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Path Analysis Studies for Growth, Yield and Quality Traits in French Bean (*Phaseolus vulgaris* L.)

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Abstract An experiment of path analysis studies in French bean (*Phaseolus vulgaris* L.) for twenty one characters were studied in 36 genotypes collected fom IIHR, Hesaraghatta, conducted during *rabi* season of the year 2015-16 to know the relative magnitude of association of various characters with yield. The studies revealed that significant positive association at genotypic level among the traits viz., number of clusters per plant (0.673), number of pods per cluster (0.523), weight of ten pods (0.345), plant spread (E-W) at 50 DAS (0.220), plant height at 50 DAS (0.144) and pod length (0.121) had exhibited true association with direct effect on yield per plant. The direct selection for these traits would be rewarding for improvement in the total yield per plant.

Keywords French bean, Genotypic path analysis, Phenotypic path analysis.

Introduction

French bean (*Phaseolus vulgaris* L., 2n = 2x = 22) is an important legume vegetable belonging to family Fabaceae. It has many synonyms like snap bean, kidney bean, haricot bean and also called raj mash in hindi. The primary center of origin of French bean is Southern Mexico and Central America. It is originated from wild species *Phaseolus aborigineus* L. Beans are essentially used for their tender green pods. The dried pods are used as pulse and provide valuable protein to the human diet. Immature pods are marketed fresh, canned or frozen. These pods are dried and fried like potato chips and can be cooked. Green pods can be used to strengthen diuretic, flushing of toxins from the body and also infused in the treatment of diabetics.

The nutritive value of the crop per 100 g of green pod is 1.7 g protein, 0.1 g fat, 4.5 g carbohydrate, 1.8 g fiber and is also rich in minerals and vitamins. French bean possesses medicinal properties which are useful against diabetes, certain cardiac problems and a good natural cure for bladder burn. It has both carminative and reparative properties against constipation and diarrhoea respectively. In India, it is mainly grown in Himachal Pradesh, Punjab, Haryana, Uttar Pradesh, Bihar, Gujarat, Madhya Pradesh, Maharashtra, Karnataka, Andhra Pradesh and Tamil Nadu.

Though correlation analysis indicates the association pattern of component traits with yield, it simply represents the overall association of a particular trait with yield rather than providing cause and effect relationship. The technique of path coefficient analysis developed and demonstrated by Dewey and Lu (1957) facilitates in partitioning the correlation coefficients into direct and indirect contribution of various

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characters on yield. It is a standardized by partial regression coefficient analysis. As such, it measures the direct influence of one variable upon other. Such information would be of great value in enabling the breeder to specifically identify important component traits of yield and utilize the genetic stock for improvement in a planned way.

Path analysis also measures the relative importance of causal factors involved. This is simply a standardized partial regression analysis, where in total correlation values were subdivided into causal factors.

Materials and Methods

The material consists of thirty six bush type genotypes of French bean collected from Indian institute of Horticultural Research, Hesaraghatta, Bangalore. The experiment was conducted in a RCBD with two replications during *rabi*, 2015-2016 at Department of vegetable science, college of horticulture, Bagalkot. Fifty plants of each genotype were grown per replication with a spacing of 60 cm between rows and 15 cm between plants. The land was brought to a fine tilth by repeated ploughing and harrowing. About 25 tonnes of FYM per hectare and recommended dose of fertilizers (63 : 100 : 75 NPK/ha) were incorporated as per the package of practices of UHS, Bagalkot. In each replication, five plants were selected randomly for recording observation. The characters viz., plant height, number of primary branches per plant, plant spread, days to first flowering, days to first flowering, days to 50% flowering, days to first pod picking, pod length, pod width, pod flesh thickness, number of seeds per pod, number of clusters per plant, number of pods per cluster, number of pods per plant, weight of ten pods, dry matter content of pods, pod yield per plant and number of root nodules per plant. Path co-efficient analysis suggested by Dewey and Lu (1957) was carried out to know the direct and indirect effect of the morphological traits on plant yield. Lenka and Mishra (1973) have suggested scales for path coefficients analysis.

Results and Discussion

In French bean 21 important growth, earliness, yield and quality parameters were subjected to genotypic and phenotypic path coefficient analysis by considering pod yield per plant as dependent variable on 20 other independent variables.

