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Association Studies for Seed Yield and Related Morpho-Physiological Traits in Faba Bean (*Vicia faba* L.) under Mid Hill Conditions of North Western Himalayas, India

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A B S T R A C T

Human malnutrition is a very serious problem of many underdeveloped and developing countries including India. To overcome this problem, there is strong need to focus on breeding of underutilized crops which are of high nutritional value. Therefore, the present investigation was undertaken to find out interrelationships among different traits and their direct and indirect contribution towards seed yield. Seed yield per plant showed significant positive correlation with pods per plant, pod length, seeds per pod, branches per plant, seed size and pod yield per plant at both phenotypic and genotypic levels while with nodes per plant, plant height, 100-seed weight and harvest index at genotypic level only. Pods per plant, seeds per pod, plant height and total soluble solids had high positive direct effects at both phenotypic and genotypic level while traits such as seed size, pod length and pod yield per plant also had positive direct contribution to the total association with seed yield per plant at phenotypic and genotypic level, respectively. From the study, it can be concluded that attention should be paid to these characters for augmentation of seed yield and these traits could be used as selection criteria in faba bean breeding programmes.

Introduction

Faba bean (*Vicia faba* L.) also known as Winter bean, Bakla bean, English bean, Windsor bean, tic(k) bean, horse bean and pigeon bean belongs to family *Leguminosae*. As its name suggests this is the only bean grown in winter. This crop has been reported to be originated in Egypt, however the evidences given by Cubero (1974) suggests that the most acceptable centre of origin is either West or Central Asia. The crop is grown in West Asia, North Africa and some parts of Europe during winter for green tender pods as vegetable and dry seeds as pulse therefore, it is an important dual purpose crop. In India it is grown as minor pulse crop in states like Uttar Pradesh, Madhya Pradesh and some parts of Bihar whereas, in hilly regions it is grown for fresh tender pods during winter. There is no systemic record of its area and production available in India.

Human malnutrition is a very serious problem of many underdeveloped and developing countries including India. Incidentally faba bean seeds are a good source of protein (27.1-36.1%) (Duc, 1997; Haciseferogullari *et al.*,

2003) and carbohydrate content varies from 51 per cent to 68 per cent, of which major proportion is contributed by starch (41–53%) (Cerning *et al.,* 1975). In India, systemic efforts have not been undertaken to seek improvement of this crop. Therefore, there is an urgent need to undertake suitable breeding programme to seek genetic upgradation of this crop.

Interrelationships and path analysis enables the breeders to select most desirable traits for selection in breeding programmes. The knowledge of inter-relationships among different traits is helpful because the selection of one trait may directly affect the performance of another, which is determining the components of a complex trait like yield. However, correlation studies do not provide an exact picture of the direct influence of each of the components traits towards the yield. Here, path coefficient proves helpful in partitioning the correlation coefficient into direct and indirect effects. Correlation and path analysis studies in faba bean are very limited and different research workers carried out these studies in their respective genetic material under different environments (Badolay *et al.,* 2009; Shrifi, 2014; Tofiq *et al.,* 2016). Keeping this in view, the present study was conducted to study correlation and path analysis of economically important characters in faba bean.

Materials and Methods

The present investigation was undertaken at Research Farm of the Department of Vegetable Science and Floriculture, CSK HPKV, Palampur during *rabi*, 2015-16. The research farm is situated at 32^0 $6^{'}$ N latitude and 76^0 3' E longitude at an elevation of 1290.8m amsl. The experimental material used for the present study comprised of 35 genotypes of faba bean including one check and trial was laid out in randomized complete block design (RBD) with three replications. Seeds of 35 genotypes were sown on 5^{th} October 2015 with row to row and plant to plant spacing of 25 cm and 10 cm, respectively. The standard cultural practices were followed to raise the crop. Data were recorded on ten plants taken at random for characters namely, days to 50% flowering, node at which first flower appears, pods per node, nodes per plant, pod length (cm), pods per plant, plant height (cm), branches per plant, seeds per pod, days to maturity, seed size (cm), 100-seed weight (g), harvest index (%), total soluble solids (ºBrix), protein content (mg/ 100g), dry matter (%), pod yield per pant (g) and seed yield per plant (g) in each treatment. In the process of random labeling the border plants were avoided. The phenotypic and genotypic coefficients of correlation were calculated as suggested by Al-Jibouri *et al.,* (1958). Path coefficient analysis of different traits with seed yield per plant was obtained by following the method suggested by Dewey and Lu (1959). Analysis has been done using software OPSTAT.

