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ASSESSMENT OF CORRELATION AND PATH ANALYSIS IN FRENCH BEAN (*PHASEOLUS VULGARIS* L.) UNDER THE CENTRAL PLAIN ZONE OF UTTAR PRADESH, INDIA

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ABSTRACT

The present investigation was carried out at the Department of Vegetable Science, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur-208002 (UP) during the Rabi season of 2021-22. During the study, the analysis of correlation and path coefficients for 39 genotypes of French bean in a randomized block design revealed significant differences for all 9 characters, justifying their suitability for selection and genetic improvement. Correlation analysis at both genotypic and phenotypic levels showed that grain yield per plant had highly significant positive associations with 100-seed weight, number of seeds per pod, number of pods per plant, days to maturity, and days to 50% flowering, indicating their strong influence on productivity. Path coefficient analysis further confirmed that 100-seed weight exerted the highest positive direct effect on grain yield, followed by days to maturity, pod length, number of seeds per pod, and number of pods per plant, highlighting their importance in selection strategies. The indirect effects of several traits *via* 100-seed weight, days to maturity, and number of seeds per pod also contributed substantially to yield enhancement. These findings suggest that direct selection for 100-seed weight, number of seeds per pod, number of pods per plant, and days to maturity would be effective in improving seed yield in French bean. The results are consistent with previous studies and reaffirm the utility of these traits as reliable indicators for genetic advancement in breeding programs.

***Keywords*:** correlation, French bean, path-coefficient analysis, seed yield.

Introduction

French bean (*Phaseolus vulgaris* L.), also referred to as rajma or common bean, is a very nutrient rich legume crop grown for both fresh pods and dry seed. It is the most significant grain legume globally because of its high protein content (20–25%), essential amino acids, dietary fiber, and micronutrients like iron, zinc, and folate (Broughton *et al.*, 2003; Blair *et al.*, 2010). Native to Central and South America, French bean has become a significant component of cropping systems in temperate, subtropical, and tropical environments, including many regions of India (Singh *et al.*, 2020). In India, French bean is mainly cultivated in hilly areas and cooler plains, but its cultivation is extending slowly to the Central Plain Zone of Uttar Pradesh, such as Kanpur districts, due to rising demand and utilization of improved short-duration and heat-tolerant varieties. This agro-climatic region, belonging to the

Indo-Gangetic Plain, has fertile alluvial soils with moderate rain, semi-arid to sub-humid conditions, and is highly suitable for multiple cropping of legumes along with French bean in rabi, kharif, and zaid seasons (Tomar *et al.*, 2021). Though high in potential, the productivity of French bean is low in most areas mainly because of genetic constraints, poor use of inputs, and climatic stress. Yield and yield-contributing characters improvement by breeding and selection require well-defined knowledge of interrelationships among traits (Kole *et al.,* 2015). Yet, yield is a polycomponent complex quantitative character with several influencing factors that interact with each other, and the interactions are usually regulated both by genetics and the environment (Rani *et al.*, 2021). Correlation and path coefficient analysis are critical statistical methods for breeders to elucidate the interrelationship between yield and its component characters. Correlation analysis determines the association between characteristics, while path coefficient analysis breaks down the link further by segregating correlations into direct and indirect effects, thereby allowing accurate selection strategy (Dewey and Lu 1959; Singh and Yadav 2022). Previous research has shown strong positive correlations of seed yield in French bean with characters like number of pods per plant, pod length, number of seeds per pod, and 100-seed weight (Kumar *et al*., 2016; Nwangburuka *et al.,* 2012; Verma *et al.*, 2023). There are few region-based studies available for the Central Plain Zone of Uttar Pradesh, where edaphic and climatic conditions could differently affect the performance of traits. Knowledge of these associations in local genotypes under particular environments is important for varietal selection and genetic improvement. Hence, the present investigation was taken up to determine the genotypic and phenotypic associations of key agronomic traits and their direct and indirect effects on seed yield in French bean through path coefficient analysis. The findings are expected to help ensure breeding decision-making and improve genetic progress for yield enhancement in French bean under the agro-climatological conditions of the Central Plain Zone of Uttar Pradesh.