Plant height at 25 DAS (Table 1) had low and direct positive effect on total yield per plant. It had negligible to low indirect and positive effects through pod length, pod flesh thickness, number of seeds per pod, weight of ten pods and dry matter content of pods. It also had low and indirect negative effects through days to first flowering, days to 50% flowering, days to first pod maturity and pod width. Similar results were obtained in French bean, in bush bean (Rai et al. 2006) and in dolichos bean (Gnanesh et al. 2006). Where as plant height at 50 DAS (Table 2) had high and direct negative effect on total yield per plant. It had moderate and indirect negative effects through plant spread (N–S) at 25 DAS, pod length, weight of ten pods and dry matter content of pods. The findings of Govanakoppa (2001), Raffi and Nath (2004), Kamaluddin and Ahmed (2011) in French bean, Chaudhari et al. (2013) and Ravinaik et al. (2014) in dolichos bean were in conformity with the present readings.

Number of primary branches at 50 DAS had negligible and direct positive effect (0.030) on total yield per plant. Plant spread (N-S) at 50 DAS (Table 1) had low and direct negative effect (-0.160) on total yield per plant. Whereas plant spread (E-W) at 50 DAS (Table 1) had negligible and direct positive effect (0.011) on total yield per plant. It had negligible indirect and positive effects through plant spread (N-S) at 25 DAS (0.011), plant spread (E-W) at 25 DAS (0.010), number of pods per plant (0.009) and dry matter content of pods (0.009).

Days to first flowering had negligible and direct negative effect (-0.005) on total yield per plant. Verma et al. (2014) in French bean, Gnanesh et al. (2006) and Singh et al. (2011) in dolichos bean and Kumar et al. (2015) in cluster bean. Whereas days to 50% flowering had low and direct negative effect (-0.128) on total yield per plant. It had negligible and indirect negative effect through days to first pod maturity (-0.058) and pod width (-0.050). It also had negligible and indirect positive effect through pod length (0.065),

Table 1. Genotypic path coefficient analysis among growth, earliness and yield parameters in French bean genotypes. Residual effect (R) = 0.04 Bold and diagonal values indicate direct effect. 1. Plant height at 25 DAS, 2. Plant height at 50 DAS, 3. No. of primary branches at 50 DAS, 4. Plant spread (N-S) at 50 DAS, 5. Plant spread (E-W) at 50 DAS, 6. Plant spread (N-S) at 25 DAS, 7. Plant spread (E-W) at 25 DAS, 8. Days to first flowering, 9. Days to 50% flowering, 10. Days to first pod picking, 11. Pod length, 12. Pod width, 13. Pod flesh thickness, 14. No. of seeds per pod, 15. No. of clusters per plant, 16. No. of pods per cluster, 17. No. of pods per plant, 18. Weight of ten pods, 19. Dry matter content of pods, 20. No. of root nodules per plant, 21. Pod yield per plant.

	1	2	3	4	5	6	7	8	9	10	11
1	**0.144**	0.138	0.093	0.079	0.088	0.089	0.098	-0.071	-0.099	-0.083	0.114
2	-0.337	**-0.352**	-0.157	-0.120	-0.171	-0.205	-0.194	0.149	0.241	0.187	-0.240
3	0.019	0.013	**0.030**	0.020	0.019	0.018	0.019	-0.010	-0.005	-0.010	0.009
4	-0.088	-0.055	-0.106	**-0.160**	-0.143	-0.131	-0.133	0.059	0.074	0.068	-0.052
5	0.007	0.005	0.007	0.010	**0.011**	0.011	0.010	-0.005	-0.005	-0.003	0.004
6	-0.063	-0.059	-0.059	-0.083	-0.093	**-0.102**	-0.101	0.048	0.049	0.031	-0.048
7	0.151	0.121	0.141	0.183	0.199	0.219	**0.220**	-0.087	-0.110	-0.082	0.103
8	0.002	0.002	0.001	0.001	0.002	0.002	0.002	**-0.005**	-0.002	-0.002	0.0001
9	0.089	0.088	0.023	0.060	0.063	0.062	0.064	-0.061	**-0.128**	-0.058	0.065
10	0.056	0.052	0.033	0.042	0.029	0.030	0.036	-0.046	-0.044	**-0.098**	0.002
11	0.096	0.082	0.036	0.039	0.045	0.056	0.056	-0.002	-0.061	-0.002	**0.121**
12	-0.027	-0.017	-0.008	-0.015	-0.009	-0.011	-0.013	0.001	0.022	0.006	-0.030
13	0.047	0.032	0.037	0.033	0.039	0.040	0.038	-0.029	-0.019	-0.006	0.043
14	0.051	0.044	0.038	0.035	0.031	0.047	0.041	-0.024	-0.036	-0.022	0.044
15	0.252	0.283	0.262	0.250	0.430	0.364	0.278	-0.183	-0.164	-0.195	0.166
16	-0.092	-0.016	-0.052	0.234	0.231	0.172	0.226	-0.120	-0.120	-0.164	-0.102
17	-0.035	-0.056	-0.042	-0.106	-0.142	-0.113	-0.108	0.066	0.067	0.076	0.019
18	0.274	0.197	0.215	0.160	0.170	0.216	0.218	-0.130	-0.176	-0.125	0.275
19	0.040	0.047	0.032	0.043	0.056	0.048	0.047	-0.047	-0.052	-0.031	0.043
20	-0.001	-0.0009	-0.001	-0.001	-0.001	-0.001	-0.001	0.008	0.0006	0.0009	-0.000

