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GENETIC VARIABILITY, TRAIT ASSOCIATION AND PATH ANALYSIS OF YIELD AND YIELD COMPONENTS IN MUNGBEAN (*VIGNA RADIATA* (L.) WILCZEK)

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Abstract

Genetic variability, heritability along with genetic advance of traits, their association and direct and indirect effects on yield are essential for crop improvement. Ten mungbean genotypes were studied to assess variability and degree to which various plant traits associate with seed yield. Primary and secondary branches, pods per cluster and pod length showed lesser variability while clusters per plant, 100 seed weight and harvest index exhibited intermediate range of variability. Sufficient genetic variability was observed for plant height, pods per plant, total plant weight and seed yield. Moderate to high heritability estimates were found for all traits. Primary and secondary branches per plant, pod length and 100-seed weight exhibited negative and non significant genotypic and phenotypic correlations with seed yield. Plant height showed positive non-significant and significant genotypic and phenotypic correlation. Pods per cluster correlated significantly negative with seed yield. Clusters per plant, pods per plant, total plant weight and harvest index showed positive significant genotypic and phenotypic correlations with seed yield. Positive direct effects were exerted through secondary branches, pods per plant, pod length, 100 seed weight, total plant weight and harvest index while primary branches, plant height, clusters per plant and pods per cluster had negative direct effects. The present findings could be useful for establishing selection criteria for high seed yield in the mungbean breeding.

Introduction

Mungbean (*Vigna radiata* (L.) Wilczek) a small, cylindrical bean with bright green skin is an important pulse legume. Among the pulse legumes it ranks second to chickpea in Pakistan. It is a cheap and rich source of vegetable protein, and therefore, commonly used as a supplement to the normal diet of many people, particularly with low income. Mungbean occupies an important position due to its high seed protein content (22 to 24%) and ability to restore the soil fertility through symbiotic nitrogen fixation (Malik, 1994). It is rich in essential amino acids specially lysine, which is deficient in most of the cereal grains.

Seed yield in mungbean is a complex character like other crops, and is determined by various components. Knowledge of genetic variability existing among different parameters is important in crop improvement. Heritability, which measures phenotypic variance and is attributable to genetic causes, is another important consideration for a successful breeding program. Heritability with genetic advance helps in understanding the mode of inheritance of quantitative traits. Correlation coefficient analysis is a handy technique, which elaborates the degree and extent of relationship among important plant characters and it provides basic criteria for selection and leads to directional model based on yield and its components in the field experiments. Yet, the information it supplies about the nature of association is often incomplete. Path coefficient analysis, on the other hand, is an efficient statistical technique specially designed to quantify the interrelationship of different components and their direct and indirect effects on seed yield. Through this technique yield contributing characters can be ranked and specific traits producing a given correlation can be heeded (Rao *et al.*, 1997). Information regarding inheritance of grain yield and its closely related components is essential to efficiently exploit the available genetic diversity in mungbean for seed yield (Khattak *et al.*, 2004).

Present research work was planned with the following objectives. First objective was to assess the genetic variability existing among morphological as well as yield parameters along with their heritability and genetic advance for understanding the mode of inheritance of quantitative traits in mungbean. Secondly, genetic correlations and direct and indirect effects of economically useful traits with seed yield were also investigated.

Materials and Methods

Plant material: The experimental material comprised of 10 mungbean genotypes viz., AUM-9, AUM-38, AUM-29, AUM-27, AUM-19, AUM-18, AUM-28, 6375, NM-54 (check) and NM-98 (check). The experiment was laid out in a randomized complete block design with three replications in experimental fields of the Department of Plant Breeding & Genetics University of Agriculture, Faisalabad, Pakistan. Spacing between row to row and plant to plant was kept 30 cm and 15 cm respectively. All the recommended cultural practices were followed up to harvest. At maturity, data were recorded for number of primary and secondary branches per plant, plant height (cm), clusters per plant, pods per plant, pods per cluster, pod length, total plant weight (g), 100-seed weight (g), seed yield per plant (g) and harvest index (%) on 10 competitive plants randomly selected from 4 middle rows of each entry.