Results and Discussion

Genotypic correlation coefficients in general were higher than the phenotypic correlations which revealed that though there is a strong inherent association between various characters, the phenotypic expression of the correlation gets modified under the influence of environment. The effective yield improvement would be achieved through the characters which have significant and positive correlation with yield and other economic traits. Genotypic correlation provides measures of genetic association between characters and is more reliable than phenotypic correlation and thus, helps to identify the characters to be utilized in breeding programme. The estimates of phenotypic and genotypic correlation coefficients among different characters have been presented in (Table 1) and described in detail as under:

Table.1 Phenotypic (P) and genotypic (G) coefficients of correlation among different horticultural traits in faba bean

T rait		Node at which first flower appears	Pods per node	Nodes per plant	Pod length (cm)	Pods per plant	Plant height (cm)	Branches per plant	Seeds per pod	Days to maturity	Seed size (cm)	100- seed weight (g)	Harvest index (%)	Total soluble (^{0}Brix)	Ascorbic acid (mg/100g))	Dry matter (%)	Protein content (%)	Pod yield per plant (g)	R
Days to 50% flowering	P	-0.217*	0.173	0.106	-0.110	-0.259**	0.431**	-0.172	-0.240*	0.196*	0.124	-0.139	-0.054	-0.153	0.165	-0.057	0.093	-0.156	-0.012
	G	-0.224*	0.202*	0.108	-0.116	-0.271**	0.453**	-0.172	-0.261**	0.206*	0.133	-0.144	-0.051	-0.161	0.172	-0.058	0.106	-0.163	-0.048
Node at which first flower appears	P		-0.014	0.057	-0.014	-0.112	0.102	-0.103	0.339**	-0.413**	0.141	0.014	-0.060	0.070	-0.022	-0.063	-0.175	-0.117	0.119
	G		0.020	0.056	-0.014	-0.115	0.103	-0.104	0.357**	-0.430**	0.148	0.012	-0.056	0.075	-0.019	-0.065	-0.180	-0.124	0.187
Pods per node	P			0.052	-0.178	-0.367**	0.207*	-0.343**	0.052	0.194*	-0.293**	-0.313**	-0.308**	-0.039	0.172	-0.028	-0.235*	-0.374**	-0.262**
	G			0.072	-0.223*	-0.480**	0.251**	-0.447**	0.083	0.267**	-0.473**	-0.413**	-0.390**	-0.062	0.193*	-0.028	-0.294**	-0.484**	-0.411**
Nodes per plant	P				0.384**	0.239*	0.506**	0.105	0.218*	0.140	0.098	-0.070	0.238*	0.027	-0.054	-0.105	0.191	0.257**	0.155
	G				0.386**	0.240*	0.509**	0.106	0.224*	0.141	0.107	-0.072	0.243*	0.024	-0.054	-0.105	0.193*	0.262**	0.226*
Pod length (cm)	P					0.263**	0.056	0.247*	0.383**	-0.087	0.107	0.173	0.115	0.049	0.047	0.087	-0.174	0.244*	0.406**
	G					0.265**	0.060	0.253**	0.378**	-0.089	0.119	0.178	0.116	0.047	0.047	0.090	-0.177	0.247*	0.632**
Pods per plant	P						-0.062	0.294**	-0.053	-0.031	0.189	0.150	0.690**	0.360**	-0.099	-0.174	0.374**	0.932**	0.260**
	G						-0.064	0.308**	-0.060	-0.031	0.195*	0.151	0.712**	0.365**	-0.102	-0.175	0.377**	0.947**	0.421**
Plant height (cm)	P							-0.011	0.079	0.178	0.099	0.178	0.035	0.203*	-0.068	-0.171	0.132	0.015	0.114
	G							-0.008	0.086	0.183	0.110	0.180	0.032	0.208*	-0.067	-0.173	0.132	0.016	0.208*
Branches per plant	P								-0.002	0.182	0.159	-0.134	0.295**	0.180	0.007	0.190	-0.055	-0.005	0.279**
	G								0.003	0.189	0.170	-0.127	0.319**	0.169	-0.003	0.202*	-0.053	-0.002	0.287**
Seeds per pod	P									-0.084	-0.025	0.184	0.020	-0.147	-0.093	-0.003	-0.316**	-0.009	0.273**
	G									-0.089	-0.016	0.202*	0.012	-0.160	-0.101	0.004	-0.336**	-0.010	0.420**
Days to maturity	P										-0.161	-0.155	-0.038	0.003	0.123	0.200*	0.124	0.022	-0.106
	G										-0.171	-0.154	-0.036	0.004	0.123	0.200*	0.126	0.020	-0.182
Seed size (cm)	P											0.374**	0.085	-0.028	-0.206*	0.221*	-0.042	0.241*	0.240*
	G											0.390**	0.118	-0.020	-0.225*	0.233*	-0.043	0.256**	0.380**
100- seed weight (g)	P												0.122	0.247*	0.099	-0.142	-0.222*	0.235*	0.148
	G												0.124	0.255**	0.098	-0.146	-0.227*	0.243*	0.246*
Harvest index (%)	P													0.274**	-0.073	-0.184	0.320**	0.722**	0.127
	G													0.279**	-0.078	-0.191	0.328**	0.747**	0.202*
Total soluble solids (^{0}Brix)	P														0.111	-0.219*	0.382**	0.455**	0.090
	G														0.121	-0.223*	0.389**	0.470**	0.128
Ascorbic acid (mg/100g)	P															0.024	0.085	-0.053	-0.045
	G															0.025	0.087	-0.055	-0.091
Dry matter (%)	P																-0.030	-0.198*	-0.068
	G																-0.031	-0.201*	-0.095
Protein content (%)	P																	0.423**	-0.031
	G																	0.434**	-0.031
Pod yield per plant (g)	P																		0.250*
	G																		0.415**