Table 1. Continued.

	12	13	14	15	16	17	18	19	20	rG
1	-0.070	0.095	0.089	0.054	-0.025	0.028	0.114	0.083	0.071	0.585**
2	0.107	-0.158	-0.189	-0.148	0.010	-0.111	-0.202	-0.237	-0.166	0.552**
3	-0.004	0.016	0.014	0.012	-0.003	0.007	0.019	0.014	0.021	0.525**
4	0.042	-0.075	-0.068	-0.059	-0.071	-0.095	-0.074	-0.099	-0.087	0.707**
5	-0.002	0.006	0.004	0.007	0.005	0.009	0.005	0.009	0.008	0.857**
6	0.0216	-0.058	-0.058	-0.055	-0.033	-0.064	-0.063	0.070	-0.079	0.815**
7	-0.053	0.117	0.110	0.091	0.095	0.133	0.139	0.149	0.166	0.807**
8	-0.0001	0.002	0.001	0.001	0.001	0.001	0.001	0.003	0.002	-0.499**
9	-0.050	0.035	0.056	0.031	0.029	0.048	0.065	0.095	0.041	-0.573**
10	-0.010	0.009	-0.026	0.028	0.031	0.041	0.035	0.0440	0.047	-0.517**
11	-0.065	0.074	0.064	0.029	-0.023	0.013	0.096	0.074	0.013	0.499**
12	**0.056**	-0.024	0.026	-0.01	0.007	-0.005	-0.030	-0.010	0.006	-0.354**
13	-0.031	**0.071**	0.045	0.018	-0.005	0.010	0.063	0.022	0.021	0.594**
14	-0.039	0.053	**0.082**	0.018	0.007	0.019	0.065	0.040	0.026	0.614**
15	-0.141	0.170	0.153	**0.673**	0.020	0.511	0.103	0.246	0.276	0.648**
16	0.073	-0.041	0.044	0.016	**0.523**	0.349	0.020	0.141	0.122	0.481**
17	0.016	-0.026	-0.043	-0.136	-0.119	**-0.179**	-0.029	-0.086	-0.083	0.809**
18	-0.189	0.305	0.273	0.053	0.013	0.056	**0.345**	0.211	0.149	0.717**
19	-0.013	0.022	0.034	0.025	0.018	0.034	0.0429	**0.070**	0.044	0.700**
20	-0.0002	-0.000	-0.000	0.0008	-0.0005	-0.0009	-0.000	-0.001	**-0.001**	**0.601****

weight of ten pods (0.065), number of seeds per pod (0.056) and number of pods per plant (0.048). Similar results were recorded by Mishra et al. (2009) in French bean, Pal and Singh (2012) in pea, Chaudhari et al.

Table 2. Fenotypic path coefficient analysis among growth, earliness and yield parameters in French bean genotypes. Residual effect (R) = 0.09 Bold and diagonal values indicate direct effect. 1. Plant height at 25 DAS, 2. Plant height at 50 DAS, 3. No. of primary branches at 50 DAS, 4. Plant spread (N-S) at 50 DAS, 5. Plant spread (E-W) at 50 DAS, 6. Plant spread (N-S) at 25 DAS, 7. Plant spread (E-W) at 25 DAS, 8. Days to first flowering, 9. Days to 50% flowering, 10. Days to first pod picking, 11. Pod length, 12. Pod width, 13. Pod flesh thickness, 14. No. of seeds per pod, 15. No. of clusters per plant, 16. No. of pods per cluster, 17. No. of pods per plant, 18. Weight of ten pods, 19. Dry matter content of pods, 20. No. of root nodules per plant, 21. Pod yield per plant.