Material and Methods

The present investigation was carried out at the Vegetable Research Farm of Chandra Shekhar Azad University of Agricultural & Technology, Kanpur, India, during the Rabi Season, 2021-22. The experimental material, consisting of 39 genotypes procured from Chandra Shekhar Azad University of Agricultural & Technology, Kanpur, India, is given in Table 1. The germplasm of French Bean was evaluated in a randomized block design with three replications, accommodating five plants from a row plot of each genotype under sprinkler irrigated conditions. All recommended agronomic practices were adopted to raise a healthy crop. Observations recorded for 9 characters *viz*., days to 50 per cent flowering, days to maturity, plant height, number of pods per plant, number of seeds per pod, pod length, pod width, 100-seed weight, seed yield per plant. The data on days to 50 per cent flowering and days to maturity were recorded on a plot basis, while five randomly selected plants from each of the entries were selected for recording the remaining observations. Analysis of variance was calculated by the method suggested by (Panse and Sukhatme, 1985). Phenotypic and genotypic correlation coefficients were worked out as per the procedure outlined by (Burton and Devane, 1953) and (Johnson *et al.,* 1955). Direct and indirect effects of component traits on grain yield were worked out using the correlation coefficient of various traits as suggested by (Wright, 1921) and elaborated by (Dewey and Lu, 1959).

Results and Discussions

The analysis of variance Table 2 indicated significant differences among thirty-nine variable genotypes for all nine characters under investigation pointing towards the existence of significant variability among the materials and thus the choice of the experimental materials. Estimates of the correlation coefficients were worked out at both genotypic and phenotypic levels for nine yield and yield-contributing characters, and the results are provided in Tables 3 and 4, respectively. These analyses give information on the magnitude and direction of association among traits and assist in selection criteria for enhancing grain yield in French bean.

Both at the genotypic and phenotypic levels, days to 50% flowering had a strongly significant positive correlated with days to maturity, pod length, pod width, and 100-seed weight. It also had a high significant positive correlation with number of pods per plant and number of seeds per pod, but a non-significant positive correlation with plant height. Days to maturity had a highly significant positive correlation with pod length and 100-seed weight, and significant positive correlation with number of pods per plant and number of seeds per pod. It was also positively but not significantly correlated with pod width, and was negatively non-significantly correlated with plant height. Plant height was significantly correlated with pod width, as well as the number of seeds per pod. But it was non-significantly correlated with number of pods

per plant and 100-seed weight, while it showed a highly significant negative correlation with pod length. Number of pods per plant was highly significantly correlated with both number of seeds per pod and 100-seed weight, while it was non-significantly correlated with pod length and pod width. In like manner, the number of seeds per pod was strongly significantly and positively associated with 100-seed weight, though it had non-significant associations with pod length and a non-significant negative association with pod width. Pod length was non-significantly and positively correlated to 100-seed weight and negatively but non-significantly with pod width, while pod width was non-significantly positively correlated to 100-seed weight. Notably, yield per plant of the grains exhibited significantly positive and highly significant correlations with the number of pods per plant, number of seeds per pod, 100-seed weight, days to 50% flowering and days to maturity. Additionally, grain yield per plant was positively significantly correlated with pod length, positively non-significantly correlated with plant height, and negatively non-significantly correlated with pod width.

These results identify 100-seed weight, number of seeds per pod, and number of pods per plant as the most important elements with positive correlation to grain yield and can be efficiently targeted in selection programs to improve productivity in French bean. Various researchers have previously reported similar results. Such as, (Singh and Yadav, 2022) reported significant positive correlations of seed yield with character such as 100-seed weight and pods per plant in French bean under subtropical conditions. (Kumar *et al.,* 2016) also noted that number of pods per plant and seeds per pod significantly influenced yield. (Rani *et al*., 2021) recorded high genotypic relations between yield and 100-seed weight, and between number of seeds per pod and pod length. Similarly, (Verma *et al*., 2023) reported significant and positive relationships among seed yield and traits for maturity, pod traits, and seed size. These findings on multiple agro-climatic zones confirm the role of these yield-contributing traits in breeding.

