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Correlations and path analysis studies on yield and its components in F₂ generation of vegetable Indian bean (*Lablab purpureus* L.) sweet

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DOI: https://doi.org/10.22271/chemi.2021.v9.i2k.11975

Abstract
The present research work was carried out at Navsari Agricultural University, Navsari during the rabi-2017 to study correlations among quantitative traits and their direct and indirect effect on pod yield per plant in F₂ populations (N1-05-19 x N1-13-465, N1-13-465 x N1-08-203 and N1-05-19 x N1-08-225) of Indian bean. Correlation analysis revealed that, pod yield per plant showed positive and significant correlation with plant height at first picking, branches per plant at first picking, pods per plant, pods per cluster and average pod weight in all the three crosses. This indicated the simultaneous improvement of these characters by selection is possible. Path coefficient analysis revealed that plant height at first picking, pods per plant, average pod weight and fibre content had direct positive effects on pod yield per plant for all the crosses. This indicated that these characters played an important role in expressing high pod yield. Pod length exhibited direct positive effects on pod yield in crosses NI-05-19×NI-13-465 and NI-05-19×NI-08-225 while, shelling ratio and protein content depicted positive direct effect on pod yield per plant in crosses NI-05-19×NI-13-465 and NI-13-465×NI-08-203, indicating that direct selection for these characters may bring about an overall improvement in the pod yield of Indian bean.

Keywords: Correlation, path analysis, Indian bean

Introduction
Indian bean (*Lablab purpureus* L.) (2n=22), is one of the most important indigenous legume vegetable crop grown in India. It is also known as lablab bean, field bean, egyptian bean, kidney bean, labia bean, dolichos bean, bonevist bean, seim bean, country bean, poor man's bean and waby bean. It is a multi-purpose crop grown for vegetable, pulse and forage throughout the country. Indian bean is predominantly a self-pollinated crop. It can fix atmospheric nitrogen to the extent of 170 kg/ha. The tender green pods and leaves are used for vegetable as they are the rich sources of protein (3.8% in green pods). The pods are naturally rich in carbohydrates, proteins, fat and fibres, as well as minerals which include Ca, P and Fe (Naeem *et al.* 2009) [10]. The protein content in pods and seeds ranges from 10-19% and 15-25% respectively. The dry seeds are primarily consumed as split pulse and also used for various vegetable preparations such as 'tofu' or 'tempeh'. Dried seeds are usually boiled in water before eating as they contain toxic cyanogenic glucosides which is a source of hydrocyanic acid. In India, two types of Indian bean are recognised, *Dolichos lablab* var. *typicus* which is commonly known as "lablab bean", "papadi", "valor", "ballar". Another, *Dolichos lablab* var. *lignosus* which is commonly used known as "field bean" and "val". Both these types are under cultivation in India. Typicus is a garden type and is cultivated for its soft and edible pods. Lignosus is mainly cultivated for dry seed as pulse.
Selection for a specific character is known to result in correlated response for certain characters. Generally, plant breeders make selection for one or two attributes at a time, then it becomes important to know the effect of selection on other characters. Improvement on seed or pod yield, the most important target in many crops can be achieved by indirect selection through other easily observable and component characters. The association between seed or pod yield and a component character may sometimes be misleading due to an over-estimation or under estimation for its association with other characters. Thus, yield components have ultimate influence on yield, both directly and indirectly. Path analysis is carried out based on assumptions of linearity and additivity.

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Splitting of total correlation into direct and indirect effects, therefore, would provide a more meaningful interpretation of such association. Path coefficient, which is a standard partial regression coefficient, specifies the cause and effect relationship and measures the relative importance of each variable (Wright, 1921) [16]. Therefore, correlation in combination with path coefficient analysis is an important tool to find out the association and quantify the direct and indirect influence of one character upon another (Dewey and Lu, 1959) [4].

