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Path analysis for pod yield in french bean (*Phaseolus vulgaris* L.)

Dipti Mehra and Dhirendra Kumar Singh

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French bean (*Phaseolus vulgaris* L.) 2n = 2x = 22 belongs to the family Fabaceae, is a native of Latin America. Over a period of at least 7,000 – 8,000 years, French bean had evolved from a wild growing vine *viz., Phaseolus aborigineus* distributed in the highlands of middle America and Andes (Brucher, 1988). Having short duration and being a nutritious legume vegetable crop, it is becoming popular with the farmers of India. It is known by different names, *viz.,* kidney bean, haricot bean, snap bean, navy bean, pole bean, bush bean etc. (Daisy 1979). The dry seed type varieties are called as "Rajmah" in India.

Correlation is useful for making rational improvement in yield and its components but these does not provide an exact picture of the relative importance of direct and indirect influences of each of these component characters. Moreover, when more and more variables are included, the indirect contribution becomes complex (Wright 1923, Dewey and Lu 1959). In such situation it becomes necessary to study path coefficient analysis which takes into account the causal relationship in addition to degree of relationship.

The relationship between productivity and its components in French bean have frequently been examined (Chand and Chand 1998). The present study was undertaken to understand and confirm the extent and nature of inter-relationship as well as the direct and indirect effects of pod yield components in seventy germplasm of French bean. For path analysis, pod yield per hectare was taken as dependent variable and all other 10 traits were considered as causal variables.

In present investigation seventy germplasm were evaluated for their genetic variability, character associations and their direct and indirect effects on pod yield per hectare during January – May, 2008 at Vegetable Research centre (VRC) of Department of Vegetable Science, G.B. Pant University of Agriculture and Technology, Pantnagar. Each germplasm was planted in three replications with a row to row distance of 50 cm and plant to plant distance was 15 cm within the rows. The observations were recorded on 22 characters. The qualitative characters were colour of hypocotyl, plant growth habit, vigour of plant, flower colour, leaf size, pod shape, pod colour, seed coat colour, seed size, disease reaction (visual), insect reaction (visual) and quantitative characters namely plant height (cm), number of primary branches per plant, days to 50% flowering, number of pods per plant, number of pods per cluster, pod length (cm), pod yield per plant (g), pod yield per hectare, days to 50% maturity, seed yield per plant (g) and 100-seed weight (g). Five plants were taken at random from each line of each replication for recording the data for plant height (cm), number of primary branches per plant, days to 50% flowering, number of pods per plant, number of pods per cluster, pod yield per plant (g), pod yield per hectare, days to 50% maturity, seed yield per plant (g) and 100-seed weight (g).The data on pod length were recorded on 5 pods taken at random from a row. Remaining characters were scored on line basis.

The component of direct and indirect effects of 10 characters on pod yield per hectare were estimated using path coefficient analysis (Dewey and Lu, 1959)

Investigation was carried out to determine direct and indirect effects of all yield contributing characters *viz.,* plant height (cm), number of primary branches per plant, days to 50% flowering, number of pods per plant, number of pods per cluster, pod length (cm), pod yield per plant (g), days to 50% maturity, seed yield per plant (g) and 100-seed weight (g) on pod yield per hectare. The path coefficient was calculated and results are presented in Table 2.

In present investigation, path coefficient analysis revealed that the pod yield per plant had highest (0.9225) direct effect on pod yield per hectare followed by number of pods per cluster(0.1640), days to 50% maturity (0.0566), number of primary branches per plant(0.0461) and number of pods per plant(0.0102). These findings are in congruity with those of Prakash and Ram (1981), Joshi and Mehra (1984), Shah *et al.* (1985) Vaid *et al.* (1986), Mishra *et al.* (1996) and Chand and Chand

Dipti Mehra and Dhirendra Kumar Singh
Department of Vegetable Science, G.B.P.U.A.T.Pantnagar
E-mail: deepti2701@gmail.com

(1998). Similar to present study Mohammed (1997) also revealed that the number of primary branches was the major component trait influencing green pod yield from 16 cultivars of common bean.

Seed yield per plant (-0.1595), 100-seed weight (-0.1029), pod length (-0.941), days to 50% flowering (-0.0540) and plant height (-0.0376) exhibited negative direct effect on pod yield per hectare. This finding is similar to Shinde and Dumbre (2001) who also reported negative direct effect of days to flowering and pod length on pod yield.

