was determined by the direct effect of seed length (Ls), 100 seed weight and pod length (Lp) as first–order variable in 2009 and the adjusted R square was 75%. Path coefficient analysis indicated that the traits number of pods per plant, 100 seed weight and seed length play major role in seed yield determination of common bean. Therefore, attention should be paid to these traits for augmentation of seed yield and these traits could be used as selection criteria in common bean breeding programs. These results reflect that the selection prospects within this genotype to improve the performance through breeding program.

*Corresponding Author: Rouhollah Radjabi ✉ rohollah_rajabi@yahoo.com

Introduction

Common bean (*Phaseolus vulgaris* L.) is a species widely cultivated crop due to its good nutritional composition (high protein content in dry seed and a good source of fiber in snap bean) and its high market value, and is consumed either as a dry bean (pulse) or as a snap bean (fresh vegetable) and it is considered one of the most important grains for human alimentation (Santalla *et al*., 1999). It is one of the most important crops in terms of both economy and nutrition and is cultivated in different regions of Iran including the Markazi, Lorestan and Isfahan provinces (Osdaghi *et al*., 2009). Common bean could be grown as a seed legume in dry-land rotations with winter wheat to increase production diversity (Nielsen *et al*., 1998). Dry legumes are rich in calcium required for bone structure and general health, in iron required for blood making, in different types of vitamin B, which are effective on the nervous system (Baysal and Basoglu, 1988).

Yield improvement is a major breeding objective of most crop improvement programs (Ghobary and Abd-Allah, 2010). Yield in dry bean like other crops, is a complex trait and many morphological and physiological traits constitute it. Seed yield is affected by genotype and environmental factors because it is a quantitative character. Using as selection criteria of characters direct relationship with seed yield increase the success of selection in plant breeding (Karasu and Oz, 2010). Therefore, progress of breeding in such traits are primarily conditioned by the magnitude and nature of variation and interrelationships among them (Raffi and Nath, 2004).

Correlation analysis describes the mutual relationship between different pairs of characters without providing the nature of cause and effect relationship of each character. Simple correlation analysis is not able to provide detailed and actual knowledge in the relation between dependent variable and predictor variables. Hence, the path analysis was also performed to determine the direct and indirect contribution of each character to seed yield (Chitra and Rajamani, 2010). This method, developed by Wright (1921) as a statistical tool, enables to study complex relationships between traits. Many researchers have studied cause and effect relationships among seed yield and yield-related traits in common bean (Dursun, 2007; Raffi and Nath, 2004; Kamelmanesh *et al*., 2009; Ghobary and Abd-Allah, 2010; Karasu and Oz, 2010; Salehi *et al., 2010*; Filho *et al*., 2011; Cabral *et al*., 2011). Ghobary and Abd-Allah (2010) indicated number of pods per plant, 100 seed weight and number of seeds per pod exhibited maximum positive direct effect on seed yield, respectively. Raffi and Nath (2004) revealed days to 50% flowering, days to maturity, plant height, number of pods per plant, pod length, number of seeds per plant and 20 seed weight had positive and significant direct effects on seed yield. Karasu and Oz (2010) indicated that seed yield per plant had the greatest direct effect on seed yield, followed by 1000 seed weight and plant height. Salehi *et al*., (2010) indicated the number of pods per plant was the only effective trait on seed yield and explained 83.2% of total yield variations. Cabral *et al*. (2011) indicated the number of seeds per pod, weight of one hundred grains, number of pods per plant and number of seeds per plant were as the primary characters affected on seed yield. Kamelmanesh *et al*., (2009) indicated at non-infected conditions, number of secondary stem, harvest index and main stem length were entered in regression model respectively and explained 84% of seed yield variations. In this manner, under infected conditions, harvest index, plant weight and number of seeds in pod justified 93% of seed yield variations. Rahnamaie *et al*., (2007) revealed seed weight and pod per plant (r=0.44) had the greatest direct and positive effect on seed yield. Sabokdast and Khyalparast (2008) indicated that the maximum variation in grain yield could be attributed to the number pod/plant, number seed/plant, 100 seed weight and pod length.

