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COEFFICIENT ANALYSIS AND ASSOCIATION BETWEEN MORPHO-AGRONOMICAL CHARACTERS IN COMMON BEAN (*PHASEOLUS VULGARIS* L.)

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ABSTRACT. Pulses are important food sources for human consumption. In an attempt to study the associations between common bean (*Phaseolus vulgaris* L.) morpho-agronomical traits, twelve genotypes and inbred lines were evaluated in a randomized complete block design (RCBD) with three replications in 2010-2011 crop season. Seed yield and 20 other morpho-agronomic characters were recorded. Analysis of variance (ANOVA) revealed a significant ($p \leq 0.01$) difference among genotypes with respect to almost all traits. Correlation analysis demonstrated that seed yield had a strong positive correlation with both seed number per plant and seed number per pod, suggesting the usefulness of these traits in common bean breeding programs. Step-wise regression analysis pointed out that the pod weight, seed number per pod and 100 seed weight contributed to the seed yield prediction, whereas other traits did not contributed to the seed yield prediction. These traits explained almost 99% of total seed yield variations. Path analysis showed that the maximum direct and positive effect was related to pod weight. Furthermore, factor analysis revealed that four factors, explained almost 71% of the total variance. The results of this research showed that biologic yield, pod weight, straw weight, number of pod per plant and seed number per plant were the most closely related traits to the seed yield.

Key words: Yield; Correlation coefficient; Factor analysis; Path analysis.

INTRODUCTION

Due to quantitative genetic determination, seed yield is affected by genotype, environment and

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interaction between these two factors. As a result, seed yield seem to have a low heritability. Selection for characters with direct influence on seed yield increases the chance of plant breeding programs. Thus, acquiring information about the relationship between seed yield and its components is key to develop high performance varieties. Understanding how morpho-agronomic characters interact with one another with regard to seed yield would improve strategies to increase common bean yield (Board *et al.,* 1999).

Correlation coefficient analysis (r) helps to unveil significant relationship between various traits. Correlation coefficient analysis is useful for making rational improvement in yield and its components; however such an analysis does not provide an exact picture of the relative importance of direct and indirect influences of each component. Moreover, when more and more variables are included, the indirect contribution becomes even more complex (Wright, 1923; Dewey and Lu, 1959). Thus, it becomes necessary to study path coefficient analysis.

Path coefficient analysis is an efficient and applicable statistical technique, which is specially designed to quantify the interrelationship among different components and their direct and indirect effects. it provides an effective way of finding out direct and indirect sources of correlation, sometimes the correlation between two variables may be due to a third factor giving misleading results. It is therefore necessary to analyze the cause and effect relationship between dependent and independent variables to entangle the nature of the relationship between the variables (Sidramappa *et al.*, 2008). Path analysis is used to determine the amount of direct and indirect effects of independent variables on the dependent variable (Ulukan *et al.,* 2003).

The variability and interrelationship of characters between productivity and its components in bean have frequently been examined (Mebrahtu *et al*. 1991; Onder and Babaoglu, 2001; Peksen and Gulumser, 2005., Karasu and OZ, 2010; Sadeghi *et al.* 2011; Golparvar, 2012a; Golparvar, 2012b; Cokkizgin *et al*. 2013). A number of studies have shown that number of pods per plant, number of seeds per pod, seed yield per plant and number of pods per plant had a positive association with seed yield, suggesting a direct effect on seed yield per hectare (Onder and Ozkaynak, 1994; Bozoglu and Gulumser, 1999; Helvacioglu and Sehirali, 2001; Yorgancilar *et al*. 2003; Peksen and Gulumser, 2005). White and Gonzalez (1990) and Singh *et al.* (1995) reported that seed yield was positively associated with seed size. Özdemir (1996) showed that number of pod per plant had a direct positive effect on grain yield in chickpea. Interestingly, Sadeghi *et al.* (2011) found that seed number per plant and harvest index had a high positive direct effect on seed yield in common bean. It was found that seed number per plant had a positive and significant direct effect on seed yield in bean, whereas seed weight per plant had a negative and significant direct effect on the seed yield (Cokkizgin *et al.* 2013).

Factor analysis is a multivariate statistical method which can reduce a large number of correlated variables in small number of uncorrelated factors. Correlation studies, using factor analysis and path analysis as multivariate statistical methods provide the possibility to recognize the most important effective characters on grain yield as well as the hidden factors causing correlation between the characters (Johnson and Wichern, 1982).