Statistical analysis: The data recorded on the above mentioned characters were statistically analyzed for the variance and covariance using the method given by Steel & Torrie (1980). Duncan's Multiple Range Test (DMRT) was applied to compare the mean values of all genotypes. Phenotypic coefficient of variability (PCV) and genotypic coefficient of variability (GCV) were calculated following (Johnson *et al.*, 1955). Heritability estimates (broad-sense) were calculated by performing analysis of variance and estimating genetic and phenotypic components of variance as given by Cochran & Cox (1957). Genetic advance at 5% selection intensity was calculated following Allard (1960). Phenotypic and genotypic correlation coefficients were calculated as outlined by Kwon & Torrie (1964). Genotypic correlation was tested for its statistical significance using the method of Reeve (1955). Phenotypic correlation coefficients were tested using t-test following Steel & Torrie (1980). Path coefficient analysis was performed according to the method of Dewey & Lu (1959) by solving simultaneous equations using genotypic correlations. Seed yield per plant was kept as resultant variable and other characters as causal variables.

Results and Discussion

The analysis of variance (Table 1) revealed highly significant ($p<0.01$) to significant ($p<0.05$) differences for all characters except for number of primary branches per plant that had non significant differences among the genotypes. This suggested adequate amount of genetic variability among genotypes that may be helpful for yield improvement by selection. A thorough probe into mean data revealed that primary branches ranged from 2.83 to 3.13 (Table 2). Maximum primary branches were produced by AUM-19 (3.13) followed by AUM-28 (3.07) whereas the minimum number was recorded for AUM-38 (2.83). Maximum number of secondary branches per plant was produced by AUM-19 (8. 93) followed by AUM-29 (8.43) whereas the minimum value was observed for 6375 (6.40). Plant height ranged from 51.09 to 67.82 cm with maximum contribution from AUM-38 while minimum contribution by 6375. Pods per plant ranged from 35.30 to 56.37. AUM-9 ranked first in cluster per plant and pods per plant production while 6375 had lowest production. The mean values for these traits ranged from 8.13 to 15.10 and 35.30 to 56.36 respectively. Pods per cluster ranged from 3.43 to 4.58. AUM-18 produced maximum number of pods per cluster and minimum number was produced by AUM-28. Maximum and minimum pod length and 100-seed weight were recorded in AUM-28 and NM-98 respectively. Contemplation of mean values for seed yield per plant and total plant weight demonstrated that cultivar AUM-9 proved its superiority by contributing maximum towards these traits while NM-54 was found poor with lowest contribution. Mean values for both these characters ranged from 12.71g to 21.41g and 40.45g to 59.39g respectively. Harvest index ranged from 30.56 to 36.79. Maximum harvest index was produced by AUM-38 followed by AUM-9 and minimum was produced by AUM-18.

Genetic components: The magnitude of phenotypic coefficients of variation was higher than genotypic coefficients for all the traits under study (Table 3) showing greater influence of environment on these traits. These results are in accordance with the finding of Siddique *et al.,* (2006) and Makeen *et al*., (2007) who also reported similar effects of environment. In the present study, clusters per plant were shown to have maximum genotypic coefficient of variation GCV (21.05%) followed by seed yield (17.12%) suggesting substantial amount of genetic variability and are in accordance with Vaithiyalingan, (2003) while differed from Loganathan *et al.*, (2001) who reported high PCV for number of clusters per plant indicating the favorable effect of environment. Sufficient genetic variability was observed for plant height, pods per plant, total plant weight and seed yield which showed that these traits can be recommended for direct selection. Previously, similar results have been reported by Sinha *et al.*, (1996) and Byregowda *et al.,* (1997). Moreover, in the present study, high heritability was manifested by number of secondary branches, plant height, clusters per plant, pods per plant, pods per cluster, pod length, 100 seed weight seed yield and harvest index. Previously, high heritability for these traits has also been reported by (Rohman and Hussain, 2003 and Siddique *et al.*, 2006). These traits were expected to remain stable under varied environmental conditions, as environment is less influential on highly heritable traits and could easily be improved by applying selection pressure. Dobhal & Rana (1997) also observed high genetic advance for pods per plant as suggested by our findings. In present study, lowest genetic advance was observed (0.085) for primary branches followed by pod length (0.336) and is comparable to the findings of Loganathan *et al.*, 2001 who also reported lowest genetic advance for these traits. High heritability and high genetic advance were indicating that these traits were controlled by additive genes and can easily be transferred to succeeding generations.