Material and Methods

The experimental material for present evaluation comprised of segregating generations of three crosses involving four diverse parents *viz.,* NI-05-19, NI-13-465, NI-08-203, NI-08-225 and three F_1 and F_2 generations derived from three crosses *viz.,* NI-05-19×NI-13-465, NI-13-465×NI-08-203 and NI-05-19×NI-08-225. The F_1s were grown during the *rabi*-2016 and F_2 generations were derived through selfing of F_1 generations. Evaluation of three F_2 generations along with the parents and F_1 generations was carried out in non-replicated trial during rabi-2017.Each row consisted of 20 plants with spacing of 90 x 45 cm² inter and intra row spacing. Each F_2 generation was raised with minimum of 240 plant population during *rabi*-2017 along with F_1s and parents and individual plant observations were recorded from 200 randomly selected plants. While, each parent and F_1 consisted of 40 plants and observations were recorded from 20 randomly selected plants. Observations on twelve different quantitative and qualitative characters *viz.,* days of first flowering, plant height at first picking, branches per plant at first picking, pods per plant, pods per cluster, pod length, number of seeds per pod, pod yield per plant, average pod weight, shelling ratio, protein content and fibre content were recorded from parents, F_1s and derived F_2 generations. Data recorded for all the characters were subjected to statistical analysis.

Results and Discussion
Correlation analysis

Positive and significant correlation of pod yield per plant with the characters plant height at first picking, branches per plant at first picking, pods per plant, pods per cluster and average pod weight was observed in all F2 generations, while pod length and number of seeds per pod also exhibited positive and significant correlation pod yield per plant in NI-05-19 x NI-13-465 (Table 1A, 2A, and 3A). These results were in close agreement with earlier workers *viz.,* Mishra *et al.* (2008) [8, 9], Katiyar and Dixit (2009) [7], Rai *et al.* (2009) [12], Upadyay and Mehta (2010) [14], Angadi *et al.* (2012) [1], Hanumantrao *et al.* (2016) [6] and Singh *et al.* (2018) [13].

Branches per plant at first picking exhibited positive and significant correlation with the traits *viz.,* pods per plant, pods per cluster, pod yield per plant and average pod weight in all segregating generations under study. The results are in accordance with the reports of Venkatesan *et al.* (2003) [15], Konda *et al.* (2008) [8] and Hanumantrao *et al.* (2016) [6]. Among all crosses, pods per plant depicted positive and significant correlation with characters like pods per cluster, pod yield per plant in all three segregating crosses. It also exhibited positive and significant correlation with average pod weight in the crosses NI-05-19×NI-13-465 and NI-05-19×NI-08-225. Similar results reported by Bangar *et al.* (2008), Mishra *et al.* (2008) [8, 9], Konda *et al.* (2008) [8], Katiyar and Dixit (2009) [7]. Plant height showed negative and significant correlation with days of first flowering in the F2

generations of NI-13-465×NI-08-203. While, positive and significant association observed with branches per plant at first picking, pods per plant, pods per cluster, pod yield per plant and average pod weigh in the all segregating populations. Positive and significant correlation observed with shelling ratio (0.148*) in the cross NI-13-465×NI-08-203. The results are in accordance with the findings of Golani *et al.* (2007) [5] and Konda *et al.* (2008) [8], Angadi *et al.* (2012) [1], Hanumantrao *et al.* (2016) [6] and Singh *et al.* (2018) [13]. Positive and significant correlation of pods per plant with pods per cluster and pod yield per plant was observed in all F_2 crosses. Pods per plant depicted positive and significant correlation with average pod weight in the cross NI-05-19×NI-13-465 and NI-05-19×NI-08-225. Similar results were reported by Hanumantrao *et al.* (2016) [6] and Singh *et al.* (2018) [13]. Pod length showed positive and significant correlation with number of seeds per pod in all F2 generations. It was positively and significantly correlated with pod yield per plant in F2 generations cross NI-05-19×NI-13-465 and NI-05-19 × NI-08-225. While, in crosses NI-05-19×NI-13-465 and NI-05-19×NI-08-225, it had positive and significant correlation with average pod weight. Similar results were obtained by Angadi *et al.* (2012) [1]. Average pod weight showed positive and significant correlation with shelling ratio in the F2 crosses NI-13-465×NI-08-203 and NI-05-19×NI-08-225 except NI-05-19×NI-13-465. Similar results were reported by Angadi *et al.* (2012) [1], Hanumantrao *et al.* (2016) [6], and Singh *et al.* (2018) [13]. Generally, the character like plant height at first picking, branches per plant, pods per plant, pods per cluster and average pod weight was observed in all F2 generations, exhibited positive and significant correlation with pod yield per plant would permissible for selecting as yield component trait for improvement of pod yield in segregating populations.