Path coefficient analysis was carried out to comprehend better the nature of the relationships between yield and its component traits. Genotypic and phenotypic correlation coefficients were decomposed into direct and indirect effects using path coefficient analysis, with grain yield per plant as the dependent variable. The obtained phenotypic and genotypic path matrices are shown in Tables 5 and 6 respectively. The interpretation given below is based on the phenotypic path matrix.

Direct Effects Among all the characters investigated, seed weight at 100 exhibited the strongest positive direct effect on grain yield per plant, pointing to it as the most contributing trait for improving yield. Other characteristics with positive direct effects were days to maturity, pod length, number of seeds per pod, number of pods per plant, and pod width. On the contrary, days to 50% flowering and plant height exerted indirect negative effects on yield, implying that early flowering or taller plant growth may not necessarily increase yield potential in the current genotypes.

Indirect Effects Direct Effects Among all the characters investigated, Days to 50% flowering had a positive indirect effect on grain yield through days to maturity, number of pods per plant, number of seeds per pod, plant height, pod width, and, importantly, 100-seed weight. An indirect effect was also found to be slightly negative through plant height. Days to maturity had significant positive indirect effects through 100-seed weight, seeds per pod, and plant height, but a negative indirect effect through days to 50% flowering. Plant height exerted positive indirect influences via number of seeds per pod, number of pods per plant, pod width, and 100-seed weight, whereas it had a negative impact on yield through days to 50% flowering, days to maturity, and pod length. The number of pods per plant had positive effects on yield using days to maturity, number of seeds per pod, and 100-seed weight, but with small negative impacts through days to 50% flowering, plant height, pod length, and pod width. Number of seeds per pod contributed positively to the yield through days to maturity, number of pods per plant, pod length, and 100-seed weight, but negatively through days to 50% flowering, plant height, and pod width. Pod length had a small positive impact via days to maturity, plant height, number of seeds per pod, and 100-seed weight, and only a small negative effect via days to 50% flowering. Pod width showed minor positive influences through days to maturity and 100-seed weight, but adverse influences through days to 50% flowering plant height, number of pods per plant, number of seeds per pod and pod length. Lastly, 100-seed weight, the strongest contributor, also had positive indirect effects by days to maturity, number of pods per plant, number of seeds per pod and pod length. There were negligible negative indirect effects through days to 50% flowering and plant height. These findings verify that 100-seed weight, number of seeds per pod, number of pods per plant, and days to maturity are the most significant traits directly or indirectly improving grain yield per plant. (Rani *et al*., 2021), (Singh and Yadav,

2022), and Verma *et al*., 2023) have also independently reached similar conclusions by highlighting the role of seed size and reproductive qualities in enhancing the yield potential in French bean.

Conclusion

The current study on French bean indicated that the grain yield per plant is significantly and positively determined by major yield-attributing traits including 100-seed weight, number of seeds per pod, number of pods per plant, days to maturity, and days to 50% flowering. Of these, 100-seed weight was the most important trait, registering both the strongest positive genotypic correlation and strongest direct effect on grain yield, reflecting its central role in productivity determination. Path coefficient analysis also confirmed the significance of these traits by breaking down the correlation into direct and indirect effects, where 100-seed weight, seeds per pod, and days to maturity had leading direct contributions to yield. The highly significant positive indirect effects transmitted by these characters also highlighted their interaction synergism in yield improvement. Therefore, these characters can be used as valid selection indices in breeding for seed yield improvement in French bean under the agro-climatic conditions of the Central Plain Zone of Uttar Pradesh. The reproducibility of these results with previous communications further strengthens their usefulness in genetic improvement programs.