This study was undertaken to characterize relationships among the important morpho-agronomical characters associated with seed yield, to unveil factors comprising important traits for improving seed yield of several genotypes in common bean, using path and factor analyses.

MATERIALS AND METHODS

Plant material for the present study consisted of 12 genotypes of common bean (DERAKHSHAN, AND1007, F_1 DERAKHSHAN × AND 1007, BC_1 DERAKHSHAN × AND 1007, BC_2 DERAKHSHAN × AND 1007, F_2 DERAKHSHAN × AND 1007, GOLI , D81083, F_1 GOLI × D81083, BC_1 GOLI × D81083, BC_2 GOLI × D81083, F_2 GOLI × D81083) obtained from National Bean Research Station in Khomein, center of Iran (*Table 1*). The genotypes and recombinant inbred lines were planted into a randomized complete block design (RCBD) with three replications, in 2010 crop season. The plots of various generations in each replication had three rows with 3 meters long, a between-row spacing of 50 cm and a within-row spacing of 10 cm. Before sowing, 50 kg ha^{-1} N fertilizer was applied. The field was irrigated every five to seven days.

Table 1 - Characteristics of the cultivars used in this study

Cultivar	Characteristics	
	Introduced place	Origin
AND1007	CIAT	Andian
DERAKHSHAN	CIAT	Andian
GOLI	IRAN	Mesoamerican
D81083	CIAT	Andian

CIAT: International Center for Tropical Agriculture

At maturity, five guarded plants per replication were randomly selected to record data on seed yield (gm^{-2}) and 20 morphological characters such plant height (cm), internode diameter (mm), node number of main stem, node number of lateral branches, number of pod per plant, pod weight (g), seed number per pod, pod tail length (mm), pod length without tail (cm), seed length (mm), seed diameter (mm), seed width (mm), straw weight (g), biologic yield (g), internode length (cm), 100 seed weight (g), 50% flowering, 50% poding, days to maturity and seed number per plant. The mean values were used for statistical analysis.

Measurements were done according to the IPGRI descriptor list for *P. vulgaris* L.

In order to determine the relationships between traits and seed yield per plant, Pearson's correlation coefficients were computed among phenotypic traits. Step-wise regression analysis was achieved for determination of the best model which accounted for variations exist in seed yield as dependent variable. In present investigation, path analysis was applied based on the method given by Dewey and Lu (1959) on the traits entered to regression model.

Factor analysis with varimax rotation was performed for the 21 characters in common bean. The number of factors was estimated, using the maximum likelihood method according to Rao (1952). The varimax rotation method (an orthogonal rotation) was used in order to make each factor uniquely defined as a distinct cluster of inter-correlated variables (Rao, 1952). The factor loadings of the rotated matrix, the percentage variability explained by each factor and the communalities for each variable were determined. Correlation coefficients, stepwise multiple regression analysis and factor analysis were carried out using SAS statistical program (SAS, 2004).

RESULTS AND DISCUSSION

Achieving the high yield through major yield attributes requires the knowledge of the magnitude of inter-correlation among various yield components. Simple correlation between important characters for common bean genotypes (*Table 2*) showed that seed yield had a highly significant correlation ($p \leq 0.01$) with the number of pod per plant (0.83), the pod weight (0.98), the seed number per pod (0.75), the pod tail length (-0.65), the biologic yield (0.79) and seed number per plant (0.91). Internode diameter, seed length and 100 seed weight showed a low and negative non-significant ($p>0.05$) correlations with seed yield, while positive non-significant ($p>0.05$) correlations were observed between the seed yield and plant height, node number of main stem, node number of lateral branches, pod length without tail, seed diameter, seed width, straw weight, internode length, 50% flowering, 50% poding. The current finding of this study agrees with pervious study on cowpea (Shanko *et al*., 2014). In contrast to Shanko *et al.* (2014), seed yield was not significantly correlated to days to maturity. Among various traits, pod weight had the strongest association with the seed yield, suggesting that pod weight might be an important yield component and can be used to improve common bean. Result of this experiment showed that in addition to pod weight, seed number per plant, number of pod per plant and seed number per pod had strong positive correlations with seed yield. It seems that these traits are useful to be used for high yield in common bean breeding programs. The similar results were also found by Sadeghi *et al.* (2011) and Cokkizgin *et al.* (2013) in common bean. Thus, it seems that selection of common bean genotypes with high pod weight as well as a high number of seeds may improve common bean grain yield.