Table 1. Analysis of variance for yield and its components in mungbean genotypes.

Source of variance	P.B	S.B	P.H	C/P	Pod/P	Pods/C	Pod.L	100-SW	TPW	H.I	S.Y
Replications	0.006	0.102	1.395	1.642	157.136	0.006	0.005	0.020	104.110	7.703	11.376
Genotypes	0.022^{NS}	1.841**	81.193**	16.209**	148.524**	0.408**	0.175**	0.680**	122.394*	20.502**	26.197**
Error	0.009	0.068	6.173	0.424	19.503	0.046	0.024	0.015	46.622	3.502	3.562

NS = Non significantly, ** = Highly Significant, * = Significant

Note: P.B= primary branches, S.B= secondary branches, P.H=plant height C/P=clusters per plant, Pod/P =pods per plant, Pods/C= pods per cluster, Pod. L=pod length, 100-SW= 100 seed weight, TPW=total plant weight, H.I=harvest index S.Y= seed yield

T able 2. Means values for yield and its components in mungbean genotypes.

Genotypes	P.B	S.B	P.H	C/P	Pod/P	Pods/C	Pod.L	100-SW	TPW	H.I	S.Y
AUM-9	3.033	7.133	64.637	15.100	56.367	3.753	7.867	4.033	59.390	36.477	21.407
NM-98	2.933	7.467	57.860	12.533	51.733	4.133	7.60	3.700	49.547	31.473	15.297
AUM-38	2.833	6.933	67.820	13.633	50.867	3.830	7.780	4.067	53.867	36.797	18.900
AUM-29	2.933	8.433	56.757	11.700	43.533	3.703	7.787	4.100	57.237	35.337	19.030
AUM-27	3.00	8.067	52.230	10.900	43.100	3.990	7.903	4.167	47.413	36.470	16.983
AUM-19	3.133	8.933	55.493	9.733	41.200	4.070	7.777	3.767	43.523	30.810	13.370
AUM-18	2.967	7.367	58.307	8.750	40.400	4.580	8.290	4.600	45.543	30.563	13.550
NM-54	2.933	7.567	60.200	8.500	39.133	4.510	7.970	3.833	40.453	31.407	12.707
AUM-28	3.067	6.733	61.593	10.000	35.933	3.433	8.470	5.300	49.437	35.930	15.787
6375	3.033	6.400	51.093	8.133	35.300	4.433	8.043	4.400	41.930	32.917	13.447

P.B= primary branches, S.B= secondary branches, P.H=plant height C/P=clusters per plant, Pod/P =pods per plant, Pods/C= pods per cluster, Pod. L=pod length, 100-SW= 100 seed weight, TPW=total plant weight, H.I=harvest index S.Y= seed yield

Table 3. Estimation of genetic components for yield and its components in mungbean.