Table 1: List of French Bean genotypes used for present investigation

Name of germplasm	Source of procurement
KRS-2006	C.S.A.U.A & T Kanpur, India
KRS-2007	C.S.A.U.A & T Kanpur, India
KRS-2008	C.S.A.U.A & T Kanpur, India
KRS-2011	C.S.A.U.A & T Kanpur, India
KRS-2012	C.S.A.U.A & T Kanpur, India
KRS-2013	C.S.A.U.A & T Kanpur, India
KRS-2021	C.S.A.U.A & T Kanpur, India
KRS-2022	C.S.A.U.A & T Kanpur, India
KRS-2023	C.S.A.U.A & T Kanpur, India
KRS-2051	C.S.A.U.A & T Kanpur, India
KRS-2052	C.S.A.U.A & T Kanpur, India
KRS-2053	C.S.A.U.A & T Kanpur, India
KRS-2081	C.S.A.U.A & T Kanpur, India
KRS-2082	C.S.A.U.A & T Kanpur, India
KRS-2083	C.S.A.U.A & T Kanpur, India
KRS-2084	C.S.A.U.A & T Kanpur, India
KRS-2101	C.S.A.U.A & T Kanpur, India
KRS-2102	C.S.A.U.A & T Kanpur, India
KRS-2111	C.S.A.U.A & T Kanpur, India
KRS-2112	C.S.A.U.A & T Kanpur, India
KRS-2113	C.S.A.U.A & T Kanpur, India
KRS-2121	C.S.A.U.A & T Kanpur, India
KRS-2122	C.S.A.U.A & T Kanpur, India
KRS-2131	C.S.A.U.A & T Kanpur, India
KRS-2132	C.S.A.U.A & T Kanpur, India
KRS-2133	C.S.A.U.A & T Kanpur, India
KRS-2141	C.S.A.U.A & T Kanpur, India
KRS-2142	C.S.A.U.A & T Kanpur, India
KRS-2143	C.S.A.U.A & T Kanpur, India
KRS-2151	C.S.A.U.A & T Kanpur, India
KRS-2161	C.S.A.U.A & T Kanpur, India
KRS-2171	C.S.A.U.A & T Kanpur, India
KRS-2174	C.S.A.U.A & T Kanpur, India
KRS-2181	C.S.A.U.A & T Kanpur, India
KRS-2182	C.S.A.U.A & T Kanpur, India
KRS-2191	C.S.A.U.A & T Kanpur, India
KRS-2192	C.S.A.U.A & T Kanpur, India
KRS-2201	C.S.A.U.A & T Kanpur, India
KRS-2202	C.S.A.U.A & T Kanpur, India

Table 2: Analysis of variance for different characters of French Bean.

S. No	Source of variance	D.F.	Days to 50% flowering	Days to maturity	Plant Height (cm)	Number of pods per plant	Number of seeds per pod	Pod Length (cm)	Pod Width (cm)	100 Seed weight (g)	Yield per plant (g)
1	Replication	2	1.085	5.564	1.310	1.145	0.412	0.009	0.929	0.442	0.252
2	Treatment	38	42.312**	80.813**	766.625**	16.400**	2.432**	8.625**	3.662**	43.725**	143.204**
3	Error	76	0.725	1.722	1.557	0.061	0.074	0.040	0.044	0.520	0.2819

* and ** significant at 5% and 1% respectively

Table 3: Genotypic (G) correlation coefficient between different characters of French Bean.

Characters	Days to 50% flowering	Days to maturity	Plant Height (cm)	Number of pods per plant	Number of seeds per pod	Pod Length (cm)	Pod Width (cm)	100 Seed weight (g)	Grain yield per plant (g)
Days to 50% flowering	**1.000**	0.871**	0.042	0.213*	0.204*	0.272**	0.267**	0.557**	0.541**
Days to maturity		**1.000**	-0.072	0.231*	0.231*	0.270**	0.056	0.716**	0.712**
Plant Height (cm)			**1.000**	0.173	0.212*	-0.250**	0.268**	0.106	0.055
Number of pods per plant				**1.000**	0.843**	-0.007	-0.106	0.673**	0.650**
Number of seeds per pod					**1.000**	0.015	-0.100	0.724**	0.708**
Pod Length (cm)						**1.000**	-0.014	0.118	0.196*
Pod Width (cm)							**1.000**	0.013	-0.007
100 Seed weight (g)								**1.000**	0.972**
Grain yield per plant (g)									**1.000**

* and ** Significant at 5% & 1% respectively.

Table 4: Phenotypic (P) correlation coefficient between different characters of French Bean.