Table 2 - Correlation coefficients between different traits and seed yield in common bean

	SY	PH	IND	NMS	NLB	NPPL	PW	NSPP	PTL	PLWT	SL	SD	SW	StW	BY	INL	100-SW	DF-50%	DP-50%	DM-90%	NSPPL
SY	1																				
PH	0.50	1																			
IND	-0.33	-0.07	1																		
NMS	0.25	0.83**	-0.12	1																	
NLB	0.21	0.77**	-0.04	0.98**	1																
NPPL	0.82**	0.64*	-0.30	0.40	0.32	1															
PW	0.98**	0.61*	-0.31	0.33	0.28	0.87**	1														
NSPP	0.75**	-0.09	-0.52	-0.24	-0.28	0.46	0.66*	1													
PTL	-0.64*	-0.48	0.55	-0.52	-0.50	-0.70*	-0.68*	-0.47	1												
PLWT	0.38	-0.33	-0.27	-0.42	-0.38	-0.05	0.27	0.71**	-0.01	1											
SL	-0.12	-0.53	0.40	-0.63*	-0.50	-0.29	-0.18	0.10	0.50	0.57	1										
SD	0.20	0.26	0.02	0.15	0.19	-0.02	0.21	-0.05	0.17	0.37	0.27	1									
SW	0.45	0.07	0.07	-0.10	-0.03	0.20	0.40	0.30	0.15	0.60*	0.62*	0.74**	1								
StW	0.54	0.83**	0.15	0.56	0.50	0.71**	0.66*	-0.04	-0.47	-0.33	-0.42	0.20	0.04	1							
BY	0.79**	0.80**	-0.01	0.51	0.45	0.83**	0.87**	0.27	-0.58*	-0.08	-0.35	0.23	0.21	0.94**	1						
INL	0.55	0.54	0.07	0.01	-0.08	0.58*	0.64*	0.23	-0.08	0.82**	0.07	0.34	0.39	0.66*	0.71*	1					
100-SW	-0.17	-0.13	0.29	-0.03	0.04	-0.50	-0.23	-0.25	0.48	0.11	0.34	0.73**	0.58*	0.20	-0.20	-0.12	1				
DF-50%	0.23	0.24	-0.50	0.53	0.56	0.13	0.21	0.23	-0.61*	0.29	0.25	0.15	0.07	0.01	0.09	-0.33	0.12	1			
DP-50%	0/17	0.04	-0.56	0.42	0.47	0.09	0.12	0.22	-0.65*	0.30	-0.28	-0.04	-0.04	-0.15	-0.06	-0.55	0.04	0.89**	1		
DM-90%	0.03	0.20	-0.52	0.46	0.49	0.01	0.04	-0.06	-0.28	0.16	-0.30	0.32	0.01	-0.03	-0.01	-0.31	0.11	0.56	0.54	1	
NSPPL	0.91**	0.49	-0.52	0.31	0.23	0.93**	0.90**	0.70*	0.75**	0.06	-0.32	-0.04	0.21	0.51	0.72**	0.43	-0.45	0.24	0.26	0.12	1

*, ** indicate significant at the 0.05 and 0.01 probability levels, respectively. SY: seed yield; PH: plant height; IND: internode diameter; NMS: number of nodes in main stem; NLB: number of nodes in lateral branches; NPPL: number of pods per plant; PW: pod weight; NSPP: number of seeds per pod; PTL: pod tail length; PLWT: pod length without tail; SL: seed length; SD: seed diameter; SW: seed width; StW: straw weight; BY: biologic yield; INL: internode length; 100-SW: 100 seed weight, DF-50%: 50% flowering, DP-50%: 50% poding, DM-90%: days to maturity, NSPPL: number of seeds per plant

Table 3 - Step-wise regression for seed yield (dependent variable) in common bean genotypes

Character entered to the model	Coefficients	Standard error	R^2	t	prob
Pod weight	0.63	0.30	0.97	21.09	0.000
Seed number per pod	3.62	0.75	0.99	4.84	0.001
100 seed weight	0.09	0.040	0.99	2.36	0.046
Constant	-16.20	2.70		-6	0.000

Table 4 - The effective traits of path analysis on seed yield (dependent variable) in common bean genotypes

Traits	DE	Indirect effects via			Total
		Pod weight	NSPP	100 SW	
Pod weight	0.87	-	0.13	-0.02	0.98
seed number per pod	0.20	0.57	-	-0.02	0.75
100 seed weight	0.08	-0.2	-0.05	-	-0.17

DE: Direct effect of traits on seed yield; NSPP: number of seeds per pod.;100 SW: 100 seed weight