Path coefficient analysis

Path coefficient analysis accommodates assistance for categorizing the total correlation in to direct and indirect effects. The results of path analysis are shown in Table 2A, 2B and 2C. Path analysis involving three segregating populations revealed that traits like plant height at first picking, pods per plant, branches per plant at first picking, pod length, average pod weight, shelling ratio, protein content and fibre content had positive direct effect on pod yield per plant in the F2 segregating population of NI-05-19 × NI-13-465, while plant height at first picking, pods per plant, number of pods per plant, average pod weight, shelling ratio, protein content and fibre content exhibit positive direct effect on pod yield per plant in NI-13-465×NI-08-203. The F2 of cross NI-05-19×NI-08-225 rendered positive direct effect of traits like days of first flowering, plant height at first picking, pods per plant, pod length, average pod weight and fibre content on pod yield per plant. The results are in accordance with the findings of Konda *et al.* (2008) [8], Mishra *et al.* (2008) [8, 9], Rai *et al.* (2009) [12], Chattopadyay and Dutta (2010) [3], Upadhyay and Mehta (2010) [14], Hanumantrao *et al.* (2016) [6] and Singh *et al.* (2018) [13].

The traits, days of first flowering, pods per cluster, number of seeds per pod showed negative direct effect on pod yield per plant in F2 cross NI-05-19×NI-13-465, while in the cross NI-13-465×NI-08-203, days of first flowering, branches per plant at first picking, pods per cluster, pod length depicted negative direct effect on pod yield per plant. The cross NI-05-19×NI-08-225 rendered negative direct effect of the traits, branches per plant at first picking, pods per cluster, number of seeds

per pod, shelling ratio and protein content on pod yield per plant. Similar results were observed by Rai *et al*. (2008) [11], Chattopadhyay and Dutta (2010) [3], Hanumantrao *et al*. (2016) [6] and Singh *et al*. (2018) [13].

The path analysis revealed that plant height at first picking, pods per plant, average pod weight and fibre content had direct positive effects on pod yield. This indicated that these characters played an important role in expressing high pod yield. Therefore, direct selection for these characters may about bring an overall improvement in the pod yield. Considering all the aspects together it is apparent from path analysis that maximum effects as well as appreciable indirect influences were exerted by branches per plant, pods per cluster and pod length. This characters also exhibited

significant and positive association with pod yield per plant. Hence, they may be considered as the most important yield contributing characters and appropriate prominence should be placed as these components while breeding for high yielding in Indian bean.

Conclusion
Based on correlation and path analysis, it could be concluded that in breeding programme aiming to improve pod yield per plant in Indian bean, more weightage should be given on pods per plant, average pod weight and plant height at first picking as they are the most important component traits. Hence, these traits should be considered as selection criteria for pod yield improvement in vegetable Indian bean.

Table 1A: Phenotypic correlation coefficients of pod yield per plant with other characters in F_2 generation of NI-05-19 × NI-13-465 in Indian bean

Characters	DFF	PH	BPP	PPP	PPC	PL	NSPP	PYPP	APW	SR	PC	FC
DFF	1.000											
PH	-0.091	1.000										
BPP	-0.101	0.301**	1.000									
PPP	-0.162*	0.585**	0.604**	1.000								
PPC	-0.005	0.174*	0.233**	0.348**	1.000							
PL	0.023	0.095	0.076	0.130	0.101	1.000						
NSPP	0.076	-0.022	0.134	0.047	0.049	0.710**	1.000					
PYPP	-0.201**	0.579**	0.593**	0.886**	0.264**	0.179*	0.090	1.000				
APW	-0.123	0.269**	0.246**	0.304**	0.005	0.173*	0.141*	0.623**	1.000			
SR	0.071	0.027	-0.045	-0.020	0.011	0.070	0.038	0.052	0.046	1.000		
PC	0.050	0.069	0.091	0.042	0.006	-0.025	0.105	0.031	-0.016	-0.099	1.000	
FC	-0.061	-0.069	-0.108	-0.140*	0.004	-0.121	-0.020	-0.112	-0.021	0.012	0.046	1.000

DFF - Days of first flowering,   **PPP -** Pods per plant,   **NSPP -** Number of seeds per pod,   **SR -** Shelling (%),
PH - Plant height (cm) at first picking   **PPC -** Pods per cluster   **PYPP -** Pod yield per plant (g)   **PC -** Protein content (%)
BPP - Branches per plant at first picking   **PL-** Pod length (cm)   **APW -** Average pod weight (g)   **FC -** Fibre content (%)

Note: * and **, significant at 5% and 1% level of probability, respectively.