The positive direct effect of pod yield per plant on pod yield per hectare was enhanced by its positive indirect effect via number of pods per cluster (0.7516), seed yield per plant (0.7226), number of pods per plant (0.7087), 100-seed weight (0.4408), days to 50% flowering (0.2845), pod length (0.1806), plant height (0.1134) and number of primary branches per plant (0.1015).

The positive direct effect of number of pods per plant on pod yield per hectare was enhanced by its positive indirect effect via pod yield per plant (0.0078), number of pods per cluster (0.0074), seed yield per plant (0.0073), days to 50% flowering (0.0046), 100-seed weight (0.0039), pod length (0.0030), number of primary branches per plant (0.0025), days to 50% maturity (0.0018) and plant height (0.0011). However, a positive indirect effect led to establishment of significant positive association between number of pods per plant and pod yield per hectare.

The positive direct effect of number of pods per cluster on pod yield per hectare was enhanced by its positive indirect effect via pod yield per plant (0.1337), seed yield per plant (0.1241), number of pods per plant (0.1192), 100-seed weight (0.0691), days to 50% flowering (0.0648), pod length (0.0462), days to 50% maturity (0.0438), plant height (0.0398) and number of primary branches per plant (0.0341).

Table1. Mean performance of different genotypes for important quantitative characters in French bean

Characters	Mini.	Max.	Mean	Promising lines
Days to 50 % flowering	52.44	75.31	56.18	EC-530983, PGRFB-28-07, EC-530942, EC-530989, PGRFB-23-07and EC-530932.
Number of pods per cluster	1.66	4.17	2.72	Swarna Lata, PGRFB-41-07, PGRFB-45-07, PGRFB-37-07, PGRFB-61-07and Pant Bean-2.
Number of pods per plant	6.7	16.03	9.22	Swarna Lata, PGRFB-41-07, PGRFB-45-07, PGRFB-37-07, PGRFB-61-07 and Pant Bean-2.
Pod length (cm)	7.38	12.43	9.80	Pant Anupama, PGRFB-35-07, PGRFB-61-07, PGRFB-45-07, PGRFB-62-07, and FBDK-2.
Plant height (cm)	19.97	102.17	45.92	PGRFB-41-07, PGRFB-48-07, PGRFB-62-07, PGRFB-45-07, PGRFB-27-07and Swarna Lata.
No. of primary branches per plant	2.53	4.43	3.60	Swarna Lata, PGRFB-22-07, EC-530873, Pant Anupama, EC-530996 and PGRFB-27-07
Days to 50 % maturity	86.73	113.5	99.33	PGRFB-28-07, EC-530933, EC-531017, EC-530932, EC-530959and PGRFB-25-07.
Pod yield per plant(g)	35.27	67.62	50.28	Swarna Lata, PGRFB-35-07, Pant Anupama, Selection-3, EC-530980 and EC-530938.
Pod yield (q/ ha)	70.54	135.23	100.57	Swarna Lata, PGRFB-35-07, Pant Anupama, Selection-3, EC-530980 and EC-530938.
Seed yield per plant(g)	7.75	19.57	11.33	Swarna Lata, PGRFB-35-07, Pant Anupama, EC-530936, Pant Bean-2 and EC-530939.
100-seed weight (g)	16.67	39.52	27.78	EC-530942, PGRFB-35-07, EC-530975, EC-530944, EC-530940 and PGRFB-49-07.

Table 2. Path coefficient analysis in French bean (*Phaseolus vulgaris* L.)