*Significant at $P \leq 0.05$; **Significant at $P \leq 0.01$; r-correlation coefficient with seed yield per plant

Table.2 Estimates of direct and indirect effects of different traits on seed yield per plant at Phenotypic (P) and genotypic (G) levels in Faba bean

T rait		Days to 50% flowering	Node at which first flower appears	Pods per node	Nodes per plant	Pod length (cm)	Pods per plant	Plant height (cm)	Branches per plant	Seeds per pod	Days to maturity	Seed size (cm)	100- seed weight (g)	Harvest index (%)	Total soluble (^{0}Brix)	Ascorbic acid (mg/100g))	Dry matter (%)	Protein content (%)	Pod yield per plant (g)	R
Days to 50% flowering	P	**0.039**	0.014	-0.055	-0.017	-0.026	-0.112	0.107	0.001	-0.078	-0.002	0.035	0.042	0.005	-0.022	0.023	0.008	-0.012	0.038	-0.012
	G	**-0.180**	0.057	-0.354	-0.017	-0.005	-0.139	0.499	0.124	-0.144	0.024	-0.018	0.141	0.025	-0.041	0.117	0.007	-0.110	-0.035	-0.048
Node at which first flower appears	P	-0.009	**-0.065**	0.005	-0.009	-0.003	-0.048	0.025	0.001	0.110	0.004	0.039	-0.004	0.006	0.010	-0.003	0.009	0.023	0.029	0.119
	G	0.040	**-0.255**	-0.036	-0.009	-0.001	-0.059	0.113	0.076	0.197	-0.049	-0.020	-0.011	0.027	0.019	-0.013	0.008	0.185	-0.027	0.187
Pods per node	P	0.007	0.001	**-0.317**	-0.009	-0.042	-0.159	0.051	0.003	0.017	-0.002	-0.082	0.094	0.030	-0.006	0.024	0.004	0.031	0.092	-0.262**
	G	-0.036	-0.005	**-1.752**	-0.011	-0.009	-0.246	0.276	0.323	0.046	0.031	0.063	0.405	0.188	-0.016	0.131	0.004	0.303	-0.105	-0.411**
Nodes per plant	P	0.004	-0.004	-0.017	**-0.164**	0.090	0.103	0.125	-0.001	0.071	-0.001	0.028	0.021	-0.023	0.004	-0.008	0.015	-0.025	-0.063	0.155
	G	-0.019	-0.014	-0.126	**-0.155**	0.015	0.123	0.560	-0.077	0.123	0.016	-0.014	0.071	-0.117	0.006	-0.037	0.014	-0.199	0.057	0.226*
Pod length (cm)	P	-0.004	0.001	0.056	-0.063	**0.234**	0.114	0.014	-0.002	0.124	0.001	0.030	-0.052	-0.011	0.007	0.007	-0.012	0.023	-0.060	0.406**
	G	0.021	0.004	0.390	-0.060	**0.040**	0.136	0.066	-0.183	0.208	-0.010	-0.016	-0.175	-0.056	0.012	0.032	-0.012	0.182	0.054	0.632**
Pods per plant	P	-0.010	0.007	0.116	-0.039	0.062	**0.433**	-0.015	-0.002	-0.017	0.000	0.053	-0.045	-0.067	0.053	-0.014	0.025	-0.049	-0.230	0.260**
	G	0.049	0.029	0.842	-0.037	0.011	**0.512**	-0.071	-0.223	-0.033	-0.004	-0.026	-0.149	-0.343	0.092	-0.069	0.023	-0.388	0.206	0.421**
Plant height (cm)	P	0.017	-0.007	-0.066	-0.083	0.013	-0.027	**0.247**	0.000	0.026	-0.002	0.028	-0.054	-0.003	0.030	-0.010	0.024	-0.017	-0.004	0.114
	G	-0.082	-0.026	-0.440	-0.079	0.002	-0.033	**1.101**	0.006	0.048	0.021	-0.015	-0.177	-0.015	0.053	-0.045	0.022	-0.136	0.003	0.208*
Branches per plant	P	-0.017	-0.003	0.000	0.005	-0.009	0.216	0.001	**0.027**	0.000	0.012	0.004	-0.006	0.032	0.021	0.001	-0.006	0.002	0.000	0.279**
	G	-0.024	-0.005	-0.058	0.006	-0.009	0.232	0.001	**0.081**	0.000	0.008	0.004	-0.010	0.055	0.019	0.000	-0.016	0.002	0.000	0.287**