	1	2	3	4	5	6	7	8	9	10	11
1	**0.031**	0.009	0.005	0.005	0.005	0.005	0.005	-0.003	-0.006	-0.004	0.006
2	-0.012	**-0.017**	-0.004	-0.004	-0.004	-0.006	-0.006	0.006	0.009	0.006	-0.009
3	-0.0007	-0.004	**-0.018**	-0.008	-0.008	-0.008	-0.007	0.002	0.002	0.005	-0.004
4	-0.003	-0.001	-0.003	**-0.007**	-0.004	-0.004	-0.004	0.001	0.002	0.002	-0.001
5	-0.004	-0.002	-0.004	-0.006	**-0.009**	-0.007	-0.007	0.002	0.003	0.002	-0.003
6	0.039	0.033	0.040	0.056	0.064	**0.087**	0.076	-0.029	-0.031	-0.018	0.0234
7	-0.029	-0.024	-0.027	-0.042	-0.050	-0.058	**-0.066**	0.024	0.025	0.020	-0.020
8	-0.002	0.002	-0.0009	-0.001	-0.002	-0.002	-0.002	**0.007**	0.002	0.002	-0.0009
9	-0.0013	-0.014	-0.003	-0.010	-0.009	-0.009	-0.010	0.010	**0.027**	0.008	-0.008
10	0.008	0.008	0.007	0.006	0.007	0.005	0.007	-0.007	-0.007	**-0.024**	0.0007
11	0.001	0.0001	0.0001	0.000	0.0001	0.0001	0.0001	0.000	-0.000	0.000	**0.0003**
12	-0.001	-0.001	-0.0009	-0.0008	-0.000	-0.000	-0.0007	0.000	0.0001	0.0008	-0.0025
13	0.004	0.003	0.003	0.003	0.002	0.003	0.003	-0.002	-0.002	-0.0007	0.003
14	-0.005	-0.005	0.004	-0.004	-0.003	-0.005	-0.004	0.003	0.004	0.002	-0.005
15	0.035	0.039	0.040	0.044	0.057	0.071	0.050	-0.031	-0.037	-0.028	0.007
16	-0.007	-0.017	0.0008	0.038	0.045	0.045	0.045	-0.018	-0.018	-0.020	-0.019
17	0.090	0.061	0.108	0.227	0.272	0.307	0.250	-0.142	-0.167	-0.122	-0.017
18	0.310	0.286	0.241	0.270	0.220	0.261	0.293	-0.184	-0.260	-0.184	0.290
19	0.016	0.016	0.007	0.018	0.022	0.018	0.017	-0.16	-0.020	-0.009	0.013
20	0.007	0.007	0.011	0.009	0.011	0.012	0.012	-0.007	-0.005	-0.007	0.003

Table 2. Continued.

	12	13	14	15	16	17	18	19	20	rP
1	-0.004	0.005	0.005	0.0030	-0.0007	0.002	0.006	0.0061	0.004	0.439**
2	0.004	-0.005	-0.007	-0.004	0.002	-0.002	-0.008	-0.007	-0.006	0.373**
3	0.003	-0.006	-0.006	-0.004	-0.0001	-0.003	-0.006	-0.003	-0.009	0.396**
4	0.001	-0.002	-0.002	-0.002	-0.001	-0.003	-0.003	-0.003	-0.003	0.593**
5	0.001	-0.002	-0.002	-0.003	-0.003	-0.004	-0.003	-0.006	-0.005	0.615**
6	-0.010	0.036	0.036	0.0405	0.027	0.049	0.036	0.0444	0.053	0.714**
7	0.008	-0.026	-0.024	-0.021	-0.021	-0.031	-0.031	-0.032	-0.0405	0.651**
8	0.000	-0.002	-0.001	-0.001	-0.0009	-0.002	-0.002	-0.003	-0.002	-0.385**
9	0.008	-0.006	-0.009	-0.006	-0.0036	-0.008	-0.011	-0.0155	-0.007	-0.479**
10	-0.003	0.001	0.005	0.004	0.0035	0.005	0.007	0.0064	0.009	-0.370**
11	-0.000	0.000	0.000	0.000	0.000	0.000	0.0001	0.0001	0.000	0.256*
12	**0.005**	-0.001	-0.002	-0.0007	-0.0006	-0.0002	-0.001	-0.0007	0.0003	-0.245*
13	-0.003	**0.009**	0.004	0.0015	-0.0005	0.0009	-0.005	0.002	0.001	0.435**
14	0.005	-0.005	**-0.012**	-0.001	-0.0005	-0.001	0.007	-0.0040	-0.003	0.465**
15	-0.021	0.023	0.0211	**0.153**	0.004	0.115	0.013	0.0475	0.048	0.612**
16	0.017	-0.007	0.005	-0.004	**0.142**	0.093	-0.014	0.0164	0.017	0.434**
17	-0.018	0.051	0.076	0.390	0.352	**0.537**	0.008	0.182	0.1718	0.771**
18	-0.239	0.360	0.363	0.053	-0.063	0.0093	**0.630**	0.244	0.210	0.638**
19	-0.005	0.009	0.11	0.011	0.0041	0.012	0.0139	**0.036**	0.018	0.519**
20	0.001	0.0041	0.005	0.006	0.002	0.006	0.006	0.010	**0.0200**	0.476**