The stepwise regression analysis considering the seed yield as the dependent variable and other characters as the independent variables was conducted. In present investigation, three characters, the pod weight, the seed number per pod and the 100 seed weight were in turn, entered to the regression model (*Table 3*), which accounted for 99% of the seed yield variation. These results are in agreement with correlation analysis results. The pod weight character, the first character entered into the regression model, had the highest correlation coefficient with the seed yield, suggesting the pod weight may have a significant influence on seed yield. The results of effective traits of path analysis on seed yield (*Table 4*) indicated that the highest direct and positive effect on seed yield was related to pod weight (0.87). The 100 seed weight had the lowest direct and positive effect on seed yield (0.08). Sadeghi *et al.* (2011) reported that 100 seed weight had the lowest direct effect on seed yield.

The path analysis of effective traits on seed yield showed that the Pod weight had an indirect and positive effects *via* seed number per pod (0.13) and an indirect and negative effects *via* 100 seed weight (-0.02). Furthermore, the seed number per pod had indirect and positive effects *via* pod weight (0.57) and an indirect and negative effects *via* 100 seed weight (-0.02). Nevertheless, the 100 seed weight had an indirect and negative effects *via* pod weight (-0.2) and seed number per pod (-0.05).

The results showed that indirect effects of pod weight are smaller than direct effects. As a result, pod weight is suggested as the best indirect selection criteria for genetic improvement of seed yield in common bean genotypes. *Table 5* shows the results of factor analysis. It should be mentioned that the variance of each factor shows its importance, on the other hand, the sign of factors' coefficients in each factor represents the relationship between these characters. Four factors explained more than 70.86% of total variations. In order to select the appropriate number of factors, only specified factors with eigen values greater than one were used.

Table 5 - Factor analysis, using varimax rotation for 20 characters and seed yield in common bean

Variables	1	2	3	4
Biologic yield	**0.98**	-0.11	0.03	0.06
Pod weight	**0.90**	0.33	0.15	0.02
Straw weight	**0.90**	-0.40	-0.05	0.04
Number of pod per plant	**0.87**	0.11	0.12	-0.17
Seed yield	**0.83**	0.46	0.18	0.04
Internode length	**0.77**	0.11	-0.49	0.15
Plant height	**0.77**	-0.46	0.21	0.21
Seed number per plant	**0.76**	0.34	0.27	-0.22
Pod length without tail	0.01	**0.89**	0.11	0.25
Seed number per pod	0.35	**0.86**	0.17	-0.19
Node number of Main stem	0.43	**-0.58**	0.58	0.20
Seed length	-0.25	**0.53**	-0.43	0.33
50% poding	-0.06	0.12	**0.96**	-0.06
50% flowering	0.09	0.10	**0.94**	0.13
Pod tail length	-0.60	-0.07	**-0.66**	0.36
Days to maturity	-0.03	-0.09	**0.63**	0.04
Node number of lateral branches	0.37	-0.56	**0.60**	0.25
Internode diameter	-0.07	-0.38	**0.59**	0.29
100 seed weight	-0.27	0.04	0.04	**0.86**
Seed diameter	0.21	0.11	0.03	**0.83**
Seed wide	0.26	0.51	-0.09	**0.73**
Eigen value	7.2	5.53	4.57	3.25
Total variance (%)	24.82	19.07	15.68	11.19
Cumulative variance (%)	24.82	43.90	59.67	70.59

The first factor, which accounted for about 24.83% of total variation, was strongly associated with biologic yield, pod weight, straw weight, number of pod per plant, seed yield, internode length, plant height and seed number per plant that indicating the importance of these characters in breeding the yield in the bean. This factor was regarded as first degree of yield factor, since it included several traits which are components of yield.

The second factor consisting of the pod length without tail, seed number per pod, node number of main stem and seed length which are associated seed yield, included 19.07% of total variation. According to the characters of this factor, it can be called the secondary degree of yield factor.

The third factor accounted 16.63% of total variation and called morpho-phonologic factor. It contained 50% poding, 50% flowering, pod tail length, days to maturity, node number of lateral branches and internode diameter.

The fourth factor accounted 11.19% of total variation. The most important coefficients in this factor were related to 100 seed weight, seed diameter and seed wide. This factor can be named the seed factor.

CONCLUSION

In addition to grouping the characters, the multi-factor analysis also shows the characters' importance and their relationship with each other. For breeding of yield, those characters with higher level of importance should be used, thus selection of variables in the first degree of yield factor (factor one) could enable breeders to better realize the desired increment in seed yield of common bean.

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