Seeds per pod	P	-0.009	-0.022	-0.016	-0.036	0.090	-0.023	0.019	0.000	**0.324**	0.001	-0.007	-0.055	-0.002	-0.022	-0.013	0.000	0.041	0.002	0.273**
	G	0.047	-0.091	-0.146	-0.035	0.015	-0.031	0.095	-0.008	**0.551**	-0.010	0.002	-0.199	-0.006	-0.040	-0.068	-0.001	0.347	-0.002	0.420**
Days to maturity	P	0.008	0.027	-0.061	-0.023	-0.020	-0.013	0.044	-0.001	-0.027	**-0.010**	-0.045	0.046	0.004	0.000	0.017	-0.028	-0.016	-0.005	-0.106
	G	-0.037	0.110	-0.468	-0.022	-0.004	-0.016	0.201	-0.137	-0.049	**0.114**	0.023	0.151	0.017	0.001	0.084	-0.026	-0.130	0.004	-0.182
Seed size (cm)	P	0.005	-0.009	0.093	-0.016	0.025	0.082	0.025	0.001	-0.008	0.002	**0.281**	-0.112	-0.008	-0.004	-0.029	-0.032	0.006	-0.060	0.240*
	G	-0.024	-0.038	0.829	-0.017	0.005	0.100	0.121	0.092	-0.009	-0.020	**-0.133**	-0.383	-0.057	-0.005	-0.153	-0.030	0.045	0.056	0.380**
100- seed weight (g)	P	-0.005	-0.001	0.099	0.011	0.040	0.065	0.044	-0.002	0.060	0.002	0.105	**-0.300**	-0.012	0.036	0.014	0.020	0.029	-0.058	0.148
	G	0.026	-0.003	0.723	0.011	0.007	0.078	0.199	-0.231	0.111	-0.018	-0.052	**-0.982**	-0.060	0.064	0.067	0.019	0.234	0.053	0.246*
Harvest index (%)	P	-0.002	0.004	0.098	-0.039	0.027	0.299	0.009	-0.001	0.006	0.000	0.024	-0.037	**-0.097**	0.040	-0.010	0.026	-0.042	-0.178	0.127
	G	0.009	0.014	0.683	-0.038	0.005	0.365	0.035	-0.122	0.007	-0.004	-0.016	-0.122	**-0.481**	0.071	-0.053	0.025	-0.338	0.163	0.202*
Total soluble solids (^{0}Brix)	P	-0.006	-0.005	0.012	-0.004	0.012	0.156	0.050	0.000	-0.048	0.000	-0.008	-0.074	-0.027	**0.147**	0.015	0.031	-0.050	-0.112	0.090
	G	0.029	-0.019	0.108	-0.004	0.002	0.187	0.229	0.002	-0.088	0.001	0.003	-0.251	-0.134	**0.253**	0.082	0.029	-0.401	0.102	0.128
Ascorbic acid (mg/100g	P	0.006	0.001	-0.054	0.009	0.011	-0.043	-0.017	-0.001	-0.030	-0.001	-0.058	-0.030	0.007	0.016	**0.140**	-0.003	-0.011	0.013	-0.045
	G	-0.031	0.005	-0.337	0.008	0.002	-0.052	-0.073	-0.146	-0.055	0.014	0.030	-0.097	0.037	0.030	**0.679**	-0.003	-0.089	-0.012	-0.091
Dry matter (%)	P	-0.002	0.004	0.009	0.017	0.020	-0.075	-0.042	0.000	-0.001	-0.002	0.062	0.043	0.018	-0.032	0.003	**-0.143**	0.004	0.049	-0.068
	G	0.010	0.017	0.050	0.016	0.004	-0.090	-0.190	0.039	0.002	0.023	-0.031	0.144	0.092	-0.056	0.017	**-0.129**	0.032	-0.044	-0.095
Protein content (%)	P	0.004	0.011	0.074	-0.031	-0.041	0.162	0.033	0.000	-0.102	-0.001	-0.012	0.067	-0.031	0.056	0.012	0.004	**-0.131**	-0.104	-0.031
	G	-0.019	0.046	0.515	-0.030	-0.007	0.193	0.145	0.002	-0.185	0.014	0.006	0.223	-0.158	0.098	0.059	0.004	**-1.031**	0.094	-0.031
Pod yield per plant (g)	P	-0.006	0.008	0.118	-0.042	0.057	0.404	0.004	-0.002	-0.003	0.000	0.068	-0.070	-0.070	0.067	-0.007	0.028	-0.056	**-0.247**	0.250*
	G	0.029	0.032	0.847	-0.041	0.010	0.485	0.018	-0.207	-0.005	0.002	-0.034	-0.239	-0.359	0.119	-0.038	0.026	-0.447	**0.218**	0.415**