(2013) in dolichos bean.

Days to first pod maturity (Table 1) had negligible and direct negative effect (-0.098) on total yield per plant. The findings of Raffi and Nath (2004) in French bean and Pal and Singh (2012) in pea were

similar.

Pod length (Table 1) had low and direct positive effect (0.121) on total yield per plant. It had negligible and direct positive effect through pod flesh thickness (0.074), number of seeds per pod (0.064), number of clusters per plant (0.029), weight of ten pods (0.096) and dry matter content of pods (0.074). It also had negligible and direct negative effect through pod width (-0.065). The findings of Verma et al. (2014) in French bean, Gnanesh et al. (2006), Singh et al. (2011) and Ravinaik et al. (2014) in dolichos bean and Karnwal et al. (2013) in pea were in conformity with present findings.

Pod width had negligible and direct positive effect (0.056) on total yield per plant. It had negligible and indirect negative effect through weight of ten pods (-0.030), pod flesh thickness (-0.024) and number of seeds per pod (-0.026). Similar results were obtained by Kumar et al. (2015) in cluster bean and Ravinaik et al. (2014) in dolichos bean.

Number of seeds per pod (Table 1) had negligible and direct positive effect (0.082) on total yield per plant. It also had negligible and indirect positive effect through number of clusters per plant (0.018), number of pods per plant (0.019), weight of ten pods (0.065) and dry matter content of pods (0.040). The findings of Singh et al. (2014a) and Verma et al. (2014) in French bean, Chaudhari et al. (2013) and Gnanesh et al. (2006)in dolichos bean,Venkatesan et al. (2003) in cowpea were similar.

Number of clusters per plant had high and direct positive effect (0.673) on total yield per plant. It also had high and indirect positive effect through number of pods per plant (0.511). It also had low to moderate and indirect positive effect through weight of ten pods (0.103), dry matter content of pods (0.246) and number of root nodules (0.276). Similar findings were recorded by Venkatesan et al. (2003) in cowpea, Idress et al. (2006) and Singh et al. (2009) in mung bean.

Number of pods per cluster (Table 1) had high and direct positive effect (0.523) on total yield per plant. It had high and indirect positive effect through number of pods per plant (0.349). It had low and indirect positive effect through dry matter content of pods (0.144) and number of root nodules (0.122). These results obtained by Mehra and Singh (2012) in French bean, Kumar et al. (2015) in cluster bean and Ravinaik et al. (2014) in dolichos bean are in accordance with present findings.

Number of pods per plant (Table 1) had low and direct negative effect (-0.179) on total yield per plant. It had low and indirect negative effect through weight of ten pod (-0.029), dry matter content of pods (-0.086) and number of root nodules (-0.083). Similar results were recorded by Verma et al. (2014) and Singh et al. (2014) in French bean, Kutty et al. (2003) in cowpea, Pal and Singh (2012) in pea.

Weight of ten pods (Table 1) had high and direct positive effect (0.345) on total yield per plant. It had moderate and indirect positive effect through dry matter content of pods (0.211) and low and indirect positive effect through number of root nodules per plant (0.149). Similar results were obtained by Kumar et al. (2014), Rai et al. (2006) and Verma et al. (2014) in French bean.

Conclusion

From this study it can be concluded that the significant positive association at genotypic level among the traits viz., number of clusters per plant, number of pods per cluster, weight of ten pods, plant spread (E-W) at 50 DAS, plant height at 50 DAS and pod length had exhibited true association with direct effect on yield per plant. The direct selection for these traits would be rewarding for improvement in the total yield per plant.

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