Traits	(GCV) %	(PCV) %	(h^2) %	(GA)	(CV) %
P.B	2.15%	2.85%	57.18%	0.0855	3.23%
S.B	10.25%	10.44%	96.33%	1.3282	3.46%
P.H	8.53%	8.88%	92.40%	8.4599	4.24%
C/P	21.05%	21.33%	97.39%	3.9840	5.97%
Pods/P	14.99%	16.08%s	86.87%	10.7576	10.09%
Pods/C	8.61%	9.14%	88.82%	0.5765	5.29%
Pod L	2.81%	3.03%	86.25%	0.3661	1.95%
100-Seed wt	11.21%	11.34%	97.77%	0.8189	2.93%
Total P. wt	10.29%	13.08%	61.9%	0.9595	13.98%
SY/P	17.12%	18.14%	86.4%	4.4937	11.76%
H.I	7.04%	7.73%	82.92%	3.8150	5.53%

GCV= genotypic coefficient of variation, PCV= phenotypic coefficient of variation, h^2= heritability, GA= genetic advance, CV= coefficient of variation, P.B= primary branches, S.B= secondary branches, P.H=plant height C/P=clusters per plant, Pod/P =pods per plant, Pods/C= pods per cluster, Pod. L=pod length, 100-SW= 100 seed weight, TPW=total plant weight, H.I=harvest index S.Y= seed yield

Genotypic and phenotypic correlations: A perusal of results (Table 4) revealed greater genotypic correlations than their corresponding phenotypic correlations indicating the preponderance of genetic variance in expression of characters (Gill *et al.,* 1995 and Biradar *et al.,* 2007). Number of primary branches as well as secondary branches, pod length and 100 seed weight had negative and non-significant genotypic and phenotypic correlations with seed yield. These results are in partial agreement with Rohman and Hussain (2003) while contradicts from Mishra *et al*., (1995), Kalpande *et al*., (1997b) and Hassan *et al*., (2003). These differences might be due to different climatic conditions and genotypic variation of cultivars. Pods per cluster had negative significant genotypic correlation with seed yield per plant while differed from previous findings of Biradar *et al*., (2007) for same parameter. In the present study, positive non-significant genetic correlation of plant height with seed yield was observed whereas phenotypic correlation was significantly positive. Similar observations have been made by Joseph and Kumar (1999) while an opposite phenomenon has been reported by Celal (2004). The results depicted positive significant genotypic and highly significant phenotypic correlations of clusters per plant, pods per plant, total plant weight and harvest index with seed yield. This indicates that selection based on these traits may result in improved yield. These observations are in accordance with Celal (2004, Rao *et al.,* (2006), Makeen *et al.,* (2007) and Biradar *et al.,* (2007). However, an inverse relationship for pods per plant and harvest index was determined by Hassan *et al.,* (2003) and Siddique *et al.,* (2006). Positive correlations occur due to the changes of genes supplying precursors. On the other hand negative correlations arise due to competition among traits for common precursors which is restricted supply (Madhur & Jinks1994).

Path analysis: The correlation values decide only the nature and degree of association existing between pairs of characters. A character like seed yield is dependent on several mutually associated component characters and change in any one of the components is likely to affect the whole network of cause and effect relationship. This in turn might affect the true association of component characters, both in magnitude and direction and tend to vitiate association of yield and yield components. Hence it is necessary to partition the phenotypic correlations of component characters into direct and indirect effects (Biradar *et al*., 2007).

Table 4. Genotypic correlation (rg) and phenotypic correlation (rp) for seed yield and its associates in mungbean.