Characters	Indirect effect										Correlation with pod yield per hectare
	Days to 50 % flowering	No. of pods per cluster	No. of pods per plant	Pod length	Plant height	No. of primary branches per plant	Days to 50% maturity	Pod yield per plant	Seed yield per plant	100 seed weight	
Days to 50 % flowering	-0.0540	-0.0213	-0.0243	0.0061	-0.0223	-0.0139	-0.0164	-0.0167	-0.0156	0.0097	0.2965*
No. of pods per cluster	0.0648	0.1640	0.1192	0.0462	0.0398	0.0341	0.0438	0.1337	0.1241	0.0691	0.7269**.
No. of pods per plant	0.0046	0.0074	0.0102	0.0030	0.0011	0.0025	0.0018	0.0078	0.0073	0.0039	0.6500**
Pod length	0.0107	-0.0265	-0.0275	-0.0941	-0.0001	-0.0109	-0.0128	-0.0184	-0.0373	-0.0307	0.0578
Plant height	-0.0155	-0.0091	-0.0039	-0.00004	-0.0376	-0.0180	-0.0300	-0.0046	-0.0073	-0.0028	0.1227
No. of primary branches per plant	0.0118	0.0096	0.0115	0.0053	0.0221	0.0461	0.0305	0.0051	0.0153	-0.0027	0.1319
Days to 50 % maturity	0.0172	0.0151	0.0101	0.0077	0.0452	0.0374	0.0566	0.0097	0.0193	0.0092	0.1605
Pod yield per plant	0.2845	0.7516	0.7087	0.1806	0.1134	0.1015	0.1582	0.9225	0.7226	0.4408	0.8650**
Seed yield per plant	-0.0461	-0.1207	-0.1136	-0.0633	-0.0309	-0.0531	-0.0544	-0.1250	-0.1595	-0.0647	0.6271**
100-Seed weight	0.0186	-0.0433	-0.0403	-0.0337	-0.0079	0.0061	-0.0167	-0.0492	-0.0417	0.1029	0.3288**

Direct negative effect of 100-seed weight was shown by its negative indirect effect via pod yield per plant (-0.0492), number of pods per cluster (-0.0433), seed yield per plant (-0.0417), number of pods per plant (-0.0403), pod length (-0.0337), days to 50% maturity (-0.0167), plant height (-0.0079), days to 50% flowering (0.0186) and number of primary branches per plant (0.061). Days to 50% maturity imposed positive indirect effect on pod yield per hectare through plant height (0.0452), number of primary branches per plant (0.0374), seed yield per plant (0.0193), days to 50% flowering (0.0172), number of pods per cluster (0.0151), number of pods per plant (0.0101), pod yield per plant (0.0097), 100-seed weight (0.0092) and pod length (0.0077).

Negative indirect effect on pod yield per hectare was observed for days to 50% flowering via number of pods per plant (-0.0243), plant height (-0.0223), number of pods per cluster (-0.0213), pod yield per plant (-0.0167), days to 50% maturity (-0.0164), seed yield per plant (-0.0156), number of primary branches per plant (-0.0139), 100-seed weight (0.0097) and pod length (0.0061).

The trait like pod length imposed negative indirect effect on pod yield per hectare through seed yield per plant (-0.0373), 100-seed weight (-0.0307), number of pods per plant (-0.0275), number of pods per cluster (-0.0265), pod yield per plant (-0.0184), days to 50% maturity (-0.0128), number of primary branches per plant (-0.0109), days to 50% flowering (-0.0107) and plant height (-0.0001).

Plant height imposed negative indirect effect on pod yield per hectare through days to 50% maturity (-0.0300), number of primary branches per plant (-0.0180), days to 50% flowering (-0.0155), number of pods per cluster (-0.0091), seed yield per plant (-0.0073), pod yield per plant (-0.0046), number of pods per plant (-0.0039), 100-seed weight (-0.0028) and pod length (-0.00004).

Direct positive effect of number of primary branches per plant was counterbalanced by its positive indirect effect via days to 50% maturity (0.0305), Plant height (0.0221), seed yield per plant (0.0153), days to 50% flowering (0.0118), number of pods per plant (0.0115), number of pods per cluster (0.0096), pod length (0.0053), pod yield per plant (0.0051) and 100-seed weight (0.0027) resulting in significant positive pod yield per hectare.

Seed yield per plant had negative direct effect on pod yield per hectare was enhanced by its negative indirect effect via pod yield per plant (-0.1250), number of pods per cluster (-0.1207), number of pods per plant (-0.1136), 100-seed weight (-0.0647), pod length (-0.0633), days to 50% maturity (-0.0544), number of primary branches per plant (-0.0531), days to 50% flowering (-0.0461) and plant height (-0.0309).

In present investigation residual effect was 0.22, indicated that approximately entire variability could be explained through the component characters under investigation.

In this investigation, path coefficient analysis revealed that pod yield per plant and numbers of pods per cluster were the most important traits affecting pod yield per hectare. However, relative importance of days to 50% maturity, number of primary branches per plant and number of pods per plant cannot be ignored when selection in practiced for improving the pod yield in French bean. For effective selection, greater emphasis should be laid on number of pod yield per plant, number of pods per cluster and number of primary branches per plant.

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