Table 1B: Phenotypic correlation coefficients of pod yield per plant with other characters in F_2 generation of NI-13-465 × NI-08-203 in Indian bean

Characters	DFF	PH	BPP	PPP	PPC	PL	NSPP	PYPP	APW	SR	PC	FC
DFF	1.000											
PH	-0.198**	1.000										
BPP	-0.102	0.255**	1.000									
PPP	-0.067	0.370**	0.637**	1.000								
PPC	0.002	0.203**	0.382**	0.466**	1.000							
PL	-0.098	0.179*	-0.102	0.004	-0.018	1.000						
NSPP	-0.038	0.026	-0.052	-0.038	-0.062	0.540**	1.000					
PYPP	-0.096	0.414**	0.639**	0.942**	0.461**	0.057	-0.010	1.000				
APW	-0.060	0.210**	0.215**	0.104	0.181*	0.153*	0.020	0.405**	1.000			
SR	-0.001	0.148*	-0.058	0.005	-0.044	0.230**	0.065	0.140*	0.375**	1.000		
PC	0.053	0.131	-0.043	0.042	0.058	0.003	-0.070	0.047	0.024	0.091	1.000	
FC	-0.030	-0.099	-0.017	-0.069	0.003	-0.039	-0.059	-0.073	-0.032	-0.044	-0.060	1.000

DFF - Days of first flowering, PPP - Pods per plant, NSPP - Number of seeds per pod, SR- Shelling (%), PH - Plant height (cm) at first picking, PPC - Pods per cluster, PYPP - Pod yield per plant (g), PC - Protein content (%), BPP - Branches per plant at first picking, PL - Pod length (cm), APW - Average pod weight (g), FC - Fibre content (%)

Note: * and **, significant at 5% and 1% level of probability, respectively.

Table 1C: Phenotypic correlation coefficients of pod yield per plant with other characters in F_2 generation of NI-05-19 × NI-08-225 in Indian bean

Characters	DFF	PH	BPP	PPP	PPC	PL	NSPP	PYPP	APW	SR	PC	FC
DFF	1.000											
PH	0.042	1.000										
BPP	0.069	0.443**	1.000									
PPP	-0.010	0.518**	0.381**	1.000								
PPC	0.003	0.236**	0.245**	0.320**	1.000							
PL	0.006	0.231**	0.085	0.134	0.024	1.000						

NSPP	-0.040	0.138	-0.022	0.003	-0.068	0.794**	1.000				
PYPP	0.010	0.526**	0.374**	0.917**	0.307**	0.182**	0.041	1.000			
APW	0.047	0.311**	0.257**	0.230**	0.244**	0.090	0.065	0.456**	1.000		
SR	-0.065	0.041	0.116	0.055	0.100	0.156*	0.093	0.101	0.199**	1.000	
PC	-0.035	-0.048	-0.058	0.066	0.041	-0.012	-0.082	0.038	-0.074	-0.069	1.000
FC	-0.093	0.025	0.025	0.089	0.063	-0.050	-0.088	0.082	-0.012	-0.093	-0.041	1.000

DFF - Days of first flowering, PPP - Pods per plant, NSPP - Number of seeds per pod, SR - Shelling (%), PH - Plant height (cm) at first picking, PPC - Pods per cluster, PYPP - Pod yield per plant, PC - Protein content (%), BPP - Branches per plant at first picking, PL - Pod length (cm), APW - Average pod weight (g), FC - Fibre content (%)

Note: * and **, significant at 5% and 1% level of probability, respectively.