The objective of the present study was to estimate the correlations and partition of the coefficient of correlation between grain yield with its primary components, into direct and indirect effects to determine the relative importance of each one in seed yield.

Materials and methods

This study was carried out in spring seasons during 2008-2009 in Broujerd agriculture and natural resources station, Lorestan province, Iran (longitude, 48° 45´ E; Latitude, 35° 55´ N; Altitude, 1629 m above sea level; Precipitation, 455.2 mm; climate, semidry and dry). Experimental material comprised 10 genotypes of common bean (*phaseolus vulgaris* L.) viz, Emerson 74, Julz, Daneshkadeh, WA8563-(1), G11867, Derakhshan, Sayad, Goli, D81083 and Azna. The sowing was conducted in 23 and 24 June every year by hand. Field experiments were conducted in a randomized complete block design with three replications. Each plot consisted of four rows, everyone 5 m in length and distance between rows was 50 cm. The seeding rate was 20 plants per m^2 (50 plants, every row). Plot size was 10 m^2 at harvest. Forty five kilogram nitrogen, phosphorus and potassium per hectare were applied as compose fertilizer (15-15-15) prior to sowing.. All recommended agronomic practices were followed to raise good crop. The following statistical model was adopted for experimental design:

$$Y_{ijkl} = \mu + E_i + R(E)_{j(i)} + G_k + GE_{ik} + e_{ijkl}$$

Where, μ: general mean; E_i: effect of i^{th} environment (i = 1,2); $R(E)_{j(i)}$: effect of j^{th} block within the i^{th} environment (j = 1,2,3); G_k: effect of k^{th} genotype (I = 1, 2..........10); GE_{ik} : effect of the interaction of the k^{th} genotype with the i^{th} environment; e_{ijk}: experimental Error.

Plots were harvested by hand. Six agronomical characters such as seed yield per 10 m^2 (kg), 100 seed weight (g), number of pods per plant, number of knobs per plant, number of branches per plant and plant height (cm) were measured on ten plants randomly selected from all plots in 2008. In addition to above traits some of characters such as seed length (cm), seed width (cm), pod length (cm) and knob distance (cm) were measured in 2009.

Significance of correlation coefficients were tested a 0.05 and 0.01 probability level. These correlations were further analyzed using path coefficients as illustrated by Li (1968). The path analysis was done as given by Wright, (1921) and elaborated by Dewey and Lu (1959) to calculate the direct and indirect contribution of various traits to yield. Combined analysis of variance and stepwise multiple regression analysis was carried out using SPSS 17. Also, the relative importance of direct and indirect effects on seed yield was determined by path analysis. In path analysis, seed yield was the dependent variable and the other traits were considered as independent variables.

Results and discussion

Analysis of variance and genotype's mean performance

Significance of mean squares due to different sources of variability for studied traits in combined analysis is summarized in Table 1. Results revealed that the studied genotypes differed significantly for all of the traits in combined analysis. Combined analysis of variance over years elucidates that years were significant or highly significant for seed yield, number of knobs per plant, number of branches per plant and plant height. Therefore, it could be concluded that environmental effects significantly affected the performance of the present bean genotypes. Results showed that year × genotype interaction effect were significant for number of pods per plant, number of knobs per plant, number of branches per plant and plant height. This declared that the studied genotypes significantly differed for their ranks from one year to another.