Characters	Days to 50% flowering	Days to maturity	Plant Height (cm)	Number of pods per plant	Number of seeds per pod	Pod Length (cm)	Pod Width (cm)	100 Seed weight (g)	Grain yield per plant (g)
Days to 50% flowering	**1.000**	0.871**	0.042	0.213*	0.204*	0.272**	0.267**	0.557**	0.541**
Days to maturity		**1.000**	-0.072	0.231*	0.231*	0.270**	0.056	0.716**	0.712**
Plant Height (cm)			**1.000**	0.173	0.212*	-0.250**	0.268**	0.106	0.055
Number of pods per plant				**1.000**	0.843**	-0.007	-0.106	0.673**	0.650**
Number of seeds per pod					**1.000**	0.015	-0.100	0.724**	0.708**
Pod Length (cm)						**1.000**	-0.014	0.118	0.196*
Pod Width (cm)							**1.000**	0.013	-0.007
100 Seed weight (g)								**1.000**	0.972**
Grain yield per plant (g)									**1.000**

Table 5: Direct and Indirect Effects of Characters on Yield per Plant (Phenotypic Level)

Character	Days to 50% flowering	Days to maturity	Plant Height (cm)	Number of pods per plant	Number of seeds per pod	Pod Length (cm)	Pod Width (cm)	100 Seed weight (g)	Grain yield per plant (g)
Days to 50% flowering	**-0.091**	0.148	-0.001	0.010	0.013	0.021	0.002	0.426	0.528**
Days to maturity	-0.076	**0.178**	0.001	0.011	0.016	0.021	0.001	0.535	0.686**
Plant Height (cm)	-0.004	-0.013	**-0.017**	0.008	0.015	-0.020	0.002	0.083	0.055

Number of pods per plant	-0.019	0.040	-0.003	**0.047**	0.058	-0.001	-0.001	0.523	0.644**
Number of seeds per pod	-0.017	0.039	-0.004	0.038	**0.072**	0.001	-0.001	0.545	0.673**
Pod Length (cm)	-0.024	0.046	0.004	0.000	0.001	**0.079**	0.000	0.088	0.194*
Pod Width (cm)	-0.023	0.010	-0.005	-0.005	-0.007	-0.001	**0.009**	0.011	-0.011
100 seed weight (g)	-0.049	0.120	-0.002	0.031	0.049	0.009	0.000	**0.793**	0.952**

R SQUARE = 0.9225 RESIDUAL EFFECT = 0.2784
Bold values show direct and normal values show indirect effects.

Table 6: Direct and Indirect Effects of Characters on Yield per Plant (Genotypic Level)

Character	Days to 50% flowering	Days to maturity	Plant Height (cm)	Number of pods per plant	Number of seeds per pod	Pod Length (cm)	Pod Width (cm)	100 Seed weight (g)	Grain yield per plant (g)
Days to 50% flowering	**-0.104**	0.121	-0.001	0.000	0.015	0.021	0.004	0.486	0.541**
Days of maturity	-0.091	**0.139**	0.002	0.000	0.017	0.021	0.001	0.624	0.712**
Plant Height (cm)	-0.004	-0.010	**-0.022**	0.000	0.015	-0.020	0.004	0.092	0.055
Number of pods per plant	-0.022	0.032	-0.004	**-0.001**	0.060	-0.001	-0.002	0.587	0.650**
Number of seeds per pod	-0.021	0.032	-0.005	-0.001	**0.071**	0.001	-0.002	0.631	0.708**
Pod Length (cm)	-0.028	0.037	0.006	0.000	0.001	**0.078**	0.000	0.103	0.196*
Pod Width (cm)	-0.028	0.008	-0.006	0.000	-0.007	-0.001	**0.016**	0.012	-0.007
100 seed weight (g)	-0.058	0.099	-0.002	0.000	0.052	0.009	0.000	**0.872**	0.972**

R SQUARE = 0.9538, RESIDUAL EFFECT = 0.2150
Bold values show direct and normal values show indirect effects.

Author's Contribution-

Krishan Kumar – Conceptualization, Conducted experiment, Data Analysis and Data Curation

P.K. Singh- Supervision, Methodology and Review

Abhishek Kumar Yadav, Suryabhan, Ankita Tiwari, Vishal Yadav - Preparation of final draft and Revision

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