Table 2A: Path coefficient analysis of component characters towards pod yield per plant in F_2 generation of NI-05-19 × NI-13-465 in Indian bean

Characters	DFF	PH	BPP	PPP	PPC	PL	NSPP	APW	SR	PC	FC	PCPY(r)
DFF	-0.03385	-0.00351	-0.00643	-0.11444	0.00005	0.00068	-0.00183	-0.04606	0.00379	0.00045	-0.00033	-0.201**
PH	0.00307	0.03861	0.01924	0.41412	-0.00150	0.00282	0.00053	0.10027	0.00143	0.00063	-0.00038	0.579**
BPP	0.00341	0.01163	0.06389	0.42749	-0.00201	0.00225	-0.00325	0.09204	-0.00239	0.00083	-0.00060	0.593**
PPP	0.00547	0.02260	0.03860	0.70747	-0.00301	0.00384	-0.00113	0.11350	-0.00106	0.00038	-0.00078	0.886**
PPC	0.00018	0.00671	0.01488	0.24649	-0.00864	0.00297	-0.00118	0.00189	0.00058	0.00006	0.00002	0.264**
PL	-0.00078	0.00368	0.00486	0.09185	-0.00087	0.02957	-0.01718	0.06466	0.00374	-0.00022	-0.00067	0.179*
NSPP	-0.00256	-0.00084	0.00859	0.03305	-0.00042	0.02100	-0.02419	0.05255	0.00206	0.00096	-0.00002	0.090
APW	0.00417	0.01037	0.01575	0.21503	-0.00004	0.00512	-0.00340	0.37343	0.00244	-0.00015	-0.00011	0623**
SR	-0.00240	0.00104	-0.00286	-0.01398	-0.00009	0.00207	-0.00093	0.01704	0.05344	-0.00090	0.00007	0.052
PC	-0.00168	0.00266	0.00584	0.02957	-0.00005	-0.00073	-0.00255	-0.00615	-0.00529	0.00910	0.00025	0.031
FC	0.00205	-0.00266	-0.00689	-0.09933	-0.00003	-0.00358	0.00001	-0.00773	0.00064	0.00042	0.00052	-0.112

DFF - Days of first flowering, PPP - Pods per plant, NSPP - Number of seeds per pod, SR - Shelling (%), PH - Plant height (cm) at first picking, PPC - Pods per cluster, PYPP- Pod yield per plant (g), PC - Protein content (%), BPP - Branches per plant at first picking, PL - Pod length (cm), APW- Average pod weight(g), FC - Fibre content (%), PCPY - Phenotypic correlation with pod yield, Residual = 0.07040

Note: * and **, significant at 5% and 1% level of probability, respectively.
Direct and indirect effect of different traits on pod yield per plant in Indian bean indicated by bold diagonal and off diagonal characters, respectively.

Table 2B: Path coefficient analysis of component characters towards pod yield per plant in F_2 generation of NI-13-465 × NI-08-203 in Indian bean

Characters	DFF	PH	BPP	PPP	PPC	PL	NSPP	APW	SR	PC	FC	PCPY(r)
DFF	-0.01527	-0.00228	0.00104	-0.06175	-0.00004	0.00155	-0.00090	-.01851	-0.00001	0.00005	-0.00010	-0.096
PH	0.00302	0.01149	-0.00259	0.34097	-0.00407	0.00282	0.00062	0.06429	0.00277	0.00012	-0.00031	0.414**
BPP	0.00156	0.00293	-0.01017	0.58739	-0.00767	0.00160	-0.00122	0.06606	-0.00108	-0.00004	-0.00006	0.639**
PPP	0.00102	0.00425	-0.00648	0.92143	-0.00934	-0.00006	-0.00091	0.03193	0.00010	0.00004	-0.00022	0.942**
PPC	-0.00003	0.00233	-0.00389	0.42919	-0.02006	0.00029	-0.00146	0.05565	-0.00082	0.00005	0.00001	0.461**
PL	0.00150	0.00206	0.00104	0.00370	0.00036	-0.01575	0.01272	0.04695	0.00432	0.00002	-0.00012	0.057
NSPP	0.00058	0.00030	0.00053	-0.03543	0.00124	-0.00850	0.02357	0.00625	0.00122	-0.00007	-0.00019	-0.010
APW	0.00092	0.00241	-0.00219	0.09594	-0.00364	-0.00241	0.00048	0.30665	0.00705	0.00002	-0.00010	0.405**
SR	0.00001	0.00170	0.00059	0.00467	0.00087	-0.00362	0.00153	0.11509	0.01879	0.00009	-0.00014	0.140*
PC	-0.00080	0.00151	0.00044	0.03895	-0.00116	-0.00005	-0.00164	0.00740	0.00171	0.00095	-0.00019	0.047
FC	0.00046	-0.00113	0.00018	-0.06384	-0.00005	0.00062	-0.00139	-0.00996	-0.00083	-0.00006	0.00318	-0.073