Table 2 presents mean values of traits across cultivars. The obtained differences for all investigated traits point out the diversity of investigated material. Common bean breeding programs are dealing with plant height as a quantitative trait that determines final plant density. Besides genetic effects, year effects also play an important role in expression of this trait. The lowest shortest high plants were determined in

Sayad cultivar (57.85 cm), whereas the highest plants were found in Azna cultivar (85.40 cm). Significantly Higher number of pods per plant was found in WA8563-(1) (30.15), whereas G11867 (19.64) cultivars significantly showed lower number of pods per plant. The highest value of number of knobs per plant was found in Azna (16.70), G11867 and WA8563-(1) cultivars and the lowest in Goli (11.33), Sayad and D81083 cultivars. The highest seed yield was determined for Sayad (3.55) and Julz (3.38). The lowest seed yield was determined for G11867 (2.42) and Azna (2.47). 100 seed weight is very interesting trait for both common bean breeders and consumers. It is also an important component of seed yield. The highest value for this trait was determined in cultivar Derakhshan (44.56 g) and the lowest in Sayad cultivar (26.71 g). The most number of branches per plant in this investigation were observed in Emerson 74 (3.20) and Julz (3.18) and lowest of this trait obtained in Sayad (2.30).

Table 1. Combined analysis of variance for some of morphological traits in common bean.

S.O.V.	d. f.	Character† (Mean of Square)					
		Y (kg/10m²)	Hs (g)	Np	Nk	Nb	H (cm)
Year	1	137.43**	25.07	0.85	15.48**	32.51**	1572.20**
Replication(year)	6	1.62	5.99	75.49	1.29	0.49	82.48
Genotype	9	1.22**	310.45**	72.53*	42.02**	0.81**	502.47**
Genotype × Year	9	0.40	22.77	159.30**	64.44**	1.78**	1260.98**
Error	54	0.26	11.84	28.85	1.77	0.22	99.97

† Y**:** Seed yield per 12m²(kg)**;** Hs: 100 seed weight (g); Np: Number of pods per plant; N: Number of knobs per plant; Nb: Number of branches per plant; H: Plant height (cm).

*significant at the 0.05 probability level

**significant at the 0.01 probability level

Table 2. Averaged performance for some of morphological traits in common bean.

Genotypes	Character†					
	Y(kg/10m²)	Hs (g)	Np	Nk	Nb	H(cm)
Emerson 74	3.24	34.45	28.03	15.65	3.20	59.60
Julz	3.38	34.85	26.70	15.45	3.18	69.29
Daneshkadeh	2.72	32.00	25.75	15.40	2.53	74.99
WA8563-(1)	2.60	31.56	30.15	16.21	2.74	68.05
G11867	2.42	29.84	19.64	16.51	2.96	65.30
Derakhshan	2.68	44.56	23.63	12.50	2.55	65.67
Sayad	3.55	26.71	25.68	11.43	2.30	57.85
Goli	3.04	28.92	25.49	11.33	2.60	63.70
D81083	3.01	44.50	22.18	11.43	2.50	64.83
Azna	2.47	29.36	27.28	16.70	2.38	85.40
Lsd 5%	0.68	4.59	7.17	1.77	0.63	13.34

† The symbol of traits is the same as in Table 1.

Table 3. Correlation coefficients between the characters† measured at 2008.

Character	Y (kg/10m²)	Hs (g)	Np	Nk	Nb	H (cm)
Y (kg/10m²)	1	0.108	0.280	-0.125	0.165	-0.082
Hs (g)		1	-0.443**	-0.719**	0.483**	-0.535**
Np			1	0.439**	0.021	0.480**
Nk				1	-0.529**	0.638**
Nb					1	-0.311
H (cm)						1

† The symbol of traits is the same as in Table 1.

*significant at the 0.05 probability level.

**significant at the 0.01 probability level.

Table 4. Correlation coefficients between the characters† measured at 2009.