	Primary branches per plant	Secondary branches per plant	Plant height	Cluster per plant	Pod per plant	Cluster per pod	Pod length	100-seed weight	Total plant weight	Harvest index	Seed yield per plant
Primary branches per plant	rg 1	0.27022NS	-0.6599NS	-0.4207NS	-0.6028NS	-0.0962NS	0.29586NS	0.34782NS	-0.6279NS	-0.3105NS	-0.5185NS
	rp 1	0.21029NS	-0.4335NS	-0.3116NS	-0.3727NS	-0.1229NS	-0.2872NS	0.24632NS	-0.2711NS	-0.1869NS	-0.2658NS
Secondary branches per plant	(rg)	1	-0.353NS	0.00268NS	0.03538NS	-0.0149NS	-0.5322NS	-0.5208NS	0.02746NS	-0.2699NS	-0.0599NS
	(rp)	1	-0.3023NS	-0.0127NS	0.04588NS	0.00474NS	-0.4939*	-0.5129*	-0.0068NS	-0.2349NS	-0.0436NS
Plant height	(rg)		1	0.65636*	0.57304NS	-0.399NS	0.02126NS	0.04452NS	0.70318*	0.41216NS	0.53733NS
	(rp)		1	0.60973**	0.55233NS	-0.37NS	-0.004NS	0.04329NS	0.53782**	0.36834NS	0.50735*
Cluster per plant	(rg)			1	0.9846*	-0.6022NS	-0.5566NS	-0.3221NS	0.9929*	0.6813*	0.97931*
	(rp)			1	0.90797**	-0.5849**	-0.507*	-0.2992NS	0.78769**	0.61403**	0.89626**
Pod per plant	(rg)				1	-0.2993	-0.7165*	-0.5822NS	0.76332*	0.45359NS	0.77763*
	(rp)				1	-0.2628NS	-0.6125**	-0.5252*	0.71863**	0.33093NS	0.72302**
Cluster per pod	(rg)					1	0.04971NS	-0.3248NS	-0.8897*	-0.9113*	-0.7764*
	(rp)					1	0.00083NS	-0.3239NS	-0.7127**	-0.7821**	-0.7021**
Pod length	(rg)						1	0.99387*	-0.4145NS	-0.0599NS	-0.4103NS
	(rp)						1	0.91395**	-0.2794NS	-0.0482NS	-0.3351NS
100-seed weight	(rg)							1	-0.0273NS	0.32156NS	-0.0588NS
	(rp)							1	-0.0088NS	0.27866NS	-0.0512NS
Total plant weight	(rg)								1	0.98518*	0.98993*
	(rp)								1	0.57737**	0.77915**
Harvest index	(rg)									1	0.93638*
	(rp)									1	0.82772**

NS = Non significantly, ** = Highly Significant, * = Significant

Direct and indirect matrix (Table 5) revealed negative direct effect of number of primary branches on seed yield per plant as well as negative indirect effects via pods per plant, total plant weight and harvest index. Previously, a negative direct effect of number of primary branches on seed yield has also been reported by Arshad *et al.*, (2004), Idress *et al.*, (2006) and Hakim (2008). This indicated that this trait is not directly associated with yield resulting in poor selection directly through this character so indirect causal factors must be considered especially the traits contributing positively. However positive indirect effects of primary branches exhibited through secondary branches, plant height, clusters per plant, pods per cluster, pod length and 100-seed weight. Number of secondary branches had positive direct effect on seed yield with positive indirect effects through plant height, pods per plant, pods per cluster, and total plant weight. These findings are in line with the reports of Kalpande *et al.,* 1997b and Arshad *et al.,* (2004). Plant height had negative direct effect on seed yield along with negative indirect effects via secondary branches per plant and clusters per plant while primary branches, pods per plant, pods per cluster, pod length, 100 seed weight, total plant weight and harvest index were found to have positive direct effects. These findings are in accordance with findings of Rohman & Hussain (2003). Clusters per plant disclosed direct negative effect on seed yield and also negative indirect effect via plant height, pod length and 100-seed weight. However, influence of primary and secondary branches, pods per plant, pods per cluster, total plant weight and harvest index was indirectly positive. These findings match with the studies conducted by Yaqoob *et al.*, (1997) while differed from Hairitha and Sekhar (2002).

