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Using Path Coefficient Analysis to Determine the Relationship between Yield and Yield Components of Dry Bean (*Phaseolus vulgaris* L.)

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ABSTRACT

This study was conducted to determine relationship between yield and yield components of 10 dry bean varieties for 2 years. Field trials were carried out under Tokat-Turkey ecological conditions and utilized a randomized complete blocks design with 3 replications. The relationship between total seed yield and plant height, number of pod per plant, number of seed per pod, number of seed per plant, seed yield per plant, 1000 seed weight, and total biological yield were investigated. Significant and positive relationship were found between total seed yield and number of pod per plant (0.594**), seed yield per plant (0.527*), total biological yield (0.877**), number of seed per pod (0.455*), number of seed per plant (0.420*). Negative and non-significant relationships were determined between total seed yield and plant height (-0.234). There was positive but no significant relationship between total seed yield and 1000 seed weight (0.245). According to path analysis results, the most important characteristics determining seed yield in dry bean were total biological yield and number of seed per pod.

Key Words: Bean, yield, correlation, path analysis.

INTRODUCTION

Dry bean constitutes one-third of the world pulses production. It is grown intensively especially in India, Canada, Brazil, China, Myanmar, Mexico and USA [1]. Dry bean has been grown in Turkey for more than two hundred years [2]. It is grown throughout Turkey and accepted as "food for poor" instead of "meat". According to 2005 Data, dry bean production area, production amount and yield in Turkey are 141200 ha, 210000 tons and 1487 kg ha^{-1}, respectively [3]. Although Turkey is one of the important countries that dry bean is grown, there is a decrease in dry bean cultivation area due to cost advantage of competitive crops and agricultural policies followed by the government in recent years [4, 5].

Development of high yielding crop varieties is the basis of plant breeding. Yield is a quantitative character and is affected by various genotypic and environmental factors. Therefore, studies targeting high yield, only focusing on yield may not be sufficient to achieve expected results.

Genetic variation among plant characteristics is important for breeding and selecting desirable types. On the other hand, an analysis of the correlation between yield and yield components is essential in determining selection criteria [6]. Correlation coefficients are used to show relationships among independent characteristics and describe relationships in a simple manner. Therefore, path coefficient analysis is needed to clarify relationships among characteristics deeply [6,7]. Path coefficient analysis separates the direct effects from the indirect effects through other related characters by partitioning the correlation coefficient [8, 9]. Path analysis plays an important role in determining the degree of relationship between yield and yield components [7].

In dry bean, which is an important yield criteria of dry bean yield, high yield potential is determined by development type, seed dimension, duration of maturity, growing environment, production systems, agricultural practice and other inputs [10]. In the studies carried out for determination of efficient crop characteristics in the merging of seed yield; it was determined that number of pod per plant, number of seed per pod, and 1000 seed weight are the primarily characteristics which are effective in yield [10, 11, 12, 13, 14, 15]. However, other characteristics out of these three features contribute to creation of yield at a certain rate. Some researchers state that there is a positive and significant relationship between seed yield and flowering period, plant height, height of first pod, length of pod and biological yield characteristics in addition to characteristics explained above paragraphs [14, 15, 16, 17]. That is, different plant characteristics have effect on seed yield in bean. In this context, there is a need for new studies to determine the relationship between yield and which are effective on yield. Therefore, the aim of this study is to determine the relationship between yield and yield components in dry bean.

MATERIALS AND METHODS

This study was carried out under Tokat ecological conditions during the two years (1997-1998) and utilized a randomized complete blocks design with 3 replications. Ten registered dry bean cultivars (Karacasehir-90, 85 AK 38, 85 AK 32, Yalova-17, Yalova-5, Sahin-90, Yunus-90, ES-1286, ES-855, Erzurum Seker) were used.

Similar average temperatures were recorded (18.6 °C first year, 17.8 °C second year) but with rainfall higher than average of long years (169.4 mm). Relative humidity values (61.8% and 65.3%) were higher-compared to average of long years (56.6%) [18].

Soils of the experimental area were clay-loam, and slightly alkaline (pH: 7.36). Lime was low (2.20%) and there was no salinity (ECe: 380 µmhos/cm) problem. Amount of organic matter (1.56%) and available phosphorus (14.25 ppm P_2O_5) were low and available potassium (130 ppm K_2O) was adequate [19].

Each genotype was sown in 2 rows of 4 m length in each replicate and planted with 10 cm intra-row spacing, whereas inter-row distance was kept 50 cm. The varieties were sown on May 23, 1996 and May 14, 1997. Before sowing, 30 kg ha^{-1} N and 70 kg ha^{-1} P_2O_5 fertilizers were applied. Genotypes were harvested starting from September 8, 1996 and September 9, 1997 with handed when they reached maturity. The plots were formed by 4-meter long rows, spaced at 0.50 m. The useful area (3 m^2) was formed by the two rows after being trimmed 0.50 m from the ends.