Character	Y(kg/10m²)	Ls (cm)	Ws(cm)	Hs (g)	Np	Nk	Nb	H (cm)	Lp(cm)	Dk(cm)
Y(kg/10m²)	1	-0.397*	-0.310	-0.047	-0.124	-0.200	0.085	-0.054	0.307	0.251
Ls (cm)		1	0.622**	0.673**	0.170	0.268	-0.303	0.282	-0.040	-0.010
Ws (cm)			1	0.466**	-.046	0.366*	-0.157	0.285	-0.226	-0.165
Hs (g)				1	0.253	0.504**	-0.161	0.565**	-0.126	-0.058
Np					1	0.461**	-0.080	0.482**	-.405**	-0.127
Nk						1	0.251	0.784**	-.672**	-.594**
Nb							1	0.017	-0.107	-0.318*
H (cm)								1	-.547**	0.009
Lp (cm)									1	0.378*
Dk (cm)										1

Y: Seed yield per 12m²(kg)**;** Ls: Seed length (cm); Ws: Seed width (cm); Hs: 100 seed weight (g); Np: Number of pods per plant; N: Number of knobs per plant; Nb: Number of branches per plant; H: Plant height (cm); Lp: Pod length (cm); Dk: Knob distance (cm).

*significant at the 0.05 probability level.

**significant at the 0.01 probability level.

Table 5. Direct (under lined) and indirect path coefficient on bean yield at 2008 (87).

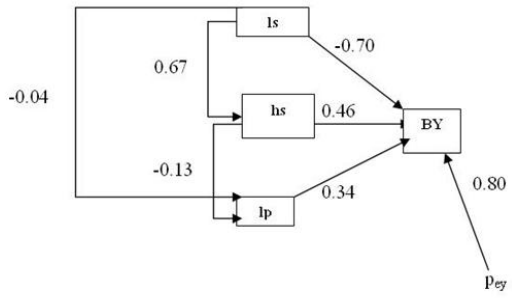
Response Variables	Predictor variables†	Np	Hs (g)	Overall effects
Y	Np	<u>0.29</u>	-0.18**	0.11
	Hs (g)	-0.13*	<u>0.41</u>	0.28

† The symbol of traits is the same as in Table 1

Table 6. Direct (under lined) and indirect path coefficient on bean yield at 2009 (88).

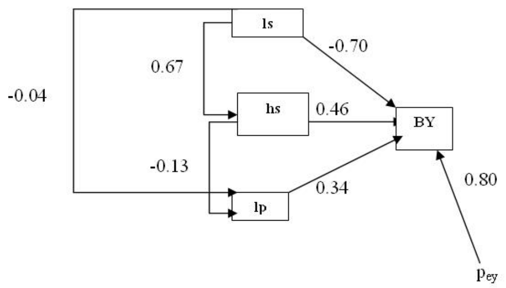
Response Variables	Predictor variables†	Ls (cm)	Hs (g)	Lp (cm)	Overall effects
Y	Ls (cm)	<u>-0.70</u>	0.31	-0.01	-0.40
	Hs (g)	-0.47	<u>0.46</u>	-0.04	-0.05
	Lp (cm)	0.03	-0.06	<u>0.34</u>	0.31

† The symbol of traits is the same as in Table 4



† The symbols of traits are the same as in table 1.

Fig. 2. Path model indicating the interrelationships among the bean yield with related characters (2008).



† The symbols of traits are the same as in table 4.

Fig. 3. Path model indicating the interrelationships among the bean yield with related characters (2009).

Correlation and regression analysis

The correlation coefficients results presented in Table 3 and Table 4. The correlation coefficients between seed yield and studied traits were not significant at any of year except seed length that negatively correlated with seed yield (Table 3 and Table 4). The correlation coefficients between Hs/Np, Hs/Nk, Hs/H and Nk/Nb were negatively significant in 2008 (Table 3). The correlation coefficient between Hs/Nb, Np/Nk, Np/H and Nk/H that were positively significant in this year, indicating dependency of these traits on each other. The positive correlation coefficients were shown between Ls/Ws, Ls/Hs, Ws/Hs, Ws/Nk, Hs/Nk, Hs/H, Np/Nk, Np/H, Nk/H and Lp/Dk in 2009 (Table 4).