DFF - Days of first flowering, PPP - Pods per plant, NSPP - Number of seeds per pod, SR - Shelling (%), PH - Plant height (cm) at first picking, PPC - Pods per cluster, PYPP- Pod yield per plant (g), PC - Protein content (%), BPP - Branches per plant at first picking, PL - Pod length (cm), APW - Average pod weight (g), FC - Fibre content (%), PCPY- Phenotypic correlation with pod yield, Residual = 0.01624

Note: * and **, significant at 5% and 1% level of probability, respectively.
Direct and indirect effect of different traits on pod yield per plant in Indian bean indicated by bold diagonal and off diagonal characters, respectively.

Table 2C: Path coefficient analysis of component characters towards pod yield per plant in F2 generation of NI-05-19 × NI-08-225 in Indian bean

Characters	DFF	PH	BPP	PPP	PPC	PL	NSPP	APW	SR	PC	FC	PCPY(r)
DFF	0.00595	0.00006	-0.00169	-0.00820	-0.00010	0.00048	0.00191	0.01249	0.00009	0.00005	-0.00098	0.010
PH	0.00025	0.00138	-0.01079	0.44745	-0.00829	0.01944	-0.00661	0.08318	-0.00005	0.00008	0.00026	0.526**
BPP	0.00041	0.00061	-0.02437	0.32874	-0.00860	0.00717	0.00104	0.06863	-0.00015	0.00009	0.00026	0.374**
PPP	-0.00006	0.00071	-0.00928	0.86332	-0.01125	0.01126	-0.00016	0.06142	-0.00007	-0.00010	0.00094	0.917**
PPC	0.00002	0.00033	-0.00597	0.27658	-0.03510	0.00198	0.00324	0.06522	-0.00013	-0.00006	0.00066	0.307**
PL	0.00003	0.00032	-0.00208	0.11568	-0.00083	0.08400	-0.03813	0.02399	-0.00020	0.00002	-0.00053	0.182**
NSPP	-0.00024	0.00019	0.00053	0.00287	0.00237	0.06672	-0.04801	0.01725	-0.00012	0.00013	-0.00093	0.041
APW	0.00028	0.00043	-0.00626	0.19855	-0.00857	0.00754	-0.00310	0.26708	-0.00026	0.00012	-0.00012	0.456**
SR	-0.00039	0.00006	-0.00283	0.04772	-0.00351	0.01312	-0.00445	0.05305	-0.00131	0.00011	-0.00098	0.101

| PC | -0.00021 | -0.00007 | 0.00141 | 0.05691 | -0.00145 | -0.00100 | 0.00394 | -0.01976 | 0.00009 | -0.00155 | -0.00043 | 0.038 |
| FC | -0.00055 | 0.00003 | -0.00061 | 0.07726 | -0.00220 | -0.00423 | 0.00424 | -0.00312 | 0.00012 | 0.00006 | 0.01054 | 0.082 |

DFF - Days of first flowering, PPP - Pods per plant, NSPP - Number of seeds per pod, SR - Shelling (%), PH - Plant height (cm) at first picking, PPC - Pods per cluster, PYPP - Pod yield per plant (g), PC - Protein content (%), BPP - Branches per plant at first picking, PL - Pod length (cm), APW - Average pod weight (g), FC - Fibre content (%), PCPY - Phenotypic correlation with pod yield, Residual = 0.09193

Note: * and **, significant at 5% and 1% level of probability, respectively.
Direct and indirect effect of different traits on pod yield per plant in Indian bean indicated by bold diagonal and off diagonal characters, respectively.

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