Plant height (cm), number of pod per plant (pod number $plant^{-1}$), number of seed per pod (seed number pod^{-1}), number of seed per plant (seed number $plant^{-1}$), seed yield per plant (g $plant^{-1}$), 1000 seed weight (g), total biological yield (kg ha^{-1}) and total seed yield (kg ha^{-1}) were recorded according to methods explained by Sehirali [2], Ozcelik [13] and Akcin [20].

Values of total biological yield and total seed yield obtained from harvest parcel area were transformed into hectare.

Values belonging to characteristics were merged and average of two years. ANOVA of factors examined in various dry bean cultivars, and mean data and statistical groups of various dry bean cultivars with respect to factor analyzed (LSD) were calculated with TARIST as suggested by Duzgunes et al. [21]. Correlation coefficients and path analysis were carried out according to Williams et al. [22], and Yucel [23].

RESULTS AND DISCUSSION

The Table 1 displays the analysis of variance for the quantitative traits evaluated. Statistically significant variations were found by ANOVA amongst the cultivars for all the variables examined ($P<0.01$).

Table 1. Summary of ANOVA of factors examined in various dry bean cultivars

SV[1]	df[2]	PH		PNP		SNPO		SNP	
		MS[3]	F[4]	MS	F	MS	F	MS	F
Cultivar	9	400.92	14.470**	71.855	11.713**	1.304	12.698**	656.753	8.720**
Error	18	7.71		6.135		0.103		75.317	
General	29	142.21		26.995		0.475		269.857	

SV	df	SYP		TSW		TBY		TSY	
		MS	F	MS	F	MS	F	MS	F
Cultivar	9	128.357	24.260**	21655.613	183.026**	25408.215	74.284**	6483.853	38.500**
Error	18	5.291		118.320		342.043		168.413	
General	29	45.282		808.659		8109.109		2131.960	

** = P<0.01 [1]= Sources of variation, [2] = Degree of freedom, [3] = Mean of squares, [4] = F values
TSY: Total seed yield, PH: Plant height, PNP: Number of pod per plant, SNPO: Number of seed per pod,
SNP: Number of seed per plant, SYP: Seed yield per plant, TSW: 1000 seed weight, TBY: Total biological yield

Mean data and statistical groups of various dry bean cultivars with respect to factor analyzed (LSD) were given in Table 2. The values for plant height ranged from 83.7 to 48.0 (cm), for number of pod per plant from 25.6 to 10.3 (pod number $plant^{-1}$), for number of seed per pod from 5.1 to 2.6 (seed number pod^{-1}), for number of seed per plant from 81.1 to 31.4 (seed number $plant^{-1}$), for seed yield per plant from 28.9 to 9.9 (g $plant^{-1}$), for total biological yield from 5209.0 to 2061.0 (kg ha^{-1}), for total seed yield from 2116.0 to 791.0 (kg ha^{-1}), and for 1000 seed weight from 502.8 to 373.9 (g). The highest total seed yield was obtained from Sahin-90 variety, while the lowest total seed yield was obtained from Erzurum Seker variety.

Table 2. Mean data and statistical groups of various dry bean cultivars with respect to factor analyzed (LSD)

Cultivars	PH	PNP	SNPO	SNP	SYP	TBY	TSY	TSW
85AK32	48.0	11.0	3.2	33.0	12.3	4332.0	1558.0	431.2
E.Seker	73.8	10.3	2.6	31.4	11.5	2061.0	791.0	373.9
85AK38	51.5	20.1	3.3	55.3	28.9	5209.0	2096.0	437.1
Sehirali	48.8	20.5	3.5	49.2	22.0	4204.0	1775.0	484.2
Es-1286	56.7	20.0	3.5	58.8	19.8	5150.0	2080.0	461.8
Es-855	52.1	24.2	3.3	48.2	18.8	4702.0	1962.0	400.7
Yunus-90	56.6	18.3	3.0	44.2	9.9	3640.0	1093.0	387.7
Sahin-90	55.8	18.2	3.2	34.4	12.2	4775.0	2116.0	502.8
Yalova-17	53.0	18.0	3.3	46.0	20.0	3949.0	1287.0	396.9
K.Sehir-90	83.7	25.6	5.1	81.1	26.3	3811.0	1861.0	197.9
Means	58.0	18.6	3.4	48.2	18.2	4183.0	1662.0	407.4
LSD	8.59**	4.04**	0.52**	14.17**	3.76**	300.20**	210.19**	17.76**
CV (%)	9.07	13.29	9.41	18.02	12.66	4.42	7.81	2.67

TSY: Total seed yield, PH: Plant height, PNP: Number of pod per plant, SNPO: Number of seed per pod, SNP: Number of seed per plant, SYP: Seed yield per plant, TSW: 1000 seed weight, TBY: Total biological yield

Correlation coefficient analysis

Correlation coefficients among investigated characteristics of dry bean were given in Table 3. Highly significant and positive correlations were found between total seed yield and total biological yield (0.877**), and number of pod per plant (0.594**). There were positive and significant relationships between total seed yield and seed yield per plant (0.527*), and number of seed per pod (0.455*), and number of seed per plant (0.420*). These results were in accordance with the findings of Nienhuis and Singh [10], Adams [11], Westerman and Crothers [12], Ozcelik [13], Bozoglu [14], Peksen and Gulumser [15].