Path coefficient analysis

The results of path analysis for data set of 2008 were presented in Table 5 and fig. 1. Based on tolerance and inflation factor values and besides the magnitude of direct effect, the number of pods per plant (Np) and 100 seed weight (Hs) were considered as the first-order variables among the various seed yield traits in 2008. These two traits explained 64% of the total variation for seed yield; this means that the most of variation in seed yield was explained by the traits included in the model. It indicated that these traits are main contributors towards yield. The direct effect of these predictor variables on seed yield were 0.29 and 0.41, respectively. The results of correlation and path coefficient analysis examined, it is observed that Np and Hs recorded a direct positive effect on seed yield, but they had a negative indirect effect via each other. Indirect effects of Hs to Np and Np to Hs were -0.13 and -0.18, respectively. Estimated coefficient of correlation between Np and seed yield was low and insignificant (0.11), but partial analysis of correlation coefficients showed higher direct effect of Np on seed yield (0.29). The reason of this matter is the negative indirect effect of Np via Hs (-0.18). The results of path analysis for data set in 2009 were showed in Table 6 and fig. 2. Seed yield was determined by the direct effect of seed length (Ls), 100 seed weight (Hs) and pod length (Lp) as first–order variable. The adjusted R square was 75% in this data set. Hs and Lp were positively related with seed yield. The only character having negative direct effect on seed yield in the trial was Ls. The highest direct effect was recorded for Ls (p = -0.70). Indirect effect of Ls to seed yield by Hs was high and positive (0.31) but low and negative by Lp (-0.01). Although coefficient of correlation showed low correlation between Hs and seed yield (-0.05), its direct effect was strong and positive indeed (0.46). It was indirectly realized via Ls (-0.47) and Lp (-0.04). The relationship between Lp and seed yield was intermediate, as was pointed out by coefficient of correlation (0.31). However, its direct effect to seed yield was 0.146. It was also realized via Ls and Hs.

The advantage of path analysis is that it permits: Ihe partitioning of the correlation coefficient into its components. One component is the path coefficient (or standardized partial regression coefficient) that measures the direct effect of a predictor variable upon its response variable. The other component is the indirect effect(s) of a predictor variable on the response variable through the predictor variables (Dewey and Lu, 1959).

Our results obtained from 10 common bean genotypes and combined 2 years showed that the coefficient of determination were 64% and 75% in 2008 and 2009, respectively. It represents the influence of the traits involved in the study on total variability of seed yield. Path coefficient analysis indicated that the traits number of pods per plant, 100 seed weight and seed length play major role in seed yield determination of common bean. This result was concured by Ghobary and Abd Allah (2010) and Raffi and Nath (2004) and indicated number of pods per plant and 100 seed weight exhibited maximum positive direct effect on seed yield in common bean. Salehi *et al.*, (2010) indicated the number of pods per plant was the only effective trait on seed yield and explained 83.2% of total yield variations. These results also agree with those of Cabral *et al.*, (2011) that showed out the number of seeds per pod, weight of one hundred grains, number of pods per plant and number of seeds per plant as predictor variable on seed yield in common bean. The results of this study is in agreement with Karasu and Oz (2010) that indicated 1000 seed weight had direct positive effect on seed yield.

Conclusively, attention should be paid to some of characters such as number of pods per plant, 100 seed weight and seed length, for augmentation of seed yield and these traits could be used as selection criteria in common bean breeding programs. Results showed that the D81083 possessed the high value for 100 seed weight and intermediate number of pods per plant. These results reflect that the selection prospects within this genotype to improve the performance through breeding program.

D81083 Possessed the high value for 100 seed weight and intermedia+e number of pods per plant. These results reflect that the selection prospects within this genotype to improve the performance through breeding program.

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