Unexplained variation (P): 0.07729; (G): 0.04534; *Significant at P≤0.05; r-correlation coefficient with seed yield per plant; bold values indicate direct effects

The correlation coefficient analysis revealed that seed yield per plant had significant positive correlation with pods per plant, pod length, seeds per pod, branches per plant, seed size and pod yield per plant at both phenotypic and genotypic levels, while with nodes per plant, plant height, 100-seed weight and harvest index at genotypic level only.

This reflects that selection on the basis of these traits might lead to developing plants with higher seed yield. However, it showed significant and negative association with pods per node at both phenotypic and genotypic levels.

Similar results were also reported by Alghamdi and Ali (2004) and Ulukan *et al.*, (2003) for plant height, Alghamdi and Ali (2004) and Badolay *et al.*, (2009) for 100-seed weight, Ahmed *et al.*, (2016) for branches per plant and pod yield per plant, Tofiq *et al.*, (2016) and Cokkizgin (2007) for number of seeds per plant, Tofiq *et al.*, (2016) and Keneni and Jarso (2002) for pods per plant in their respective studies under different set of genetic material under different environment.

The path coefficient analysis allows partitioning of correlation coefficients into direct and indirect effects of various traits towards dependent variable and thus, helps in assessing the cause-effect relationship as well as effective selection. It plays an important role in determining the degree of relationship between yield and its component effects and also permits critical examination of specific factors that provide a given correlation. Seed yield per plant was taken as dependent variable and rest of the traits used for correlation were used as causal variables (Table 2).

The perusal of data (Table 2) revealed that the direct effects at genotypic level were markedly different from those at phenotypic level. These differences might be due to varying degree of influence of environment on the traits studied, which were also observed from variance analysis and correlation studies. Path analysis at the phenotypic level may not provide a true picture of direct and indirect causes and therefore, it would be advisable to understand the contribution of different traits at genotypic level.

Pods per plant, seeds per pod, plant height and total soluble solids had high positive direct effects at both phenotypic and genotypic level while traits such as seed size, pod length and pod yield per plant also had positive direct contribution to the total association with seed yield per plant at phenotypic and genotypic level, respectively (Table 2). The direct effects of remaining traits were low.

Pods per plant and plant height were the main contributors of positive and significant association of seed yield per plant at phenotypic level, while harvest index, seed size and nodes per plant at genotypic level negated the negative direct effects of these traits on seed yield per plant. Bora *et al.*, (1988), Vandana and Dubey (1993) and Abdelmula and Abdalla (1994) reported the highest positive direct effect of number of pods per plant, followed by 100-seed weight, number of branches per plant and number of seeds per pod on seed yield per plant. Shrifi (2014) also found that number of pods per plant, pod length, seed size and 100-seed weight had positive direct effect on dry seed yield per plant.

On the basis of correlation and path analysis, it can be concluded that the traits like pods per plant, pod length, seeds per pod, seed size and pod yield per plant play major role in seed yield determination of faba bean.

Therefore, attention should be paid to these characters for augmentation of seed yield and these traits could be used as selection criteria in faba bean breeding programmes.

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