Table 3. Correlation coefficients between investigated characteristics of dry bean

Features	TSY	PH	PNP	SNPO	SNP	SYP	TSW	TBY
TBY	0.877**	-0.526**	0.453*	0.223	0.253	0.414*	0.425*	---
TSW	0.245	-0.760**	-0.273	-0.598**	-0.533**	-0.234	---	
SYP	0.527*	0.112	0.603**	0.572**	0.705**	---		
SNP	0.420*	0.402*	0.751**	0.843**	---			
SNPO	0.455*	0.459*	0.630**	---				
PNP	0.594**	0.146	---					
PH	-0.234	---						

TSY: Total seed yield, PH: Plant height, PNP: Number of pod per plant, SNPO: Number of seed per pod, SNP: Number of seed per plant, SYP: Seed yield per plant, TSW: 1000 seed weight, TBY: Total biological yield

Path coefficient analysis

The path coefficients were partitioned into direct and indirect effects using total seed yield (kg ha^{-1}) as a dependent variable. Direct and indirect effects were given in Table 4. The path coefficient analysis based on total seed yield revealed that all characteristics, except number of seed per plant, had positive direct effects.

Path analysis of total seed yield demonstrated that total biological yield and number of seed per pod exerted the highest direct effect, with 56.971% and 30.401%, respectively.

Both correlation and path coefficient analyses showed that total biological yield and number of seed per pod were the major contributors to total seed yield. These results were in accordance with the literature. For example, Albayrak and Tongel [24] reported that biological yield had substantial direct effect on enhancement of seed yield. Reberio et al. [25] found that number of seed per pod had the highest contribution to seed yield in dry bean. Bozoglu [15], and Ciftci and Sehirali [14] stated that genetic structure on total biological yield was very high. Therefore, it can be used as significant criteria in selection studies. Scully and Wallace (17) reported that there was a linear relationship between biologic development rate and daily pod development and seed development.

Although 1000 seed weight and plant height had positive direct effects on total seed yield, with 24.532% and 22.908%, respectively, the correlation between total seed yield and these traits was not significant. The direct effect of number of pod per plant (16.213%) and seed yield per plant (10.685%) on total seed yield was positive but low. Number of seed per plant had a negative and low direct effect on total seed yield but it had positive and high indirect effect on total seed yield via number of seed per pod (25.561%), total biological yield (14.912%), and number of pod per plant (11.076%). All traits, except plant height, had positive and highly indirect effects on total seed yield via total biological yield.

CONCLUSIONS

There was a significant and positive relationship between total seed yield and total biological yield, number of pod per plant, seed yield per plant, number of seed per pod, number of seed per plant (Table 4).

Table 4. Path coefficients analyses between total seed yield and other factors examined in different dry bean cultivars

Features		Direct effects	Indirect effects						
			PH	PNP	SNPO	SNP	SYP	TSW	TBY
PH	p[1]	0.281		0.027	0.175	-0.101	0.124	-0.390	-0.239
	%[2]	22.908		2.217	14.299	8.252	1.010	31.827	19.487
PNP	p	0.186	0.041		0.240	-0.189	0.066	-0.085	0.336
	%	16.213	3.593		21.013	16.532	5.799	7.498	29.352
SNPO	p	0.382	0.129	0.117		-0.212	0.063	-0.188	0.165
	%	30.401	10.266	9.309		16.903	5.018	14.971	13.133
SNP	p	-0.252	0.113	0.139	0.322		0.078	-0.168	0.188
	%	20.008	8.958	11.076	25.561		6.174	13.318	14.912
SYP	p	0.110	0.032	0.112	-0.176	-0.074		0.074	0.307
	%	10.685	3.066	10.860	21.213	17.242		7.144	29.792
TSW	p	0.314	-0.213	-0.051	-0.228	0.134	-0.026		0.315
	%	24.532	16.650	3.953	17.817	10.482	2.011		24.565
TBY	p	0.741	-0.148	0.084	0.085	-0.064	0.046	0.133	
	%	56.971	11.362	6.466	6.530	4.904	3.504	10.263	

[1]= path coefficients, [2]= ratios
TSY: Total seed yield, PH: Plant height, PNP: Number of pod per plant, SNPO: Number of seed per pod, SNP: Number of seed per plant, SYP: Seed yield per plant, TSW: 1000 seed weight, TBY: Total biological yield

Path analysis showed that positive direct effects of traits on total seed yield were as follows: total biological yield (56.971%), number of seed per pod (30.401%), 1000 seed weight (24.532%), plant height (22.908%), and seed yield per plant (10.685%). However, number of seed per plant (20.008%) had negative direct effect on total seed yield. All traits, except plant height, had positive and highly indirect effects on total seed yield via total biological yield. When correlation coefficients of features and their effects are taken into consideration, it was found that total biological yield and number of seed per pod were two most important plant features in determination of dry bean total seed yield. According to these results, first of all, total biological yield and number of seed per pod should be taken into consideration while creating new bean varieties having high seed yield.

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