Positive direct effect of pods per plant on seed yield was found along with indirect positive effects through branches per plant, pods per cluster, total plant weight and harvest index. Plant height, clusters per plant, pod length and 100 seed weight revealed negative indirect effects. These findings are in accordance with previous reports (Rohman & Hussain, 2003; Celal, 2004; Makeen *et al*., 2007; Rao *et al*., 2006; Hakim, 2008) proving the effectiveness of direct selection through pods per plant for yield improvement. Pods per cluster had negative direct effect on seed yield. Positive indirect effects were exerted through primary branches per plant, plant height, clusters per plant and pod length, while negative indirect effect through secondary branches per plant, pods per plant, 100-seed weight, total plant weight and harvest index. These results are not in agreement with those previously reported by Hairitha & Sekhar (2002) and Biradar *et al.,* (2007). Present results depicted a positive direct effect of pod length on seed yield per plant with positive indirect effects *via* clusters per plant and 100-seed weight. It was indirectly influenced negatively via branches per plant, plant height, pods per plants, pods per cluster, total plant weight and harvest index. Similar observations have been reported by Islam *et al*., (1999) and Biradar *et al.,* (2007). However our findings are not in line with those reported by Hakim (2008). Positive direct effect of 100-seed weight having positive indirect effects *via* clusters per plant pods per cluster, pod length and harvest index were derived from present studies. These results are in consensus with Rohman & Hussain (2003), Celal (2004) and Biradar *et al*., (2007). Seed yield affected positively with direct influence by total plant weight and this is tenable in the light of other experiments by Haritha & Sekhar (2002), Hassan *et al*., (2003) and Rao *et al*., (2006). Branches per plant, pods per plant, and pods per cluster and harvest index had positive indirect effect while plant height, clusters per plant, pod length and 100-seed weight were shown to have negative indirect effects. Positive direct effect of harvest index on seed yield per plant was suggested by these results with positive indirect effects through primary branches, pods per plant, and pods per cluster, total plant weight and 100-seed weight. However, a negative indirect effect *via* secondary branches, plant height, cluster per plant, and pod length and was also reported by Ajmal & Hassan (2002); Celal (2004) and Rao *et al*., (2006). It was concluded that characters with positive effects should be significantly considered in selection criteria for yield improvement in mungbean breeding programs.

Table 5. Direct and indirect effect matrix of yield components in mungbean.

Traits	Primary branches	Secondary branches	Plant height	Clusters / plant	Pods /plant	Pods/ cluster	Pod length	100-grain weight	Total plant weight	Harvest index
Primary branches	**-0.0232**	0.02345	0.013938	0.08627	-0.481	0.00107	0.03268	0.06207	-0.2422	-0.1169
Secondary branches	-0.0063	**0.08679**	0.07455	-0.0005	0.02823	0.00017	-0.0588	-0.0929	-0.01059	-0.1017
Plant height	0.01532	-0.0306	**-0.2112**	-0.1346	0.45725	0.00444	0.00235	0.00795	0.27123	0.15523
Clusters per plant	0.00976	0.00023	-0.1386	**-0.2051**	0.78564	0.00671	-0.0615	-0.0575	0.38298	0.25663
Pods/ plant	0.01399	0.00307	-0.121	-0.2019	**0.79793**	0.00033	-0.0791	-0.1039	0.29443	0.17084
Pods/ cluster	0.0023	-0.0013	0.08427	0.12349	-0.2388	**-0.0111**	0.00549	-0.058	-0.3432	-0.3394
Pod length	-0.0069	-0.0462	-0.0045	0.11413	-0.5717	-0.0006	**0.11045**	0.17735	-0.1599	-0.0225
100-grain weight	-0.0081	-0.0452	-0.0094	0.06605	-0.4645	0.00362	0.10977	**0.17845**	-0.0105	0.12111
Total plant weight	0.01457	0.00238	-0.1485	-0.2036	0.60908	0.00991	-0.0458	-0.0049	**0.38572**	0.37105
Harvest index	0.00721	-0.0234	-0.0871	-0.1397	0.36193	0.01004	-0.0066	0.05738	0.038	**0.37663**

Conclusion

In aforesaid discussion it can be concluded that the magnitude of all the phenotypic variances was higher than genotypic variances showing the pronounced effects of environment. Higher heritability showed additive effects and more gain of selection in next generations when coupled with high genetic advance. The seed yield is an important parameter among all the morphological as well as yield traits. Improvement in seed yield in mungbean could be brought through selection of component characters directly concerned with final yield in pulse crops like secondary branches, pods per plant, pod length, 100 seed weight, total plant weight and harvest index which showed positive direct effects.

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